Annex 4

Phosphorus in the Hampshire Avon Special Area of Conservation Technical Report

Final

30 April 2015

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with contributions from: Natural England: Orlando Venn, Dianne Matthews, Doug Kite, Environment Agency: Sharon May , Mitch Perkins and Phil Connelly and Wessex Water: Ruth Barden, Jane Youdan

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Preamble

This document is the technical report to support the Nutrient Management Plan (NMP) for the Hampshire Avon. The purpose of this document is to recommend measures to reduce Phosphorus loading derived from point and diffuse sources across the Hampshire Avon Catchment (c 1700km^2), so that the conservation objectives across the River Avon Special Area of Conservation and where technically feasible, Good Status by 2027 can be met.

The Nutrient Management Plan has two primary objectives:

1. To achieve compliance with the requirements of the Habitats Directive; in particular:
    a. To establish the necessary conservation measures and implement appropriate steps to avoid deterioration within the River Avon SAC which might result from nutrient loading.
    b. To achieve the ambition reduction targets in the short term and the conservation objectives targets for phosphorus in the longer term.
    c. To facilitate development within the catchment in a manner which is compliant with the requirements of the Habitats Regulations, whilst securing that existing consented activities do not adversely affect the integrity of the River Avon SAC.
2. To achieve compliance with the Water Framework Directive through delivery of the 'protected area' standards.

This first iteration of the plan considers a range of options for addressing phosphorus pollution. These options are not exhaustive and should not be considered prescriptive. The plan also provides an estimate of the cost of delivering such measures. These costs are only indicative and should be treated with caution.

The NMP focuses on phosphorus, as this is the chemical that is thought to be most significant in preventing favourable conservation status from being achieved across the catchment. Elevated freshwater phosphorus concentrations can have a detrimental effect on the ecology and biodiversity of a river system. Deleterious effects include increased growth rate and abundance of individual plant species (algae and higher plants) and consequential eutrophication. Changes in the competitive balance of plant communities have potential knock-on effects for the associated animal life populations, as well as altering the chemical (Biochemical Oxygen Demand) and physical (increased turbidity) properties of the water. Mainstone *et al*. (2000) provides a detailed review of this process in UK rivers. Pitt (2002) provides details of the likely ecological consequences of phosphorus enrichment in relation to specific habitats and features.

Controlling anthropogenic enrichment of phosphorus in the River Avon at levels that limit the growth of plant species is necessary to restore and protect the characteristic biodiversity.

In the future, it may be necessary for the plan to be updated with measures to reduce the impact of other chemicals, such as nitrogen. Plan delivery is necessary for the management of the River Avon SAC and to meet requirements of the Habitats Directive. The delivery of measures recommended by the plan should contribute to the achievement of favourable conservation status of the SAC features

Delivery of this plan will be achieved through a partnership approach with local planning authorities & water industry. The aim being to ensure that phosphorus from future development will not lead to further deterioration. Diffuse phosphorus reductions will be achieved in partnership with the agricultural sector, to enable diffuse agricultural sources of nitrogen to be managed downwards to achieve overall target concentrations/loadings.

The plan is a working document that will be reviewed within each Water Framework Directive planning cycle, and updated and amended as appropriate. A formal governance structure for this plan is described in more detail in Section 5.

1.0 INTRODUCTION

1.1 Purpose of this report & outcomes required

The purpose of this Technical Document is to:

- identify the key sources of phosphorus in the catchment
- quantify the proportion of phosphorus originating from anthropogenic sources
- consider the measures required to reduce phosphorus loading in the catchment to meet the River Avon SAC Conservation Objectives and where technically feasible, the Water Framework Directive Good Status by 2027 and also meet the WFD 'no deterioration' requirement
- propose a monitoring program
- identify where further investigation is required

The Hampshire Avon failed to achieve Good Ecological or Groundwater Chemical Status under the Water Framework Directive in 2014 River Basin Management Plan (RBMP) and will not meet it for RMBP2 (2015), in part due to failure of those elements indicative of eutrophication, such as phosphorus.

Eutrophication is the process whereby nutrient enrichment can cause excessive growth of plants and algae, resulting in adverse impacts on the ecology, quality and uses of water bodies. Phosphorus (P) is the main cause of eutrophication in fresh waters.

The components of the definition of eutrophication are incorporated into the WFD definitions for good and moderate status of the plant and algal quality elements in freshwaters. Under the WFD, nutrients are supporting elements to the biology. Nutrient concentrations at good ecological status (the default WFD objective) must not exceed levels established to ensure ecosystem functioning and achievement of the values for the biological elements. UK WFD standards for ecological status, for P in rivers were introduced via ministerial directions in December 2009.

Water Framework Good Status Objectives:

The WFD classification scheme for water quality includes five status classes: high, good, moderate, poor and bad.

'High status' is defined as the biological, chemical and morphological conditions associated with **no** or **very low** human pressure. This is also called the 'reference condition' as it is the best status achievable - the benchmark. These reference conditions are type-specific, so they are different for different types of rivers, lakes or coastal waters so as to take into account the broad diversity of ecological regions in Europe.

Assessment of quality is based on the extent of deviation from these reference conditions, following the definitions in the Directive. *'Good status' means 'slight' deviation, 'moderate status' means 'moderate' deviation, and so on. The definition of ecological status takes into account specific aspects of the biological quality elements, for example "composition and abundance of aquatic flora" or "composition, abundance and age structure of fish fauna"* (see WFD Annex V Section 1.1 for the complete list). These definitions are expanded in Annex V to the WFD.

http://ec.europa.eu/environment/water/water-framework/objectives/status_en.htm

Favourable Conservation Status under the Habitats Directive:

Conservation objective standards for phosphorus in designated rivers (SSSIs and SACs) as have been revised (JNCC, 2014)[36]. This revision takes into account recent scientific knowledge on relationships between ecological responses to nutrient enrichment and phosphorus concentrations. The standards prior to this revision were 60 µg/l soluble reactive phosphorus on chalk rivers, 100 µg/l on the lowland type river below Fordingbridge and 40 µg/l on the Dockens Water and upper Till tributary.

The revised standards for designated rivers were derived using a slightly different methodology to those used for WFD, and take into account river flow size as well as alkalinity type and altitude. More stringent standards are set for rivers that are at or close to a near-natural state compared with those in catchments where much of the land is utilised for agriculture and development. Table 2.1:1 gives the revised standards for both the SAC and SSSI only rivers by WFD water body. The SAC/SSSI standards mostly lie near the top of the WFD Good class range. Some near-natural rivers form part of the River Avon SAC or are SSSI only. The designated sites standard for these rivers lies within WFD High class. SAC/SSSI standards are applied as an annual average and also as a growing season average to cover separately the period when the ecological response to nutrient enrichment is stronger.

Elevated freshwater phosphorus concentrations can have a detrimental effect on the ecology and biodiversity of a river system. Deleterious effects include increased growth rate and abundance of individual plant species (algae and higher plants) and consequential eutrophication. Changes in the competitive balance of plant communities have potential knock-on effects for the associated animal life populations, as well as altering the chemical (Biochemical Oxygen Demand) and physical (increased turbidity) properties of the water. Mainstone *et al*. (2000) provides a detailed review of this process in UK rivers. Pitt (2002) provides details of the likely ecological consequences of phosphorus enrichment in relation to specific habitats and features.

The main sources of phosphorus in the catchment are point source loads from Sewage Treatment Works (STW), Fish Farms and Cress Beds, diffuse loads, largely from agriculture and natural contribution from the Upper Greensand Aquifer. Unconsented discharges only contribute a small proportion of the overall load (Section 2).

As outlined above the purpose of the technical document is to identify how sources of phosphorus can be reduced further, so, where technically feasible, the river meets its conservation objectives by 2027. These sources are primarily diffuse from agriculture. An updated source apportionment for the Avon is outlined in Section 2 and summarised in Section 2.5.

Where it is not technically feasible to achieve SAC targets through the implementation of diffuse measures alone, the plan will consider the additional measures that will be needed to achieve these targets. These measures will include further tightening of STW permit conditions. Any such improvements where required and justified would be considered for inclusion under Periodic Reviews 19 and subsequent reviews.

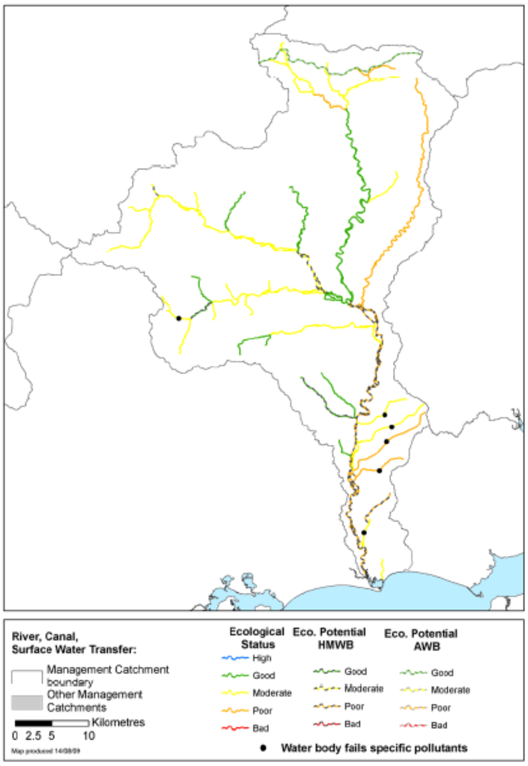
The plan identifies the monitoring that will be undertaken to track improvements in water quality and ecology resulting from the implementation of measures. This data will help to inform future drafts of the NMP which will be reviewed in line with the River Basin Management Planning Cycle every 6 years (as a minimum).

Outcomes required from the plan are:

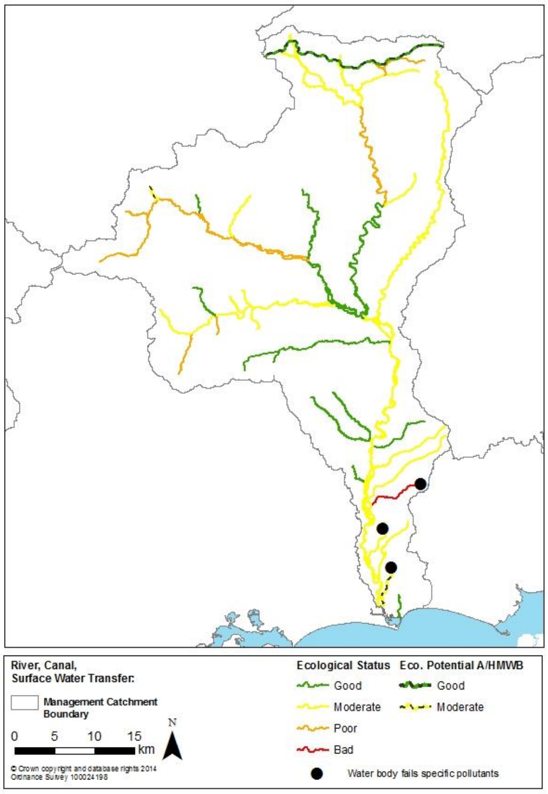
- Surface Water Quality meets quality standards necessary for the catchment to be compliant with the Conservation Objectives for the SAC and SSSI and to meet Water Framework Directive Habitats Directive compliance (Section 2.1).
- Anthropogenic Phosphorus concentrations/loading in the Avon does not prevent the SAC from achieving Favourable Conservation Status.

To achieve these objectives, it will be necessary for measures recommended by the plan to be implemented across the Hampshire Avon catchment.

Figure 1.1: Hampshire Avon Ecological Status from River Basin Management Plan 2009 & 2014 (see Figure 2.1.1a&b for potential influence of Phosphate)



2009



2014

1.2 Local Setting

The Hampshire Avon is a large groundwater fed river in Southern England with a catchment area of c 1700km^2. The river flows from its headwaters in the Vale of Pewsey, Wiltshire and outflows into the English Channel at Christchurch, Dorset, some 75km to the south (Figure 1.2). A number of large tributaries join the Avon north of Salisbury, including the Nadder and Wylye that draining Salisbury Plain and land to the west and Upavon East and West that drains the Vale of Pewsey. Further smaller tributaries join the Avon south of Salisbury

Flow in the upper reaches of Upavon East, Upavon West, the Wylye and Nadder are fed by large springs from the Upper Greensand aquifer. This aquifer then dips south below the chalk aquifer, which in turn becomes confined beneath the lower permeability London Clay south of Fordingbridge (Figure 1.3).

	Waterbodies	
1	Hampshire Avon (Lower)	GB108043015840
2	Mude	GB108043011020
3	Clockhouse Stream	GB108043011011
4	Ripley Brook	GB108043011010
5	Bisterne Stream	GB108043011012
6	Linford Brook	GB108043015720
7	Dockens Water	GB108043015740
8	Sleep Brook	GB108043015730
9	Huckles Brook	GB108043015750
10	Ditchen Brook	GB108043015770
11	Ashford Water (Allen River)	GB108043015800
12	Sweatfords Water	GB108043015810
13	Ebble	GB108043015830
14	Ebble Trib (Chalke Valley Stream)	GB108043015860
15	Ebble (Upper)	GB108043015870
16	Bourne (Hampshire Avon)	GB108043022390
17	Nadder (Lower)	GB108043015880
18	Nadder (Middle)	GB108043022470
19	Fovant Brook	GB108043016190
20	Teffont	GB108043022471
21	Nadder Trib (Swallowcliffe)	GB108043016180
22	Fonthill Stream	GB108043022500
23	Nadder (Upper)	GB108043016200
24	Sem	GB108043016210
25	Nadder (Headwaters)	GB108043016160
26	Wylye (Lower)	GB108043022510
27	Wylye (Middle)	GB108043022550
28	Till (Hampshire Avon)	GB108043022570
29	Chitterne Brook	GB108043022560
30	Wylye Trib (Heytesbury Stream)	GB108043022530
31	Wylye Trib (The Were or Swab)	GB108043022540
32	Wylye (Headwaters)	GB108043022520
33	Hampshire Avon (Upper) d/s Nine Mile River confl	GB108043022352
34	Nine Mile River	GB108043022360
35	Hampshire Avon (Upper) u/s Nine Mile River confl	GB108043022351
36	Hampshire Avon (West)	GB108043022370
37	Etchilhampton Water	GB108043022430
38	Hampshire Avon (East) and Woodborough Stream	GB108043022410
39	Deane Water	GB108043022420

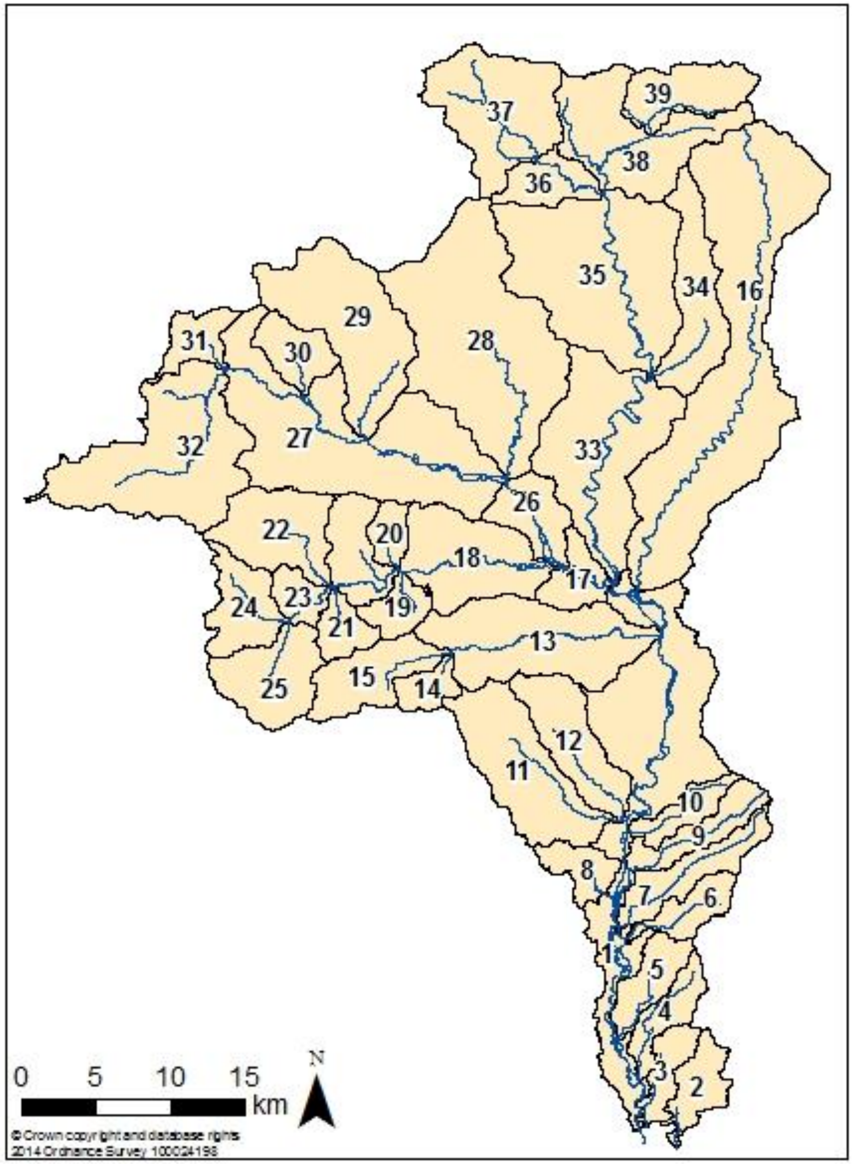


Figure 1:2 Sub-catchments of the Hampshire Avon

Baseflow contributions to the Avon and its tributaries are high with groundwater contributing at Knapp Mill 86% of river flows, Upavon East 89% , Upavon West 70%, the Wylye 89%, Nadder at Wilton 81% and Bourne 91% (CEH; National Flow Archive 2012, Table 1). South of Fordingbridge a greater contribution of river flow is from surface run-off and the river has a more dendritic nature (Figure 1:1 & 1.2).

Table 1 Flow Records to 2013 from the National Flow Archive (http://www.ceh.ac.uk/data/nrfa/)

Gauge		Record	Catchment Area km2	BFI	Mean Flow m3/s	95% ile	10%ile
Knapp Mill	Avon	1975-2012	1706	0.86	20.11	6.184	38.98
Laverstock	Bourne	1965-2012	163.6	0.91	0.766	0.191	1.468
Wilton	Nadder	1966-2012	220.6	0.81	2.865	0.9	5.779
South Newton	Wylye	1967-2012	445.4	0.89	4.004	1.104	8.487
East Avon	Avon	1971-2012	85.8	0.89	0.817	0.437	1.275
West Avon	Avon	1971-2012	84.6	0.70	0.679	0.114	1.55

Baseflow to the rivers follow two typical pathways, matrix flow and fracture flow. The first accounts for approximately 80% of the recharge in the chalk aquifer and the majority in sandstone catchments and moves through the rock matrix. Water following this pathway to the Avon is on average 55 years old (Figure 1.4) and infiltrates at a rate of approximately 1m/yr through the unsaturated zone (Figure 1.4). Fracture flow pathways in the chalk are initiated when the ground becomes saturated and recharge flows through any rock fractures. Recharge can reach the water table through these pathways within days or weeks. This pathway accounts for approximately 20% of recharge.

The flow pathway is important in influencing groundwater chemistry, as the slower the flow mechanisms, the more opportunity there will be for natural minerals within the rock to be dissolved into solution and for other chemicals within recharge water to undertake chemical changes as a result of oxidation and reduction processes (such as ammonia to nitrate) and the precipitation and adsorption of chemicals to the rock matrix.

Water following the more rapid fracture pathways will have less time to pick up natural mineral content in the rock but are likely to be carrying more recent contaminants (Nitrate Phosphorus, Herbicides Pesticides etc) released from pollution sources. There will also be less time for these chemicals to be attenuated.

Figure 1.3: Geology of the Hampshire Avon and Depth of Upper Greensand Aquifer

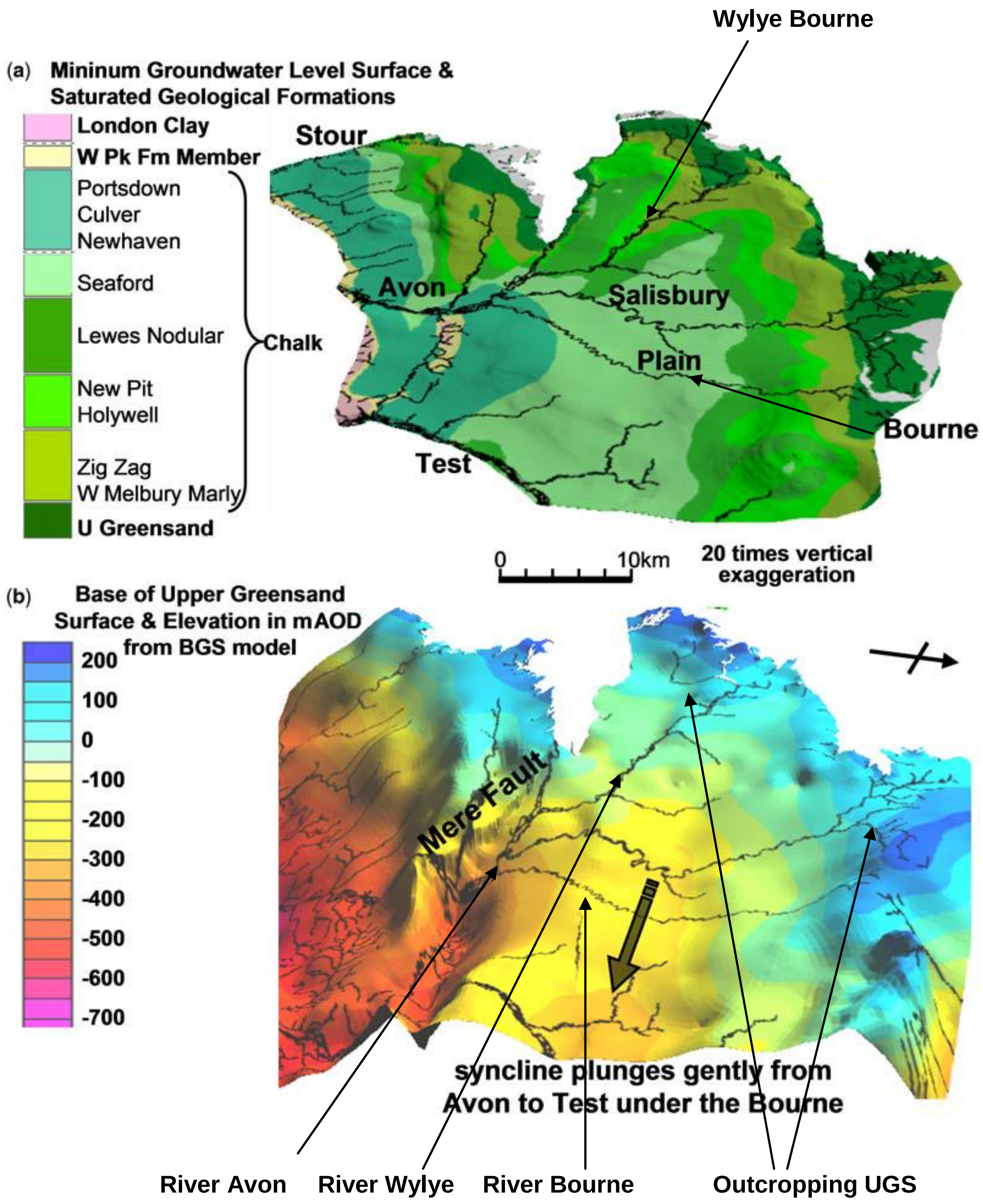
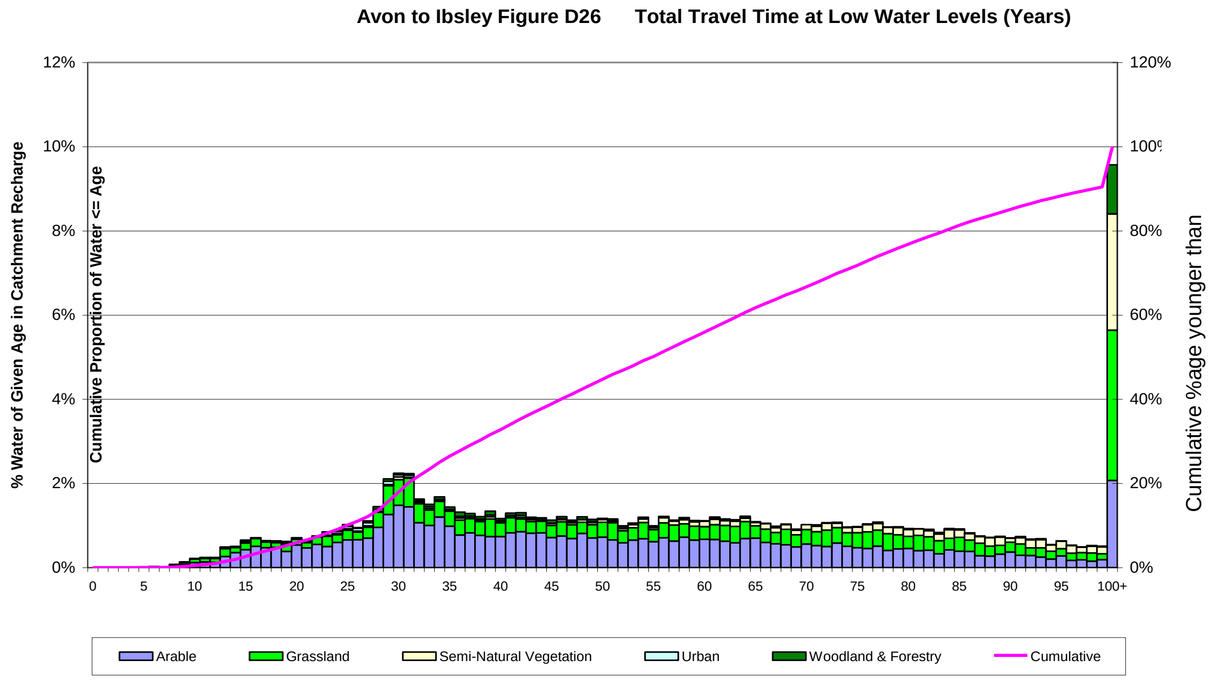


Figure 1.4 Average Age of Water in the Hampshire Avon to Ibsley (from nitrate trend modelling)



The geology is also important in influencing the movement of chemicals through the groundwater environment by influencing the mineralogy of recharging waters, Ph (acidity/alkalinity) and the oxygen content. 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 (Lapworth et al., 2011)[35]. 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's and Ph change (Section 3).

Therefore across much of the Avon catchment underlain or influenced by chalk and calcium rich mineralogy (Figure 1.3), chemical reactions occur in the subsurface help to remove or reduce the concentration of phosphorus in groundwater and discharged to surface waters.

Land use

The Avon catchment is rural in nature (Table 1a & 1b), with approximately 65% of the catchment used for intensive agriculture (arable and managed grazing) and 22-30% in lower intensity agriculture such as grazing and woodland.

Water quality is monitored at a number of sites and is directly influenced by discharges from large Sewage Treatment Works, Fish Farms and Water Cress discharges (Figure 1.5) and other discharges and releases to surface and groundwater.

Table 1a: Land Use Based on Agricultural Census 2010, with Urban Area from Land Cover Map 2007 and woodland, water and rough grazing adjusted 2010 data

(proportioned to account for difference in urban areas in census and LCM 2007 data sets)

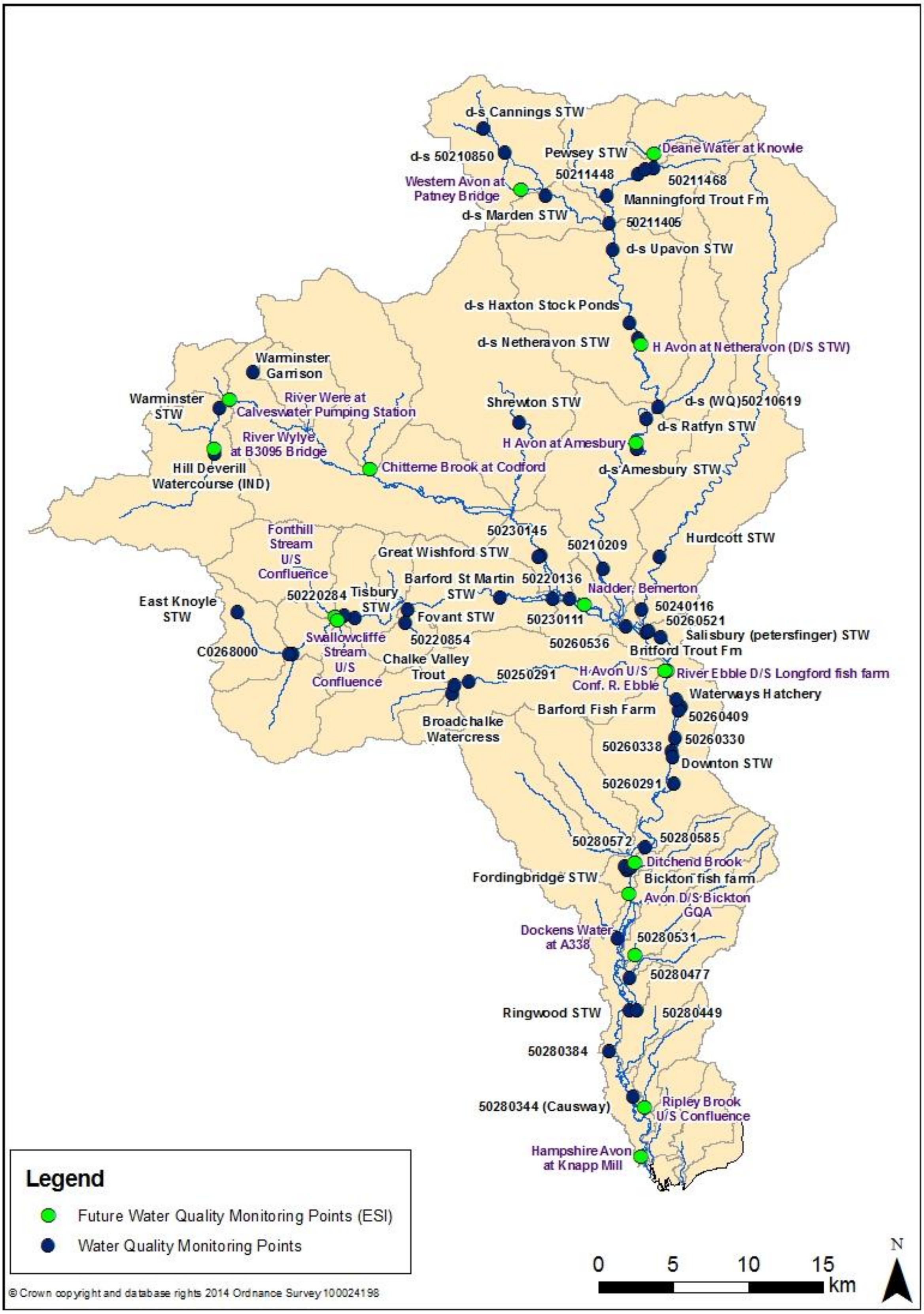
	Agri Census 2010		**LCM 2007**		**Adjusted Land Use**	
	Land Area (ha)	Percentage	Land Area (ha)			
Area of urban (ha) ADJUSTED: USING LCM 2007 DATA	19380	11%	5432	3%	5432	3%
Area of Water and Sea (ha)	1020	<1%	479	<1%	581	<1%
Area of woodland (ha) ADJUSTED: USING Agric Census 2010	19493	11%	21565	12%	26111	15%
Area of rough grazing (ha) ADJUSTED: USING Agricensus 2010	18987	11%	31548	18%	26111	15%
Area of arable (ha)	62375	37%	73529	42%	62375	36%
Area of grassland (ha)	49445	29%	40706	24%	49445	29%
Total	**170700**		**173259**		**170059**	

Table 1b: Land Use Based on Agricultural Census 2010, with Urban Area from Land Cover Map 2007 and woodland, water and rough grazing adjusted 2010 data (proportioned to account for difference in urban areas in census and LCM 2007 data sets)

Sub Catchment	Total Area (ha)	Area of urban (ha)	Area of water (ha)	Area of woodland (ha)	Area of rough grazing (ha)	Area of sea (ha)	Area of arable (ha)	Area of grassland (ha)
Upavon East	8544	179	13	1041	1101	0	3981	2228
Upavon West	8128	152	10	834	492	0	3772	2868
Upper Avon	21446	1085	13	1324	2616	0	9612	6796
Wylye	45736	824	76	4818	6880	0	16283	16855
Nadder	25359	574	58	5141	5438	0	8000	6148
Bourne	15298	727	2	1136	1951	0	8254	3229
Ebble	10281	100	15	652	1290	0	4852	3371
Lower Avon	35380	1791	394	11271	6342	13	7620	7948
Total	**170171**	**5432**	**581**	**26215**	**26111**	**12.88**	**62374.6**	**49444.98**

Sub Catchment	Total Area (ha)	Area of urban (ha)	Area of water (ha)	Area of woodland (ha)	Area of rough grazing (ha)	Area of sea (ha)	Area of arable (ha)	Area of grassland (ha)
Upavon East	8544.0	2.09%	0.16%	12.18%	12.89%	0.00%	46.60%	26.08%
Upavon West	8128.3	1.87%	0.12%	10.26%	6.05%	0.00%	46.41%	35.29%
Upper Avon	21445.9	5.06%	0.06%	6.17%	12.20%	0.00%	44.82%	31.69%
Wylye	45735.9	1.80%	0.17%	10.53%	15.04%	0.00%	35.60%	36.85%
Nadder	25359.1	2.26%	0.23%	20.27%	21.44%	0.00%	31.55%	24.25%
Bourne	15297.5	4.75%	0.01%	7.42%	12.75%	0.00%	53.95%	21.11%
Ebble	10281.0	0.97%	0.15%	6.34%	12.55%	0.00%	47.20%	32.79%
Lower Avon	35379.5	5.06%	1.11%	31.86%	17.93%	0.04%	21.54%	22.47%
Catchment Total	170171.2	3.19%	0.34%	15.41%	15.34%	0.01%	36.65%	29.06%

Figure 1.5 Monitoring Sites Used in the Report Interpretation (2013)



1.3 Progress to Date in Achieving Phosphorus Load Reduction across the Hampshire Avon

Substantial (c80 tonnes P/yr) reductions in stream ortho-phosphate concentrations have been achieved through the installation of phosphate removal at 17 of the largest water company Sewage Treatment Works (STW) in the Avon from the year 2000 and one MOD discharge at Warminster Garrison. Treatment on the 7 STW that were thought to have the greatest impacts on water quality were undertaken under AMP3. Treatment on the remainder of sites was completed under AMP 4 (Section 2.3.2). Changes under PR14 are anticipated to reduce point source loads further, by c 0.9tonnes P/yr in compared to 2011.

Differential permit limits at a number of large Fish Farms and Water Cress Farmers were also tightened following the Review of Consents (Section 2.3.2).

Diffuse phosphorus loads have also been reduced through the implementation of measures by Catchment Sensitive Farming initiatives (c 1 tonne P/yr, Section 2.3.3)

Further details relating to these improvements are outlined in Section 2 & 3.

1.4 Phosphorus Definitions

Phosphorus: Haygarth and Sharpley (2000) discuss in detail the subject of environmental phosphorus terminology including presentation of a new classification of terms. For the purposes of simplicity, this study uses the terms and abbreviations summarised below, in the same form as these are discussed in individual references.

Term	Abbreviation in use
Total Phosphorus	TP
Orthophoshate	OP
Particulate Phosphorus	PP
Dissolved Phosphorus, comprising:	DP
Bio available Phosphorus	BAP
Soluble Reactive Phosphorus	SRP
Soluble Unreactive Phosphorus	SUP
Olsen P; Concentration of available P in soil	Olsen P

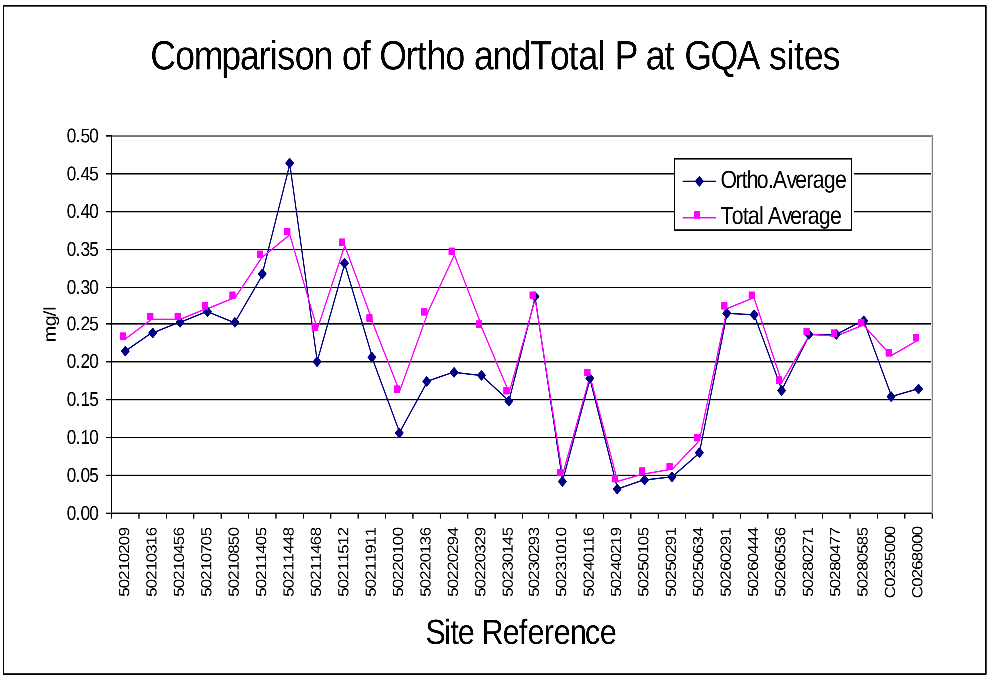
Phosphorus is analysed and reported as micro-grams per litre (ug/l) or milligrams per litre (mg/l). They are reported by the Environment Agency for groundwater as “Orthophosphate (OP), reactive as P” in and “Phosphate: - {TIP}” referring to Total Inorganic Phosphate in mg/l. Surface water is also measured by the Environment Agency as “Orthophosphate, reactive as P”. Wessex Water analysed and reported phosphorus data for surface water as total phosphorus, total dissolved phosphorus and soluble reactive phosphorus), and groundwater as orthophosphate as P [3].

For the purposes of this TECHNICAL DOCUMENT, soluble reactive phosphorus (SRP) and Dissolved phosphorus are taken as equivalent to Orthophosphate (OP). This is accepted

convention in studies of nutrients in freshwater systems. OP plus Particulate Phosphorus is taken to be equivalent to Total Phosphorus (TP).
Where analysis of water quality samples has given concentrations below the limits of detection, the approach has been to assume a concentration of half of the minimum value, i.e. if the limit of detection is 0.02mg/l, the concentration for that sample has been assumed as 0.01mg/l.

A comparison between TP and orth-p (SRP) at GQA sampling points in the Hampshire Avon was carried out by Ash et al (2006) and is replicated in Figure 1.4:1. The comparison is of mean values, typically involving approximately 100 ortho-p samples. The total P samples were usually less in number; where there are less than 20 Total P samples, the site is ignored. In general the two profiles follow each other; the group of sites where the two profiles diverge (in the middle of the graph) are in the Nadder catchment.

Figure 1.4:1. Comparison of ortho- and total-P at GQA sites (from Ash etal



2008).

Amec analysis of water quality data in sub catchments in the Avon[29], identified that OP represented 83% and 91% of TP in the Bourne and the Wylye, but only 57% of that in the Ebble. This is reflective of a higher PP in the Ebble as observed by Stromqvist etal (2008) with elevated suspended sediment loads.

Wessex Water reporting of phosphorus loads in their STW in the Avon shows a large difference in recorded value of TP and OP (Appendix 2.3.2.1). Salisbury STW had a "Crude Total Phosphorus Concentration of 6.9 mg P/L and an OP of 4.7 mg P/l. Measured Average Effluent TP was 0.56 mg P/l and OP of 0.28 mg P/l (Appendix 2.3.2:1). Here OP was 68 % and 50% of TP. Again the main reason for this larger variance within STW is likely to be the increase PP element; however it is surprising that the variance between the two values was greater post settlement in the effluent rather than load prior to treatment.

In some parts of the catchment where lower suspended sediments and so PP are observed, OP and TP can almost be considered to be comparable as indicated by Ash etal[23], but for many other parts of the catchment there is a significant difference between these loads.

Other definitions are outlined in the appropriate section of this report or Glossary (Section 8.0)

1.5 Modelling Approaches & Assumptions

1.5.1 Water Quality

Water Quality data outlined in this report are calculated at a specific gauge or at the downstream end of any water body.

Different approaches have been used to model observed flow and quality data and separate the various sources of phosphorus. The Agency SIMCAT model (as described in Ash et al (2008)[23]) was used to replicate average annual flow and water quality along the Avon. The EA SIMCAT model includes the point sources that make up 98% of the original point source load, prior to Phosphorus stripping being installed[23]. Discharges of <50m3/d are not directly included in the EA SIMCAT model, but these contribute less than 2% of the original point source load.

The difference in river concentration at any point in the model between the observed (or calibrated SIMCAT) concentration and the concentration that can be calculated from the upstream point sources discharges, is ascribed to the diffuse load [which includes small discharges (<50m^3/d)]. The SIMCAT model does not break this diffuse load down into relative sources.

To achieve a suitable calibration, the SIMCAT [model] also includes an in river "decay factor" which coarsely replicates phosphorus losses down the river system from natural uptake of phosphorus from plants, precipitation from chemical reactions (such as could occur with mixing of iron rich waters). The decay rate is in units of recipricol days and the equation used is detailed below.

So $\boldsymbol{C}(\boldsymbol{t}) = \boldsymbol{C_0} * \boldsymbol{e}^{-0.1*days}$

To find what the concentration is a given distance from input, you need to know the velocity. SIMCAT uses a default of 0.4m/s or 33km/day

So $\boldsymbol{C}(\boldsymbol{x}) = \boldsymbol{C_0} * \boldsymbol{e}^{-0.1*\frac{x}{33}}$

x = distance in km.
C= concentration
C0= concentration at the start time 0
e= Exponential function
t= time in days

As an example

Example 1:

The decay modelled along the Hampshire Avon (c74km), assuming a starting concentration of 100ug/l would be:

C(75km) $= 100 * \boldsymbol{e}^{-\mathbf{0.1} * \frac{\mathbf{75}}{\mathbf{33}}}$

$= 100 * \boldsymbol{e}^{-\mathbf{0}.23}$

=80ug/l

A decay of 100-80= 20ug/l

Example 2:

decay after 1 days travel time:

C(33km) $= 100 * \boldsymbol{e}^{-\mathbf{0.1} * \frac{\mathbf{33}}{\mathbf{33}}}$

$= 100 * \boldsymbol{e}^{-\mathbf{0}.1}$

=90 ug/l

Discharge quality in SIMCAT is modelled as TP. The difference in OP and TP is considered to be small (c3% Ash etal).

The SIMCAT model originally described in Ash et al (2008)[23] was updated and re-calibrated against river flow and quality for 2010-11. This is a period of time after P stripping had been installed and was in operation at the majority of WW STW. The SIMCAT model was then further updated in 2012-13 with Long Term Average (LTA) river flow data and used to forecast likely river quality under LTA flow conditions (Runs 2a to 2c).

Results from the two SIMCAT models were compared, to identify the differences between 2010-11 and LTA flows to determine which SIMCAT model period should be used for the TECHNICAL ASSESSMENT.

When LTA and 2010-11 flows are compared (Figures 1.5.1:1-2), low flows represented by the Q95ile flows are within around 10% of each other. LTA mean flows in contrast are 20-30% higher. 2010-11 is therefore noted to be a drier year and diffuse phosphorus loads during this year are likely to be lower than would have been observed during wetter years (reflected under LTA statistics).

Data from 2010-11 has however primarily be used in the NMP because it was based on observed flow and quality during this specific year and reflects a period of time after which all major phosphorus stripping has been installed. Results found in Murdoch (2011)[7] paper was also based on 2010-11 results from this model, but in the updated runs undertaken for the NMP, some refinement of input data has been undertaken and results will not match exactly. The changes made to the model include increasing the modelled input water quality for fish farms and water cress farms from 10ug/l to 40-70ug/l P, based on observed water quality. This has resulted in change to modelled water quality and so the results of the NMP and the paper are not identical across the Avon.

Scenario results as described in Section 2.3.2 were then undertaken to assess the loading from different sources across the Avon.

Figure 1.5.1:1: Comparison of Mean Long Term Average Flow in the Avon and Flow Data 2010-11 used in Murdoch2011[7] [flow in million litres per day (ml/d)]

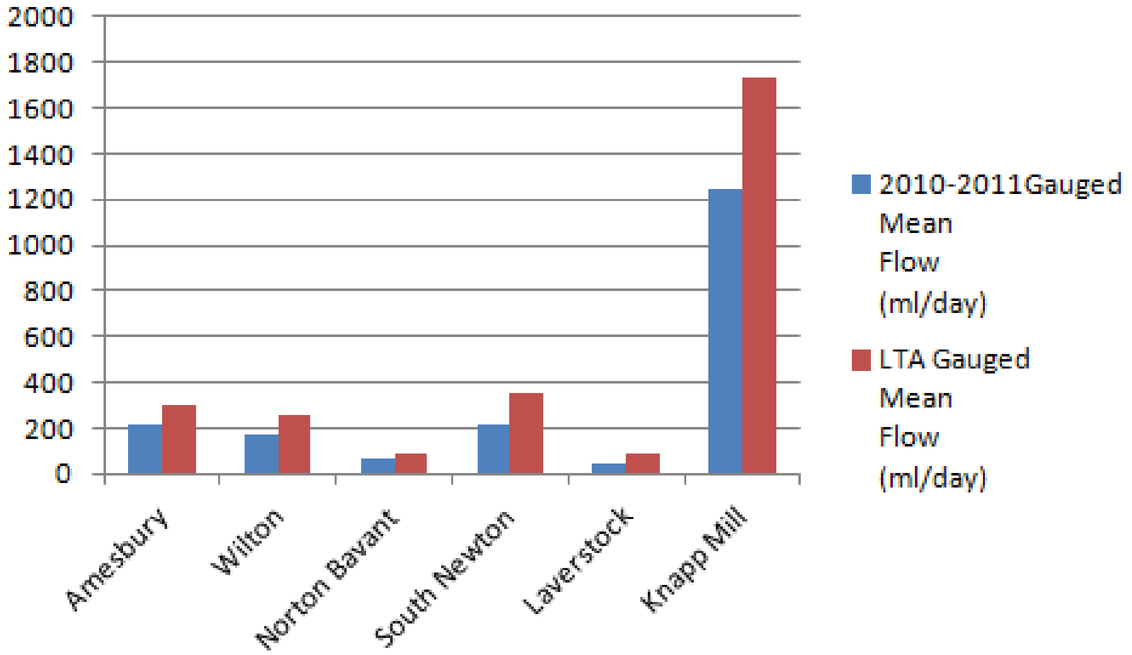


Figure 1.5.1:2 Comparison of Low Flows (Q95) Long Term Average Flow in the Avon and Flow Data 2010-11 used in Murdoch2011[7] [flow in million litres per day(ml/d)]

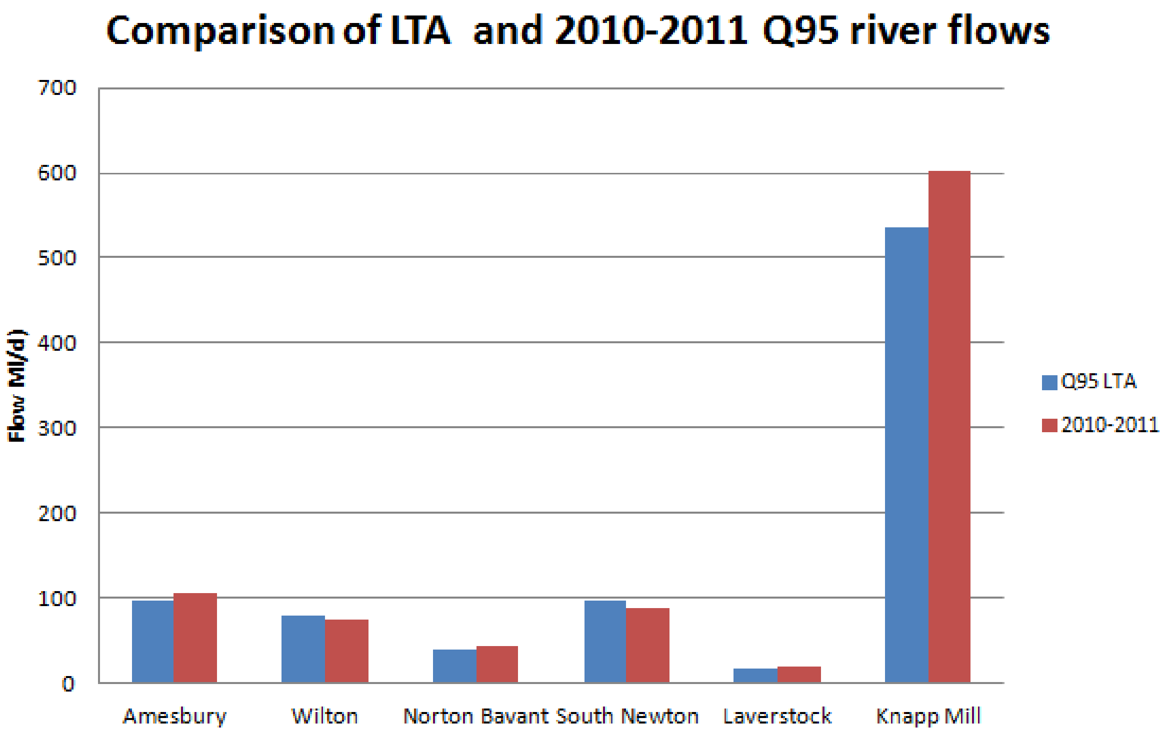
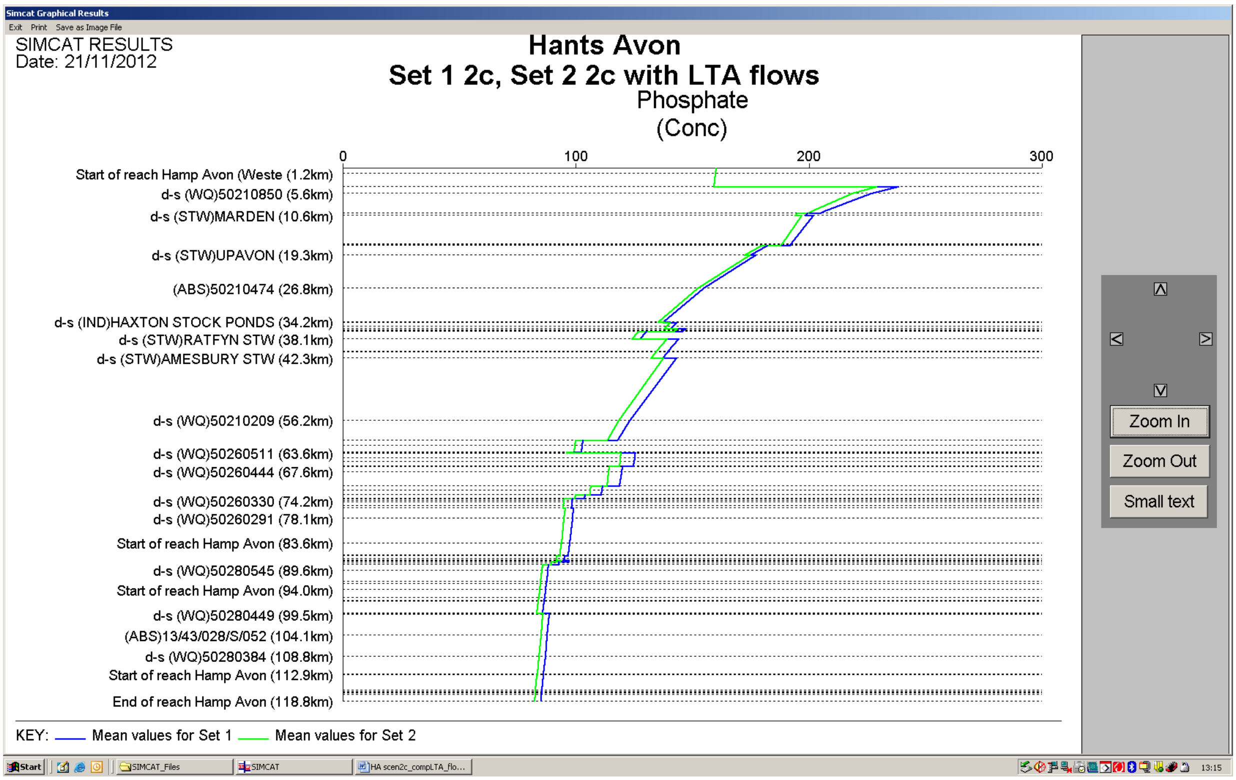


Figure 1.5.1:3 Comparison of SIMCAT Water Quality Model Results Using LTA flow data (Set 2) & 2010-11 data (Set 1), used in Murdoch2011[7]



1.5.2 Water Quantity

Whilst undertaking work on the NMP, it was also necessary to be able to understand and calculate across the Avon and through time, the river baseflow component derived from the Chalk and Upper Greensand aquifers during average high and low flows. This allowed some assessment of influence each aquifer has on water quality across the Avon and its tributaries to be made (Section 2.3.1).

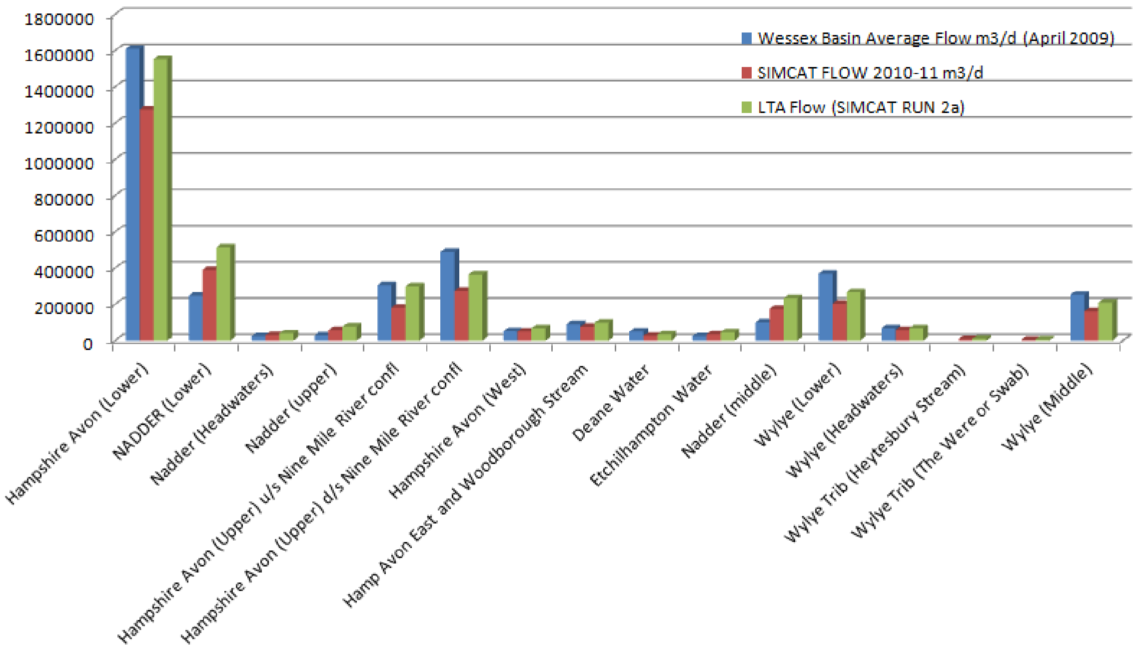
The hydrological system (from rainfall, recharge through to surface and groundwater flow) were extensively conceptually modelled by the Environment Agency and Wessex Water from 2002 to 2014[31 & 32]. A numerical groundwater model [the Wessex Basin Groundwater Model (WBGM)] was developed to replicate these processes, modelling rainfall recharge across the catchment and its influence on surface and groundwater levels and flows at a spatial resolution of 250m grid and temporal resolution of 10 day time steps from 1970-March 2014.

The model covers the whole of the Wessex Basin, including the Hampshire Avon, Frome and Piddle (and tributaries), in three dimensions. The chalk and upper greensand aquifers are modelled as separate layers within the model and their relative contribution to surface waters can be calculated along the river. The WBGM is one of the best calibrated groundwater flow models across the country and has been used to make major water resource management decisions under Review of Consents 2010.

For the NMP, output from this model has been used to identify along each 250m stream cell across the Avon, the groundwater contribution from the Chalk and Upper Greensand aquifer to the river during a time step that reflects high, average and low groundwater level and flow periods. These are February 1995 (time step 1086), April 2009 (1595) and August 2003 (1391) respectively.

A comparison of the WBGM forecast average flow to Long Term Average Flows and to 2010-11, the year used in later source apportionment calculations is shown in Figure 2.3.1a

Figure 1.5.2:1 Average River Flow Comparison from Wessex Basin Groundwater Model, Long Term Average Flow predicted from analysis of flow records and average flow for the year 2010-11



Results from this show that WBGM average and LTA flow data are similar but that average flow in 2010-11 was lower than LTA and so reflective of a drier year/conditions.

1.5.3 Diffuse Agricultural Loading

The export of phosphorus to surface waters from agricultural land were estimated for water bodies within the Avon using the Phosphorus Indicator Tool (PIT) (Heathwaite et all 2003) and using Agricultural Census 2010 data. The reader is referred to that paper for full details of the model and Section 5 of the Environment Agency Wessex Phosphorus Investigations report[17].

Improvements in water quality that would result from the implementation of pollution reduction measures were estimated by multiplying baseline diffuse loads calculated using PIT and SIMCAT approach, with the percentage reduction in pollution estimated for a suite of measures, estimated by the Environment Agency Catchment Change Matrix. The details of this approach are further discussed in Section 3.2.

A comparison of these results was then made to an estimate of the diffuse load reduction that could be achieved by similar diffuse pollution reduction measures estimated using ADAS, Farm Scale Optimisation of Pollution Emissions Reductions (FARMSCOPER) tool[35]. Result from this presented in Sections 3 & 4.

2.0 IMPACT OF PHOSPHORUS ON OBJECTIVE STANDARDS AND COMPLIANCE ACROSS THE AVON.

Standards are required on water quality and biology to determine compliance with legislative drivers on the water environment and designated conservation sites. The main drivers are requirements in the Water Framework Directive to achieve 'Good status' as defined in the Directive, and requirements in this Directive and the Habitats Directive for the River Avon, as a Protected Area (SAC), to achieve the site's conservation objective standards for favourable conservation status. The standards are different. Those for the SAC are generally more stringent reflecting its status as being a 'special area' for the designated habitat and species interest features and the meaning given to favourable conservation status defined in the Habitats Directive.

2.1 WFD and Protected Area/SAC objective standards

2.1.1 WFD class standards

Class standards for phosphorus in rivers under the WFD are being revised (DEFRA, 2014) and are expected to be applied in updated River Basin Management Plan (RBMP2). The UK Technical Advisory Group (2013) found the statutory standards set by government in 2009 (HMSO, 2009) were not sufficiently stringent. In 75% of rivers with clear ecological impacts of nutrient enrichment, these standards placed the rivers in Good or even High class for phosphorus concentrations. The 2009 standard for Good class on much of the River Avon system was ≤120 µg/l soluble reactive phosphorus as an annual average; that for High class was ≤50µg/l.

The revision takes account of the latest scientific evidence on the effect of phosphorus concentrations on plant communities. Class standards are calculated using information that is specific to particular conditions at each water quality monitoring site in a river waterbody, especially alkalinity and altitude.

The revised boundary values for High and Good class for the water bodies covering the River Avon SAC are given in table 2.1:1. These are applied as an annual average.

2.1.2 SAC conservation objective standards

Conservation objective standards for phosphorus in designated rivers (SSSIs and SACs) have also been revised (JNCC, 2014)[36]. This revision again takes into account recent scientific knowledge on relationships between ecological responses to nutrient enrichment and phosphorus concentrations. The standards prior to this revision were 60 µg/l soluble reactive phosphorus on chalk rivers, 100 µg/l on the lowland type river below Fordingbridge and 40 µg/l on the Dockens Water and upper Till tributary.

The revised standards for designated rivers were derived using a slightly different methodology to those used for WFD, and take into account river flow size as well as alkalinity type and altitude. More stringent standards are set for rivers that are at or close to a near-natural state compared with those in catchments where much of the land is utilised for agriculture and development. Table 2.1:1 gives the revised standards for both the SAC and SSSI only rivers by WFD water body. The SAC/SSSI standards mostly lie near the top of the WFD Good class range. Some near-natural rivers form parts of the River Avon SAC are SSSI only. The designated sites standard for these rivers lies within WFD High class. SAC/SSSI standards are applied as an annual average and also as a growing season average to cover separately the period when the ecological response to nutrient enrichment is stronger.

The WFD and SAC standards for phosphorus are based on ecological response against reference (near-natural) conditions. They do not include consideration of catchment geologies that can contain deposits with high natural phosphorus content (Section 4 Common Standards Monitoring Guidance JNCC[36]). Such deposits can naturally elevate the phosphorus concentration of ground and possibly also surface water that discharges to the river system, referenced in this document as modelled background (Section 2.3.1). In the Avon catchment phosphorus rich deposits occur in the Upper Greensand geology and some layers in the Lower Chalk can also be more phosphorus rich. The near-natural (reference) condition of rivers in catchments influenced by phosphorus rich geologies is presently unknown and requires more research. Other environmental factors probably operate alongside phosphorus in near-natural rivers helping to ameliorate the ecological response to elevated nutrient concentrations. These factors include shade and the role of sediment. There is ongoing research on this matter.

As scientific knowledge increases the WFD and SAC standards on phosphorus may be further revised to account for additional local factors affecting ecological response to nutrient enrichment, such as a background phosphorus rich geology. This could include a combination of a phosphorus standard with standards for other factors affecting ecological response. There is presently insufficient evidence of a robust nature to determine any local refinement of the standards for the Avon river system. In the interim, the standards for water bodies draining naturally phosphorus rich geologies should be treated with caution. The background phosphorus concentration in drainage to the Avon river system is considered in more detail in Section 2.3.1 and recommendations of this report are that further refinement of phosphorus standards should be undertaken necessary to deliver favourable status in a natural phosphate environment.

Table 2.1:1 WFD class boundary standards and Protected Area/SAC and SSSI standards for phosphorus in the SAC/SSSI designated length of the River Avon system by WFD water body.

Water Bodies	Reported as annual mean of soluble reactive phosphorus (µg per litre) at sampling site at the downstream end of each waterbody			Assessed as annual and growing season means (March-September) of reactive phosphorus (µg per litre) for latest 3 year period along length of waterbody	
Listed D/S to US	WFD High/Good class boundary	WFD Good/Moderate class boundary	WFD Moderate/Poor	SAC standard for favourable condition	SAC near-natural standard for favourable condition
Hampshire Avon (Lower)	52	93	219	50	
Dockens Water	17	37	107		15
Nadder (Lower)	Not available	Not available		50	
Nadder (Middle)	42	78	193	50	
Wylye (Lower)	44	81	197	50	
Wylye (Middle)	42	78	190	50	
Wylye (Headwaters)	35	66	169	50	
Till Tributary - lower	43	79	194		20
Till Tributary - upper			194		30
Hampshire Avon (u/s Nine Mile River)	45	83	201	50	
Hampshire Avon (d/s Nine Mile River)	43	79	193	50	
Nine Mile River [1]	40	75	186		20
Bourne	45	82		50	
Hampshire Avon (West) [2]	40	75		50	
Additional Water Bodies Outside SAC					
Fonthill Streams	38	71	178	NA	NA
Nadder Headwaters	45	66	169	NA	NA
Hampshire Avon (West)	40	75	185	NA	NA
Hampshire Avon (East)	40	74	184	NA	NA

Soluble reactive phosphorus is usually measured as orthophosphorus.[1]. The Nine Mile River is designated only along its upper reach as river SSSI and lies in Salisbury Plain SSSI and SAC [2]. The Hampshire Avon West tributary is designated as river SSSI only and extends upstream from the head of the River Avon SAC.

2.1.3 Compliance with WFD and Protected Area/SAC standards

Compliance with the standards for river phosphorus has been assessed along the River Avon system for the three year period 2011 to 2013 (Figure 1.1). WFD class is normally reported on an annual basis using 3 years of data to allow a comparison of compliance with the SAC/SSSI standards.

The period included very wet weather in summer 2012 and at the end of 2013. This affected river orthophosphorus concentrations; there were noticeable increases on some rivers compared with earlier three year periods from 2009. Where comparable data were available, on headwaters there was an increase in concentrations on 11 Avon catchment water bodies and a decrease within 7 water bodies. In contrast, on the spine River Avon and main spine tributaries there was an increase on only one water body (Ebble) and decrease on 4 water bodies.

Table 2.1:2 shows the assessment results and compliance of each water body covered by the SAC or SSSI against WFD classes and the SAC/SSSI conservation objective standards. The results show compliance with WFD Good class in lower water bodies and also the Bourne. A few tributaries achieve High class (Dockens Water, Till and Nine Mile River). Non-compliance with Good status occurs on the whole of the Nadder in the SAC, the Middle and Headwater Wylye, and on the Avon upstream from the Nine Mile River. At some water bodies the scale of non-compliance is considerable, notably so on the Wylye and Hampshire Avon West. In these catchments both natural geological sources of phosphorus and anthropogenic sources are involved.

Only the lower Till is fully complied with the more stringent SAC/SSSI standards. The Bourne came close to full compliance. The Dockens Water fully complied with the near-natural standard in the earlier 2009-11 period but the annual mean concentration increased in the 2011-13 period (15 µg/l to 29 µg/l) and the growing season mean increased even more (14 µg/l to 44 µg/l). Parts of the spine river Avon and Lower Wylye came close to compliance (within 10 µ/l) during the growing season. This may be due to uptake of soluble phosphorus by the biology and lower input from the upstream catchment.

Table 2.1:2. Mean of observed orthophosphate concentrations in the SAC/SSSI designated length of the River Avon system by WFD water body for the three year period 2011-2013 (See Also Figure 1.1), and compliance with WFD class standards and SAC/SSSI conservation objective standards.

Waterbody (listed in d/s to u/s order along spine river)	Annual mean concentration at sampling site nearest bottom of water body (µg/l)	Mean concentration range at sampling sites along water body	
		Annual	Growing season
Hampshire Avon (Lower)	82	68-104	Not available
Dockens Water	29	29	44
Nadder (Lower)	72	72	Not available
Nadder (Middle)	91	91-120	Not available
Wylye (Lower)	73	64-73	52-61
Wylye (Middle)	155	149-155	Not available
Wylye (Headwaters)	113	90-113	
Till Tributary – lower [1]	26	26	15
Till Tributary - upper		Not available	Not available
Hampshire Avon (to near Nine Mile River)	70	70	57
Hampshire Avon (from d/s Nine Mile River)	98	98-129	81-118
Nine Mile River	18	na	Not available
Bourne	57	57	49
Hampshire Avon (West)	243	243-299	Not available
WFD class	High	Good	Moderate
	Poor	Bad	
Protected Area/SSSI compliance	Favourable	Unfavourable	

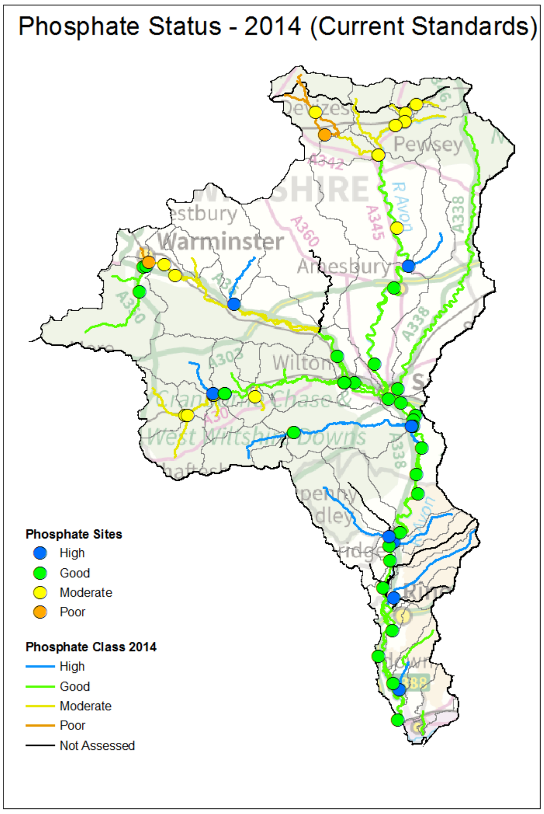
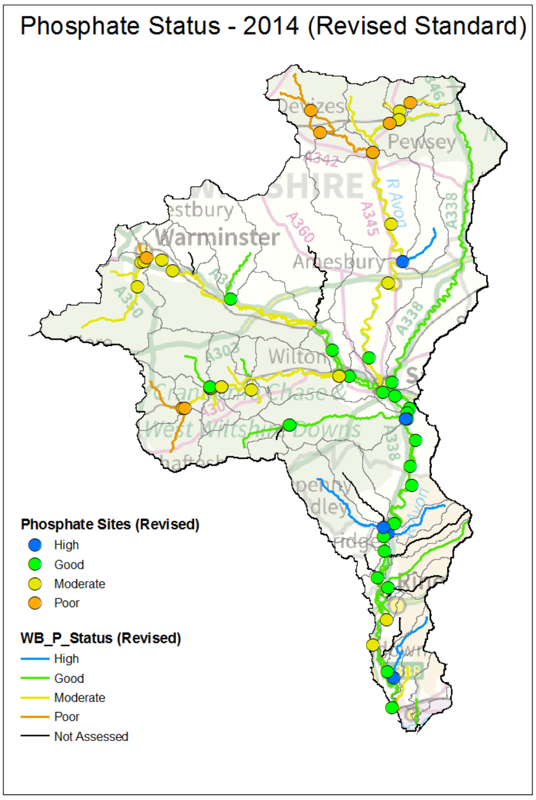
[1]. Inadequate data for 2011-2013. Mean values for 2009-2011 given. .na: Not available. No sampling point on water body in SAC/SSSI water body; analysis not undertaken for growing season mean on some water bodies.

The expected WFD compliance in 2021 at the end of the next RBMP cycle is outlined in Table 2.1:3 and discussion about future targets in the Avon in Section 2.3.1.1.

Table 2.1:3 Expected WFD Chemical Status 2021 under RBMP2

WB Name	WB ID	WB Name	Class Item Name	Status	Year
Ripley Brook	GB108043011010	Ripley Brook	Phosphate	High	2021
Clockhouse Stream	GB108043011011	Clockhouse Stream	Phosphate	NA	2021
Bisterne Stream	GB108043011012	Bisterne Stream	Phosphate	NA	2021
Mude	GB108043011020	Mude	Phosphate	Good	2021
Linford Brook	GB108043015720	Linford Brook	Phosphate	High	2021
Sleep Brook	GB108043015730	Sleep Brook	Phosphate	High	2021
Dockens Water	GB108043015740	Dockens Water	Phosphate	Good	2021
Huckles Brook	GB108043015750	Huckles Brook	Phosphate	High	2021
Ditchend Brook	GB108043015770	Ditchend Brook	Phosphate	High	2021
Ashford Water (Allen River)	GB108043015800	Ashford Water (Allen River)	Phosphate	High	2021
Sweatfords Water	GB108043015810	Sweatfords Water	Phosphate	High	2021
Ebble	GB108043015830	Ebble	Phosphate	Good	2021
Hampshire Avon (Lower)	GB108043015840	Hampshire Avon (Lower)	Phosphate	Good	2021
Ebble Trib (Chalke Valley Stream)	GB108043015860	Ebble Trib (Chalke Valley Stream)	Phosphate	Good	2021
Ebble (Upper)	GB108043015870	Ebble (Upper)	Phosphate	Good	2021
Nadder (Lower)	GB108043015880	Nadder (Lower)	Phosphate	Good	2021
Nadder (Headwaters)	GB108043016160	Nadder (Headwaters)	Phosphate	Moderate	2021
Nadder Trib (Swallowcliffe)	GB108043016180	Nadder Trib (Swallowcliffe)	Phosphate	Moderate	2021
Fovant Brook	GB108043016190	Fovant Brook	Phosphate	Moderate	2021
Nadder (Upper)	GB108043016200	Nadder (Upper)	Phosphate	Moderate	2021
Sem	GB108043016210	Sem	Phosphate	Moderate	2021
Hampshire Avon (Upper) u/s Nine Mile River confl	GB108043022351	Hampshire Avon (Upper) u/s Nine Mile River confl	Phosphate	NA	2021
Hampshire Avon (Upper) d/s Nine Mile River confl	GB108043022352	Hampshire Avon (Upper) d/s Nine Mile River confl	Phosphate	Good	2021
Nine Mile River	GB108043022360	Nine Mile River	Phosphate	High	2021
Hampshire Avon (West)	GB108043022370	Hampshire Avon (West)	Phosphate	Moderate	2021
Bourne (Hampshire Avon)	GB108043022390	Bourne (Hampshire Avon)	Phosphate	Good	2021
Hampshire Avon (East) and Woodborough Stream	GB108043022410	Hampshire Avon (East) and Woodborough Stream	Phosphate	Moderate	2021
Deane Water	GB108043022420	Deane Water	Phosphate	Moderate	2021
Etchilhampton Water	GB108043022430	Etchilhampton Water	Phosphate	Moderate	2021
Nadder (Middle)	GB108043022470	Nadder (Middle)	Phosphate	Moderate	2021
Teffont	GB108043022471	Teffont	Phosphate	NA	2021
Fonthill Stream	GB108043022500	Fonthill Stream	Phosphate	High	2021
Wylye (Lower)	GB108043022510	Wylye (Lower)	Phosphate	Good	2021
Wylye (Headwaters)	GB108043022520	Wylye (Headwaters)	Phosphate	Good	2021
Wylye Trib (Heytesbury Stream)	GB108043022530	Wylye Trib (Heytesbury Stream)	Phosphate	High	2021
Wylye Trib (The Were or Swab)	GB108043022540	Wylye Trib (The Were or Swab)	Phosphate	Moderate	2021
Wylye (Middle)	GB108043022550	Wylye (Middle)	Phosphate	Good	2021
Chitterne Brook	GB108043022560	Chitterne Brook	Phosphate	High	2021
Till (Hampshire Avon)	GB108043022570	Till (Hampshire Avon)	Phosphate	High	2021

Figure 2.1:1 a & b Hampshire Avon WFD Phosphorus Status 2014 using existing and Revised Standards

2014 Current Standards	2014 Revised Standards
	

2.2 Biological status

2.2.1 WFD class standards

Biological class refers to the WFD class of the plant and algal communities as assessed using standard WFD methodologies.

Macrophytes are the most reliable element for assessing nutrient impacts for WFD in high alkalinity rivers such as the Hampshire Avon (which is predominantly fed by chalk aquifer in much of the catchment, whilst diatoms are used in low alkalinity rivers (New Forest Streams).

Excess nutrients can impact upon macrophytes and diatoms by causing an imbalance (changes to diversity & abundance) in community composition. The resultant macrophyte/diatom community will be different to that expected under reference (ie. Un-impacted) conditions. Some species are more sensitive to high nutrients than others, Where impacts are severe this may result in the macrophyte community being dominated by filamentous algae.

Under the WFD, a waterbody achieving good status would have a plant/diatom community only slightly deviating from reference conditions. It is not possible to give an exact composition of 'good status' communities in the Hampshire Avon as WFD uses several indices to determine status (number of functional groups, algal cover and a nutrient index). 'Good status' would also vary according to distance from source, alkalinity and gradient. Species typical of a chalk stream would be expected such as Water Crowfoot, Lesser Water Parsnip and Water Starwort (Callitriche).

WFD ‘status investigations’ have been completed to confirm whether the ecology is failing to achieve good status, the likely cause of these failures and measures required to achieve good status.

The level of confidence of a water body being at less than good status or achieving good status is assigned the following definitions:

- >95% confidence in face value class = very certain
- 75-95%=quite certain
- <75%=uncertain.

The following is a summary of the available ecological data for the Avon up to Dec 2013. This is refined in Table 2.2.1 and detailed in Figure 2:2:1.

- Macrophytes are failing to achieve WFD good status (very certain) widely within the catchment (on Hampshire Avon East and West, Wylye and up stream of Nadder Middle catchment and the Lower Avon).
- Macrophtes have been found to achieve good status on the Nadder Middle, Chitterne Brook, Nine Mile River, Ebble and some of the New Forest streams.
- On the New Forest streams diatoms have been found to achieve at least good status on the Ditchend and Ripley Brooks. The achievement of good status is less certain on other
- Diatoms on the Ditchend, Dockens and Ripley Brook are currently achieving good status.

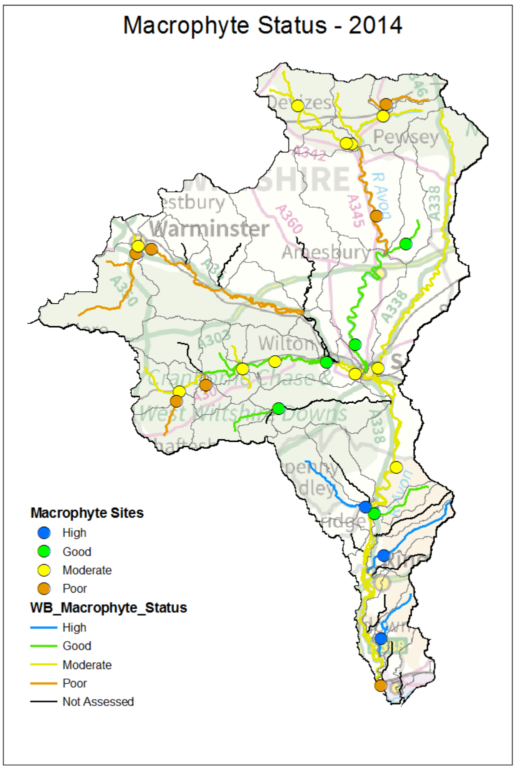
Table 2.2.1: 2014 Macrophyte and Diatom Status of the Hampshire Avon and Tributaries

		WFD Waterbodies	Macrophytes*	Diatoms**
1	Upavon East	1. Hampshire Avon (East) & Woodborough Stream 2. Deane Water	1. Less than Good (Quite Certain) 2. Less than Good (Very Certain)	Not assessed
2	Upavon West	1. Etchilhampton Water 2. Hampshire Avon (West)	1. Less than Good (Very Certain) 2. Less than Good (Very Certain)	Good
3	Middle Avon	1. Hampshire Avon (Lower)	Less than Good (Very Certain)	Not assessed
4	Nine Mile Bourne	1. Nine Mile River 2. Bourne	1. Good Status 2. Less than Good (Uncertain)	Not assessed Not assessed
5	Wylye	1. Wylye (Headwaters) 2. Wylye (Middle) 3. Heytesbury Stream 4. The Were 5. Chitterne Brook 6. Till 7. Wylye (Lower)	1. Less than Good(Very Certain) 2. Less than Good (Very Certain) 3. Not assessed 4. Less than Good (Very Certain) 5. Good 6. Not assessed 7. Not assessed	1-4 Not assessed 5. Good 6-7. Not assessed
6	Nadder	1. Sem 2. Nadder (Headwaters) 3. Nadder (Upper) 4. Nadder (Middle)	1. Less than Good (Very Certain) 2. Less than Good (Very Certain) 3. Less than Good (Quite Certain) 4. Good Status	1. Not assessed 2. Not assessed 3. Not assessed 4. Not assessed
7	Ebble	1. Ebble (Lower) 2. Ebble (Upper)	1. Not assessed 2. Good	Not assessed
8	Lower Avon	1. Hampshire Avon (Lower) 2. Linford Brook 3. Ditchend Brook 4. Huckles Brook 5. Dockens Water 6. Ripley Brook	1. Less than Good (Very Certain) 2. Not assessed 3. Good Status 4. Not assessed 5. High Status 6. High Status	1. Not assessed 2. High Status 3. Good Status 4. High Status 5. Less than Good (Uncertain) 6. High Status

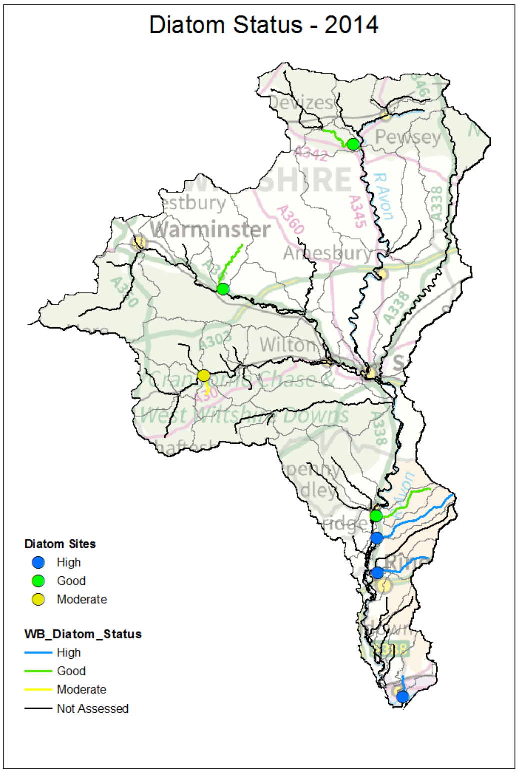
*This assessment has been produced using the revised macrophyte classification tool LEAFPACS 2
**This assessment has been produced using the revised diatom tool DARLEQ2.
*** In high alkalinity lowland rivers, macrophytes are considered to be the most important biological component with which to judge eutrophication impacts (EA Internal Guidance note v1.2, May 2011).

Figure 2.2:1 Macrophyte and Diatom Status across the Avon 2007 to 2014

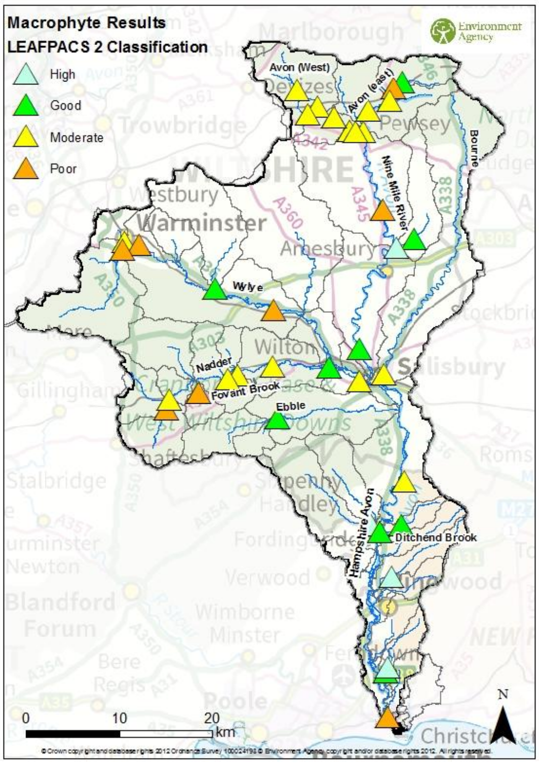
Macrophyte Status 2014



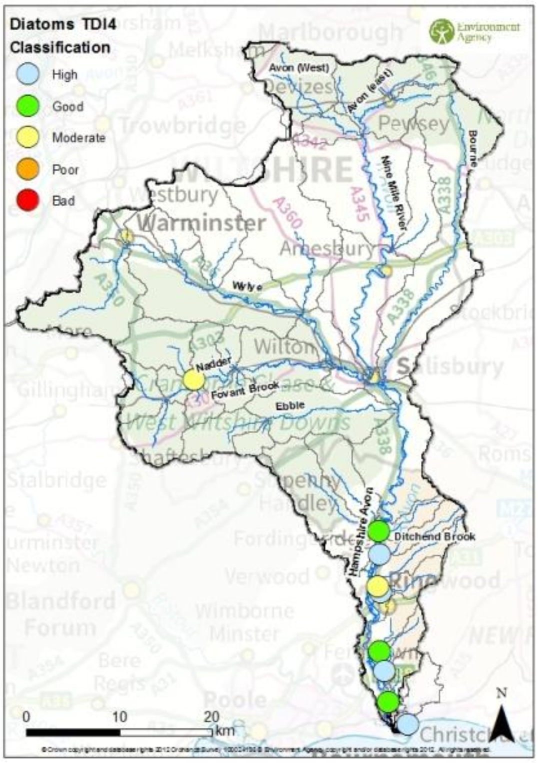
Diatom Status 2014 DARLEQ 2



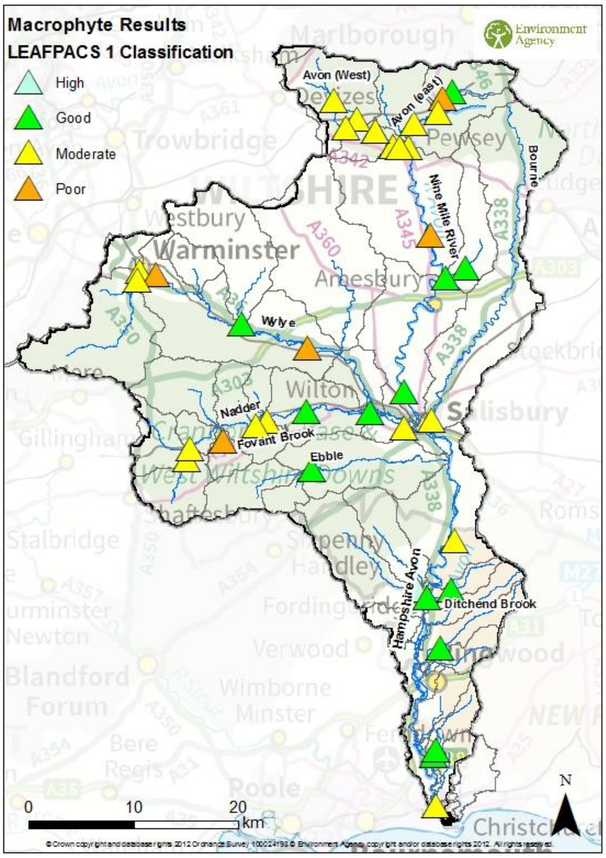
Macrophyte Status 2011-13



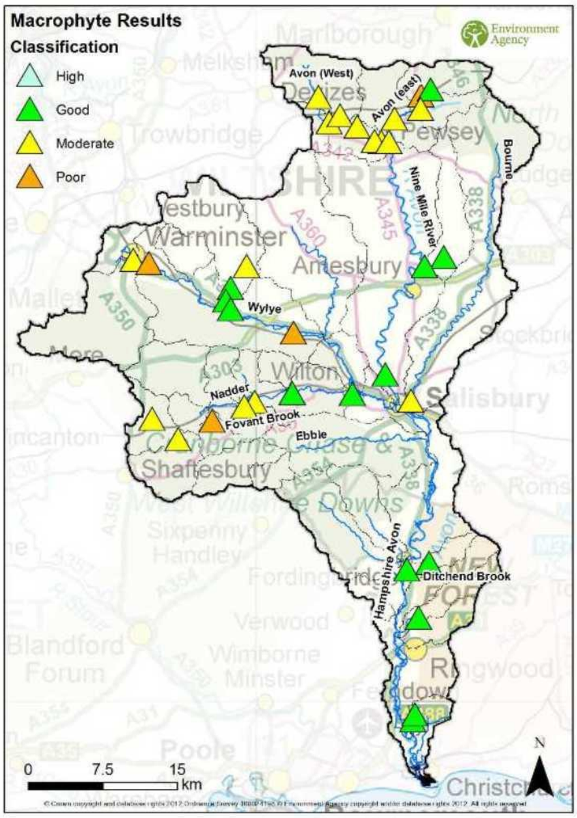
Diatom Status: DARLEQ 2 (2011-13)



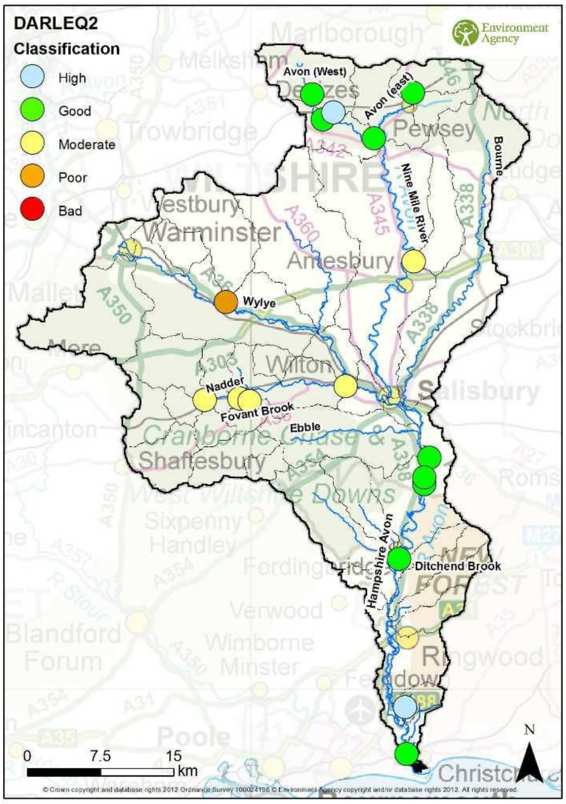
Macrophyte Status 2011-13 LEAFPACS 1



Macrophyte Status 2011-12



Diatom Status: 2009-11 DARLEQ 2



2.2.2 SAC conservation objective standards

The conservation objective standards for designated rivers (SSSIs and SACs) include several biological indicators of condition. Some can indicate adverse eutrophication pressure from elevated nutrient levels, such as from phosphorus, but biological indicators may also reflect a combination of pressures, including siltation and channel morphology effects on flow.

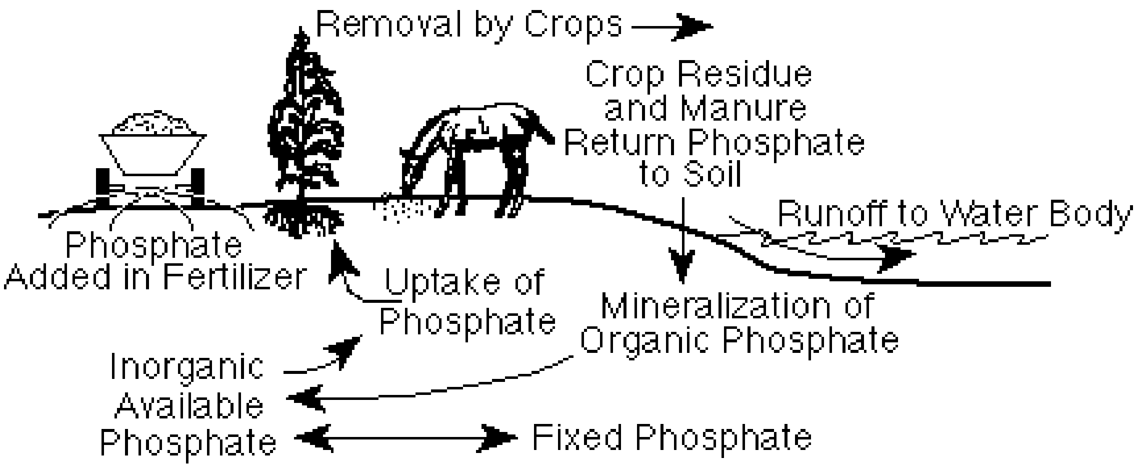
The principal indicators for eutrophication pressure are the same as those used for determining WFD status: river macrophytes and diatoms. For macrophytes the WFD RIVPACS assessment method is used and the conservation objective standard equates to WFD high class. For diatoms the conservation objective standard is also equivalent to WFD high class but the assessment is based on the trophic diatom index.

Assessments of macrophytes and diatoms carried out in the period 2011-2013 found only the Dockens Water to meet the SAC conservation objective standard and for macrophytes only. All other assessments of macrophytes and all assessments of diatoms along the SAC (and SSSI) river system failed to meet the conservation objective standards.

The widespread failure of these biological indicators of eutrophication pressure combined with widespread failure against the site's phosphorus water quality standards adds weight to there being a nutrient pressure on the river system that exceeds the standard required favourable conservation status (and SSSI favourable condition).

2.3 Sources of Phosphorus P across the Catchment & P Loading Through Time

Phosphorus enters the river system, through surface (run-off) and groundwater flow pathways and through direct discharges. A conceptual diagram of the phosphorus cycle and description of the nature of phosphorus in soils is shown below.



A great deal of work has been carried out looking at the source apportionment of the Hampshire Avon over the last decade. A review of this work prior to 2011 is provided in Bewes etal (2011)[3], summarised in Appendix 2.3:1. Many of these studies were carried out before phosphate stripping had been installed at Wessex Waters largest Sewage Treatment Works (Table 2.3.2c) and so are largely outdated.

A number of additional pieces of work have been undertaken, to update and improve our understanding of the source apportionment in the Hampshire Avon and better understand the origin of each source of phosphorus. The findings of this work are summarised in Section 2.3.1 to 2.3.3 below. AMEC on behalf of the Environment Agency also undertook a literature review considering "the Source and Pathway of Phosphorus in the Hampshire Avon[37]. Key findings from all this work have fed in to subsequent work undertaken for the NMP and so fed in to the NMP & Technical Annex.

To assist in understanding the source of phosphorus and likely measures that could be put in place to improve water quality across the Avon, water quality in terms of OP, TP concentration (expressed in either ug/l or mg/l) are discussed in the report as well as load (kg/yr). Typically it will be the concentration of phosphorus within surface water that will affect the ecology and is the basis for WFD and SAC objectives. Any improvement in P concentrations across the Avon is however in many places converted to a load reduction, to assist in identifying how such water quality improvements can be achieved. The underlying basis for this conversion should therefore always be remembered.

The overall observed P load within the Avon has been calculated using observed flow and quality data. The accuracy of these calculations is dependent on the frequency of measurements. Continuous flow and quality measurements would provide the greatest accuracy, but whilst river flow records are available at 15 minute intervals, water quality data is only available at weekly and in more recent year's monthly frequency. These records therefore miss the increase in P loading that may occur at high flow events as increased run-off (and so P loading) enters the river system. Observed water quality data will also change as P is taken up by plants during the growing season and as P is precipitated out.

As continuous water quality data is not available, phosphorus loading to the Avon have been calculated using a number of different approaches. An annual average apportionment has been calculated using average annual flow at the downstream end of a water body, or location [representative of a single year or Long Term Average (LTA)] and multiplying this by the average water quality at the same point. A second approach was to calculate the "flow apportioned" source apportionment. This uses daily flow data and multiplies this by the weekly/ monthly water quality data that might be available for a point. This therefore calculates the loading at a number of different times through the year and then adds these figures together to provide our best estimate of P loads.

Calculations using an average annual apportionment approach are typically lower than flow apportioned calculations as they do not include the loads generated during times of high flow when more erosion, run-off and so phosphorus loads are entering the water course. Flow apportioned results in contrast calculate loadings on a daily basis using average flow data and the most frequent water quality results available. For the Avon this is typically weekly or monthly.

Because water quality data is not available on a daily basis, flow apportioned results presented in this report are themselves considered an under-estimation of total P loads passing through the Avon. Results of the flow weighted source apportionment results for the Avon are however presented in Figures 2.3.1 and Table 2.3.1a-c.

These show that the total phosphorus load and orthophosphate load to the Avon and sub-catchments have reduced from around 208 and 167 tonnes/yr in 2000 to approximately 61 and 42 tonnes/yr respectively in 2012. The main reason for the reduction in loads are the installation of phosphate stripping at 17 of the largest STWs, reduction in use of inorganic fertilizer P (Figure 2.3.1:4) and results of some of the catchment management work (such as CSF, Landcare) undertaken since 1997.

Figure 2.3.1 Flow Weighted Source Apportionment For the Hampshire Avon from 2000 to 2012 for Orthophosphate (OP) and Total Phosphate (TP) at Knapp Mill (based on daily flow data and monthly water quality data)

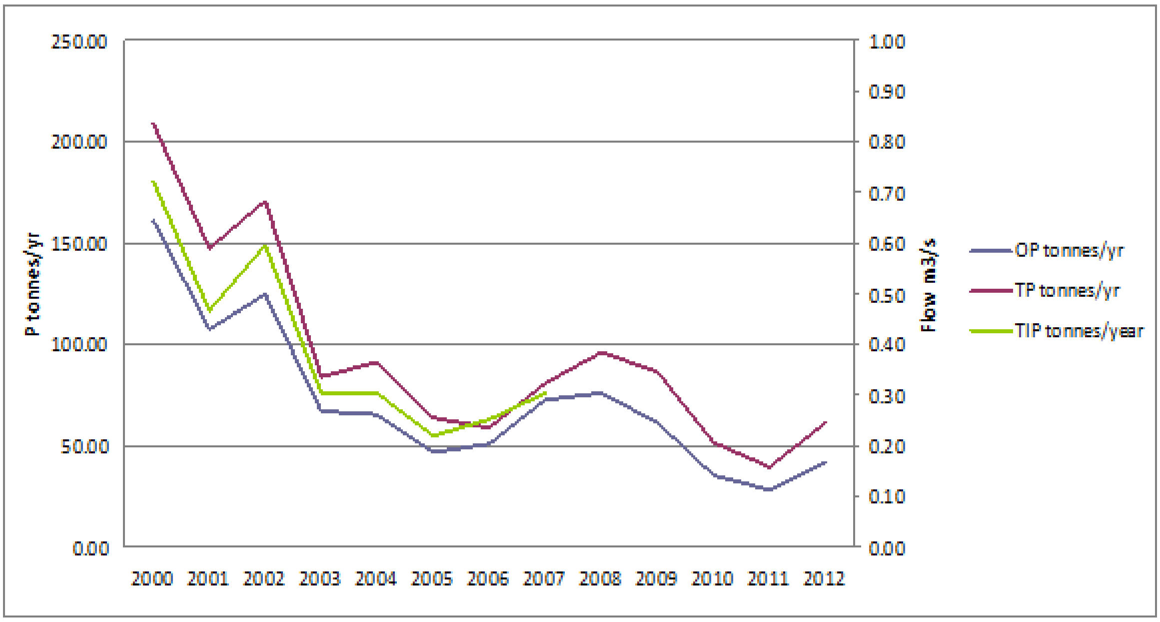


Table 2.3:1a Flow Weighted Phosphorus Loading for the Hampshire Avon 2000 to 2012 at Knapp Mill (Using Quality data from Hampshire Avon Causeway sampling site)

	Flow weighted			Annual averages			
Year	OP tonnes/yr	TP tonnes/yr	TIP tonnes/year	Av flow m3/s	Av OP mg/l	Av TP mg/l	Av TIP mg/l
2000	160.60	208.77	180.78	30.57	0.19	0.24	0.22
2001	107.92	147.34	116.21	27.84	0.15	0.20	0.17
2002	124.70	170.90	148.99	24.46	0.17	0.23	0.20
2003	67.46	83.79	75.90	20.93	0.12	0.15	0.14
2004	65.87	91.72	75.97	16.15	0.13	0.17	0.15
2005	47.21	64.16	55.37	11.60	0.13	0.18	0.15
2006	50.72	59.45	62.79	14.57	0.11	0.12	0.12
2007*1	72.73	80.81	76.31	23.33	0.10	0.12	0.11
2008*2	75.75	96.24		21.10	0.11	0.14	0.13
2009*3	61.28	86.78		19.07	0.10	0.14	
2010*4	35.31	52.05		17.20	0.06	0.09	
2011	28.12	39.34		12.00	0.07	0.10	
2012	42.02	61.48		19.37	0.07	0.10	
Average	72.28	95.60		r-squared	0.42	0.39	
2005-12	51.64	67.54			0.10	0.12	0.13
2009-12	41.68	59.91			0.08	0.11	0.13

*1 STW *improvements at Warminster,* *2 STW *improvement Netheravon, Ringwood, Salisbury, Shrewton, Amesbury,* *3 STW *improvements at Pewsey, Ratfyn, Upavon, Tisbury, Fovant, Hurdcott,* *4 STW *improvements at Downton and Great Wishford*

Table 2.3.1b Annual Average Orthophosphate (OP) Loads, as Tonnes/yr and kg/ha of Catchment Area, for 2009-2012 (Amec)[29]

Gauging Station	OP Load (t/yr)	Catchment Area (ha)	OP Load (kg/ha)
Upavon East	3.71	8 731.25	0.42
Amesbury	10.34	32 018.75	0.32
Knapp Mill	47.79	168 389.1	0.28
AP5, Salisbury	13.47	39 001.66	0.35
Laverstock	2.35	8 800[1]	0.27
Nunton Bridge	2.62	10 009.38	0.26
Wilton	8.33	20 753.13	0.40
Norton Bavant	4.17	10 225	0.41
South Newton	9.03	42 332.53	0.21
Upavon West	3.77	7 606.25	0.50

Notes:

1. Estimated area of groundwater catchment (substantially lower than area of surface water catchment).

Table 2.3:1c Orthophosphate Load (tonnes per annum) Calculated from Water Quality Data and by the PIT Model (2008-2012) (AMEC)[29]

Catchment	Calculated OP Load (tonnes/yr)	Modelled OP Load (PIT) (Tonnes/yr)	% Difference (Modelled - calculated
Knapp Mill (Avon)	47.8	49.9	4.5
Upavon East (Avon)	3.7	2.4	-35.3
Upavon West (Avon)	3.8	2.9	-23.8
Salisbury (Avon)	13.5	10.6	-21.7
South Newton (Wylye)	9	10.9	20.9
Wilton (Nadder)	8.3	6.9	-17.4
Laverstock (Bourne)	2.3	3.3	40.8
Nunton Bridge (Ebble)	2.6	2.4	-8.7

From Table 2.3.1b, average OP loads to the Avon (2009-12) are around 47 tonnes P/yr, using quality data from Knapp Mill. This is equivalent to around 0.28kg/ha. This loading increases to around 0.5kg/ha for Upavon West with the loading in UGS catchments being significantly greater than chalk catchments[29]. OP and TP loadings for the Avon using quality data from Causeway are estimated to be c42 and c60 tonnes P/yr respectively (Table 2.3:1a).

An assessment of the likely sources of phosphorus entering the Avon are discussed below. Section 2.3:1 discusses potential modelled background sources of P and Section 2.3.2 and 2.3.3 anthropogenic sources. Future pressures that may increase phosphorus loads in the future are discussed in Section 2.4.

2.3.1: Baseline (Modelled Background; near natural) Sources of Phosphorus

The baseline modelled background concentration is the phosphorus concentration in surface and ground waters that, on basis of information currently available and which requires further refinement, is likely to be near natural but with an uncertain component of anthropogenic influence and error margin in functioning of the model.

2.3.1.1 Typical natural phosphorus concentrations in Upper Greensand

Phosphorus is a naturally occurring mineral and can be found in many geological deposits. Investigations in 2012 to 2014 were undertaken to identify the baseline (predominantly natural) source of phosphorus in Hampshire Avon. The work included an analysis of surface and groundwater quality data, borehole drilling, coring and pore water analysis and production of “natural phosphorus accretion profiling” based on the conclusions of these investigations.

Source Apportionment was carried out to identify the likely sources of phosphorus in the Avon and to consider if any “un-accounted for P” was observed, that could result from a natural mineral source. This work is presented in the Wessex Phosphorus Investigations report[17] and subsequent technical addendums to this report[29].

In 2012-13, the Environment Agency commissioned further work to determine the impact of these minerals on surface and groundwater quality. This work involved commissioning the British Geological Survey to produce a report, looking at potential phosphatic minerals within the Chalk and Upper Greensand[24], drilling of a number of boreholes, removing rock cores and analysing these cores and the water within them for phosphorus and other chemicals which may influence the presence of phosphorus in solution. The Environment Agency oversaw the drilling work and British Geological Survey (BGS) undertook the core logging, sampling and pore water chemical analysis[27]. NRM Laboratories undertook mineral analysis from solid samples. Professor Paul Withers from Bangor University carried out an interpretation of these results[28], (Appendix 2.3.1:1).

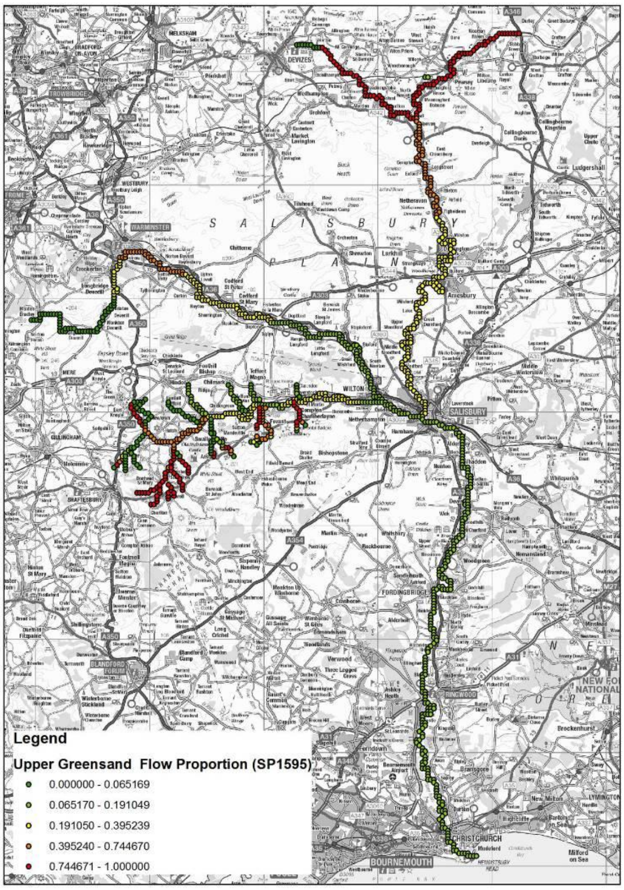
Results from BGS work[24], identified that phosphate deposits are found extensively within the UGS across the Wessex Basin and in the Lower Chalk. The flow contribution from UGS sources and chalk sources using methods outlined in Section 1.5.1), also vary. Results from the WBM clearly identified that the UGS aquifer outcropping at the headwaters of the Hampshire Avon, Wylye and Nadder, provided all or the majority of baseflow in these reaches and the influence of the UGS baseflow gradually reduces as you move down the Avon (Figure 2.3:1:1 & 2.3.1:1b taken from the Wessex Basin Groundwater Model). In the headwaters of the Upavon West and East 100% of baseflow is from the UGS. At the bottom of the Lower Avon 9% is derived from the UGS, approximately 76% of the river flow is derived from the chalk baseflow and % from run-off.

Interpretation of water quality results from public water supply boreholes and springs abstracting from the UGS and or mixed UGS & Chalk aquifers (Figure 2.3.1), showed average UGS concentrations of around 154ug/l[17] (compared to the SAC target of 60ug/l). This varies from around 50-100ug/l in UGS/chalk boreholes to 100 to >-300ug/l from UGS boreholes or springs. Average orthophosphorus concentrations in the Upper Nadder and Wylye are around 200ug/l as detailed in Table 2.3.1:1 below.

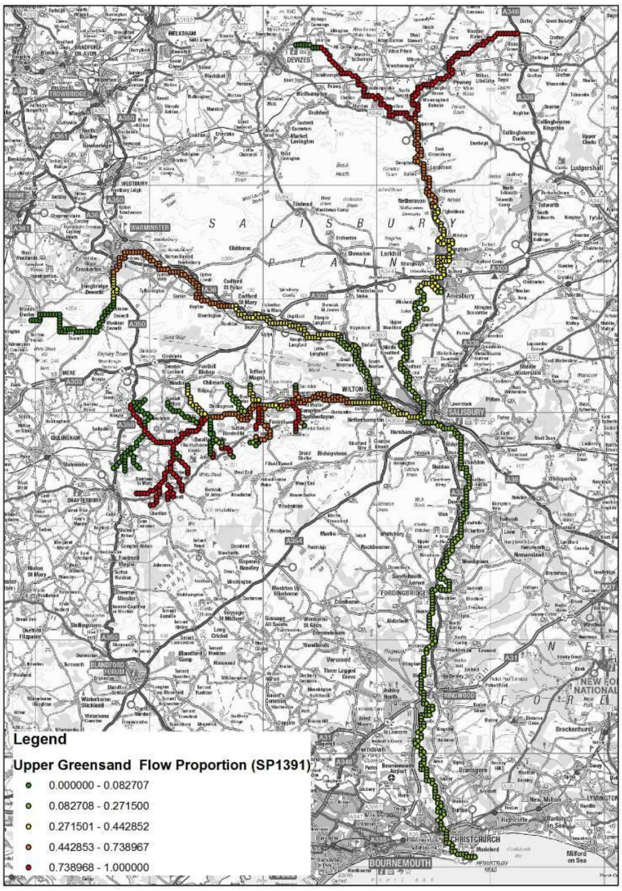
Further extensive "one off"; (and so not representative of annual trends), sampling of springs and streams was undertaken as part of Environment Agency, "walk over surveys" of the Nadder & Sem and Upper Avon West in 2013. Average orthophosphate concentrations from laboratory analysis of samples were 366ug OP/l and 342 ug/l OP respectively. When samples taken at points that are likely to be influenced by anthropogenic sources are removed, these figures reduce to 290ug/l and 260ug/l respectively.

These results together with average water quality data from the EA Groundwater Network and Public Water Supply results are presented in Figure 2.3.1:3a & b.

Figure 2.3.1:1 Upper Greensand Flow Proportion Under Average (Model time step 1595) and Low (Model time step 1391) Groundwater Levels (based in Wessex Basin Model)



Average Groundwater Levels (low flows)



Low Groundwater Levels (low flows)

Figure 2.3.1:1b: Geology (overlying topography) of the Hampshire Avon

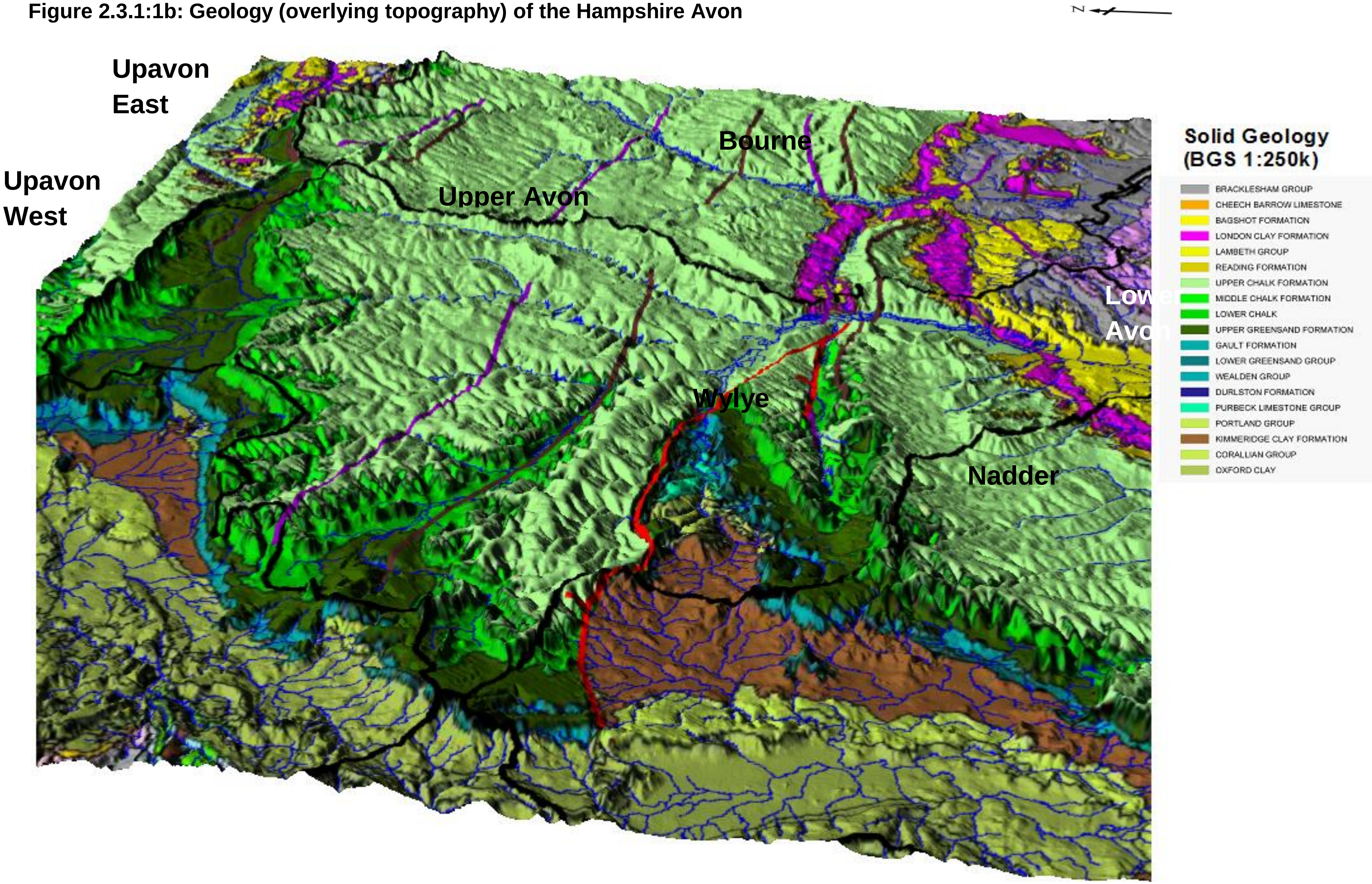


Figure 2.3.1:2a Observed Phosphorus Concentrations in Surface Waters and Groundwater Public Water Supplies (from Wessex Water

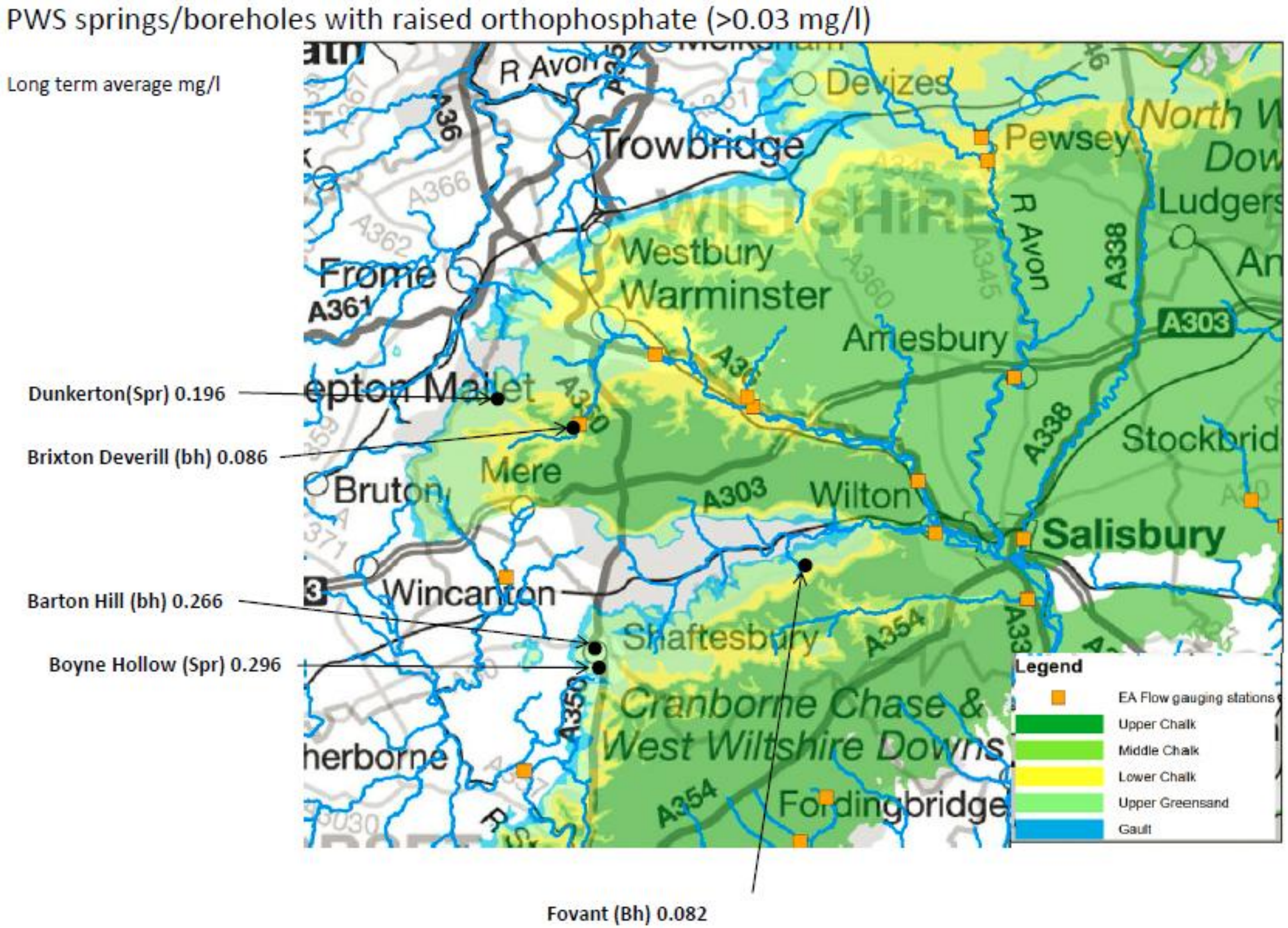


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Figure 2.3.1:2b Observed Phosphorus Concentrations in Surface Waters and Groundwater Public Water Supplies

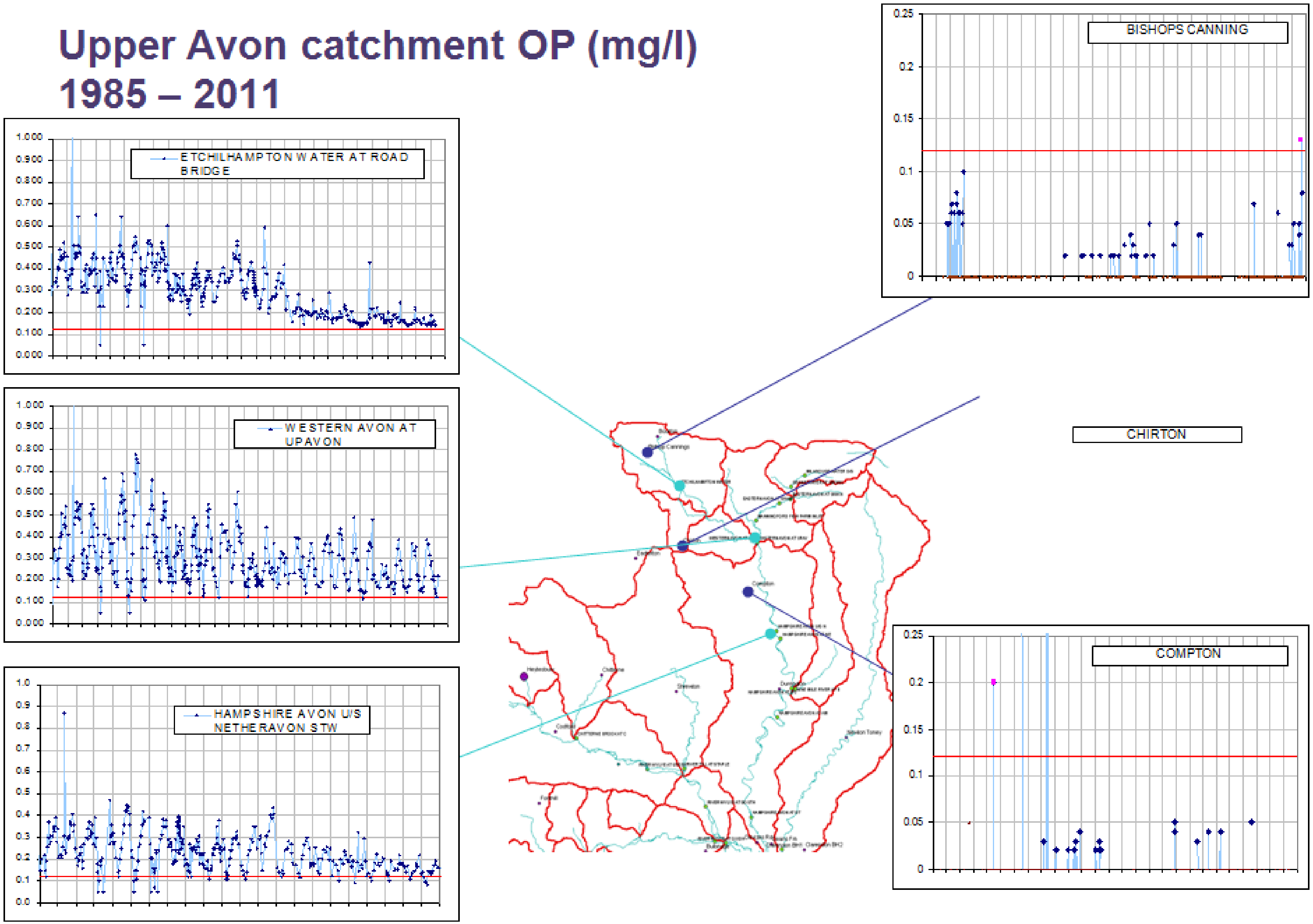


Figure 2.3.1:2c Observed Phosphorus Concentrations in Surface Waters and Groundwater Public Water Supplies

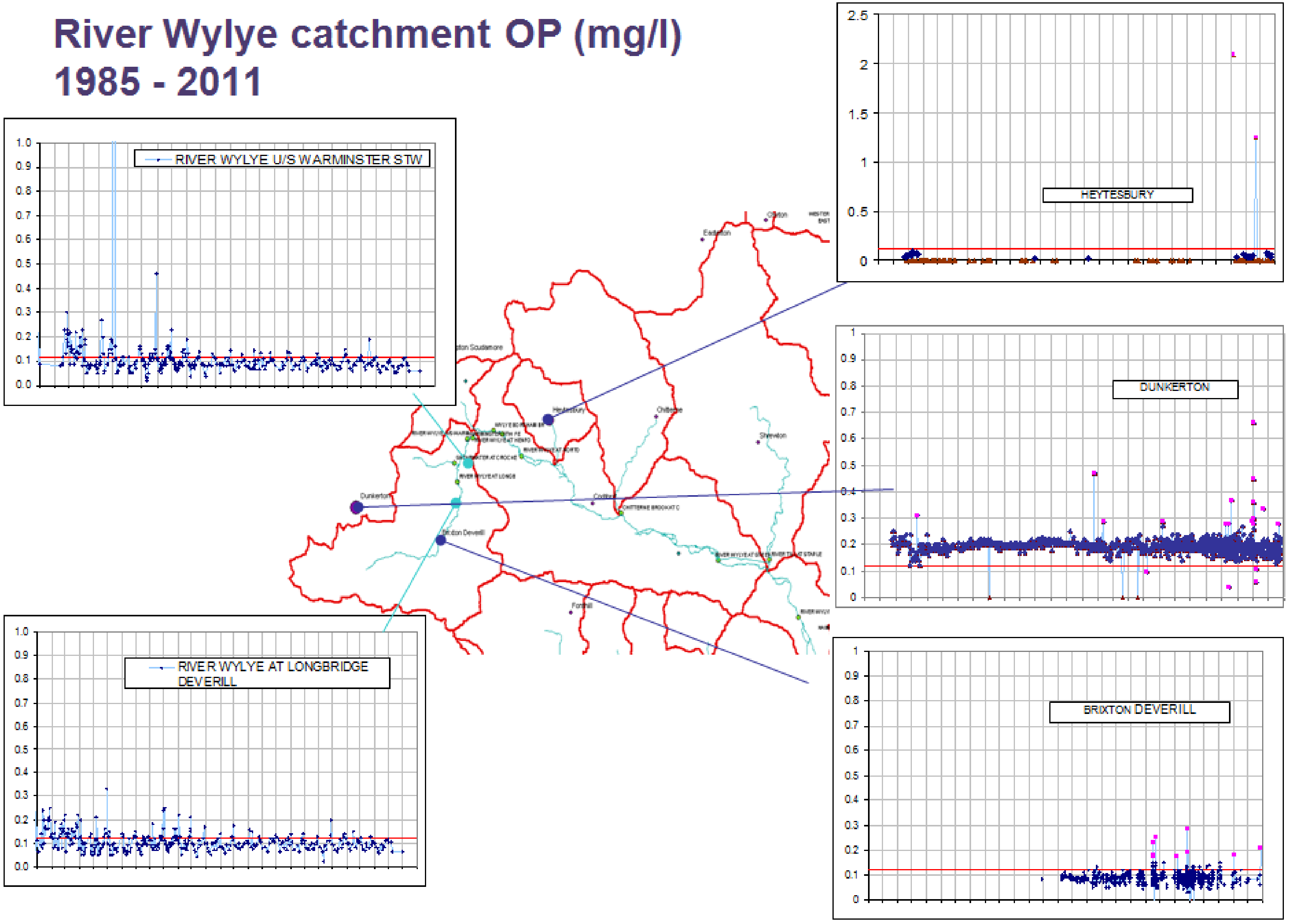


Figure 2.3.1:2d Observed Phosphorus Concentrations in Surface Waters and Groundwater Public Water Supplies

Nadder Catchment OP (mg/l) 1985 - 2011

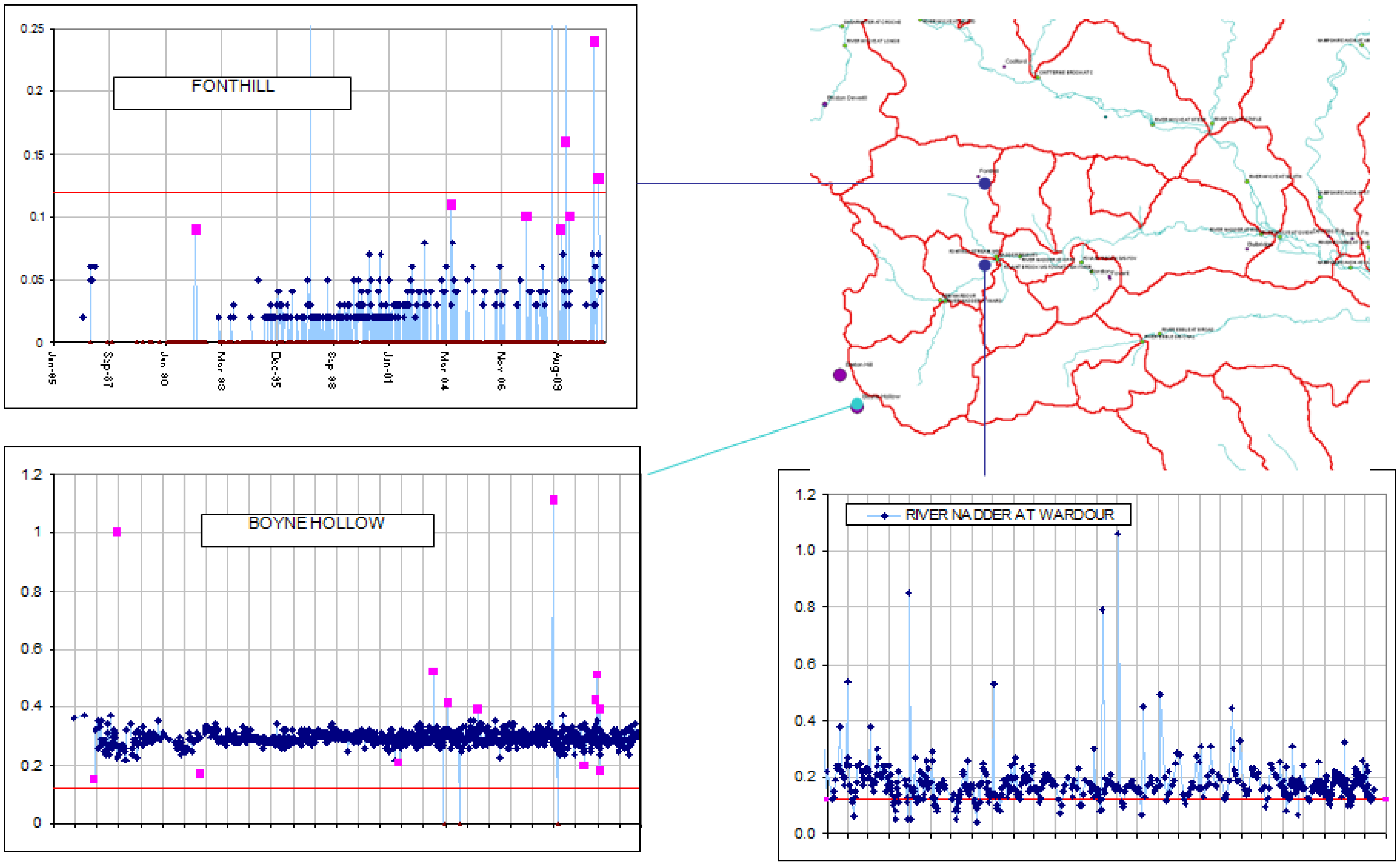


Fig 2.3.1:3a Walk Over Survey Results for Upper Avon and Nadder Headwaters and Sem Catchments

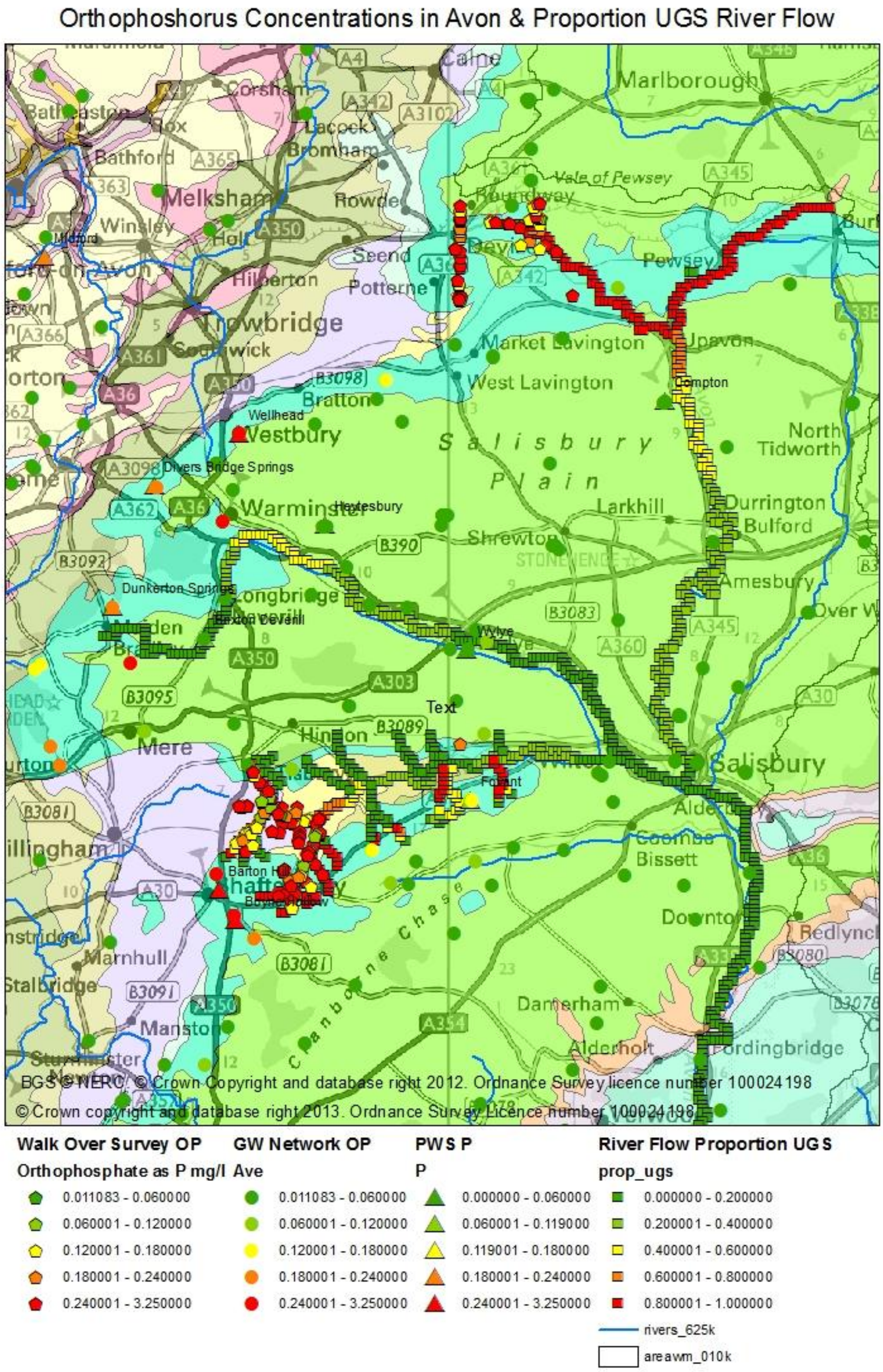


Fig 2.3.1:3b Walk Over Survey Results for Upper Avon

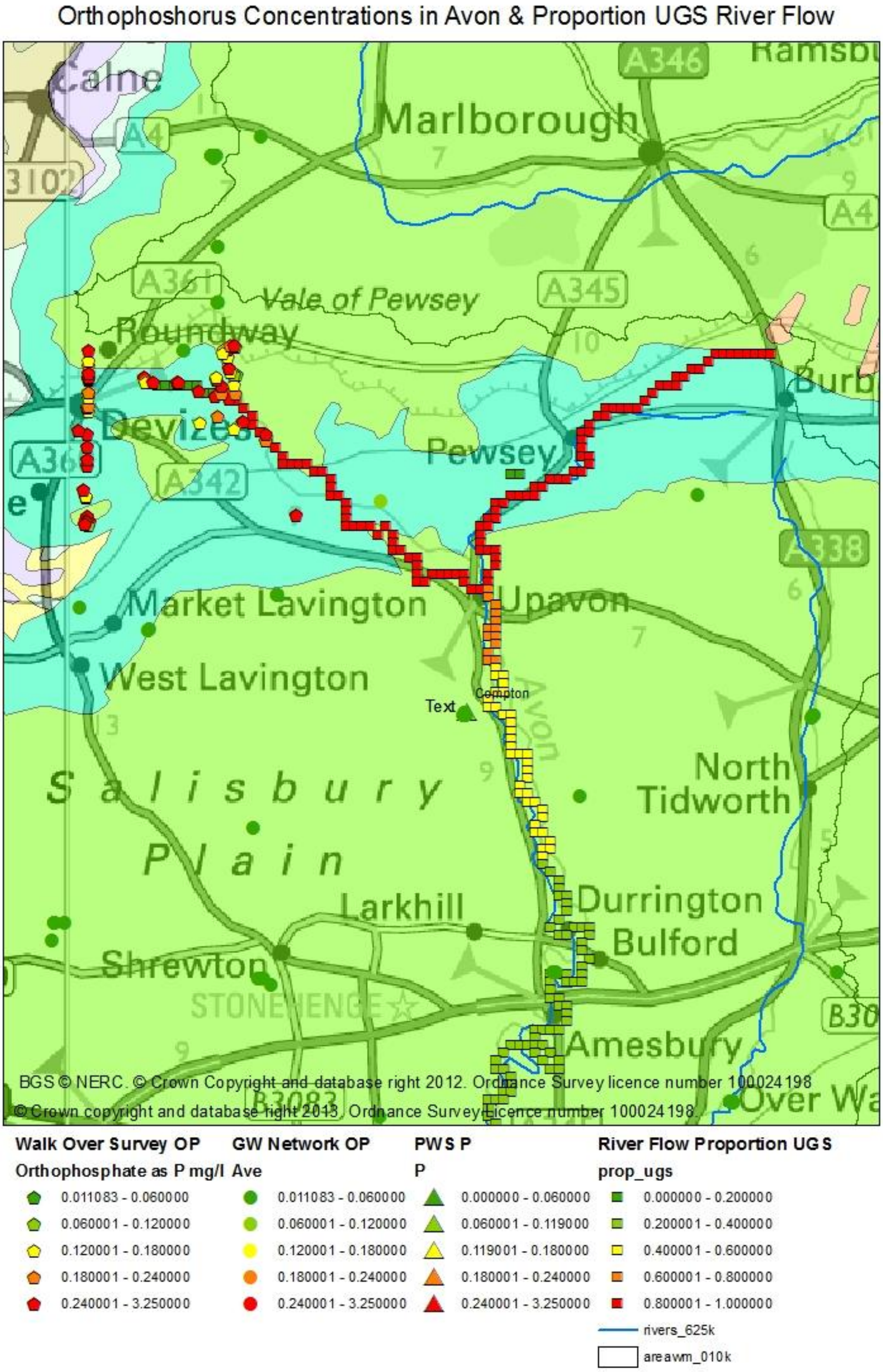


Fig 2.3.1:3c Walk Over Survey Results for the Nadder Headwaters and Sem Catchments

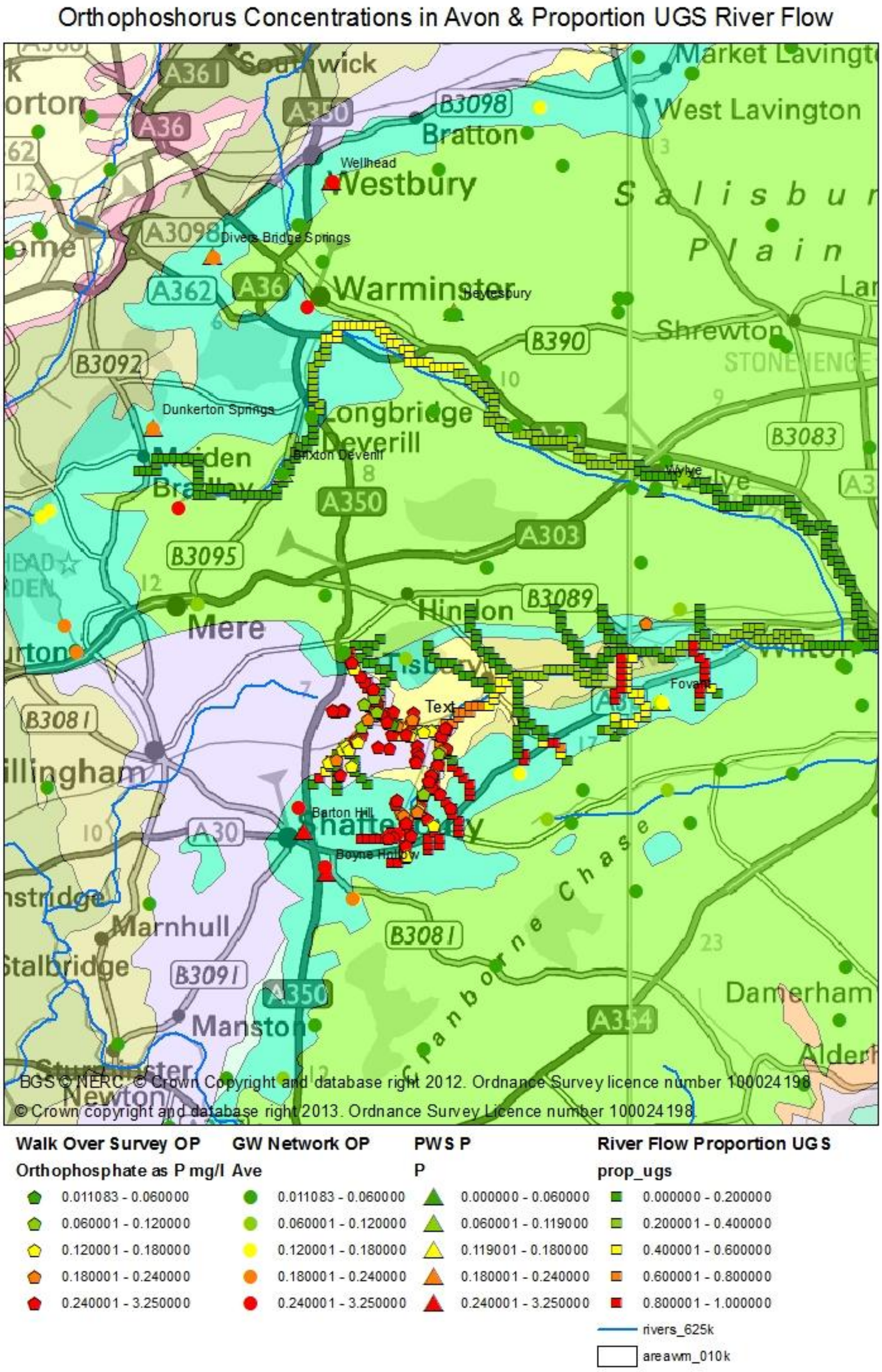


Table 2.3.1:1a Public Water Supply Upper Greensand Water Quality (Orthophosphate, reactive as P)

Groundwater source name (borehole unless given otherwise)	River catchment	Surface geology of source catchment	Wessex Water Quality (without adjustment for non detects)	Updated by WW (adjusting for non detects)
Forston		chalk	37	28
Brixton Deverill	Wylye	Chalk (lower)/UGS	86	86
Chirton	West Avon	Chalk (middle lower)/UGS	59	21
Bourton	West Avon	Chalk (middle lower/UGS	32	21
Codford	Wylye	chalk/UGS	48	21
Heytesbury	Wylye	chalk/UGS	187	53
Upton Scudmore	Wylye	Chalk/UGS	37	19
Upton Scudmore Springs	Wylye	Chalk/UGS	79	60
Compton	c.West Avon	Chalk/UGS	107	21
Barton Hill	Stour/(Nadder)	UGS	266	266
Divers Bridge Springs	Wylye	UGS	197	198
Dunkerton Springs	Wylye	UGS	196	196
Puckshipton Farm, Marden	West Avon	UGS		
Boyne Hollow Spring	Stour/(Nadder)	UGS	296	296
Boyne Spring	Nadder	UGS		
Bishops Canning	West Avon	UGS overlain chalk	50	21
Fovant	Nadder	UGS overlain chalk	82	82
Manor Farm Wedhampton	West Avon	UGS overlain chalk		
Wellhead	Wylye	UGS?	469	338
Average (all sources)		**Chalk & UGS**	**139**	**108**
Average (UGS sources)		**UGS**	**222**	**200**

Data from “26522392 ww pws ...xls “

There is a close correlation between water bodies with elevated phosphorus concentrations in surface and groundwater (and failing SAC targets) and locations with the highest UGS baseflow contribution (Figure 2.3.1:1 to 3).

Trend in national inorganic fertiliser use in England and Wales and phosphorus balance in grassland systems (Figure 2.3.1:4a) show a declining trend in phosphorus use over the last 40 years. Recent DEFRA analysis of P input and oftake also shows a declining phosphorus balance from 2000 to 2009 and a slight increase from 2009-2013 (Figure 2.3.1:4b). However analysis of laboratory results by NRM show a gradual increase in soil P in arable soils and grassland, but with grassland 2014 results returning to 1995 values (Figure 2.3.1:4c)

Public water supply records have shown in contrast little variation since records began in 1980's (Figure 2.3.1:2a). Despite the extended time required to reduce P index of soils, if there was a significant anthropogenic load in public water supply waters, we would expect to see a similar trend to the above figures. As in many cases there is no trend, this indicates that the primary source of phosphorus in the Avon may be natural baseline loading from Upper Greensand mineralogy with little anthropogenic influence at depth in deeper boreholes and springs that are largely sourced from groundwater originating deeper in the aquifer.

Figure 2.3.1:4a Historical Inorganic Fertiliser P Use in England Wales and Scotland

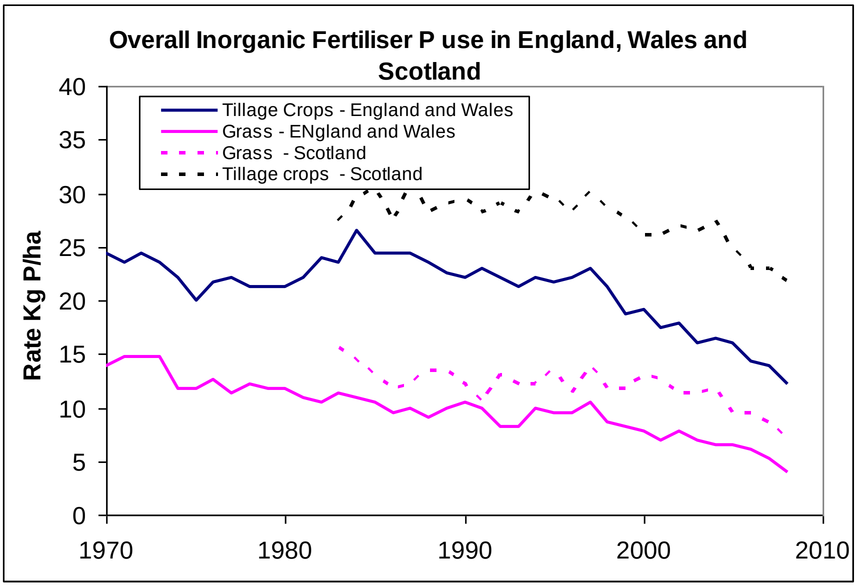


Figure 2.3.1:4b Soil Phosphorus Balance for the UK 2000 to 2012 (kg/ha) (DEFRA Soil Nutrient Balance UK Provisional Estimates April 25 July 2013)

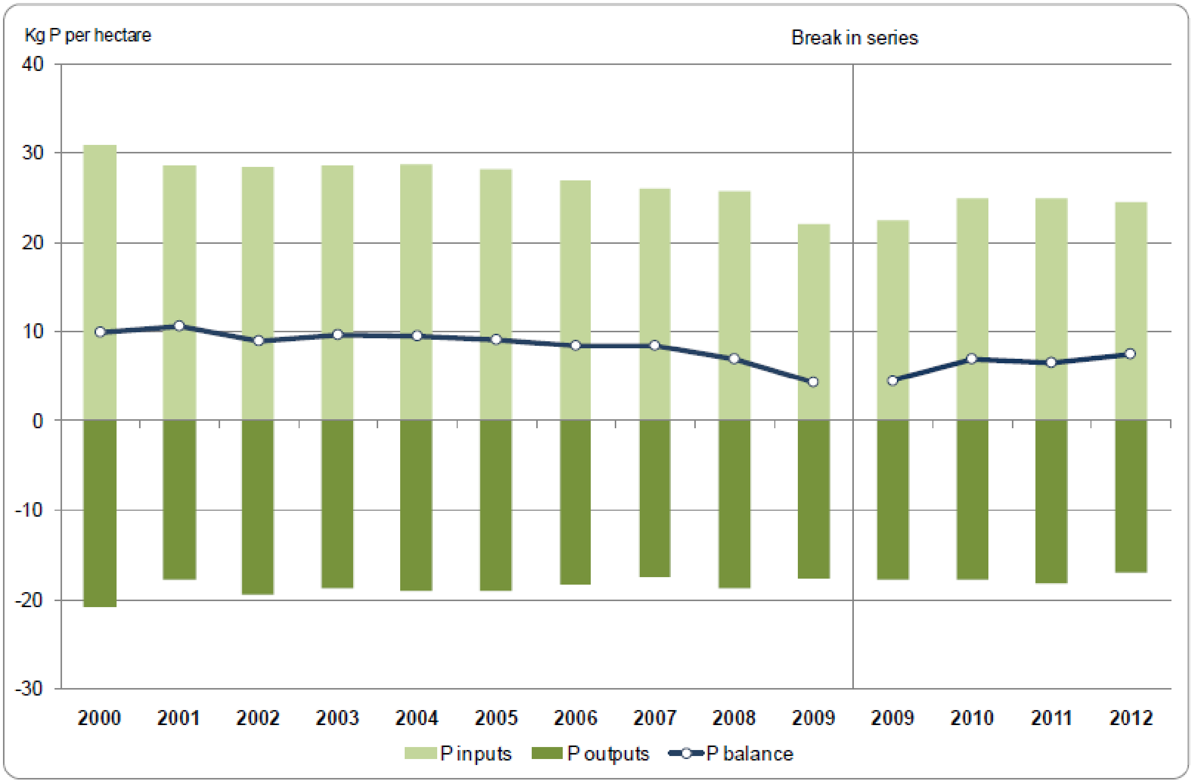
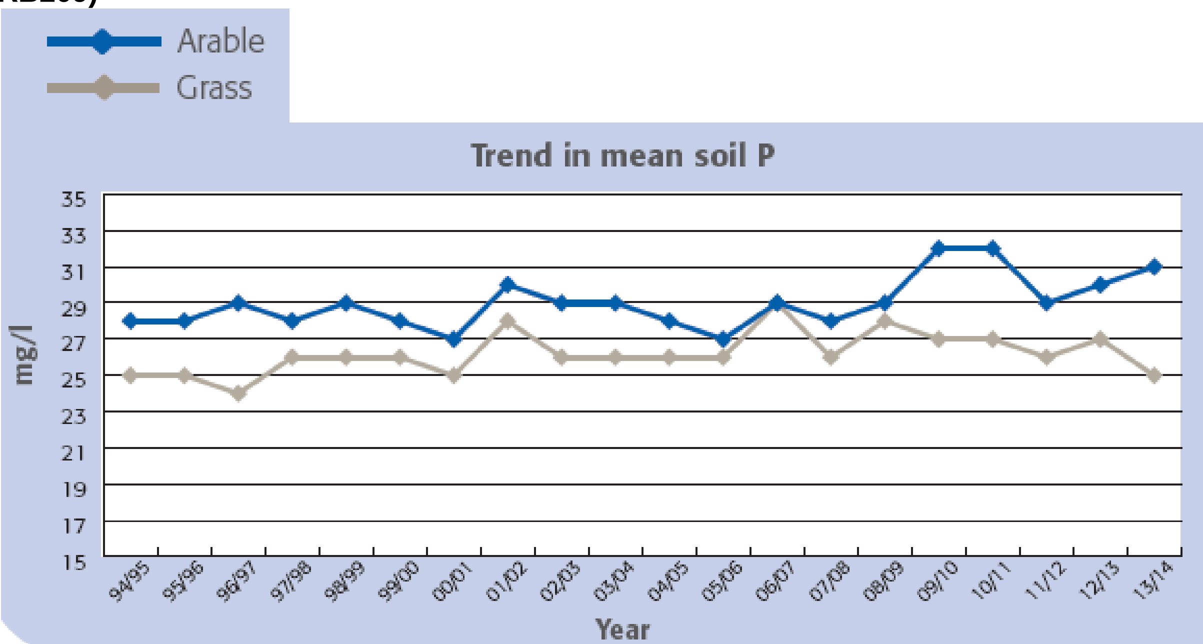


Figure 2.3.1:4c Trend in mean soil P *expressed in mg/litre scoop* (reported by NRM Laboratories Soil Nutrient Status 2013-14 & following methods recommended in RB209)



]To determine the likely source of elevated phosphorus concentration in the UGS, a number of chalk/UGS boreholes were drilled in 2013, rock cores and pore water samples taken and chemically analysed[27]. Results from this have confirmed that soluble reactive phosphorus (SRP) observed within UGS pore water at depth (and that would contribute to baseflow from the UGS, (typically >2m depth) largely result from dissolution of natural phosphorus within the UGS aquifer.

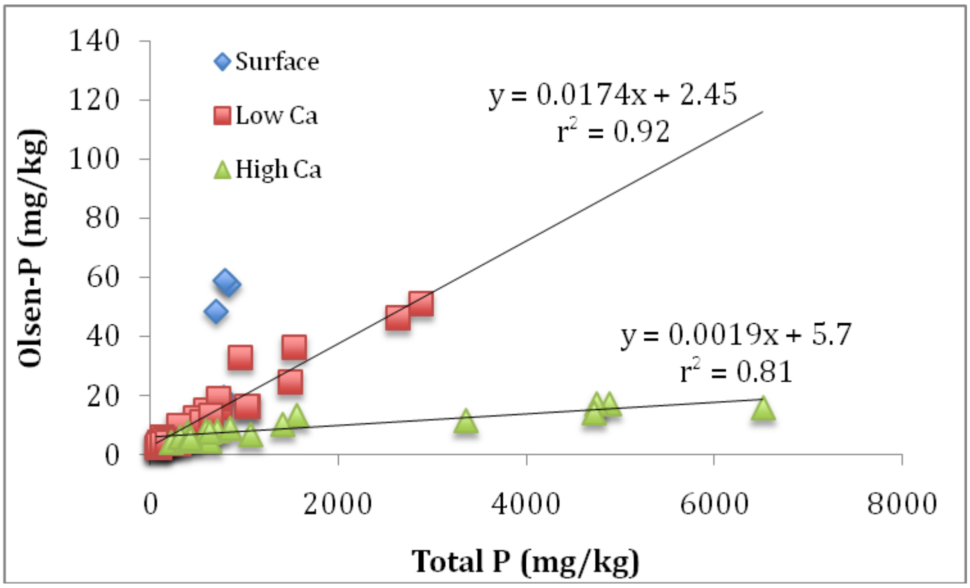
The work concluded that considerable total P enrichment is present at the junction of Lower Chalk and UGS lithologies and within different horizons in the UGS[24]. The amount of phosphorus that is dissolved in pore water is primarily controlled by the buffering capacity of the soil/rock matrix, primarily controlled by the calcium concentration in pore water. Where higher mineralogical concentrations of calcium are observed (>100,000mg/kg ca), phosphorus becomes bound up in the soil matrix. Where mineralogical rock concentrations are lower (10,000mg/kg) typical soluble reactive phosphorus concentrations are higher. Similar observations were made by Diaz[33], when looking at the solubility of inorganic phosphorus in stream water. Here concentrations of >100mg/l and pH 8 resulted in precipitation of phosphorus in the form Calcium -phosphate.

Near surface accumulation of P were observed to varying depths: 0.2 m at Wellhead, 1.6m at Divers Bridge and at least 2m at Cannfield Farm and these were typically related to precipitation of anthropogenic inputs of phosphorus.

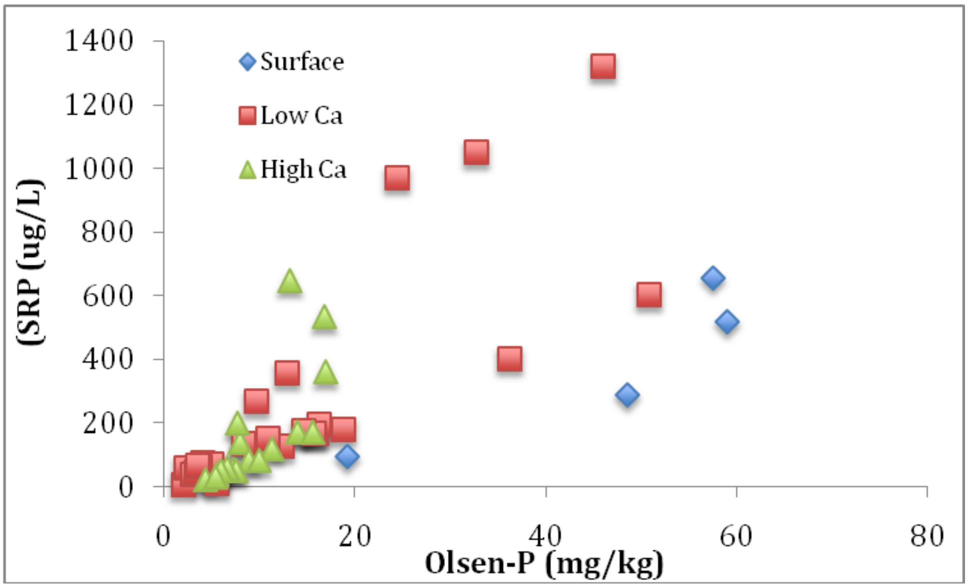
At depth however, natural enrichment in P typically occurred within distinct bands adjacent to higher phosphatic minerals. Where this coincides with reduced calcium concentrations, soil available Olsen P concentrations increased, as did soluble P (Figure 2.3.1:5)

Figure 2.3.1:5 Calcium concentrations govern (a) the relationship between Olsen-P (OP) and total P (TP) concentrations in the solid matrix, but (b) further factors are affecting the concentration between OP and soluble reactive P concentrations in the extracted pore waters at the same depths.

(a)



(b)



Conclusions from the drilling work were therefore that natural concentration pore water concentrations in groundwater of at least 50ug/l, 200ug/l and 300ug/l could be supported by drilling data at Wellhead, Divers Bridge and Cannfield Farm respectively and an average natural phosphorus concentration of at least 150ug/l can be supported (Appendix 2.3.1:1, Table 3.3). When further evidence from public water supply data, walk over survey and the Environment Agency groundwater network is considered, average baseline UGS concentrations of c200ug/l are calculated.

Surface Water quality across the upper reaches of the Avon has also shown consistently high phosphorus concentrations. Evidence for this for the Hampshire Avon East, at Swan Bridge and Sharcott Bridge (up and down stream of Pewsey STW) can be seen in Figure 2.3.1:6 and results for Upavon West in Figure 2.3.1:7. Both sets of results show improvements in water quality that have resulted from installation of phosphorus stripping at Pewsey STW (in AMP3 operational on 01/02/01) and Marden STW respectively but with a significant baseline trend maintained above and below these STW.

Results for Sharcott Bridge, downstream of the Pewsey STW, clearly show a significant improvement in water quality with P concentrations reducing from an average of 591ug/l OP before stripping (1995 to 2001) to 218ug/l OP after (2002 to 2011). This compares with the average concentration up stream of the STW at Swan Bridge of 192ug/l OP (1995 to 2001) to 178ug/l OP (2002 to 2011). This implies that the average input to the river from diffuse sources reduced by 14ug/l before and after stripping (due to other reason such a climatic variability or a result of measures being implemented up stream) but the greatest changes result from P removal. As indicated above they also show a high baseline of c178 ug/l from other sources, largely natural P.

Figure 2.3.1:6 Phosphorus concentrations in Hampshire Avon East, up and downstream from Pewsey STW

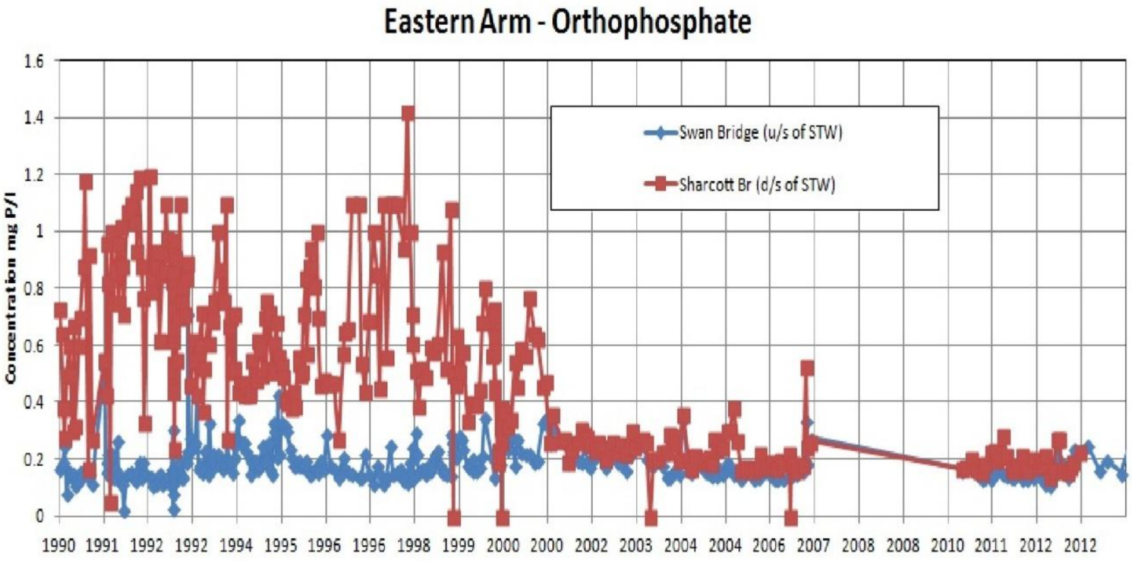
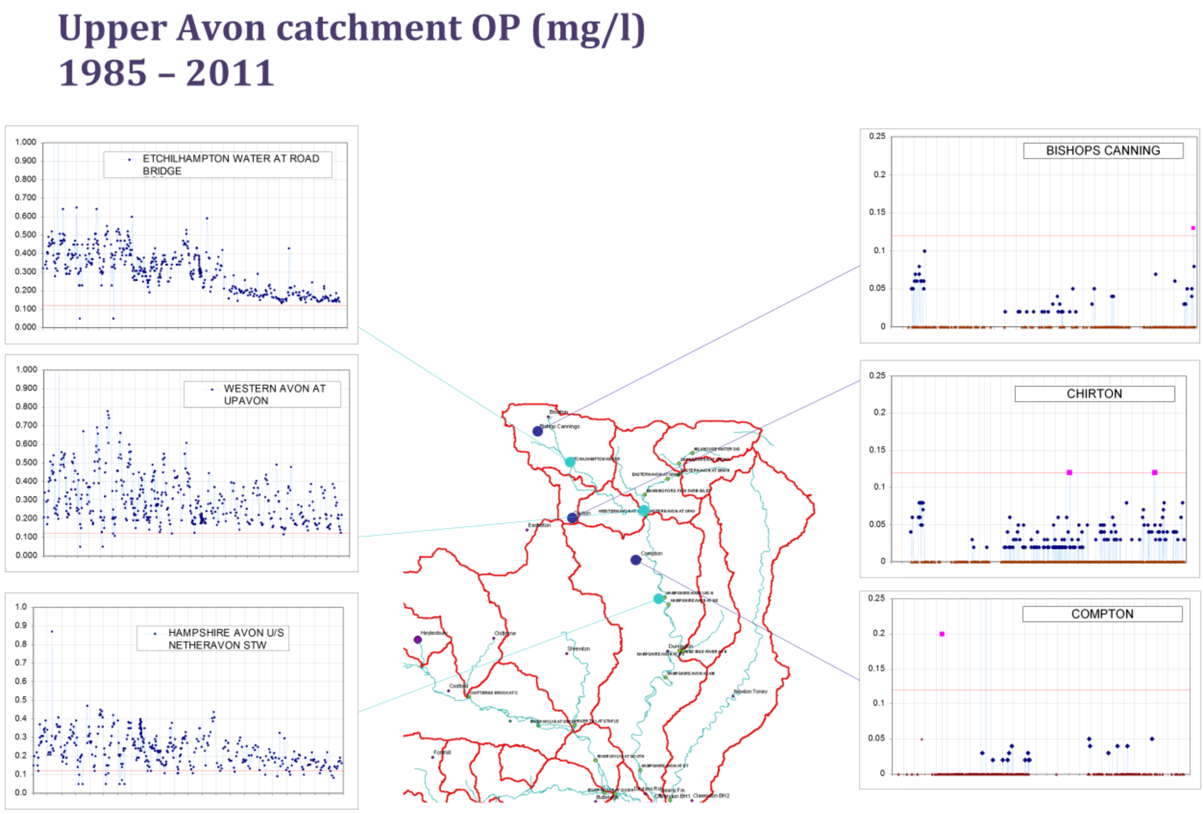


Figure 2.3.1:7 Phosphorus concentrations in Hampshire Avon West



Spatial variation in phosphorus/OP concentrations in surface and ground waters are clear from the data presented in this section and in supporting material. Evidence from public water supply data in particular indicates that UGS concentrations to the west (in the Wylye and Nadder) are higher than concentrations to the east (Upavon East and West). This in part is due to mixing of water entering public water supply boreholes to the east (chalk and UGS) but may also be due to the extent of UGS intersected, the recharge pathways and concentration of calcium and other chemicals that may limit the concentration of phosphorus that dissolves into solution.

The amalgamation of this data indicates therefore that a modelled background UGS baseflow quality of c200ug/l in the Nadder and Wylye can be assumed and c154ug/l for Upavon East, West and the Avon.

Modelled background phosphorus concentrations of c200ug/l from the UGS in the Wylye and Nadder catchments and c154ug/l from the UGS for the Avon and Upavon East and West can be supported by the evidence from surface and groundwater sampling

Further variation in modelled background UGS pore water concentrations are likely to be warranted beyond the Wylye/Nadder and Avon/West and East proposed above, but at this stage there is insufficient evidence to justify any further refinement. It is therefore recommended that investigations should be undertaken over the next 5-6 years to refine our spatial understanding of the modelled background phosphorus concentrations across the Avon. This will assist in improving model water quality forecasts in each water body and assists in identifying suitable water quality targets for the Avon. It will however be subject to funding.

2.3.1.2 Chalk Phosphorus Concentrations:

Total dissolved phosphorus in the Chalk varies widely over the area with the 5-95 percentiles varying from 10-193ug/l and median of 19ug/l[14]. BGS report that there are no apparent correlations between P and other indicators of agricultural/domestic pollution such as Nitrate or DOC[14]. From EA sampling, Orthophosphorus (OP) concentration in the Chalk, also vary from <20ug/l in the Bourne catchments (Newton Toney and Leckford Bridge public water supply abstractions) & River Till (Shrewton PWS) to around 107ug/l at Compton public water supply. Average chalk water quality in public water supplies in the Avon are < 39ug/l[17].

Variations in OP occur as a result of varying anthropogenic loads and natural sources of phosphorus. Significant concentrations of Phosphorus occur naturally within Lower Chalk, Chalk Basement beds, Glauconitic Marl[24], but this is often not soluble due to the calcium concentrations in pore water (Appendix 2.3.1.1). Natural concentrations of phosphate minerals also occur in chalk hard grounds and exchangeable P from iron oxides have been observed[14].

As the P value reported in the above studies include some proportion of anthropogenic loading as well as natural load, conservatively, a modelled background chalk P concentration of approximately 8ug/l is assumed in the NMP. As with the UGS, this varies spatially and further understanding of this should be developed over the next 5 years.

2.3.1.3 Tertiary Phosphorus Concentrations.

Orthophosphorus concentrations in the tributaries feeding the lower Avon, where flow emanates from the tertiary gravels, are typically very low (Table 2.3.1:2) with a significant (>50%) number of results being below the level of detection (20ug/l). A modelled background river water quality of half the level of detection 10ug/l has been assumed (including run-off loading) within these catchments.

2.3.1:2 Tertiary River Water Quality (Orthophosphate concentrations) where data

Site Name	Description	Units	Number of results	Number below detection limit	Mean (excluding non detec's)	Min	Max
RIPLEY BROOK U/S CONFLUENCE	Orthophosphate, reactive as P	mg/l	60	58.00	0.02	0.02	0.03
LINFORD BROOK U/S CONFLUENCE	Orthophosphate, reactive as P	mg/l	28	23.00	0.02	0.02	0.04
DOCKENS WATER AT A338	Orthophosphate, reactive as P	mg/l	60	45.00	0.03	0.02	0.24
HUCKLES BROOK DOWNSTREAM GARAGE A338	Orthophosphate, reactive as P	mg/l	29	20.00	0.03	0.02	0.13
DITCHEND BROOK	Orthophosphate, reactive as P	mg/l	60	56.00	0.02	0.02	0.03
BISTERNE GARDENS, RINGWOOD WELL	Orthophosphate, reactive as P	mg/l	7	0.00	0.26	0.16	0.41
NEW FOREST SPRING WATER	Orthophosphate, reactive as P	mg/l	12	11.00	0.02	0.02	0.02

2.3.1.4 Typical Natural River Quality Calculations in UGS, Chalk and Tertiary's

Baseflow contribution to the Avon vary from 70% in Upavon West to 91% in the Bourne (Table 1). The remaining flow comes from run-off. Amec in an assessment of natural phosphorus in run-off concluded that under natural conditions phosphorus concentrations at the lower end of estimates would be approximately 25-32ug/l but on average 50-100ug/l in run-off (Appendix 2.3.1:2). However earlier JNCC (2014) Common Standards Monitoring Guidance for Rivers, indicated run-off concentrations of <30ug/l from chalk catchments and slightly higher concentrations in sandstone dominated catchments.

To calculate the likely river water quality that would be observed naturally in UGS, Chalk and Tertiary areas, the NMP uses modelled background baseflow quality from each geological area as defined above and conservatively a value of 25ug/l OP for run-off. The resulting river water quality for each geological unit is shown in Table 2.3.1:3a below.

Table 2.3.1:3a Natural River Water Quality from UGS and Chalk Geologies

		Geology Concentration			Adjusted River P		Flow Model Adjustment
Catchment	BFI	UG S P	Chalk P	Run-off P	UGS catchment	Chalk Catchments	observed mean flow as % of modelled
Nadder	0.81	200	8	25	167	11	100%
Wylye	0.89	200	8	25	181	10	100%
East Avon	0.89	154	8	25	140	10	83.00%
West Avon	0.7	154	8	25	115	13	93.00%
Avon	0.86	154	8	25	136	10	100%

Further water quality sampling across the Avon should continue over the next 5-6 years to identify if any further local refinement of these figures may be required. This for example may justify using a different UGS concentration in Upavon East compared to the Nadder.

Modelled background phosphorus river water quality in UGS vary from 115ug/l in West Avon to 181ug/l in the Wylye and Chalk concentrations from 10-13ug/l

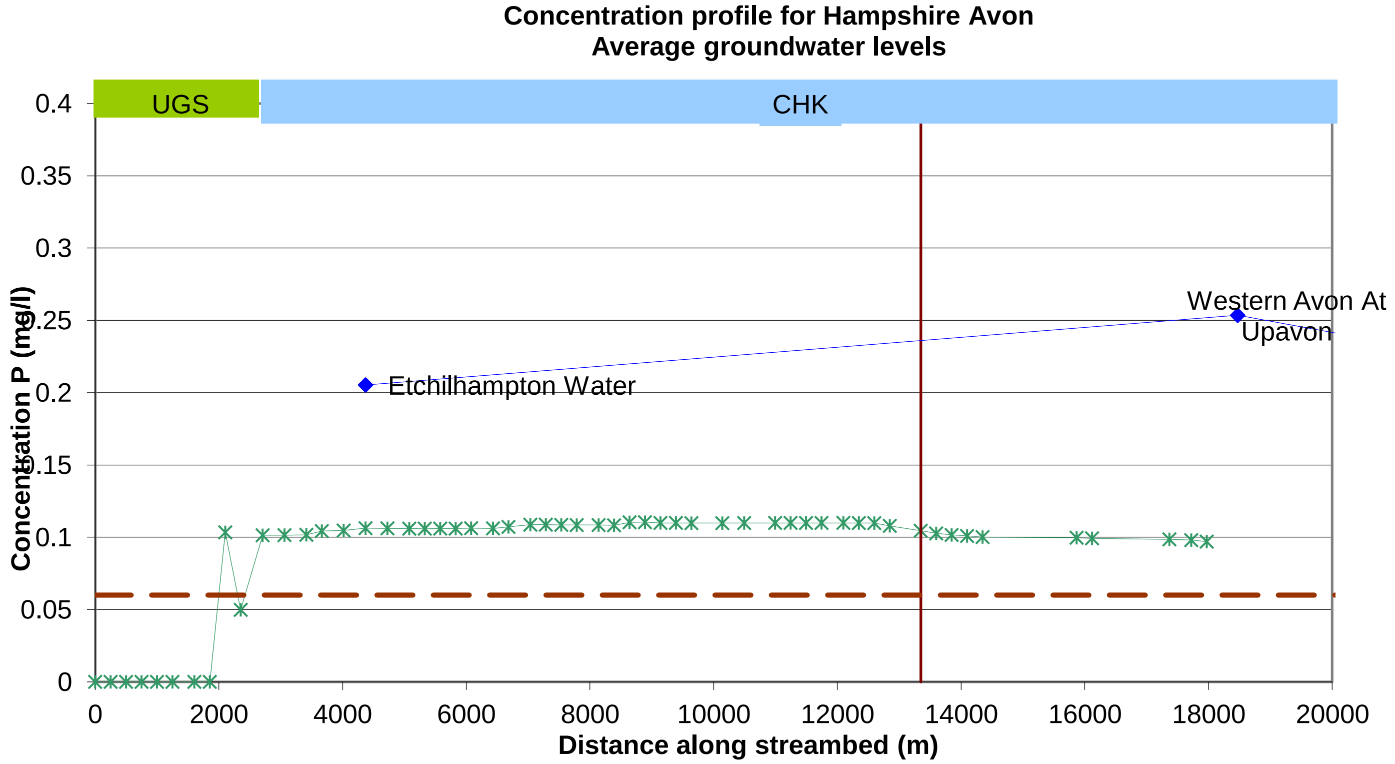
These modelled background water quality figures were then inserted into a P-apportionment tool, developed from the Wessex Basin Model (Under EA commissioned work[17]) to calculate the mixing of flow from each geological unit down the Avon. Results from this then forecast the modelled background P concentration we would expect under average, high and low flows within water bodies in the Avon.

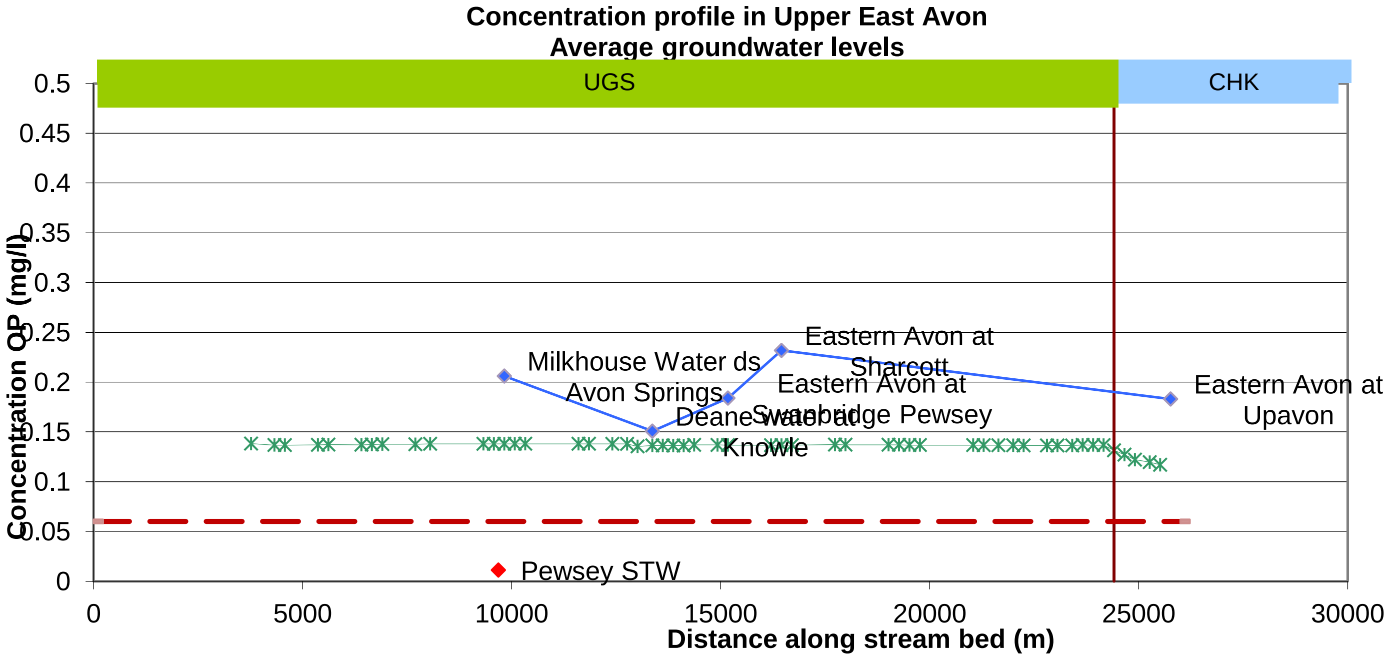
Adjustments to the baseflow contribution in Upavon East and West were made to the model to account for the poorer flow calibration of the version of the Wessex Basin Model used at that stage, in Upavon East and West. These adjustments are highlighted in Table 2.3.1:3a & b and baseline modelled near natural river concentrations along the Avon are shown in Figure 2.3.1:6a-e

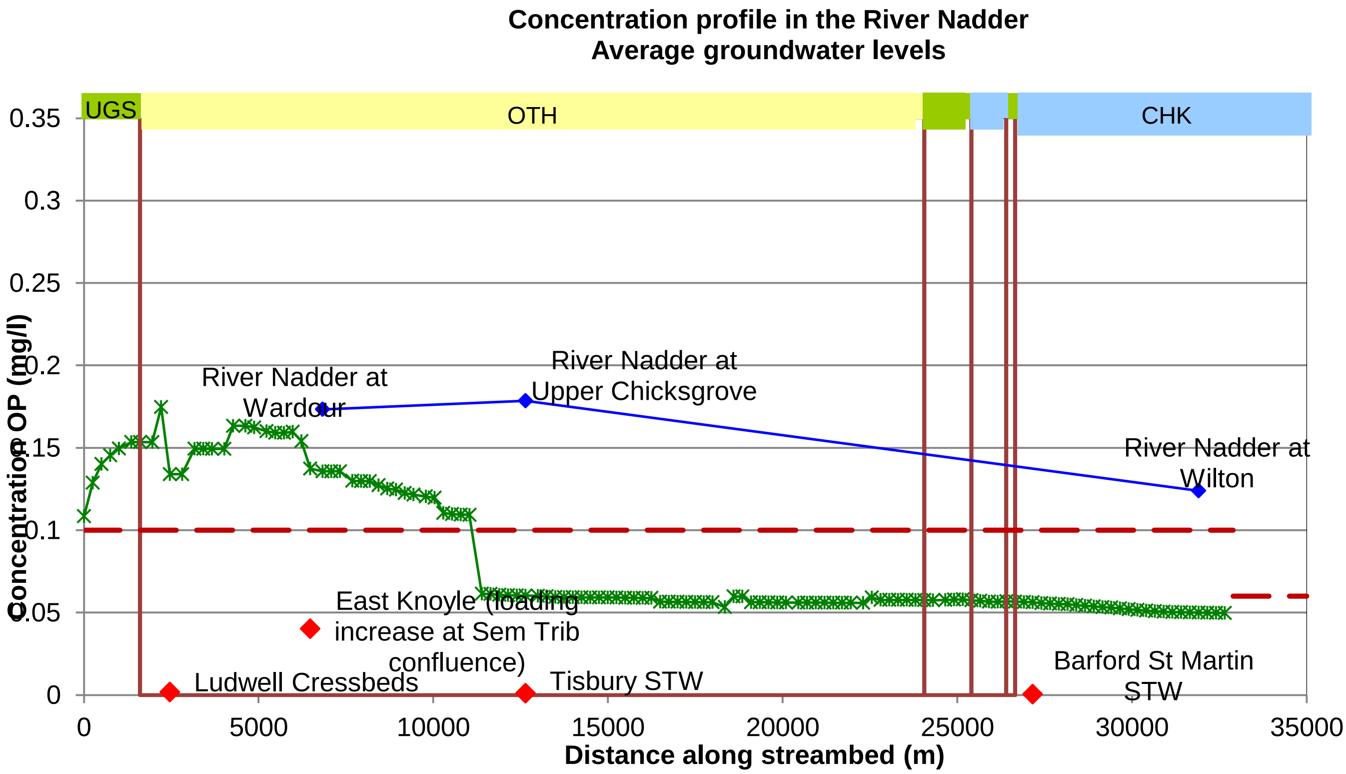
Table 2.3.1:3b Wessex Basin Model and Observed Flow for Upavon East and West

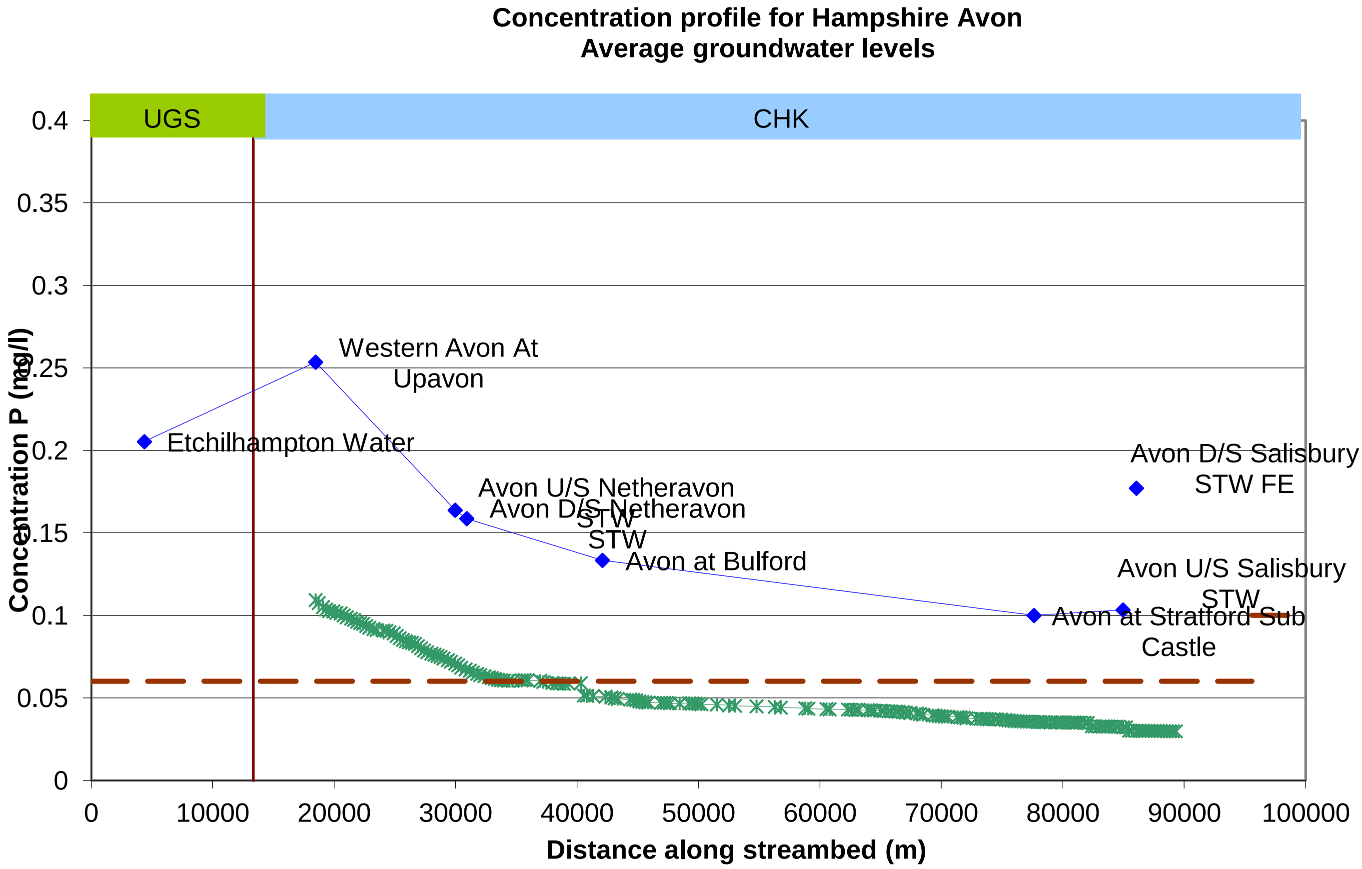
	Mean Modelled Flow (Ml/d) using WBM	Mean Observed Flow (Ml/d)	Obs v Model	Adjustment to model flow
Upavon East	86	71	83.1%	*0.83
Upavon West	65	60	92.5%	*0.925

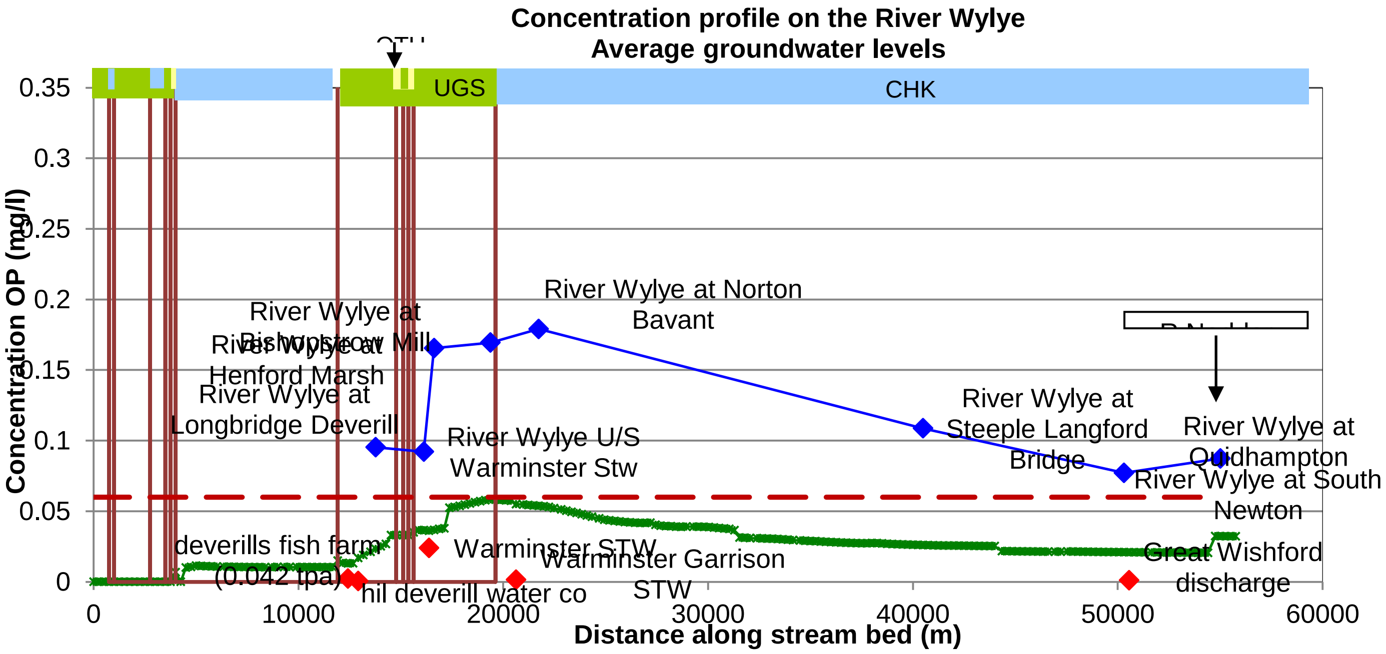
Figure 2.3.1:6a-d Modelled Background (Natural) Phosphate Concentrations Along the Hampshire Avon (shown in green) Assuming River Water Quality outlined in Table 2.3.1:3 & Compared against OLD WFD Standards (red line) & Average Observed Water Quality from 2002 (blue line)






Concentration profile in the River Nadder
Average groundwater levels
UGS
OTH
CHK
River Nadder at Wardour
River Nadder at Upper Chicksgrove
River Nadder at Wilton
East Knoyle (loading increase at Sem Trib confluence)
Ludwell Cressbeds
Tisbury STW
Barford St Martin STW
Concentration OP (mg/l)
Distance along streambed (m)


Concentration profile for Hampshire Avon
Average groundwater levels
UGS
CHK
Western Avon At Upavon
Etchilhampton Water
Avon U/S Netheravon
Avon D/S Netheravon STW
Avon at Bulford
Avon D/S Salisbury STW FE
Avon U/S Salisbury STW
Avon at Stratford Sub Castle
Concentration P (mg/l)
Distance along streambed (m)


Concentration profile on the River Wylye
Average groundwater levels
UGS
CHK
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Concentration OP (mg/l)
River Wylye at Norton Bavant
River Wylye at Bishopstrow Mill
River Wylye at Henford Marsh
River Wylye at Longbridge Deverill
River Wylye U/S Warminster Stw
River Wylye at Steeple Langford Bridge
River Wylye at Quidhampton
River Wylye at South Newton
deverills fish farm (0.042 tpa)
Warminster STW
Warminster Garrison STW
hil deverill water co
Great Wishford discharge
0
10000
20000
30000
40000
50000
60000
Distance along stream bed (m)

2.3.1:1 Future Water Quality Targets for the Avon

Because of the natural presence of phosphorus in the Avon, resulting from dissolution from minerals within the UGS aquifer, it will be necessary in the future to consider the appropriateness of generic water quality targets and where necessary adjust these to account for site specific natural loads.

From Figure 2.3.1:6a-e, it is clear that the predicted modelled background phosphorus load within the Avon are close to or in many cases above the earlier SAC targets in the catchment (defined by the red dashed line). From Upavon West, down the Avon, natural phosphorus concentrations exceed the original SAC target of 60ug/l to a point just above Salisbury. At the bottom of the Lower Avon, average natural concentrations are forecast to be 28ug/l. Similarly, natural concentrations along the whole of Upavon East and the Upper Nadder are forecast to exceed current SAC targets of 60 & 100ug/l respectively and updated JNCC targets. In the Wylye, the contribution of UGS spring water at Warminster, bring baseline water quality very close to the SAC targets of 60ug/l.

Modelled background river phosphorus concentrations are forecast to vary significantly throughout the catchment under high, low and average flows (Table 2.3.1:4). This is as a result of the changing baseflow contribution to the river from the UGS, Chalk and Tertiary geologies. In catchments influenced by UGS and Chalk baseflow, as rivers recede to low flows, the proportion of UGS water entering the system increase (due to the greater storage volume within the aquifer and slower release mechanisms). This results in an increasing P concentration. Under high water levels and flows, the opposite occurs, with a greater baseflow contribution from the Chalk aquifer and so increased effective dilution from lower P Chalk aquifer. At the bottom of the Avon, baseline P concentrations are forecast to vary between 28 & 41ug/l under high and low flows respectively.

In catchments fed predominately from UGS baseflow, such as the Nadder Swallowcliff, little modelled background changes in quality occur through the year and baseline modelled background concentrations remain high, as there is little dilution from lower P baseflow. Modelled background P concentrations in catchments fed predominantly from the chalk, remain fairly low under high and low flows. Some variation in modelled background concentrations does however occur, influenced by presence of phosphatic minerals in the chalk. Seasonal variations in river water quality can be seen in Appendix 2.3.1:3a & b.

Figure 2.3.1:4 Modelled background Phosphorus Concentrations (ug/l) for Low, High and Average Groundwater Levels (From Wessex Basin Time Step 1391, 1595, 1086 respectively: August 2003, April 2009, Feb 1995)

		Average Water Level (April 2009 time step1595)	LOW Water Level (Aug 2003; time step 1391)	HIGH Water Level (Feb 1995 time step 1086)
Ripley Brook	GB108043011010	10	10	10
Clockhouse Stream	GB108043011011	10	10	10
Bisterne Stream	GB108043011012	10	10	10
Linford Brook:	GB108043015720	10	10	10
Sleep Brook:	GB108043015730	10	10	10
Dockens Water:	GB108043015740	10	10	10
Huckles Brook:	GB108043015750	10	10	10
Ditchend Brook:	GB108043015770	10	10	10
Ashford Water (Allen River):	GB108043015800	10	10	10
Sweatford Water:	GB108043015810	10	10	10
Ebble	GB108043015830	10	10	10
Hampshire Avon (Lower)	GB108043015840	28	41	22
EBBLE TRIB (Chalke Valley Stream)	GB108043015860	10	10	10
EBBLE (Upper)	GB108043015870	10	10	10
NADDER (Lower)	GB108043015880	31	62	19
Nadder (Headwaters)	GB108043016160	154	163	105
Nadder Tribs (Swallowcliff)	GB108043016180	157	162	151
Fovant Brook	GB108043016190	86	110	82
Nadder (upper)	GB108043016200	109	154	42
Sem	GB108043016210	112	113	102
Hampshire Avon (Upper) u/s Nine Mile River	GB108043022351	51	77	44
Hampshire Avon (Upper) d/s Nine Mile River	GB108043022352	35	42	34
Nine Mile River	GB108043022360	10	10	10
Hampshire Avon (West)	GB108043022370	97	109	96
BOURNE	GB108043022390	10	10	10
Hampshire Avon East and Woodborough Stream	GB108043022410	117	125	113
Deane Water	GB108043022420	137	140	129
Etchilhampton Water	GB108043022430	108	109	108
Nadder (middle)	GB108043022470	50	104	30
Teffont	GB108043022471	24	58	20
FONTHILL STREAM	GB108043022500	25	59	18
Wylye (Lower)	GB108043022510	20	35	15
Wylye (Headwaters)	GB108043022520	38	59	26
Wylye Trib (Heytesbury Stream)	GB108043022530	10	10	10
Wylye Trib (The Were or Swab)	GB108043022540	175	172	179
Wylye (Middle)	GB108043022550	25	41	19
Chitterne Brook tributary	GB108043022560	10	10	10
Till Tributary	GB108043022570	10	11	10

Current generic water quality targets across the Avon in most catchments are likely to be too low and it is recommends that a new typology should be developed for UGS fed catchments, to reflect the natural P contributions. Further research should be undertaken to understand the impact of these elevated baseline P concentrations on ecology and to identify baseline ecology that would be expected in such catchments.

Until these revised target have been developed, it is proposed that in the short term (2021) the measures delivered through the NMP are intended to achieve the agreed 'ambition reduction targets' primarily through action on diffuse sources and, where necessary, through further point source measures . Any point source improvements to water company asset, subject to the relevant agreements would be implemented under AMP7 (2020-25). Ambition phosphorus reduction targets are water quality reductions at different points across the Avon, which are required to work towards favourable status. They are reflective of modelled background water quality, observed current water quality and the improvements in water quality likely to be required to achieve these objectives. They should be challenging but achievable by 2021 with additional water company STW improvements, where required being installed under AMP7 (2020-25). It is recommended that the ambition targets are reviewed in line with the WFD planning cycle, in light of any improved understanding of phosphorus loads to the Avon and diffuse pollution prevention delivery. Recommended ambition targets are outlined in Table 2.3.1:5.

When analysing the change in water quality over any cycle, it is important that an assessment is made to identify if this period is drier or wetter than the LTA and for water quality results to be compared with earlier modelling periods. This understanding will allow an interpretation of the likely changes in quality that would result as a response to the changing recharge and flow processes (and different proportion of river baseflow derived from chalk and UGS aquifers) and the changes resulting from the implementation of measures across the catchment. If the year or period of years was wetter than the long term average, we may expect more run-off (with associated sediments) and flow from the chalk aquifer. In the Upper Greensand reaches increased chalk baseflow and more rapid through flow through the UGS aquifer may result in increased dilution of modelled background baseline phosphorus concentrations. From this, we may expect average P concentrations in UGS fed reaches during wetter years to reduce. In the lower reaches of the Avon we would expect concentrations to exceed LTA because of increased run-off volumes containing suspended sediment and dissolved and particulate P. During drier periods of time the opposite will happen with reduced dilution of baseline modelled background UGS P concentrations and reduced run-off.

Table 2.3.1:5 Proposed Ambition Phosphorus Reduction Targets (ug/l P and KG/yr P) across the Hampshire Avon. Note: all targets will be subject to review following the development of new typology for the Avon.

		Forecast natural WQ at Average Flow (April 2009)	Model Flow (m3/d) Run 1a (Cannings & East Knoyle @ 1mg/l P)	Modelled Water Quality 2010-11 baseline (Run 1a) with PR14 (ug/l) *2	Average Water Quality (WFD) 2010-12 data	Target reduction ug/l	Target load reductions (2010-11) (kg/yr)
Ripley Brook	GB108043011010	10	2520	30	11	0	0
Clockhouse Stream	GB108043011011	10				0	0
Bisterne Stream	GB108043011012	10				0	0
Linford Brook:	GB108043015720	10	2610	30	16	0	0
Sleep Brook:	GB108043015730	10	1960	30	15	0	0
Dockens Water:	GB108043015740	10	2990	29	25	-15	-16
Huckles Brook:	GB108043015750	10	3350	29	23	0	0
Ditchend Brook:	GB108043015770	10	2030	30	12	0	0
Ashford Water (Allen River):GB108043015800	GB108043015800	10	22800	37	26	0	0
Sweatford Water:	GB108043015810	10	4690	30	15	0	0
Ebble	GB108043015830	10	108000	61	40	0	0
Hampshire Avon (Lower)	GB108043015840	28	1275600	69	71	-20*2	-9312
EBBLE TRIB (Chalke Valley Stream)	GB108043015860	10	24100	67	81	0	0
EBBLE (Upper)	GB108043015870	10	23400	59	60	0	0
NADDER (Lower)	GB108043015880	31	389300	80	69	-10	-1421
Nadder (Headwaters)	GB108043016160	154	29200	125	175	0	0
Nadder Tribs (Swallowcliff)	GB108043016180	157	9280	124	156	0	0
Fovant Brook	GB108043016190	86	17800	139	137	0	0
Nadder (upper)	GB108043016200	109	57100	129	146	-20	-417
Sem	GB108043016210	112	19700	146	179	0	0
Hampshire Avon (Upper) u/s Nine Mile River confl	GB108043022351	51	180600	133	#N/A	-20	-1318
Hampshire Avon (Upper) d/s Nine Mile River confl	GB108043022352	35	274900	95	65	-10 (-20)*1	-1003*1 (-2007)*1
Nine Mile River	GB108043022360	10	24800	20	13	0	0
Hampshire Avon (West)	GB108043022370	97	50200	167	240	-40	-733
BOURNE	GB108043022390	10	52200	53	49	-10	-191
Hampshire Avon East and Woodborough Stream	GB108043022410	117	76000	177	161	-20	-555
Deane Water	GB108043022420	137	25300	159	144	0	0
Etchilhampton Water	GB108043022430	108	33700	165	309	0	0
Nadder (middle)	GB108043022470	50	174000	115	116	-20	-1270
Teffont	GB108043022471	24	174000	115	44	0	0
FONTHILL STREAM	GB108043022500	25	30000	124	35	0	0
Wylye (Lower)	GB108043022510	20	203800	55	72	-10	-744
Wylye (Headwaters)	GB108043022520	38	57500	90	77	-30	-630

Wylye Trib (Heytesbury Stream)	GB108043022530	10	7460	60	211	0	0
Wylye Trib (The Were or Swab)	GB108043022540	175	4180	60	532	0	0
Wylye (Middle)	GB108043022550	25	161200	58	92	-10	-588
Chitterne Brook tributary	GB108043022560	10	26400	20	35	0	0
Till Tributary	GB108043022570	10	39800	39	34	0	0

*[1] Agreed ambition target for Hampshire Avon d/s of Nine Mile Confluence is -10ug/l or -1003 kg/yr. For ease of analysis the whole upper Avon was modelled with an ambition target of -20ug/l. *[2] PR 14 runs include All Cannings STW and East Knoyle STW running with P stripping and operating at full permit conditions of 1mg/l discharge quality (See Section 2.3.2).

2.3.2: Point Source

The Environment Agency SIMCAT model (Section 1.5.1) was used to make an initial assessment of point source loads across the Avon. Following Murdoch (2011)[7], a number of additional scenarios runs were undertaken in SIMCAT to assist in identifying how phosphorus should be managed across the Avon. These model runs, similarly applied a decay function of 10% to improve the calibration of the model of -0.1mg/l reduced from water results p[7].

- ***Run 1a****:* represents the current baseline, where 2010-11 water quality data was calibrated in SIMCAT and point source discharges were included at current discharge volumes and quality. This scenario is therefore considered to represent the current status of the river. Note changes to discharge quality for fish farm and water cress compared to Murdoch 2011[7]. Model file HAB_1a result v1.
- ***Run 1a+PR14****:* As Run 1a, but modelling the effect of P stripping at All Cannings and East Knoyle STW, as proposed under PR14 (operating at maximum permit condition of 1mg/l P). This is the water quality we would have expected downstream of these STW, had PR14 improvements been made before 2010. Model file: HAB_1a E Knoyle_Cannings.
- ***Run 1a+PR14+full practical permit uptake:*** As Run1a+PR14 but modelling full practical permit uptake scenario with all STW discharging at maximum permit flow and 70% of permit water quality. This represents a realistic upper discharge quality that water companies might operate at, ensuring that any peak concentrations do not exceed permit conditions. Model file HAB 2c E Knoyle Cannings.
- ***Run 1a_No STW*****:** As Run 1a but all STW set to zero flow and zero quality Model file Avon_2010_11_No STW.
- ***Run 1a_No Point Source Load*****:** As Run 1a but with all point source loads set to zero. Model file:SIMCAT_Avon_11_V9.

Water Quality results from these runs are presented in Figure 2.3.2:1 to 14 and Table 2.3:2

Analysis of SIMCAT model output data showed that Sewage Treatment Works (STW) contributed the greatest point source P loads in the Avon. Fish Farms and Water Cress Farms and small discharges make up the remaining sources (Table 2.3.2a). A further discussion of each of these point sources is outlined below.

STW loadings calculations were also undertaken by Wessex Water for 2011 and these are presented in Table 2.3.2d.

A summary of the source apportionment results from the updated baseline scenarios are presented in Table 2.3:2a.

Figure 2.3.2:1 Change in Phosphorus concentration (ug/l) at Sub Catchments within the Avon from Modelled Point Source Scenarios

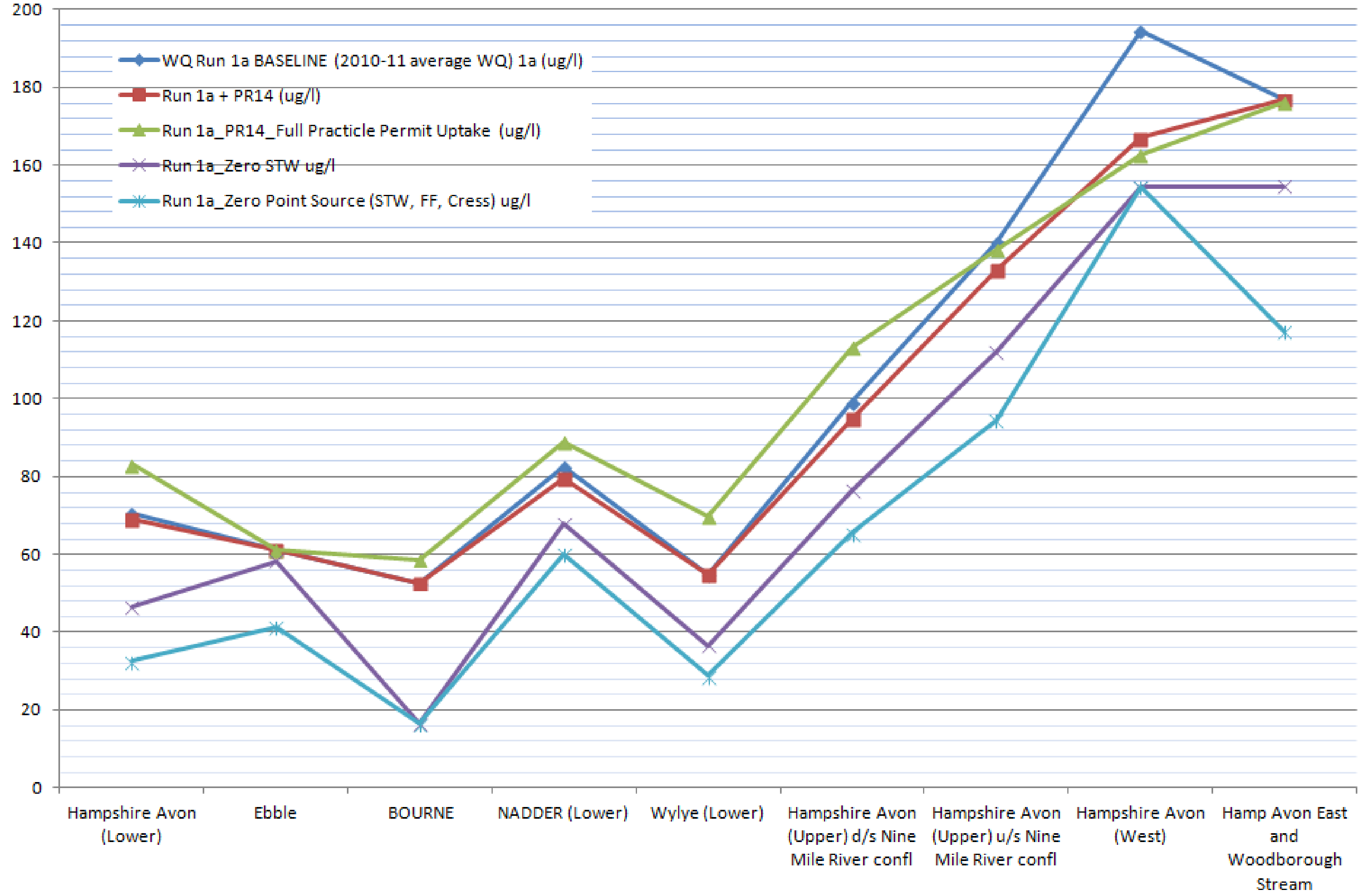


Figure 2.3.2:2 Forecast Phosphorus Concentration (ug/l) from Avon Run 1a baseline (blue), Run1a+PR14 (green)

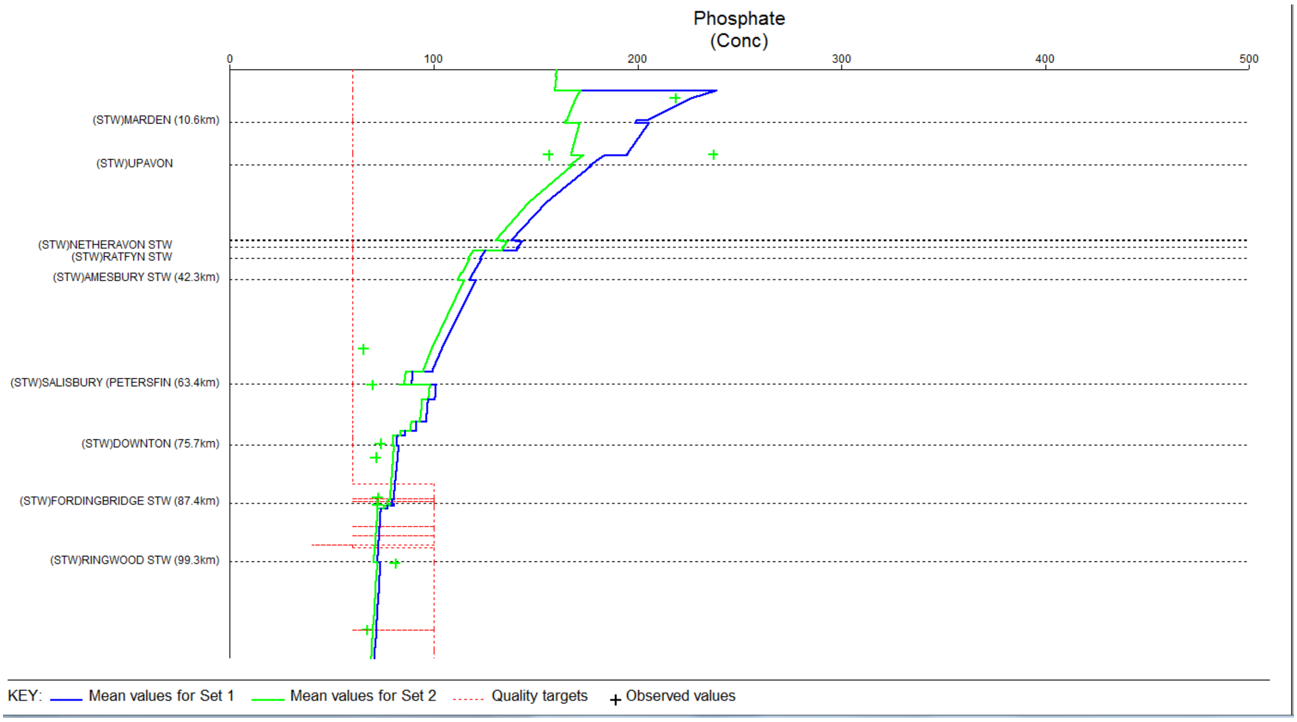


Figure 2.3.2:3 Forecast Phosphorus Concentration (ug/l) from Avon Run 1a+PR14+full practical permit uptake (blue) V Run 1a+PR14 (green)

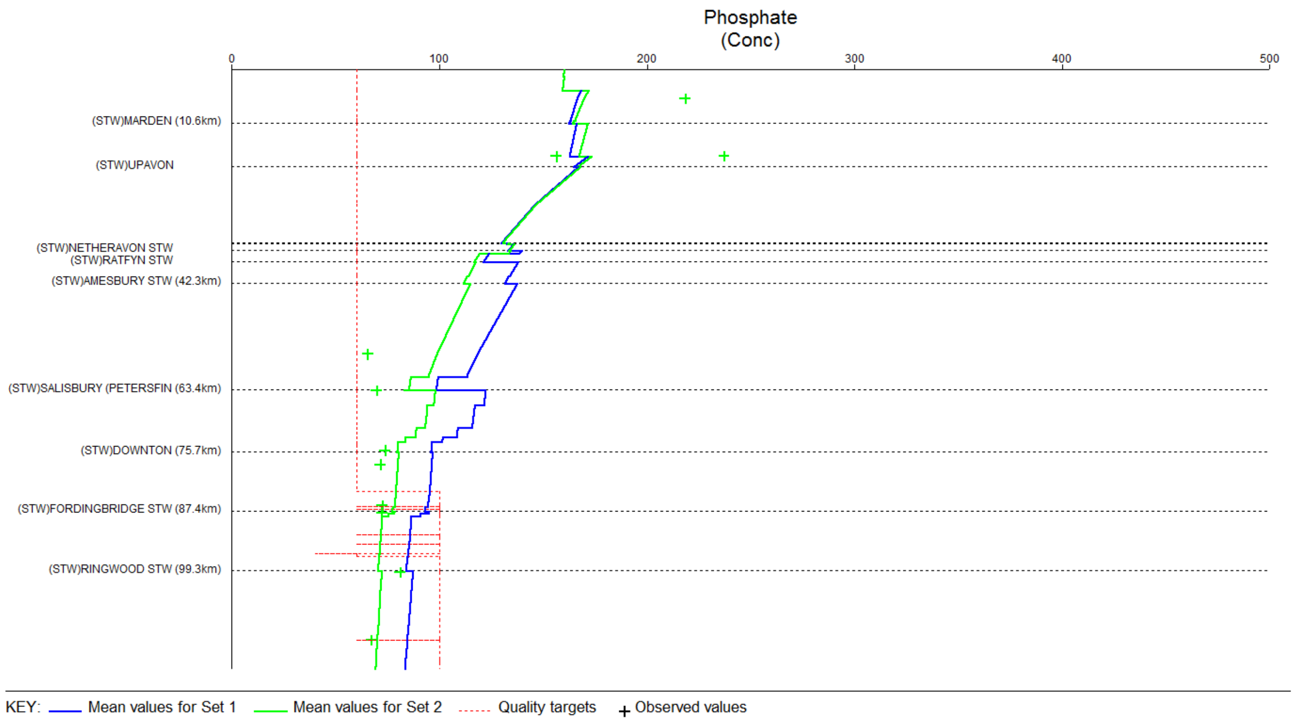


Figure 2.3.2:4 Forecast Phosphorus Concentration (ug/l) from Avon Run 1a+ NO PR14+full practical permit uptake (blue) V Run 1a+PR14 (green)

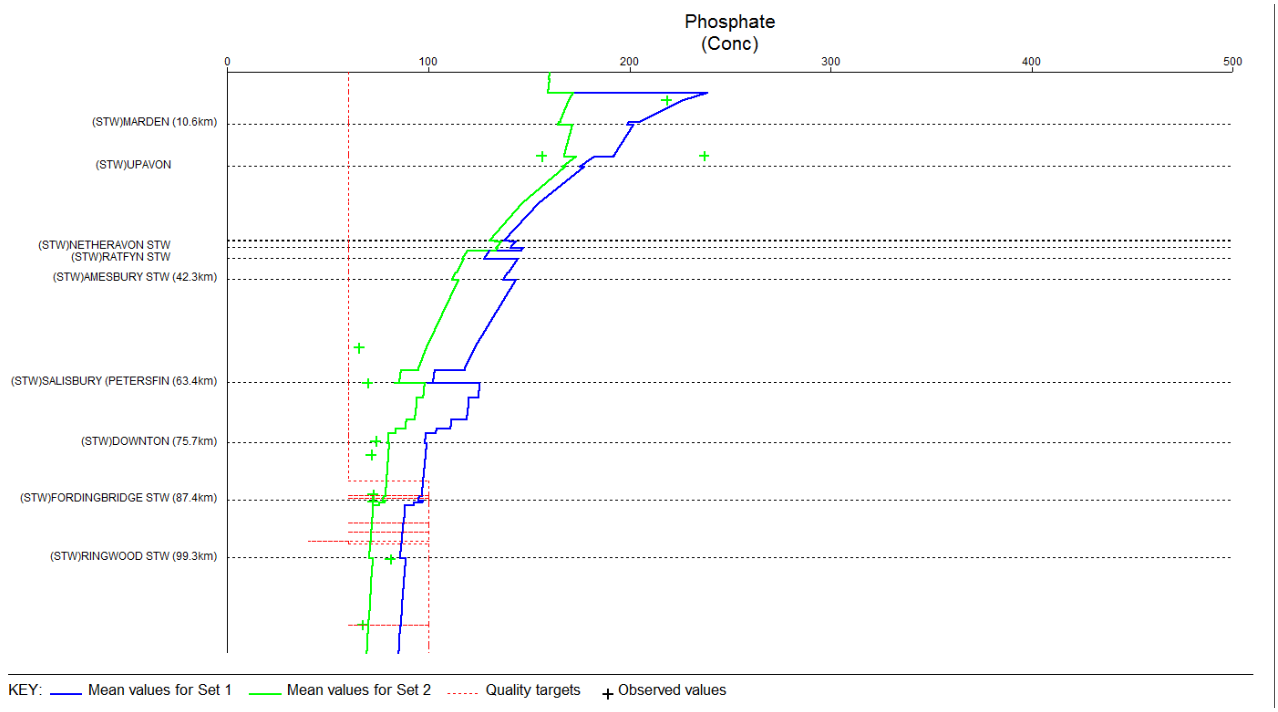


Figure 2.3.2:5 Forecast Phosphorus Concentration (ug/l) from Avon Run 1a+ No STW (blue) V Run 1a+PR14 (green)

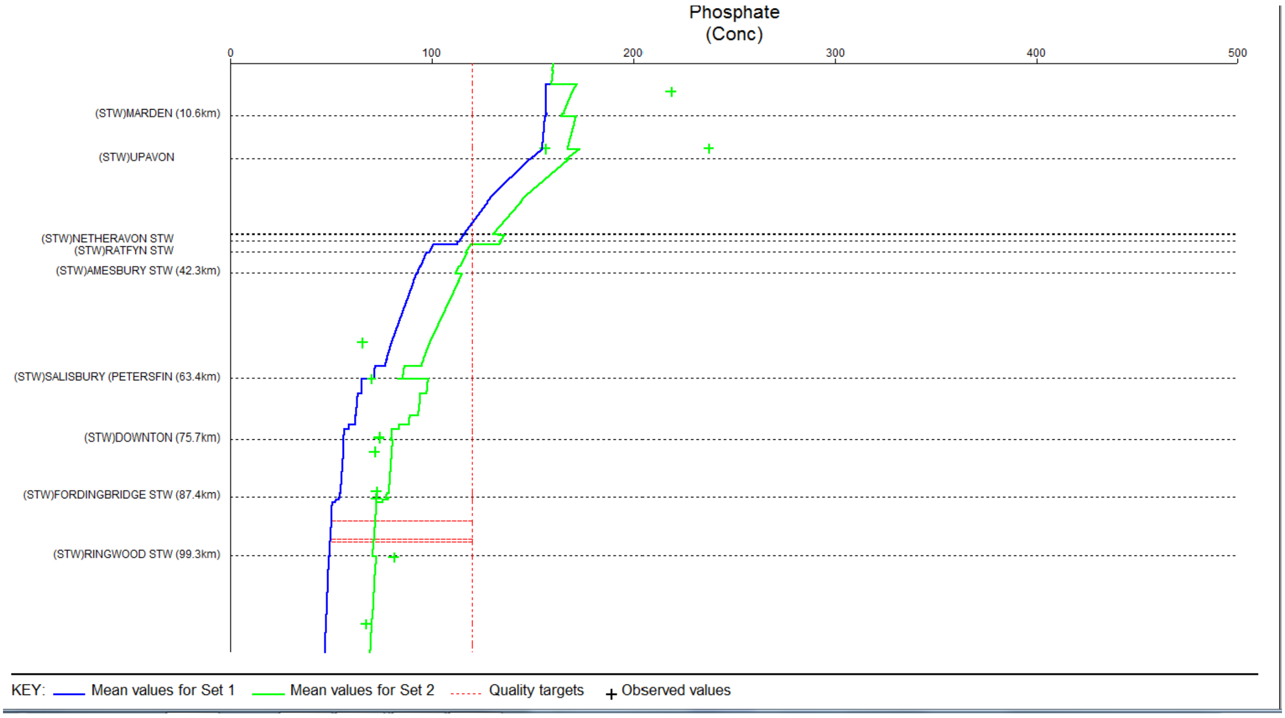


Figure 2.3.2:6 Forecast Phosphorus Concentration (ug/l) from Avon Run 1a+ No Point Source Load (blue) V Run 1a+PR14 (green)

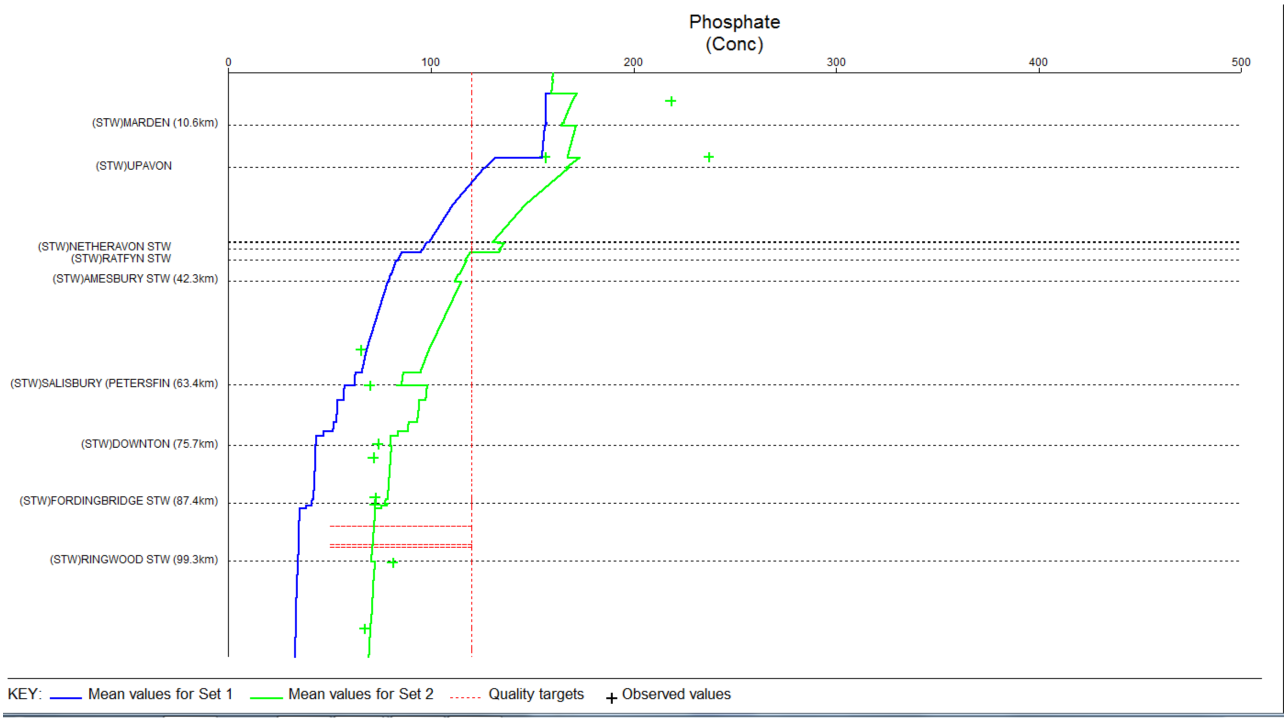


Figure 2.3.2:7 Forecast Phosphorus Concentration (ug/l) from Wylye Run 1a baseline (blue), Run1a+PR14 (green)

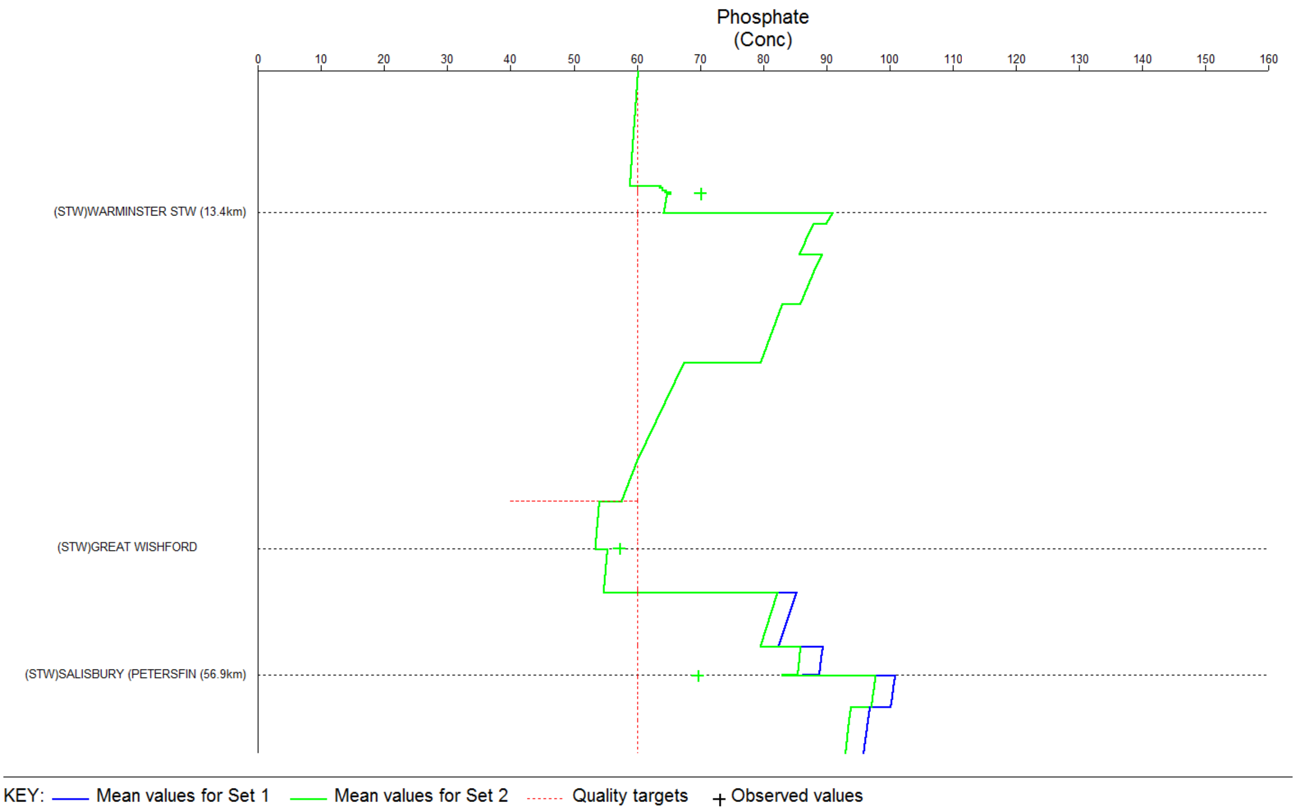


Figure 2.3.2:8 Forecast Phosphorus Concentration (ug/l) from Wylye Run 1a+PR14+full practical permit uptake (blue) V Run 1a+PR14 (green)

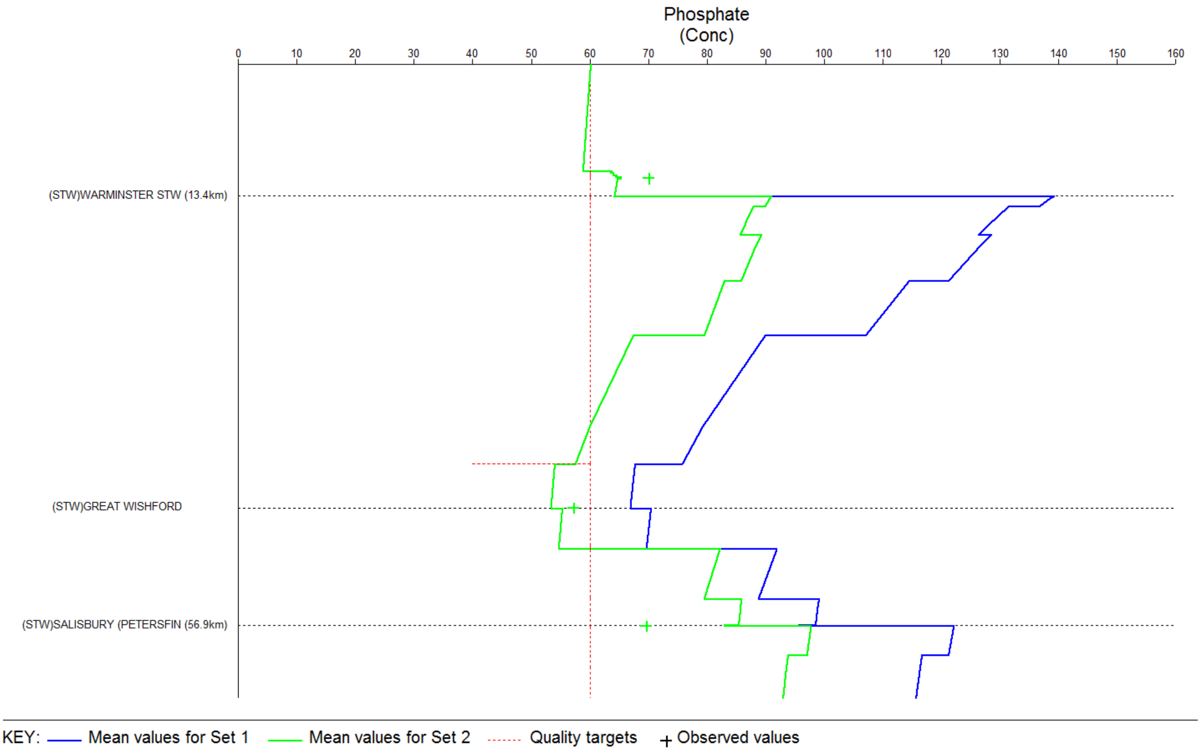


Figure 2.3.2:9 Forecast Phosphorus Concentration (ug/l) from Wylye Run 1a+ No STW (blue) V Run 1a+PR14 (green)

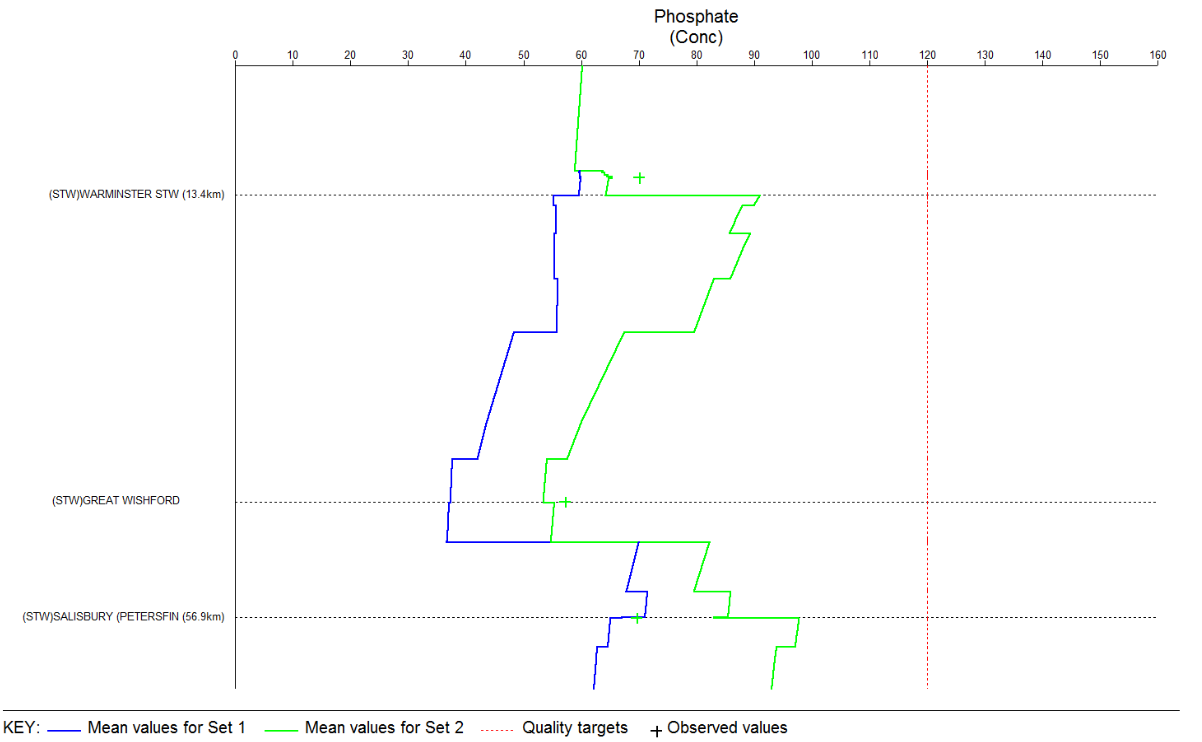


Figure 2.3.2:10 Forecast Phosphorus Concentration (ug/l) from Wylye Run 1a+ No Point Source Load (blue) V Run 1a+PR14 (green)

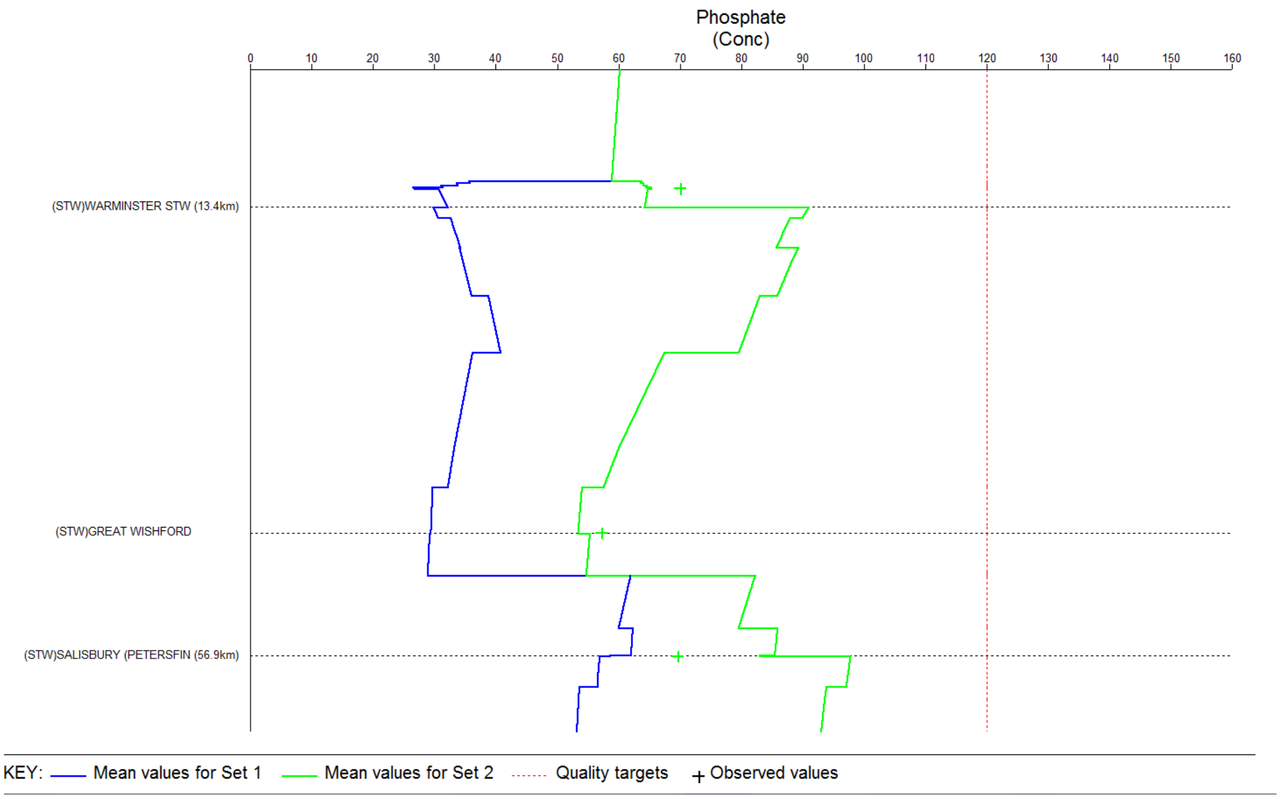


Figure 2.3.2:11 Forecast Phosphorus Concentration (ug/l) from Nadder Run 1a baseline (blue), Run1a+PR14 (green)

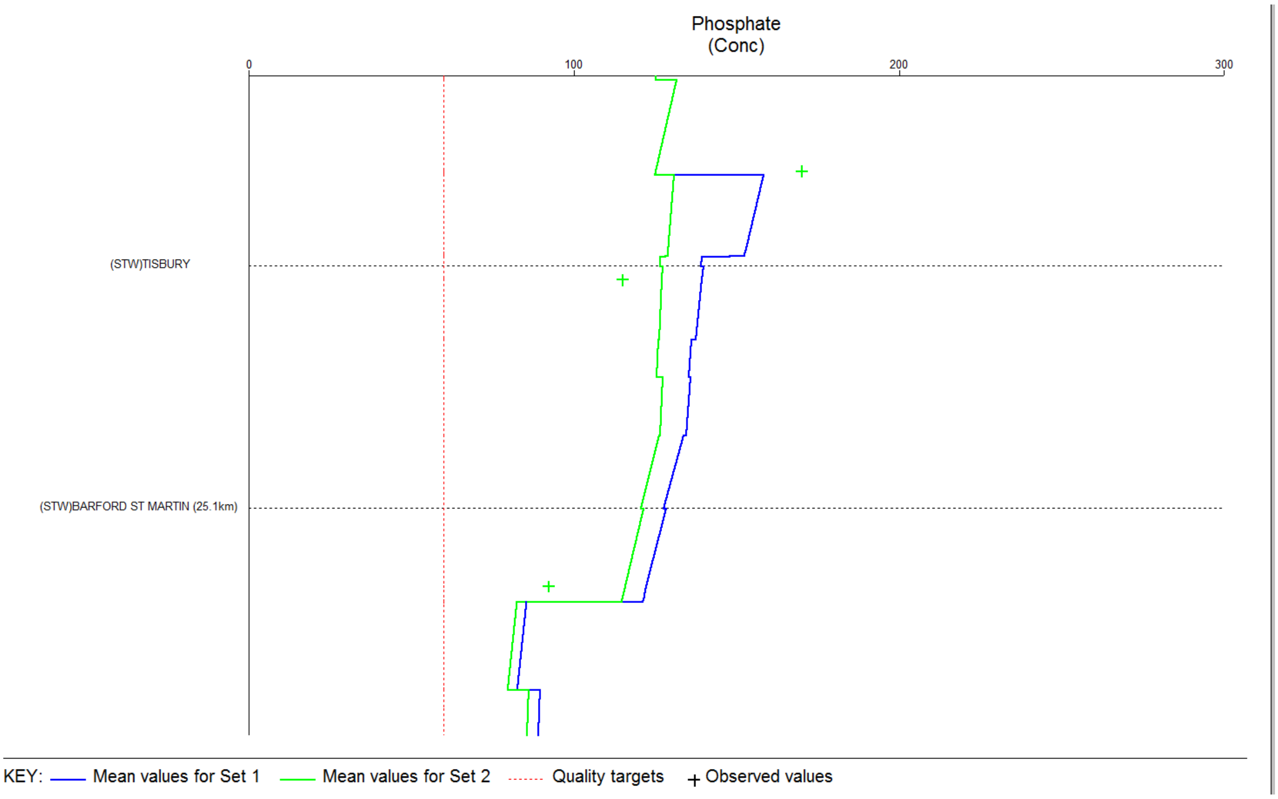


Figure 2.3.2:12 Forecast Phosphorus Concentration (ug/l) from Nadder Run 1a+PR14+full practical permit uptake (blue) V Run 1a+PR14 (green)

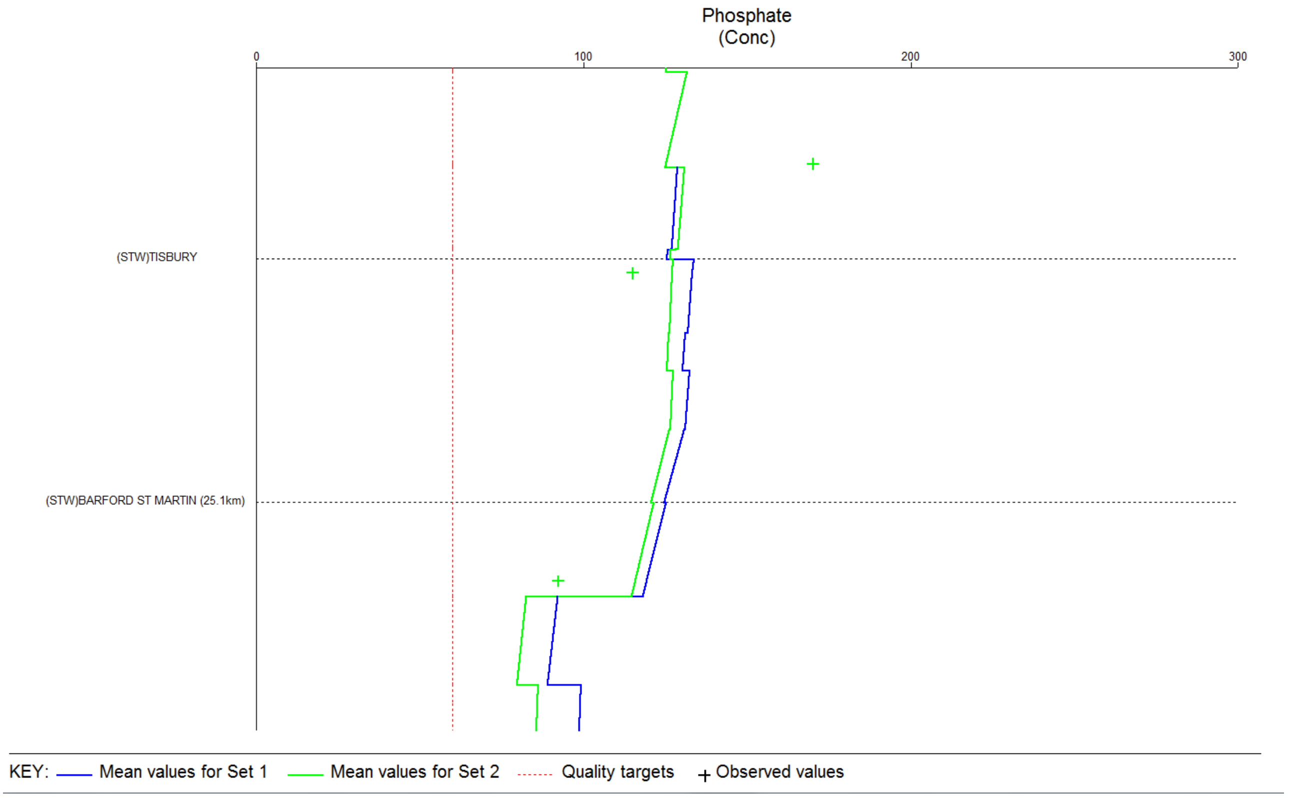


Figure 2.3.2:13 Forecast Phosphorus Concentration (ug/l) from Nadder Run 1a+ No STW (blue) V Run 1a+PR14 (green)

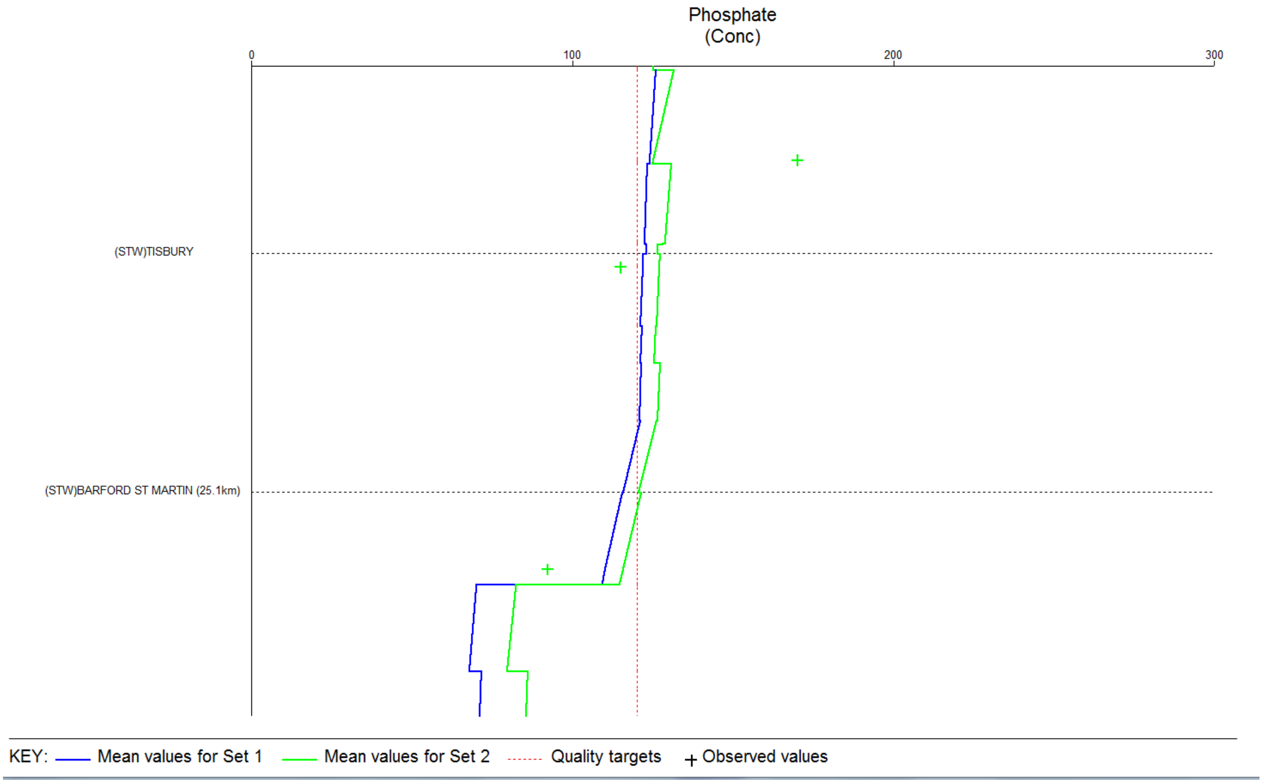


Figure 2.3.2:14 Forecast Phosphorus Concentration (ug/l) from Nadder Run 1a+ No Point Source Load (blue) V Run 1a+PR14 (green)

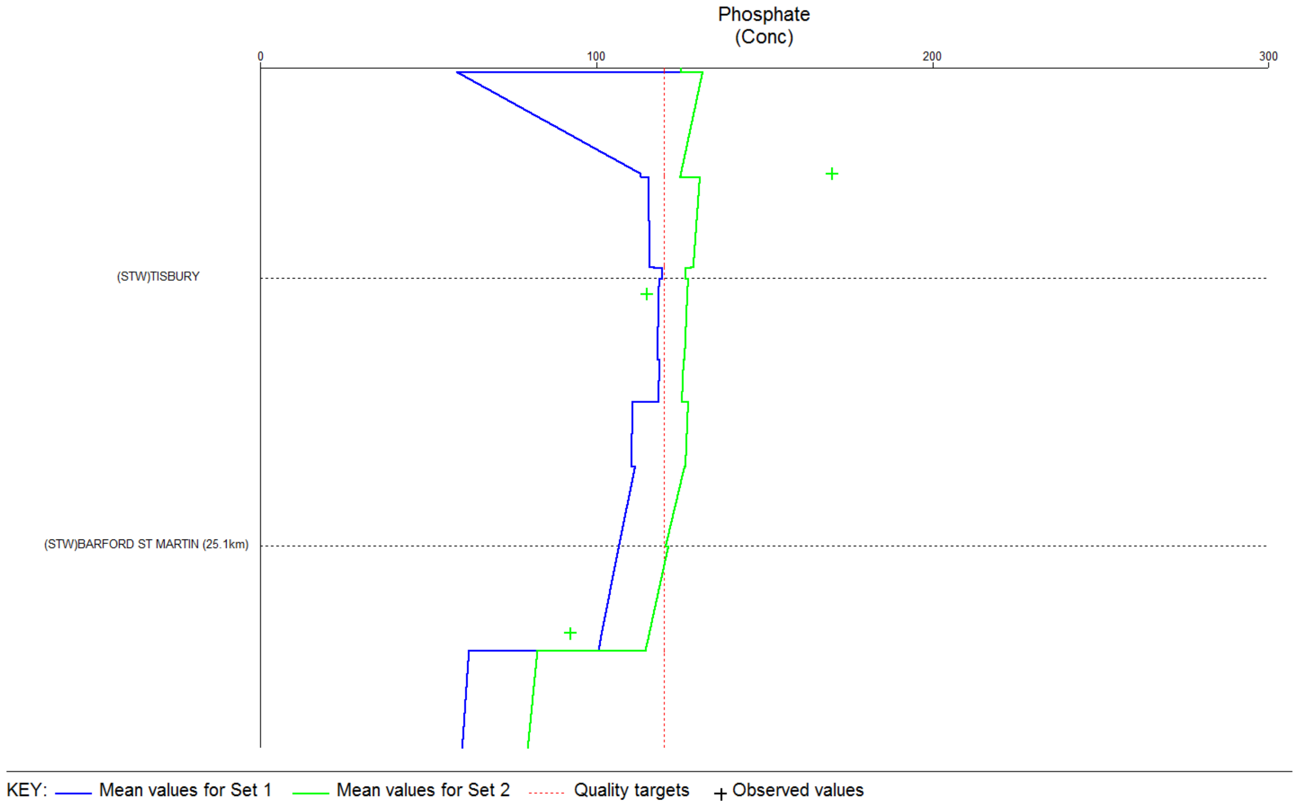


Table 2.3.2 Forecast Phosphorus Concentration (ug/l) For Each Water Body from SIMCAT model Scenarios

Catchment		WQ Run 1a BASELINE (2010-11 average WQ) 1a (ug/l)	Run 1a + PR14 (ug/l)	Run 1a_PR14_ Full Practical Permit Uptake (ug/l)	Run 1a_Zero STW ug/l	Run 1a_Zero PS (STW, FF, Cress) ug/l
Hampshire Avon (Lower)	GB108043015840	71	69	83	47	33
Ripley Brook	GB108043011010	30	30	30	30	30
Linford Brook:	GB108043015720	30	30	30	30	30
Dockens Water:	GB108043015740	29	29	29	29	29
Sleep Brook:	GB108043015730	30	30	30	30	30
Huckles Brook:	GB108043015750	29	29	29	29	29
Ditchend Brook:	GB108043015770	30	30	30	30	30
Ashford Water (Allen River):GB108043015800	GB108043015800	37	37	37	30	9
Sweatford Water:	GB108043015810	30	30	30	30	30
Ebble	GB108043015830	61	61	61	58	41
EBBLE TRIB (Chalke Valley Stream)	GB108043015860	67	67	67	60	20
EBBLE (Upper)	GB108043015870	59	59	59	59	59
BOURNE	GB108043022390	53	53	59	16	16
NADDER (Lower)	GB108043015880	82	80	89	68	60
Nadder (middle)	GB108043022470	121	115	118	109	101
Fovant Brook	GB108043016190	139	139	144	123	66
Teffont	GB108043022471	121	115	118	109	101
Nadder Tribs (Swallowcliff)	GB108043016180	124	124	124	124	124
FONTHILL STREAM	GB108043022500	124	124	124	124	124
Nadder (upper)	GB108043016200	152	129	127	122	116
Sem	GB108043016210	249	146	139	121	121
Nadder (Headwaters)	GB108043016160	125	125	125	124	113
Wylye (Lower)	GB108043022510	55	55	70	37	29
Wylye (Middle)	GB108043022550	58	58	76	42	32
Till Tributary	GB108043022570	39	39	32	19	19
Chitterne Brook tributary	GB108043022560	20	20	20	20	20
Wylye Trib (Heytesbury Stream)	GB108043022530	60	60	60	60	60
Wylye Trib (The Were or Swab)	GB108043022540	60	60	60	60	60
Wylye (Headwaters)	GB108043022520	90	90	137	55	30
Hampshire Avon (Upper) d/s Nine Mile River confl	GB108043022352	99	95	113	77	66
Nine Mile River	GB108043022360	20	20	20	20	20
Hampshire Avon (Upper) u/s Nine Mile River confl	GB108043022351	140	133	138	112	95
Hampshire Avon (West)	GB108043022370	194	167	163	154	154
Etchilhampton Water	GB108043022430	206	165	163	156	156
Hampshire Avon East and Woodborough Stream	GB108043022410	177	177	176	155	117
Deane Water	GB108043022420	159	159	159	159	159

Table 2.3.2 Continued: Forecast Phosphorus Concentration (ug/l) Downstream of STW from SIMCAT model scenarios

STW	Model Baseline Run 1a	Model Run 1a (Cannings & East Knoyle @ 1mg/l P)	Run 1a_PR14_Full Practical Permit Uptake (ug/l)	Model Run 1a but No STW	Model Run 1a_no discharge_from Avon 11 v9
AMESBURY STW	120.3	114.7	137.3	91.9	78.2
BARFORD ST MARTIN	128.1	121.2	124.9	115.4	106.3
BRADLEY STW PRIOR TO SOAKAW	140.2	132.9	132.3	115.7	97.6
CANNINGS	394.9	196.5	185.6	151.5	151.5
CHERRY ORCHARD STW FE	143.3	136	135.4	115.4	97.4
COLLINGBOURNE DUCIS	20.7	20.7	20.7	19	19
DOWNTON	82.1	80.1	96.6	55.7	42.6
EAST KNOYLE	950.4	271.2	222.5	104	104
FORDINGBRIDGE STW	80	78.1	94.7	53.5	40.7
FOVANT	138.7	138.7	143.9	122.6	65
GREAT WISHFORD	55.2	55.2	70.3	36.9	29.1
HURDCOTT	58.3	58.3	65.2	16.1	16.1
MARDEN	205.2	171.2	165.9	155.6	155.6
NETHERAVON STW	141.4	134.2	139.4	112.9	95.3
PEWSEY STW	191.1	191.1	189.5	150.7	150.7
RATFYN STW	123.1	117.2	137.8	97	82.4
RINGWOOD STW	73.5	71.9	86.7	48.5	33.8
SALISBURY (PETERSFIN	100.7	97.6	122	64.9	56.8
SHIPTON BELLINGER	24.7	24.7	24.7	16.1	16.1
SHREWTON	73.9	73.9	56.1	18.4	18.4
TIDWORTH GARRISON STW FE	24.4	24.4	24.4	16.4	16.4
TISBURY	139.5	127.1	133.4	121.8	118.4
UPAVON	177.3	167.4	166.6	148.1	125.9
WARMINSTER STW	90.9	90.9	139.1	55	29.7

Table 2.3:2a Hampshire Avon P Loading (kg/P/yr) Using Updated Source Apportionment Results from SIMCAT Scenarios using 2010-11 and Long Term Average Flow data and using SIMCAT point Sources and updated Wessex Water STW Loading (note SIMCAT decay function of 10% has not been added back into SIMCAT results

	Phosphorus Load (using Wessex Water STW Loads, all other loads from SIMCAT scenario Run 1a (baseline) (kg/yr)	Phosphorus Load In 2025 with PR-14 improvements (using Wessex Water forecast STW Loads, all other loads from SIMCAT scenario Run 1a (baseline) (kg/yr)	Phosphorus Load to 2035 (using Wessex Water STW Loads), all other loads from SIMCAT scenario 2c) (baseline) (kg/yr)	SIMCAT (2010-11) Run 1a*1 (baseline)	SIMCAT (2010-11) Run 1a+PR14*1 (baseline)	SIMCAT (2010-11) Run 1a+PR14+Full practical permit uptake*1 (baseline)	SIMCAT Phosphorus Load ScenarioRun 2a *1 (baseline) (kg/yr)	Phosphorus Load Scenario Run 2c*1 (full practical permit uptake) (kg/yr)
Cumulative STW	11061	11792	14147	11263	10564	17639	11263	17639
Cumulative Fish Farm & Water Cress	6491.74	6491.74	6491.74	6492	6492	6492	6492	6492
Total point source	17553	18283	20639	17754	17056	24130	17754	24130
Total Diffuse (including natural)	15070	15070	15070	15070	15070	15070	21361	22857
Grand Total	32623	33354	35709	32824	32126	39200	39115	46987

*[*1]Note SIMCAT model includes a decay function of 0.1 to achieve calibration. Total Phosphate input loads are likely to be around 10% higher that reported by the SIMCAT model. LTA Diffuse Load Likely to be higher than SIMCAT modelled [*2] Note the main difference in WW forecast phosphorus load and SIMCAT forecast loads under the full practical permit uptake scenario (SIMCAT model run 2c) is that SIMCAT run is 2, 1.2 and 0.5 tonnes P/yr greater under SIMCAT than WW forecast for Salisbury STW, Ratfyn STW and Warminster STW respectively.*

Source Apportionment Based on SIMCAT and Updated Wessex Water Loading Figures

Table 2.3:2b Hampshire Avon P Loading (kg/P/yr) Using Flow Apportionment OP Loads, SIMCAT Point Source Scenarios (2010-11) and Long Term Average Flow data and using SIMCAT point Sources and updated Wessex Water STW Loading (note SIMCAT decay function of 10% has not been added back into SIMCAT results

	Phosphorus Load (using Wessex Water STW Loads, Flow Apportioned Diffuse all other loads from SIMCAT scenario Run 1a (baseline) (kg/yr)	Phosphorus Load In 2025 with PR-14 improvements (using Wessex Water forecast STW Loads, Flow Apportioned diffuse, all other loads from SIMCAT scenario Run 1a (baseline) (kg/yr)	Phosphorus Load to 2035 (using Wessex Water STW Loads, Flow apportioned diffuse, all other loads from SIMCAT scenario Run 1a) (baseline) (kg/yr)	SIMCAT (2010-11) diffuse based on flow apportionment Run 1a*1 (baseline)	SIMCAT (2010-11) Run 1a+PR14*1 diffuse based on flow apportionment (baseline)	SIMCAT (2010-11) Run 1a+PR14+Full practical permit uptake*1 diffuse based on flow apportionment (baseline)
Cumulative STW	11061	11792	14147	11263	10564	17639
Cumulative Fish Farm & Water Cress	6492	6492	6492	6492	6492	6492
Total point source	17553	18283	20639	17754	17056	24130
Total Diffuse (including natural)	30237	30431	30431	30036	30036	30036
Grand Total	47790	48714	51070	47790	47092	54166

*1 *Note SIMCAT model includes a decay function of 0.1 to achieve calibration. Total Phosphate input loads are likely to be around 10% higher that reported by the SIMCAT model. LTA Diffuse Load Likely to be higher than SIMCAT modelled* *2 *Note the main difference in WW forecast phosphorus load and SIMCAT forecast loads under the full practical permit uptake scenario (SIMCAT model run 2c) is that SIMCAT run is 2, 1.2 and 0.5 tonnes P/yr greater under SIMCAT than WW forecast for Salisbury STW, Ratfyn STW and Warminster STW respectively.*

Source Apportionment Based on SIMCAT and Updated Wessex Water Loading Figures

2.3.2:1 Sewage Treatment Works (STW)

Wessex Water is the main Sewage Undertaker across the Avon catchment, serving an estimated residential population of around 140,000 people in 2011 and a Population Equivalent (including residential and commercial loads) of 156,000 PE (Tables 2.4.1:2a & b).

Between 2002 and 2009, Wessex Water installed phosphate stripping at 17 of their largest STW (Table 2.3.2c) to achieve the "proportionate" loading reductions required under the Review of Consents[11]. This has resulted in STW phosphorus loading to the Avon reducing from around 80 tonnes yr[23] to c11 tonnes P/year (Table 2.3.2a-c).

Under Periodic Review 14 (PR14) and between 2015 and 2020, Wessex Water proposes to install further phosphorus stripping at East Knoyle and All Cannings STW. This will reduce the overall phosphorus load further by approximately 0.7-0.8 tonnes/yr (assuming operating quality of 0.7mg/l). Water quality improvements as a result of All Cannings PR 14 improvement are modelled to result in average phosphorus concentrations at the bottom of Hampshire Avon (West) (and top of Hampshire Avon Upper (u/s nine mile) reducing from 194ug/l to 167ug/l (27ug/l improvement). Upstream of the confluence of the Wylye and Nadder the water quality improvement resulting from All Cannings takes average quality from 99 to 95ug/l at the bottom of Hampshire Avon Upper d/s Nine Mile.

East Knoyle PR14 improvements are modelled to reduce average OP concentrations at the bottom of the Sem (top of Nadder Upper) from 249ug/l to 146ug/l. At the bottom of the Nadder Upper this equates to a water quality improvements from 152 to 129 ug/l.

At Warminster STW, where the proportionate target had not been met, [but treatment to the best available technology (BAT) at the time of planning the wastewater improvements (c2004) had been installed], Wessex Water will be trialling under PR14 their operations to identify the greatest phosphorus reduction that can be sustainably achieved using the current infrastructure.

The current permit limit for each STW and date at which phosphorus stripping became effective are detailed in Table 2.3.2c.

Future forecast STW loadings are presented in Table 2.3.2d.

Table 2.3.2c Sewage Treatment Works Where Phosphate Stripping is occurring and date of installation

Permit No.	Site Name	River	P removal installed		NGR	Sampling point
			2mg/l treatment	1mg/l treatment		
401518	AMESBURY STW	RIVER AVON	31/07/04	31/03/10	SU1526041020	50210329
041560	BARFORD ST MARTIN STW	River Nadder	31/03/10		SU0605030980	50220210
041354	DOWNTON		03/03/10	31/03/10	SU1742020450	50260306
401342	FORDINGBRIDGE	RIVER AVON (S)		31/12/08	SU1433013280	50280581
041565	FOVANT	TRIB OF RIVER NADDER (S)		31/03/10	ST9996030050	50220811
041799	GREAT WISHFORD	RIVER WYLYE (S)		31/03/10	SU0862033730	50230170
040044	HURDCOTT	RIVER BOURNE (S)		31/05/09	SU1668033780	50240179
040056	MARDEN	RIVER AVON	31/03/10		SU0913057800	50210755
040061	NETHERAVON	River Avon	31/05/04	31/03/10	SU1540048340	50210465
042464	PEWSEY STW	RIVER EASTERN AVON (S)	01/02/01	30/09/09	SU1564059370	50211458
401500	RATFYN	HAMPSHIRE AVON	30/06/03	30/09/09	SU1586042800	50210352
041352	RINGWOOD STW	THE BICKERLEY STREAM(S)	31/10/04	30/09/09	SU1493003610	50280457
401382	SALISBURY STW	HAMPSHIRE AVON (S)	01/02/01	31/03/10	SU1604029130	50260511
040080	SHREWTON	River Till		31/05/09	SU0726042610	50231076
040095	TISBURY	Nadder		31/03/10	ST9569129808	50220288
041321	UPAVON	Hampshire Avon		31/03/10	SU1365054220	50210530
402466	WARMINSTER STW	Wylye	30/09/01	30/06/09	ST8738043640	50240544
043172	Warminster Garrison (MOD)	Wylye		31/03/13	ST89 45	C1475900

Table 2.3.2d Current & Forecast Future Wessex Water Sewage Treatment Work Loads to the Avon: Values in brackets are post PR-14 Improvements (from Wessex Water DM-#1504533-V3-Hamsphire_Avon_SIMCAT_reporttable)

Wessex Current and Forecast Future Phosphate Loads for discharges (>50m^3/day) (for period 1 April 2010-31 March 2011)

Site	Consent	Mean Flow	Mean Total P	Sample	Load Total P (2011)*1	Forecast Total P (2025)_pr 14	Forecast Total P (2030)_pr 14	Forecas t Total P (2035)_ pr14
		(mega litres/day)	(ug/l)	Count	(tpa)			
SALISBURY STW FE	1000	20.511	561	120	4.200	4.949	5.260	5.592
WARMINSTER STW	1000	4.312	608	13	0.957	1.090	1.142	1.196
RINGWOOD STW	1000	4.49	542	12	0.888	1.158	1.158	1.158
CANNINGS STW		0.399	5000 (700)		0.728	0.799 (0.112	0.861 (0.121)	0.947 (0.133)
HURDCOTT	1000	3.297	575	12	0.537	0.551	0.560	0.568
COLLINGBOURNE DUCIS STW		0.318	5000		0.930	1.019	1.052	1.089
PEWSEY STW	1000	1.857	683	12	0.463	0.495	0.503	0.511
FORDINGBRIDGE STW	1000	2.312	542	12	0.457	0.474	0.481	0.488
DOWNTON	1000	1.832	487	22	0.326	0.367	0.396	0.435
EAST KNOYLE STW*1		0.161	5000 (700)		0.294	0.309 (0.043)	0.317 (0.044)	0.324 (0.045)
AMESBURY STW	1000	1.199	606	12	0.265	0.379	0.408	0.440
SHREWTON	1000	1.104	517	12	0.208	0.231	0.247	0.268
RATFYN STW	1000	2.359	183	12	0.158	0.186	0.207	0.234
GREAT WISHFORD	1000	1.153	342	12	0.144	0.165	0.179	0.197
FOVANT STW	1000	0.401	700	13	0.102	0.118	0.133	0.154
MARDEN	2000	0.177	1292	12	0.083	0.095	0.104	0.115
UPAVON	1000	0.438	462	13	0.074	0.088	0.097	0.110
NETHERAVON STW	1000	0.423	469	13	0.072	0.076	0.079	0.083
TISBURY	1000	0.844	208	12	0.064	0.077	0.090	0.108
MAIDEN BRADLEY STW PRIOR TO SOAKAWAY		0.035	5000		0.064	0.067	0.069	0.070
BARFORD ST MARTIN	2000	0.083	1552	23	0.047	0.051	0.055	0.061
Total (no PR14 improvements)					**11.061**	**12.745**	**13.396**	**14.147**
Total with East Knoyle & All Cannings improvements						(11.79)	(12.39)	(13.06)

*[1] *assuming operational discharge quality of 700ug/ installed under AMP6*

There are also a large number of Ministry of Defence (MOD) camps within the Hampshire Avon. These are either connected to Wessex Water or Veolia STW, or have their own permits to discharge to surface or groundwaters. The only non water company STW with phosphorus stripping is Warminster Garrison, where stripping became operational in March 2013. Excluding Warminster Garrison, the sum of the remaining discharges is low (less than 2% of overall point source load to the Avon, pre P stripping)[23] and is not further considered in this report. Local impacts may however result down stream of these sites and further improvement in treatment may in the future be required on a case by case basis (see Section 2.3.2.2 for further consideration of this).

A further sub-catchment analysis of STW loads is highlighted in Table 2.3.2e using SIMCAT model and Table 2.3.2f, using flow apportioned total P loads (from AMEC[29]) and SIMCAT modelled point source. Note Diffuse loads are then calculated as the difference between total and diffuse loads.

Table 2.3.2e Sub Catchment Ortho Phosphorus Source Apportionment based on SIMCAT Modelling & estimated Modelled Background using P-Apportionment Model (2010-11 flows)

Sub Catchment	Water Body ID	Total P load Run 1a_PR14 P/kg/yr :	Total Point Source Run 1a_pr14 Load P kg	Total Diffuse Load (including natural) (P kg/yr)	STW Load 2010-11 Run 1a+PR14	Fish Farm & Water Cress Load (P kg/yr)	Modelled background (P kg/yr) based on 2010/11 flow
Upavon East Catchments	GB108043022410	4904	1668	3237	638	1029	3242
Upavon West Catchments	GB108043022370	3060	237	2823	237	0	1777
Upper Avon	GB108043022352	9512	2957	6555	1856	1101	3499
Wylye (Lower)	GB108043022510	4069	1934	2135	1356	578	1522
Nadder (taken to Nadder Middle Water body at confluence with Wylye)	GB108043022470	7278	900	6378	361	539	3159
Bourne	GB108043022390	1004	693	311	693	0	191
Ebble	GB108043015830	2409	777	1632	110	666	394
Lower Avon	GB108043015840	32126	17056	15070	10564	6492	12860

Table 2.3.2f Sub Catchment Ortho Phosphorus Source Apportionment Based on Flow Apportioned OP (AMEC[29]) & SIMCAT Point Sources. Modelled background using P-Apportionment Model (2010-11 flows)

Sub Catchment	Water Body ID	Total P Flow Apportioned 2009 to 2012 kg/yr	Total Point Source Run 1a_pr14 Load kg/ha	Total Diffuse Load (including natural) (P kg/yr)	STW Load 2010-11 Run 1a+PR14	Fish Farm & Water Cress Load (P kg/yr)	Modelled background (P kg/yr) based on 2010/11 flow
Upavon East Catchments	GB108043022410	3710	1668	2042	638	1029	3242
Upavon West Catchments	GB108043022370	3770	237	3533	237	0	1777
Upper Avon at Salisbury	GB108043022352	13470	2957	10513	1856	1101	3499
Wylye at South Newton	GB108043022510	9030	1934	7096	1356	578	1522
Nadder at Wilton	GB108043022470	8330	900	7430	361	539	3159
Bourne at Laverstock	GB108043022390	2350	693	1657	693	0	191
Ebble at Nunton Bridge	GB108043015830	2620	777	1843	110	666	394
Lower Avon at Knapp Mill	GB108043015840	47790	17056	30734	10564	6492	12860

2.3.2:2 Un-sewered Loading & Small Discharges

An updated source apportionment considering likely impact of un-sewered development using results from the Agency N & P Loading[25] research has been used and draft results from an Environment Agency- Anglian Region River Nar Diffuse Pollution Investigation[26].

Phosphorus loads from un-sewered discharges (typically to ground) are included within the "diffuse" load in SIMCAT models. Murdoch 2010[6], estimates that approximately 14% of the population in the Avon as whole is un-sewered (c14500PE) and the un-sewered population equivalent (PE) as a proportion of the population to be 10% for the Upper Avon West and East Avon [c3500 PE] and Wylye (c2800 PE), 18% in the Bourne (c3000 PE), 21% in the Nadder (c2100 PE) and 96% in the Ebble (c3200 PE) Figure 2.3.2:15a & Figure 2.3.2:16.

Gross phosphate loading from un-sewered properties, are thought to equate to around 0.3-0.44 kg/P/person/year[25], or 4.36 t/yr. An estimate of the un-sewered loads in each of the Avon catchments is provided in Murdoch (2010)[6] and summarised below, Appendix A of Murdoch 2011[7] and the gross load proportioned for the updated SIMCAT model in Table 2.3.2f

May *et al* (2011) estimated that up to 23% of the annual P loading to the R Wylye came from this source. The disparity between the estimate made by May *et al* and Murdoch (2010) stems from the different methods employed to estimate the initial P load from the un-sewered population and also the export coefficients used to calculate the amount that reaches the watercourse (assumptions about septic tank management, loss from the units, and attenuation through the drainage field).

Where these discharges go to soakaway in the chalk (the predominant bedrock geology across most of the Avon where un-sewered discharges are most common), the majority of the phosphorus will be attenuated within the chalk and not be transported to surface or groundwater. EPA (2006) reported in "Cumulative Nitrogen and Phosphate Loading to Groundwater report"[25] that between 66% and 99% (average of 88%) of phosphorus were attenuated in the drainage blanket. This would therefore indicate that the proportionate loads estimated by Murdoch would be far too high. An adjustment has therefore been made to these figures applying 66% attenuation to un-sewered loads in UGS catchments and 88% in chalk catchments (Table 2.3:2g).

No estimate of un-sewered loading directly in the Lower Avon was made by Murdoch and there remains some uncertainty in these figures. A number of investigations are being undertaken to further understand the impact of septic tanks on water quality. The Environment Agency is undertaking a study in the Anglian Region looking at this issue and Natural England have commissioned work in the Avon to look at the impact of Septic Tank discharges to surface and groundwater quality. Findings from these pieces of work should be used to refine our understanding of total loads in the Avon and to increase our confidence that septic tanks are only likely to make a small difference to the overall phosphorus loading to the Avon.

Table 2.3:2g Estimates of Un-sewered Loads to the Avon

i)

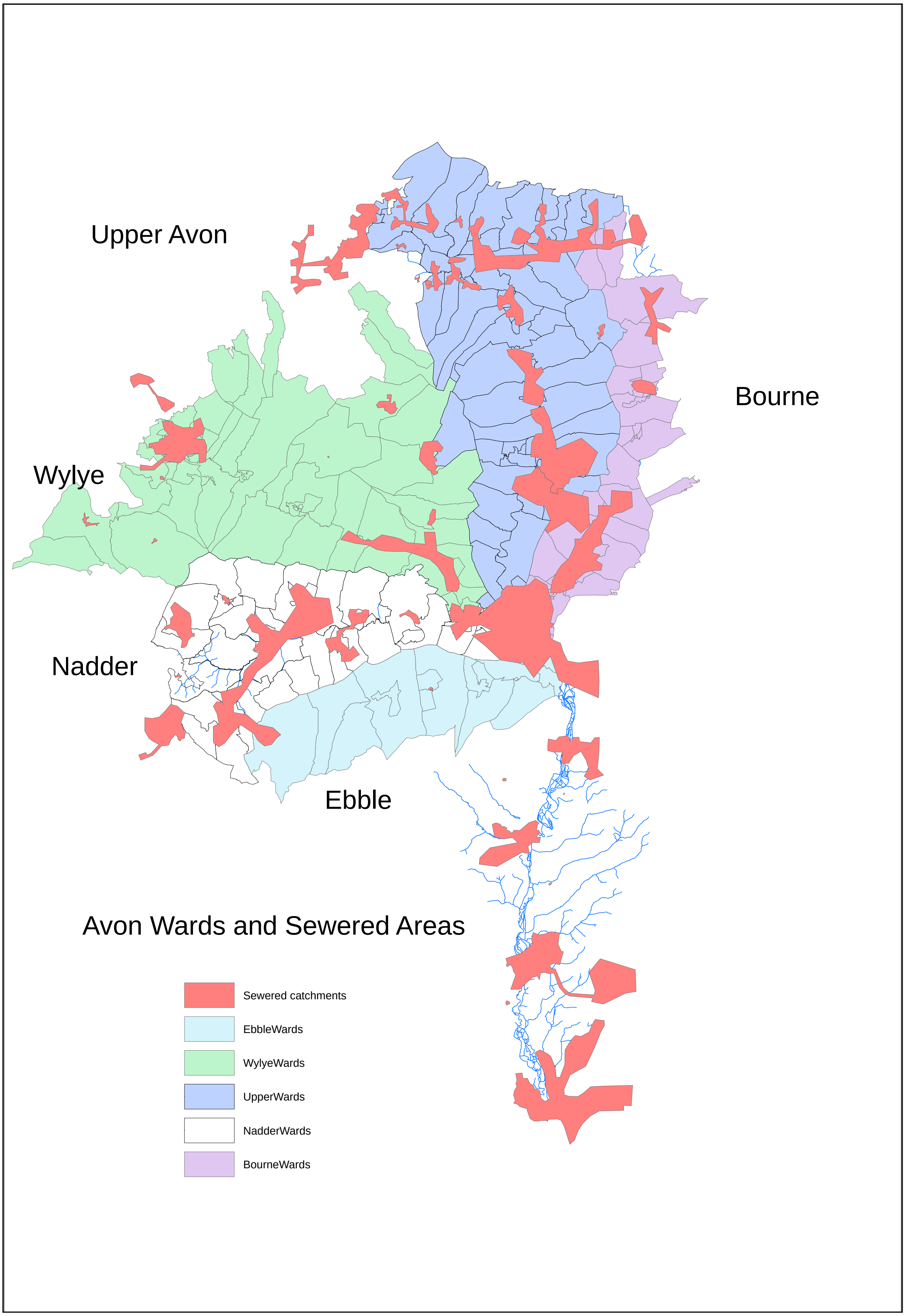
Method	Gross Phosphate Load tonnes/P/yr	Estimated Load Reaching Surface and Groundwater following 88% attenuation
As reported Murdoch 2010[6]	8300 kg/yr	<1000 P kg/yr
Method 2 lower load reported[25]	26000 people[6] *0.3= 7800 kg/yr	<1000 P kg/yr
Method 3: Upper estimated reported[25]	26000 people[6] *0.44= 11440 kg/yr	1373 P kg/yr

ii) Estimates Applying Attenuation outlined in EPA (2006) reported in "Cumulative Nitrogen and Phosphate Loading to Groundwater report"[25]

Catchment	Geology	Gross un-sewered (kg)	Un-sewered Load kg/yr	Assumed attenuation
Upavon East	UGS	350	119	66%
Upavon West	UGS	350	119	66%
Upper Avon	Chalk	1050 (350)	280	88% in Upper Avon, + UAE +EAW
Wylye	Chalk	950	114	88%
Nadder	UGS/other	630	189.6	66% + Wylye
Bourne	Chalk	860	103.2	88%
Ebble	Chalk	970	116.4	88%
Lower Avon*1		4800	689.2	Sum of above

***1 taken as the sum of catchments feeding the Lower Avon but excluding any estimate of un-sewered contribution within the Avon**

Figure 2.3.2:15 Locations of Sewered Areas in the Hampshire Avon and Catchment Wards (from Murdoch 2010)



2.3.2.3 Cress Farms

Further point source loading can result from watercress farming. Because P concentrations in chalk groundwater is typically low, cress farms need to add fertilisers to aid the growth of cress. If this is not managed correctly, it can lead to dissolved phosphates entering the river. To reduce the risk of this occurring, cress farmer must ensure that fertilisers are only added in sufficient quantity to produce a healthy crop. They may also need to manage the take up of phosphates by the crop. Recent water quality monitoring shows however that water cress farms can act as a P sink, taking up available phosphorus (Table 2.3.2h).

A review under the Habitats Directive was carried out by the Environment Agency in 2009, of the watercress farms across the Catchment[12]. As a result of this differential permit limits were applied to the discharges at Hill Deverill Table 2.3.2g.

Although there is very little monitoring data available, the catchment with the greatest modelled phosphate load from Water Cress growers is the Ebble. In the absence of any real data a figure of 40ug/l P was used in the model to assess these discharges (i.e. 2/3 of the proposed 60ug/l differential limit). The model predicts that approximately 86% of the point source load comes from Fish Farms and cress beds. Of this 16% is from Cress Farms (Table 2.3.2e).

The largest cress bed in a non compliant WFD reach of the Avon is Ludwell Cress Beds and modelling predicts a loading of 0.008tonnes/year (Table 2.3.2c) but this was not included in the Habitats Review of Consents as it was too distant from the Hampshire Avon SAC (>10km).

2.3.2.4 Fish Farms

Elevated phosphate concentrations can also occur downstream of fish farms, as a result of release from food and excreta (Table 2.2.2h). These loads can often be equivalent to or greater than a small sewage treatment works. A review of the fish farms in the Catchment[12] was carried out by the Environment Agency in 2009 under the Habitats Directive. Differential permit limits of 0.06 mg/l Ortho-phosphate (as P) were applied to all the fish Farms in 2012 (the only exception being Haxton ponds where the consent had already been issued under the Habitats Directive), Table 2.3.2g.

Table 2.3.2h Fish Farms and Water Cress Farms where Permit Changes Were Made Following Review of Consents.

Site Reference	VERSION	Site Name	Sampling Location	Effective Date of Permit Change
040171	2	ASHFORD WATER FISH FARM	ASHFORD FISH FARM EFFLUENT	07-Dec-12
040171	2	ASHFORD WATER FISH FARM	ASHFORD FISH FARM 2	07-Dec-12
040622	2	BARFORD FISH FARM	TRAFALGAR FISH FARM OUTLET C1 BARFORD	12-Dec-12
040623	2	BARFORD FISH FARM	TRAFALGAR FISH FARM OUTLET B2 NEW COURT	12-Dec-12
041927	2	BICKTON FISH FARM	BICKTON EARTHPONDS OUTLET	12-Dec-12
050109	2	BICKTON FISH FARM	BICKTON RACEWAY FISHERMANS BRIDGE OUTLET	12-Dec-12
050109	2	BICKTON FISH FARM	BICKTON RACEWAY PIPED OUTLET	12-Dec-12
400194/TF/01	2	BRITFORD TROUT FARM	BRITFORD FISH FARM OUTLET	02-Nov-12
040182	2	CHALKE VALLEY TROUT FARM	CHALKE VALLEY TROUT FARM UPPER OUTLET	12-Dec-12
050751	2	CRYSTAL SPRINGS TROUT FARM	CRYSTAL SPRINGS FISH FARM EFFLUENT	07-Dec-12
040181	2	GOULD'S COPSE HATCHERY	DAMERHAM FISH FARM HATCHERY	07-Dec-12
043223	4	HILL DEVERILL WATERCRESS FARM	HILL DEVERILL WATERCRESS EAST OUTLET	11-Dec-12
043224	3	HILL DEVERILL WATERCRESS FARM	HILL DEVERILL WATERCRESS WEST OUTLET	11-Dec-12
401224	3	HILL DEVERILL WATERCRESS FARM	HILL DEVERILL WATERCRESS NORTH OUTLET	11-Dec-12
040477	2	HOME FARM (RACEWAY)	DAMERHAM FISHERIES EFFLUENT	07-Dec-12
041917	2	LONGFORD MILL FISH FARM	LONGFORD FISH FARM	12-Dec-12
050104	2	MANNINGFORD TROUT FARM	MANNINGFORD FISH FARM DISCHARGE B	30-Nov-12
041892	2	MILLBROOK TROUT FARM	FOVANT FISH FARM EFFLUENT	19-Oct-12
042989	2	RIVERSIDE TROUT FARM	CHALKE VALLEY FISH FARM OUTLET 1	12-Dec-12
050748	2	WATERWAYS HATCHERY	WATERWAYS HATCHERY CHARLTON	12-Dec-12

Fish farms can also act as a phosphate sink, where phosphate associated with turbid water enters the farm but settles out in their settlement facilities. This deposited phosphorus then has the potential to be released through disturbance of the pond or through diffusion unless they are properly maintained and regularly de-silted[1].

The phosphorus load from the largest fish farms is around 4 tonnes/p/yr (Calculated using SIMCAT), which is around 10% of the total phosphorus load under baseline conditions and 5-7% of loads using PIT source apportionment. The catchments with the greatest modelled phosphate load from fish farm are the Ebble, Upavon East and Upper Avon catchments

[1] Silt from ponds is often added to neighbouring land for agricultural benefit. This can result in fish farms removing phosphorus loads from the river.

where approximately 81%, 69% and 39% of point source phosphorus loads respectively are from fish farms.

Table 2.3.2i in contrast calculates the load at a point in time at each of the fish farms and water cress farms using observed data. Many of the largest fish farms are in the lower reaches of the Avon, where typically there is greater dilution available and where the Avon largely achieve Good Status for P under the WFD **(**Figure 2.1:1 a & b) but may remain in unfavourable status under the Habitats Directive (Table 2.1:2).

The abstraction volume to these fish farms can however be very great and the proportionate dilution low, reflecting this. Bickton, Barford and Britford Fish Farms are estimated to add 1106 kg P/yr, 879 kg P/yr to the overall phosphate load to the Lower Avon from SIMCAT model results, when it is assumed discharge phosphorus loading of 40ug/l. The largest fish farm within a non compliant reach of the Avon is Manningford Trout Farm with an estimated model loading of 606 kg P/yr assuming 40ug/l P. The values calculated in Table 2.3.2i differ from these model results but reflect the observed water quality at one point in time and not over the whole of the year.

There remains uncertainty regarding the load generated by fish farms and it is recommended that further work is carried out to refine these calculations. Fish farms should implement all reasonable measures, to reduce the nutrient loads entering the river.

Table 2.3.2i Observed Water Quality at Fish Farms and Water Cress Farms

FISH FARMS					
	Site	Permit Volume (m3/day)	P Load (Kg P/yr)	Average difference in ortho-phosphate (Outlet-Inlet) µg/l	Comments
50270111	ASHFORD FISH FARM EFFLUENT	16875	-16	-2.6	
C0182100	ASHFORD FISH FARM 2	1125	-2	-4.2	
50260323	TRAFALGAR FISH FARM OUTLET C1 BARFORD	196135	1263	17.6	Average annual volume used
50260341	TRAFALGAR FISH FARM OUTLET B2 NEW COURT	160062	653	11.2	
50280549	BICKTON EARTHPONDS OUTLET	181872	921	13.9	
50280547	BICKTON RACEWAY FISHERMANS BRIDGE OUTLET	59271	219	10.1	Assumed 50% of licensed volume flows through each raceway
50280565	BICKTON RACEWAY PIPED OUTLET	59271	341	15.8	
50260468	BRITFORD FISH FARM OUTLET	82000	75	2.5	
50250510	CHALKE VALLEY FISH FARM OUTLET 1	15900	-14	-2.4	
50250524	CHALKE VALLEY TROUT FARM UPPER OUTLET	21800	151	19.0	
50270136	CRYSTAL SPRINGS FISH FARM EFFLUENT	9000	59	18.1	
50270143	DAMERHAM FISHERIES EFFLUENT	3100	3	2.7	
50270155	DAMERHAM FISH FARM HATCHERY	3100	2	1.5	
50260448	LONGFORD FISH FARM	18181	57	8.5	
50211509	MANNINGFORD FISH FARM DISCHARGE B	36400	35	2.7	
50210474	Haxton Ponds (West)	0		No data	No flow through west pond since 2011: Settlement only
50210475	Haxton Ponds (Middle)	1632		No data	Assumed 50% of licenced volume flows through each raceway
50210476	Haxton Ponds (East)	1632		No data	
50260411	Waterways Hatchery	6400		Not operating	
WATERCRESS FARMS					
50250701	HILL DEVERILL WATERCRESS EAST OUTLET	4773	-128	-73.7	
50250714	HILL DEVERILL WATERCRESS WEST OUTLET	6873	-57	-22.7	

Figure 2:3.2:16 Point Source Loading Post P Stripping in the Hampshire Avon (from SIMCAT modelling and ranked ordered by load).

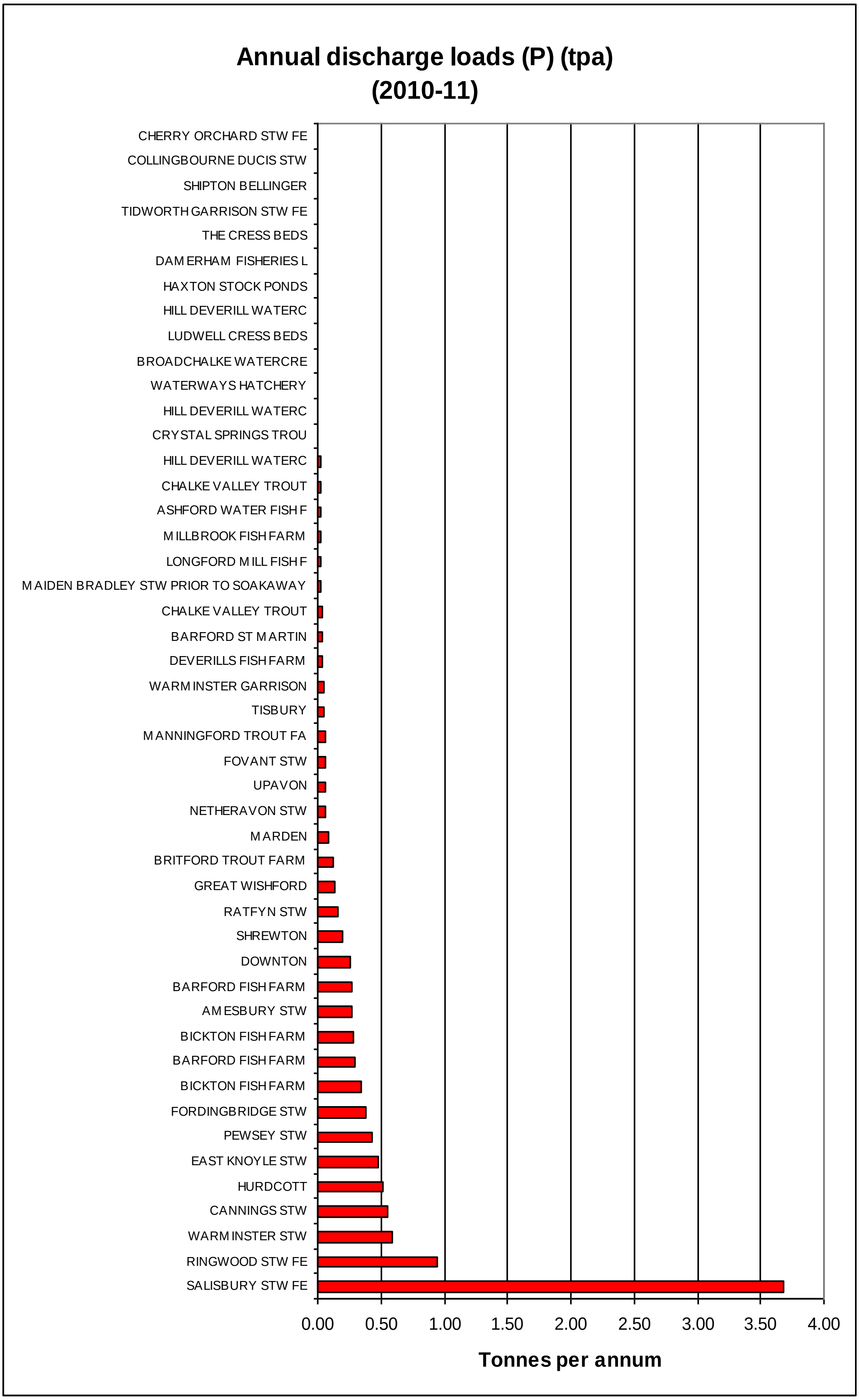
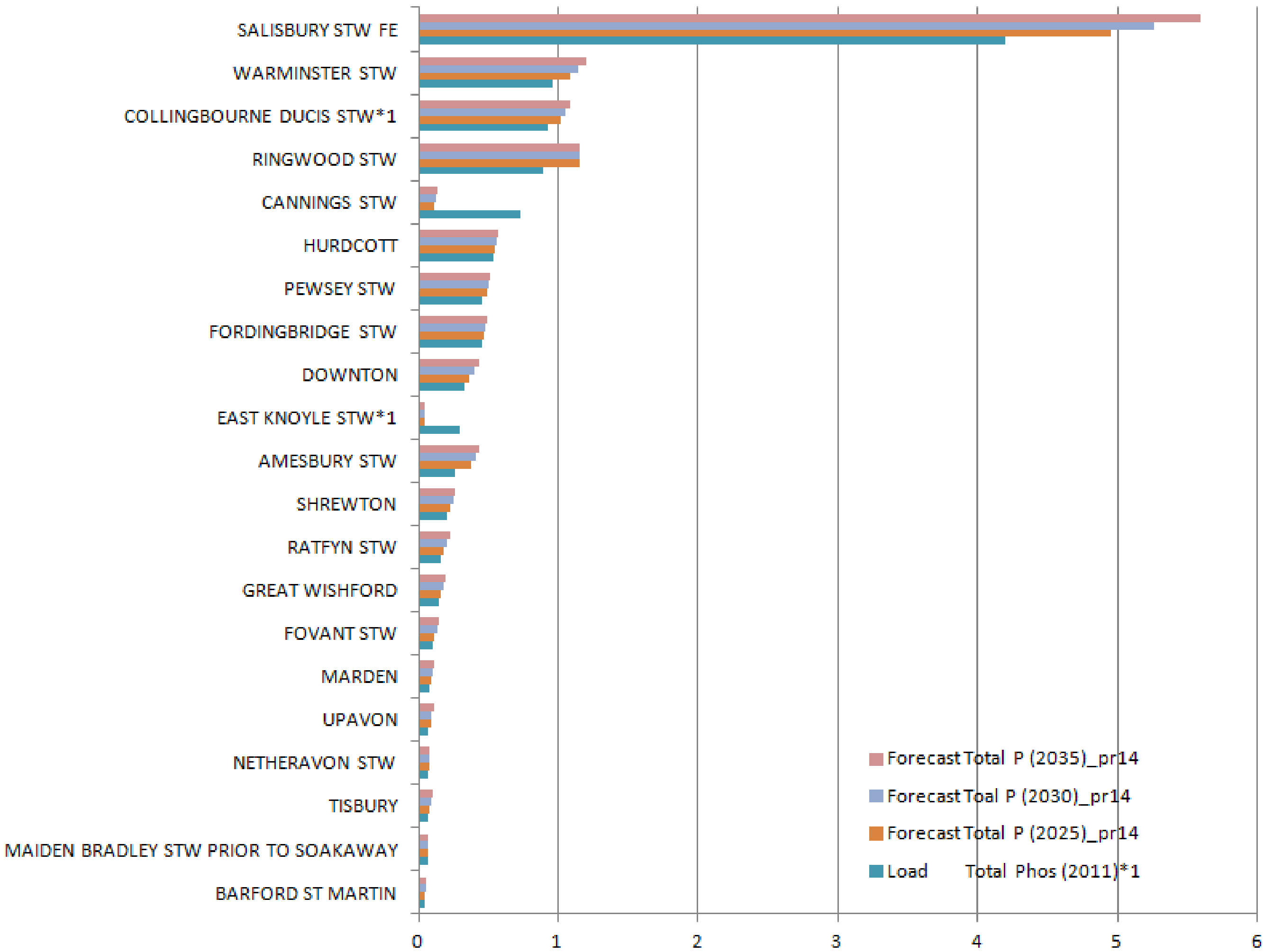


Figure 2:3.2:17 Point Source Loading (tonnes P/yr) Post P Stripping in the Hampshire Avon, based on Wessex Water Growth Forecast



***1**: Collingbourne Ducis Discharge Largely goes to ground (through drying of the River Bourne) and will be attenuated in Chalk

2.3.3: Diffuse Sources

A number of approaches have been used to calculate diffuse loads within the Avon. SIMCAT modelling separates out the larger point source loads and the difference between these and observed load calculated at any point in the river is assumed to be from diffuse sources. In this context, diffuse sources will include small discharges that were not included in the SIMCAT model as discreet point discharges (Section 1.5.1) and any natural modelled background sources. SIMCAT modelling results indicate diffuse OP loads are approximately 15 tonnes P and represent c45% of the total baseline load (Table 2.3.2a).

Diffuse loads calculated by taking the SIMCAT point source loads from flow apportioned total phosphorus loads in the Avon provide a more realistic estimates. Results from this indicate diffuse loads of c30 tonnes OP/yr for 2010-11, around 63% of overall load (Table 2.3.2b).

When it is assumed that all STW & other large discharges operate under their full practical permit uptake, the diffuse load as a proportion of the total, reduces to 55-60% (when using Wessex Water growth to 2035 and SIMCAT Run 1a_PR14_Full practical permit uptake) Table 2.3.2b. This again is likely to be an under estimate of total diffuse loads because the diffuse losses that occur during heavy rainfall events may not be fully represented by weekly or monthly water quality sampling.

The proportion of diffuse and point source loads impacting the Avon also vary spatially, with diffuse loads vary from 64% of total loads at the bottom of the Avon to 94% on Upavon West (using SIMCAT and flow apportioned total river loads).

Modelled Source Apportionment

Different modelling approaches can be used, to calculate likely phosphorus loads that would be generated in the Avon. These can then be compared with observed data.

A number of these approaches are discussed in Section 5 of AMEC Wessex Phosphorus Investigation report[17] and updated source apportionment[29]. These approaches are useful to breakdown the likely diffuse sources and to estimate total P generated from these source before in river attenuation and P uptake take place. The results of EA updated PIT calculations are outlined in Tables 2.3.3:1a-b and Figure 2.3.3:1a-c, using adjusted Agricultural Census 2010 data (Table 1a&b).

A breakdown of the source of Fertiliser and Manure phosphorus load are estimated in Tables 2.3.3:2 & 3a-b respectively. Total P loads estimated using PIT methodology are around 67 tonnes/P/yr (including point sources). A comparison of the diffuse loading from each of these methods is highlighted in Table 2.3.3:4.

Transport pathways predicted by PIT are detailed below.

	Surface	Sub-surface
Manure	40%	29%
Fertiliser	47%	36%
Non Agricultural	86%	14%

Table 2.3.3:1a & b Phosphorus Load (P kg/yr) From EA Updated PIT Calculations for Hampshire Avon Based on Pit Export Co-efficient Approach kg/yr (note zero input calculated from Woodland and Rough Grazing) & SIMCAT Point Source Loads Run 1a_PR14 (see also Figure 2.3.1.1 a-b)

Catchment Results	Total Manure (kg/yr)	Total Fertiliser	Olsen P	Particulate P	Direct delivery (agri roads and yards)	Woodland	Urban areas	Rough grazing land	total Point sources (STW, FF, WC) Run 1a_PR14 (2010-11)	Total
Upavon East	457	841	851	190	20	0	125	0	1668	4153
Upavon West	703	861	1003	224	29	0	107	0	237	3163
Upper Avon	1583	2113	1840	412	68	0	760	0	1052	7828
Wylye	3633	3981	4545	1017	193	0	577	0	1934	15879
Nadder	1775	1814	2966	664	82	0	402	0	863	8566
Bourne	851	1573	1207	270	28	0	509	0	693	5130
Ebble	684	1051	1213	271	37	0	70	0	777	4103
Lower Avon	1837	1836	3310	741	89	0	1254	0	9833	18898
Total Catchment	11523	14069	16933	3790	547	0	3802	0	17056	67720

Catchment Results	Total Manure	Total Fertiliser	Olsen P	Particulate P	Direct delivery	Woodland	Urban areas	Rough grazing land	Point sources	Catchment Results
Upavon East	11%	20%	20%	5%	0%	0%	3%	0%	40%	4153
Upavon West	22%	27%	32%	7%	1%	0%	3%	0%	7%	3163
Upper Avon	20%	27%	24%	5%	1%	0%	10%	0%	13%	7828
Wylye	23%	25%	29%	6%	1%	0%	4%	0%	12%	15879
Nadder	21%	21%	35%	8%	1%	0%	5%	0%	10%	8566
Bourne	17%	31%	24%	5%	1%	0%	10%	0%	14%	5130
Ebble	17%	26%	30%	7%	1%	0%	2%	0%	19%	4103
Lower Avon	10%	10%	18%	4%	0%	0%	7%	0%	52%	18898
Total Catchment	17%	21%	25%	6%	1%	0%	6%	0%	25%	67720

Manure: All phosphorus derived from animals in the catchment, Fertiliser: All phosphorus loads derived from leaching of fertilizers applied to crops, Olsen P: *Concentration of available P in soil determined by a standard method (developed by Olsen) involving extraction with sodium bicarbonate solution at pH 8.5. The main method used in the England, Wales and Northern Ireland and the basis for the* ***Soil Index*** for P, Particulate P: phosphorus load held on soil particles, by reducing transport of particles you can reduce particulate p entering a watercourse, Direct Delivery; Urban: Taken as 0.7kg/P/ha derived from urban load such as sewage leaking

Table 2.3.3:1c & d Estimated Phosphorus Load (P kg/yr) Delivered to the Avon From EA Updated PIT Calculations for Hampshire Avon Based on Pit Export Co-efficient Approach (note zero input calculated from Woodland and Rough Grazing) & Calculated Total Point Source Loads Under Run 1a_PR14_Full practical permit uptake Scenario

Catchment Results	Total Manure (KG/YR)	Total Fertiliser	Olsen P	Particulate P	Direct delivery (agri roads and yards)	Woodland	Urban areas	Rough grazing land	Total Point sources Run 1a_PR14_Full practical permit uptake	Total
Upavon East	457	841	851	190	20	0	125	0	1645	4131
Upavon West	703	861	1003	224	29	0	107	0	156	3083
Upper Avon	1583	2113	1840	412	68	0	760	0	3243	10018
Wylye	3633	3981	4545	1017	193	0	577	0	3088	17033
Nadder	1775	1814	2966	664	82	0	402	0	1086	8789
Bourne	851	1573	1207	270	28	0	509	0	805	5242
Ebble	684	1051	1213	271	37	0	70	0	777	4103
Lower Avon	1837	1836	3310	741	89	0	1254	0	13331	22396
Total Catchment	11523	14069	16933	3790	547	0	3802	0	24130	74795

Catchment Results	Total Manure	Total Fertiliser	Olsen P	Particulate P	Direct delivery	Woodland	Urban areas	Rough grazing land	Point sources (for water body)	Total
Upavon East	11%	20%	21%	5%	0%	0%	3%	0%	40%	4131
Upavon West	23%	28%	33%	7%	1%	0%	3%	0%	5%	3083
Upper Avon	16%	21%	18%	4%	1%	0%	8%	0%	32%	10018
Wylye	21%	23%	27%	6%	1%	0%	3%	0%	18%	17033
Nadder	20%	21%	34%	8%	1%	0%	5%	0%	12%	8789
Bourne	16%	30%	23%	5%	1%	0%	10%	0%	15%	5242
Ebble	17%	26%	30%	7%	1%	0%	2%	0%	19%	4103
Lower Avon	8%	8%	15%	3%	0%	0%	6%	0%	60%	22396
Total Catchment	15%	19%	23%	5%	1%	0%	5%	0%	32%	74795

Manure: All phosphorus derived from animals in the catchment, Fertiliser: All phosphorus loads derived from leaching of fertilizers applied to crops, Olsen P: *Concentration of available P in soil determined by a standard method (developed by Olsen) involving extraction with sodium bicarbonate solution at pH 8.5. The main method used in the England, Wales and Northern Ireland and thebasis for the **Soil Index*** for P, Particulate P: phosphorus load held on soil particles, by reducing transport of particles you can reduce particulate p entering a watercourse, Direct Delivery; Urban: Taken as 0.7kg/P/ha derived from urban load such as sewage leaking

Table 2.3:3:1e & f Phosphorus Load From EA Updated PIT Calculations for Hampshire Avon Based on Pit Export Co-efficient Approach kg/yr (note zero input calculated from Woodland and Rough Grazing) & cumulative Point Source Load to Additional Sub-catchments

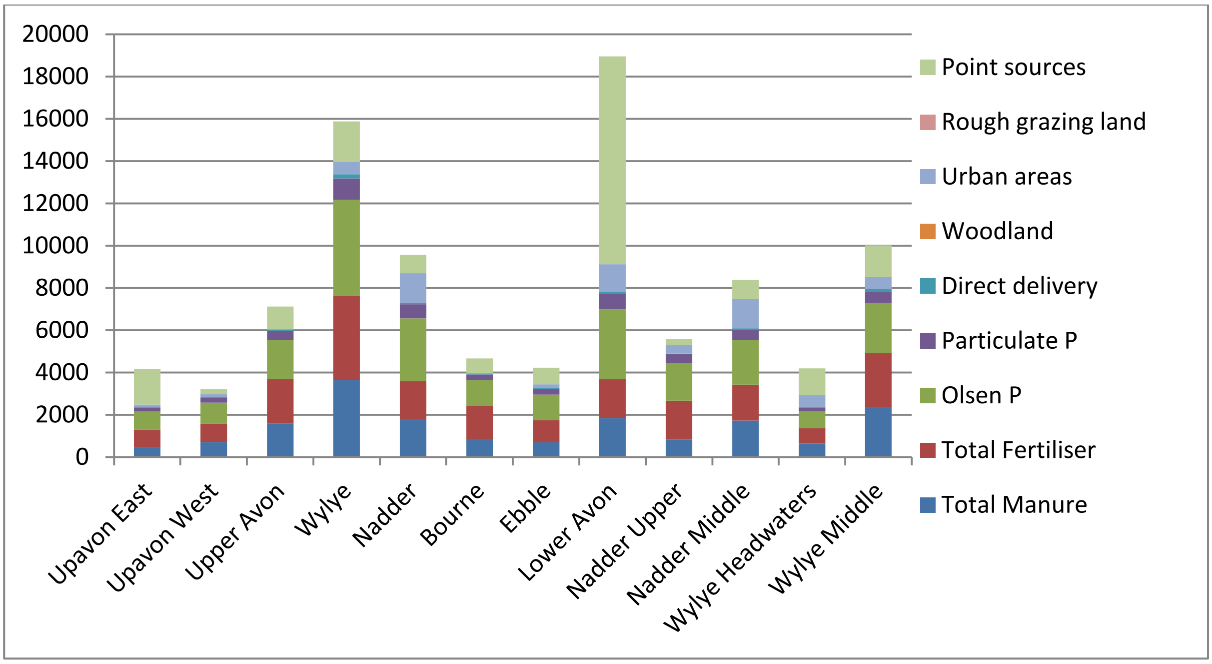
Source Apportionment For Sub Other Sub-catchments

Water Body	Catchment Results	Total Manure	Total Fertiliser	Olsen P	Particulate P	Direct delivery	Woodland	Urban areas	Rough grazing land	Point sources	Total
GB108043016200	Nadder Upper	821	1836	1794	401	41	0	398	0	273	5564
GB108043022470	Nadder Middle	1723	1700	2112	473	80	0	1382	0	900	8371
GB108043022520	Wylye Headwaters	625	733	796	178	32	0	564	0	1264	4191
GB108043022550	Wylye Middle	2332	2583	2371	531	131	0	564	0	1499	10010

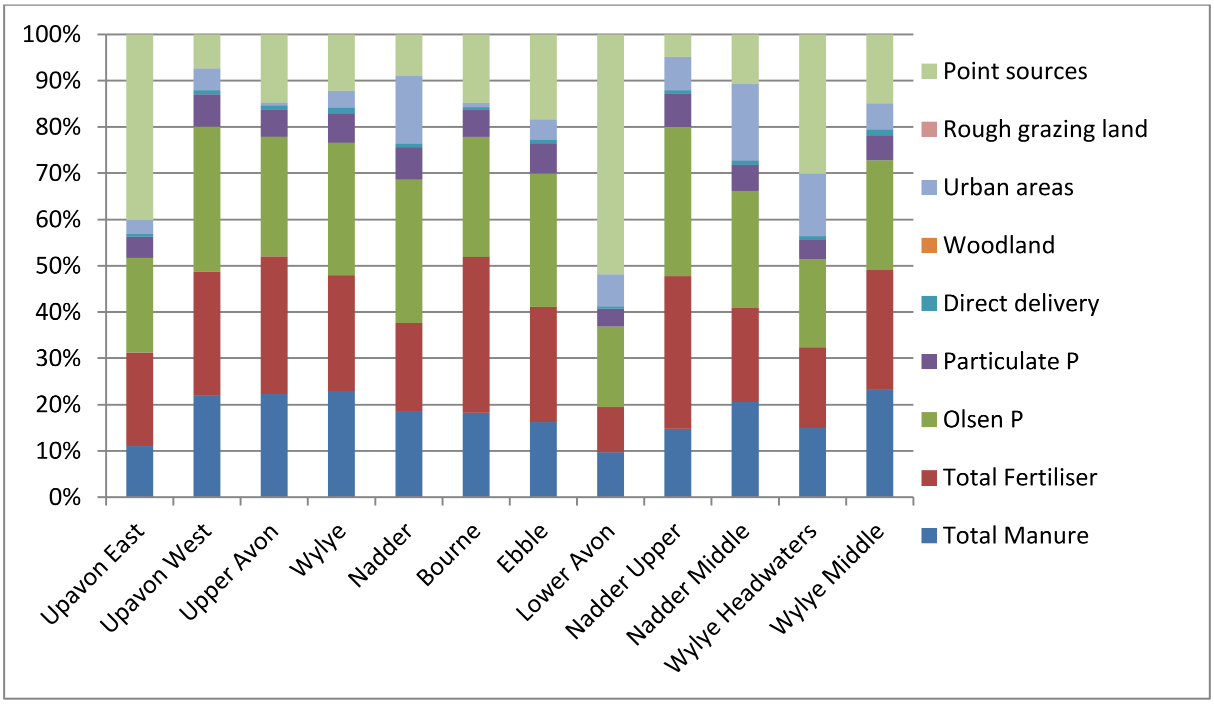
Water Body	Catchment Results	Total Manure	Total Fertiliser	Olsen P	Particulate P	Direct delivery	Woodland	Urban areas	Rough grazing land	Point sources	Total
GB108043016200	Nadder Upper	15%	33%	32%	7%	1%	0%	7%	0%	5%	100%
GB108043022470	Nadder Middle	21%	20%	25%	6%	1%	0%	17%	0%	11%	100%
GB108043022520	Wylye Headwaters	15%	17%	19%	4%	1%	0%	13%	0%	30%	100%
GB108043022550	Wylye Middle	23%	26%	24%	5%	1%	0%	6%	0%	15%	100%

Figure 2.3.3:1 a and c: Source Apportionment Based on Environment Agency Calculations Using Phosphate Indicator Tool (PIT) Calculations & SIMCAT Point Source Loading Run 1a_PR14 (STW+FF+WC) (excluding modelled background)

a) Phosphorus loads (kg/yr)



b) Percentage of subcatchment load from each source (% of sub catchment load)



c) Total Catchment Phosphorus Load P kg/yr Based on Agricultural Census 2010 data

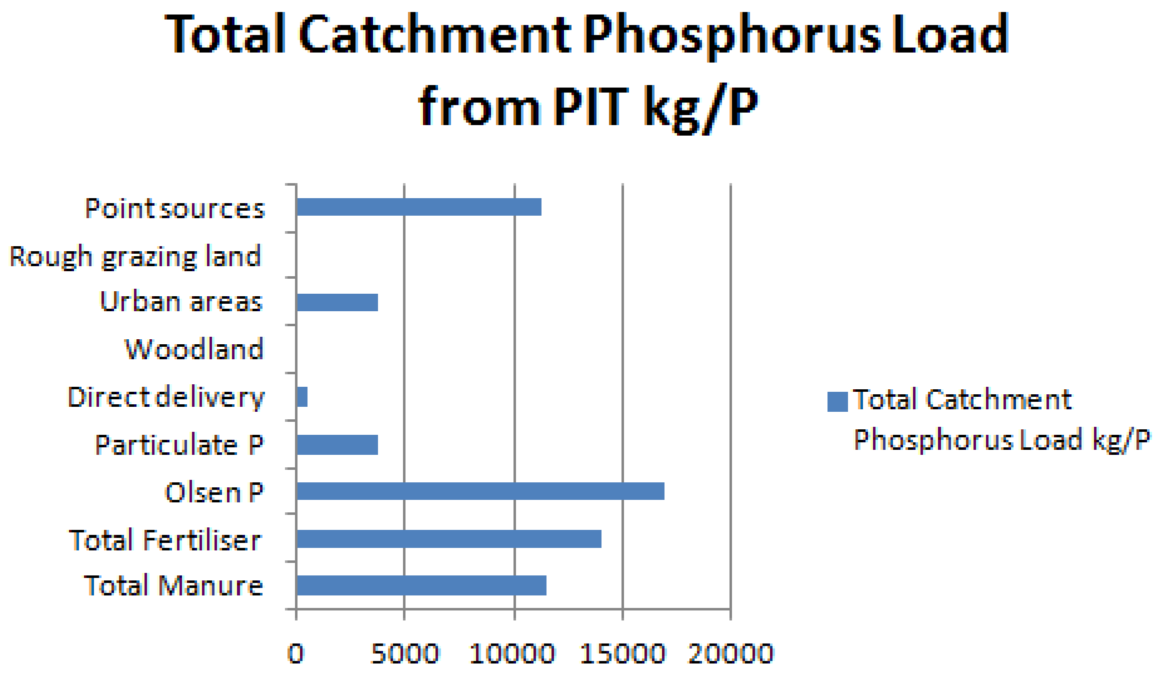


Table 2.3.3:2 a & b Phosphate Load Breakdown for Fertilisers, Calculated by the Environment Agency using Phosphorus Indicator Tool (PIT) (Heathwaite etal 2003) and Adjusted Agricultural Census 2010 Data

P LOAD FERTILISER P Kg

Fertiliser	Winter wheat	Grass > 5 years	Oilseed rape	Spring barley	Grass < 5 years	Winter barley	Maize	Oats/rye	Field peas and beans	Linseed	Horticultural / hops	Kale/cabbage etc stock feed
Upavon East	322	130	130	29	52	42	60	35	15	5	21	0
Upavon West	304	185	138	34	42	48	57	21	19	7	1	2
Upper Avon	703	444	324	250	91	145	52	45	27	26	2	2
Wylye	1176	1024	500	336	339	176	249	84	29	44	2	9
Nadder	596	365	196	152	136	94	94	118	38	15	2	7
Bourne	536	164	285	200	111	112	31	65	38	26	1	0
Ebble	323	209	155	133	62	58	66	17	15	8	1	0
Lower Avon	479	498	202	167	138	136	92	53	32	26	5	2
Total Catchment	4439	3018	1930	1300	972	811	701	438	214	158	35	22

Fertiliser	Winter wheat	Grass > 5 years	Oilseed rape	Spring barley	Grass < 5 years	Winter barley	Maize	Oats/rye	Field peas and beans	Linseed	Horticultural / hops	Kale/cabbage etc stock feed
Upavon East	38%	16%	15%	3%	6%	5%	7%	4%	2%	1%	2%	0%
Upavon West	35%	21%	16%	4%	5%	6%	7%	2%	2%	1%	0%	0%
Upper Avon	33%	21%	15%	12%	4%	7%	2%	2%	1%	1%	0%	0%
Wylye	30%	26%	13%	8%	9%	4%	6%	2%	1%	1%	0%	0%
Nadder	33%	20%	11%	8%	7%	5%	5%	6%	2%	1%	0%	0%
Bourne	34%	10%	18%	13%	7%	7%	2%	4%	2%	2%	0%	0%
Ebble	31%	20%	15%	13%	6%	6%	6%	2%	1%	1%	0%	0%
Lower Avon	26%	27%	11%	9%	8%	7%	5%	3%	2%	1%	0%	0%
Total Catchment	32%	21%	14%	9%	7%	6%	5%	3%	2%	1%	0%	0%

Table 2.3.3:2 a & b Phosphate Load (P kg/yr) Breakdown for Manure, Calculated by Environment Agency using Phosphorus Indicator Tool (PIT) (Heathwaite etal 2003) and Adjusted Agricultural Census 2010 Data

P LOAD: MANURE kg

Manure	Dairy adult	Dairy young stock	Beef > 2 years	Beef 1-2 years	Cattle < 1 year	Sheep	Lambs	Breeding sows	Small fattening pigs	Large fattening pigs	Laying hens	Broiler hens	Total Manure
Upavon East	169	54	57	42	21	20	5	4	25	3	14	44	457
Upavon West	293	106	46	52	28	23	6	4	50	8	19	68	703
Upper Avon	489	140	238	142	85	57	13	35	155	21	44	164	1583
Wylye	1245	374	726	434	234	90	22	31	183	27	69	199	3633
Nadder	717	176	228	168	92	103	27	12	74	18	49	111	1775
Bourne	175	45	115	62	40	33	8	32	116	23	27	175	851
Ebble	204	67	138	100	54	51	13	16	30	3	4	5	684
Lower Avon	370	107	460	214	117	44	10	47	156	80	90	142	1837
Total Catchment	3661	1068	2007	1213	671	421	105	180	790	183	317	908	11523

Manure	Dairy adult	Dairy young stock	Beef > 2 years	Beef 1-2 years	Cattle < 1 year	Sheep	Lambs	Breeding sows	Small fattening pigs	Large fattening pigs	Laying hens	Broiler hens	Total Manure
Upavon East	37%	12%	13%	9%	5%	4%	1%	1%	5%	1%	3%	10%	457
Upavon West	42%	15%	7%	7%	4%	3%	1%	1%	7%	1%	3%	10%	703
Upper Avon	31%	9%	15%	9%	5%	4%	1%	2%	10%	1%	3%	10%	1583
Wylye	34%	10%	20%	12%	6%	2%	1%	1%	5%	1%	2%	5%	3633
Nadder	40%	10%	13%	9%	5%	6%	2%	1%	4%	1%	3%	6%	1775
Bourne	21%	5%	13%	7%	5%	4%	1%	4%	14%	3%	3%	21%	851
Ebble	30%	10%	20%	15%	8%	7%	2%	2%	4%	0%	1%	1%	684
Lower Avon	20%	6%	25%	12%	6%	2%	1%	3%	8%	4%	5%	8%	1837
Total Catchment	32%	9%	17%	11%	6%	4%	1%	2%	7%	2%	3%	8%	11523

Table 2.3.3:4 Comparison of Diffuse Loads Predicted From SIMCAT, PIT and PSYCHIC

			SIMCAT	EA PIT	AMEC PIT[29]	PSYCHIC[29]
Sub Catchment	**Bottom catchment of group**	**Total Area (ha)**	Total Cumulative Diffuse Load (P kg/annum)	Total diffuse(P kg/annum)		
Upavon East	GB108043022410	8595	3237	2360	2400	400
Upavon West	GB108043022370	7896	2823	2820	2700	700
Upper Avon (including UAE and UAW)	GB108043022350	39080	6555	6015 (11195)	11200	2000
Wylye	GB108043022510	45776	2135	13369	12000	3000
Nadder	GB108043015880	22887	6364	7301 (20669)*2	6800	5800
Bourne	GB108043022390	17190	311	3929	3500	800
Ebble	GB108043015830	11193	1632	3256	3000	900
Lower Avon (including all above)	GB108043015840	170594	15070	7812 *3 (46862)	46800	18600

Note: a) SIMCAT is based on average annual model. PIT may better reflect flow apportioned loading (but is still based in export co-efficient approach)

*2 *including Wylye,* *3 *load for lower Avon catchment alone*

From this work it can be seen that SIMCAT and PSYCHIC models calculate a similar total diffuse loads to the Avon (15-19 tonnes P/yr).

Total diffuse loads from the PIT model in contrast are double SIMCAT, but are similar to the flow apportioned load, which are considered to better reflect the total loads passing through the Avon (taking into account the loads at high and low flows; see Section 2.3, Table 2.3:1a& Figure 2.3:1).

Estimated loading results from PIT indicate that the greatest diffuse source of phosphorus in the catchments are from Fertilizers, Manure and Soil available Phosphorus (Olsen –P) (Figure 2.3.3:1a&b). Particulate P typically makes up around 6-7% of the total load.

These sources typically make up more that 75% of the total load in the catchment and the greatest diffuse load when considering PIT diffuse loads and point source loads calculated under SIMCAT Run 1a_PR14 (Table 2.3.2:1a &b). Any efforts to reduce diffuse phosphorus loads in the catchment should therefore focus on these diffuse sources.

The further discussion of these results and a refinement of the source apportionment are presented in Section 2.5.

2.4 Future Pressures

Population growth and climate change may result in changes in phosphorus loading to the Avon in the future. This section briefly considers these pressures and the impact they may have on achieving SAC standards across the catchment.

2.4:1 Population Growth & Uptake of Permit Headroom

As outlined in Section 2.3.2, Wessex Water is responsible for mains sewage across the Avon catchment. In 2012/2013 WW updated their phosphorus loading calculations for the Avon, using monitored flow and quality data and calculated the residential populations being served by their 21 largest STW's across the catchment. Using commercial sewage loads, Wessex Water calculated the Population Equivalent load for each, in 2011. Using information provided in local plans and historic development rates they have also estimated the likely population growth that may occur within each STW distribution network to 2035 (Table 2.4.1:1a&b). Using this information and assuming that discharge quality does not change they have calculated likely future discharge loads from each STW. Full results from this are presented in Appendix 2.3.2:1 and summarised in Table 2.3.2d.

The number of people living and working within sewered areas of the Avon is forecast to increase over the next 20 years by around 31,000 to the year 2035. When considering potential increases in commercial load and residential load the increase may be in the order of 40,000 Population Equivalents (PE) (Appendix 2.3.2.1).

These figures compare favourably with Wiltshire's Infrastructure Delivery Plan Update (September 2014) that indicate a potential residential population increase of around 24,000 people assuming the number of people in existing housing numbers do not change and an estimated number of people per house of 2.2 (Table 2.4.1:3)

Results from Wessex Water's forecast indicate that phosphorus loads into the Avon catchment from their STW, may increase from around 11 tonnes P/yr to around 14 tonnes P/yr, or 13 tonnes when PR14 improvements at East Knoyle and All Cannings STW are implemented (Table 2.3.2d). This is less than the worst case full practical permit uptake forecast in SIMCAT of c18 tonnes P/yr (Table 2.3:2a & b). The difference between WW and SIMCAT scenarios are that WW based their forecast on population projections and current STW performance and modelled SIMCAT full practical permit uptake scenario assumes all STW are operating at full permit flow and at 700ug/l P limit (70% of permit quality conditions).

As a result of future growth, it is likely that current dry weather flow (DWF) permitted at a number of STW will be exceeded in the future if other measures to reduce inflow volumes are not implemented. The STW where this applies to and the dates at which permit headroom may be exceeded are highlighted below (Table2.4.1:2).

Any increase in growth leading to an increase in STW discharge load in failing water bodies will make it more difficult to achieve the WFD 'no deterioration' requirement and the ambition targets. Whilst the EA conclusions from the Review of Consents (2010) were that Wessex Waters proportionate P reductions had been achieved (at full permit flow) by P stripping installed by WW in between 2002 and 2009 (with the only exception to this being Warminster STW).

At East Knoyle and, All Cannings STW, P stripping is proposed under PR14. At Warminster, treatment is already being carried out to around the proportionate target (≈0.5 P mg/l) and a pilot is proposed to see how low the STW can operate with its existing infrastructure.

From Figure 2.4.1.2, the STW's which are close to their permit flow and quality are clear, showing that developments that link to these STW may not be possible without varying permit headroom or measures to reduce groundwater ingress to the site where this is an issue. The process in determining any application to vary a permit, will apply a no deterioration criteria to the permit.

Local Authorities have not been able to provide their assessment of likely population growth within the Avon, but it would be recommended that this should be undertaken using the 2011 Census data.

Population growth in un-sewered areas is also likely, leading to increased discharge to surface and groundwater's through septic tanks and small package treatment works.

An analysis by Wiltshire Unitary Authority identifies that c5% of total building completions were in un-sewered areas, c9% of dwellings permitted through application and 28% of permitted applications (Table 2.4.1:5).

The overall increase is likely to be small compared to other loading and if it were assumed that all future development outlined in Wiltshire's Infrastructure Delivery Plan Update (September 2014) outside the towns, were to go to non sewered areas, this would result in <13% of total growth (Table 2.4.1:3).

Additional Houses outside towns	1422	houses
increased population outside towns @ 2.2/P/unit	3128	people
Gross loading (using 0.3kg/p export co-efficient)	939	kg/P/yr
Net load increase outside towns after 88% attenuation	113	kg/P/yr

Whilst overall loadings may be small, where they take place in the upper reaches of the catchment where dilution volumes from stream or groundwater flow are small, they can have a localised, detrimental impact on water quality and ecology.

Future reductions in phosphate loading across the Avon driven by recent changes to legislation, restricting the use of phosphorus in laundry detergents under **“**REGULATION (EU) No 259/2012 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 March 2012” **(**which has been in force since 30th June 2013 for laundry detergents) will help to restrict use of phosphorus in dishwasher from 1st January 2017 and some of the local impacts of un-sewered discharges.

http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32012R0259&from=EN

Table 2.4.1:1a Wessex Water Current and Forecast Future Population Growth within its Sewage Treatment Works (from Appendix 2.3.2:1)

Wessex Water Current and Forecast Residential Population

Site	Residential 2011	2015	2020	2025	2030	2035
SALISBURY STW FE	50,859	52,507	55,646	59,265	63,126	67,244
WARMINSTER STW	16,771	17,292	18,138	19,119	19,987	20,898
RINGWOOD STW	14,242	14,284	14,424	14,637	14,853	15,072
CANNINGS STW	1,090	1,100	1,120	1,142	1,165	1,189
HURDCOTT	3,358	3,367	3,398	3,445	3,494	3,542
COLLINGBOURNE DUCIS STW	1,246	1,280	1,318	1,361	1,405	1,451
PEWSEY STW	6,957	7,239	7,311	7,420	7,531	7,644
FORDINGBRIDGE STW	8,803	8,828	8,912	9,039	9,168	9,299
DOWNTON	4,525	4,606	4,709	4,779	4,850	4,922
EAST KNOYLE STW	603	608	619	631	644	657
AMESBURY STW	8,423	9,555	10,658	11,969	12,916	13,952
SHREWTON	1,750	1,781	1,798	1,824	1,851	1,878
RATFYN STW	10,014	10,037	10,118	10,240	10,364	10,489
GREAT WISHFORD	1,819	1,879	1,898	1,927	1,956	1,985
FOVANT STW	1,239	1,259	1,297	1,340	1,384	1,430
MARDEN	799	819	833	850	867	884
UPAVON	977	1,016	1,034	1,054	1,076	1,097
NETHERAVON STW	1,749	1,754	1,771	1,798	1,825	1,853
TISBURY	4,011	4,082	4,225	4,393	4,569	4,752
MAIDEN BRADLEY STW PRIOR TO SOAKAWAY	284	287	292	298	304	310
BARFORD ST MARTIN	379	382	389	397	405	413
Total	139,898	143,962	149,908	156,928	163,740	170,961

Table 2.4.1:1b Wessex Water Current and Forecast Future Population Equivalent Growth within its Sewage Treatment Works (from Appendix 2.3.2:1). Note this figure includes estimated growth in trade discharge volumes, reflecting in increased PE to Population figures

Wessex Water STW Total Population (Residential and Commercial: excluding Trade & Tankered)

Commercial and Residential Population Equivalents (excludin tankered)

Site	2011	2015	2020	2025	2030	2035
SALISBURY STW FE	56,853	59,515	63,011	66,989	71,210	75,691
WARMINSTER STW	21,873	22,471	23,621	24,913	26,101	27,339
RINGWOOD STW	15,337	20,000	20,000	20,000	20,000	20,000
CANNINGS STW	1,163	1,175	1,199	1,225	1,253	1,280
HURDCOTT	3,415	3,425	3,459	3,510	3,562	3,614
COLLINGBOURNE DUCIS STW	1,329	1,365	1,407	1,456	1,504	1,556
PEWSEY STW	7,286	7,576	7,663	7,787	7,915	8,044
FORDINGBRIDGE STW	9,317	9,350	9,475	9,646	9,790	9,937
DOWNTON	4,800	4,890	5,006	5,092	5,179	5,267
EAST KNOYLE STW	658	664	679	693	710	726
AMESBURY STW	9,112	10,283	11,545	13,017	14,017	15,110
SHREWTON	1,818	1,859	1,879	1,910	1,941	1,973
RATFYN STW	10,566	10,770	11,152	11,576	11,768	11,966
GREAT WISHFORD	2,023	2,087	2,115	2,152	2,191	2,229
FOVANT STW	1,292	1,313	1,355	1,400	1,448	1,497
MARDEN	820	840	856	874	893	910
UPAVON	1,015	1,056	1,075	1,097	1,122	1,145
NETHERAVON STW	2,033	2,040	2,059	2,088	2,117	2,147
TISBURY	4,331	4,421	4,602	4,814	5,018	5,231
MAIDEN BRADLEY STW PRIOR TO SOAKAWAY	327	331	339	347	356	364
BARFORD ST MARTIN	404	407	416	425	435	445
Total	155,772	165,838	172,913	181,011	188,530	196,471

Table 2.4.1:2: Wessex Water Current and Forecast Future Phosphate Loads for Discharges at their 21 largest STW in Avon

Site	Consent	Mean Flow	Mean Total P	Sample	Load Total P (2011)*1	Forecast Total P (2025)	Forecast Total P (2030)	Forecast Total P (2035)
		(ml/day)	(ug/l)	Count	(tpa)			
SALISBURY STW FE	1000	20.511	561	120	4.200	4.949	5.260	5.592
WARMINSTER STW	1000	4.312	608	13	0.957	1.090	1.142	1.196
RINGWOOD STW	1000	4.49	542	12	0.888	1.158	1.158	1.158
CANNINGS STW		0.399	5000 (700)		0.728	0.799 (0.112	0.861 (0.121)	0.947 (0.133)
HURDCOTT	1000	3.297	575	12	0.537	0.551	0.560	0.568
COLLINGBOURNE DUCIS STW		0.318	5000		0.930	1.019	1.052	1.089
PEWSEY STW	1000	1.857	683	12	0.463	0.495	0.503	0.511
FORDINGBRIDGE STW	1000	2.312	542	12	0.457	0.474	0.481	0.488
DOWNTON*1	1000	1.832	487	22	0.326	0.367	0.396	0.435
EAST KNOYLE STW*[1]		0.161	5000 (700)		0.294	0.309 (0.043)	0.317 (0.044)	0.324 (0.045)
AMESBURY STW	1000	1.199	606	12	0.265	0.379	0.408	0.440
SHREWTON	1000	1.104	517	12	0.208	0.231	0.247	0.268
RATFYN STW	1000	2.359	183	12	0.158	0.186	0.207	0.234
GREAT WISHFORD *2	1000	1.153	342	12	0.144	0.165	0.179	0.197
FOVANT STW	1000	0.401	700	13	0.102	0.118	0.133	0.154
MARDEN	2000	0.177	1292	12	0.083	0.095	0.104	0.115
UPAVON	1000	0.438	462	13	0.074	0.088	0.097	0.110
NETHERAVON STW	1000	0.423	469	13	0.072	0.076	0.079	0.083
TISBURY	1000	0.844	208	12	0.064	0.077	0.090	0.108
MAIDEN BRADLEY STW PRIOR TO SOAKAWAY		0.035	5000		0.064	0.067	0.069	0.070
BARFORD ST MARTIN	2000	0.083	1552	23	0.047	0.051	0.055	0.061
Total					**10.868**	**12.745**	**13.396**	**14.147**
Total with East Knoyle & All Cannings improvements						**(11.79)**	**(12.39)**	**(13.06)**

Permit flow may be exceeded

***1:** Wessex Water have recently completed sewer sealing work at Downton STW and have seen a downwards trend in flow over the last 3 years. They are not therefore anticipating flow exceedence at this site

*2: Wessex Water has proposals for extensive sewer sealing and inflow reduction plan in the Great Wishford catchment by March 2017 to try and prevent the need for any permit variations.

Table 2.4.1:3 Estimated Population Growth Forecast from Wiltshire Infrastructure Delivery Plan Update (2014)

	Housing numbers (town)			Housing Numbers Rest of Community Area		
	2006-14	2014-26	Indicative remaining	2006-14	2014-26	Indicative remaining
Amesbury Bulford & Durrington	1019	1352	69	130	31	184
Devizes	1316	361	333	225	55	210
Pewsey	0	0	0	306	157	137
Salisbury town	1518	4093	0			
Wilton	78	497	0	111	42	102
Southern Wiltshire Community Area (including Downton)	54	14	122	315	54	56
Tidworth & Ludgershall	330	1338	82	80	6	84
Tisbury	124	37	39	51	11	158
Warminster	504	1099	317	67	24	49
Westbury *1	674	752	74	53	7	55
Total	4943	8791	962	1338	387	1035

**1 Town centre development excluded from calculations, wider community area (including Salisbury Plain) included*

Gran Total 2014-26	10129
Indicative remaining	1997
Total	12126
Population @ 2.2/house	26677.2

Table 2.4.1:4 Estimated Population Growth Forecast from Hampshire Population Project for Catchment within the Hampshire Avon (Hampshire County Council Nov 2012; EA Ref 26521512)

Hampshire Population Projections (from 26521512)

ONS 2010 based Sub National Population Projections

Population		**Increase In Population from 2011**		
Area	**District**	**2021**	**2027**	**2035**
Test Valley District	Test Valley	3600	5900	8300
New Forest District	New Forest	11100	17800	25400
Ashford Allen C043027	New Forest	220	350	500
Avon Hants Lower C043028	New Forest	1090	1750	2490
Avon Hants Middle C043026	New Forest	330	530	750
Bourne Hants C043024	Test Valley	50	80	110
Subtotal Hampshire		**16390**	**26410**	**37550**

Table 2.4.1:5 Wiltshire Unitary Authority Analysis of Sewered and Un-sewered Development in the Hampshire Avon from 2006 to 2014.

	Total Building Completions by Sub-Catchment Area		Sum of Dwellings Permitted Through Applications by Sub-Catchment Area		Count of Permitted Applications by Sub-Catchment Area	
Total Building Completions by Sub-Catchment Area	Non-STW	STW	Non-STW	STW	Non-STW	STW
Ashford Water (Allen River)						
Bourne (Hampshire Avon)	56	544	2	14	2	8
Chitterne Brook	30		2		2	
Deane Water	9	184	5	41	3	11
Ebble	24	13	2		2	
Ebble (Upper)	6	5	1	1		1
Ebble Trib (Chalke Valley Stream)	7				1	
Etchilhampton Water	5	737		6		3
Fonthill Stream	3	76	4	1	2	1
Fovant Brook	2	9	1	1	1	1
Hampshire Avon (East) and Woodborough Stream	8	97	4	26	4	8
Hampshire Avon (Lower)	10	495		35		18
Hampshire Avon (Upper) d/s Nine Mile River confl	29	1931		209		14
Hampshire Avon (Upper) u/s Nine Mile River confl		234				
Hampshire Avon (West)		19				
Nadder (Headwaters)	10	19				
Nadder (Lower)		308		2		1
Nadder (Middle)	12	75	2	6	2	5
Nadder (Upper)	3	64		1		1
Nadder Trib (Swallowcliffe)	4		1		1	
Nine Mile River		264				
Sem	7	3	4		4	
Sweatfords Water	2					
Teffont	2	9		1		1
Till (Hampshire Avon)	7	76	3	1	3	1
Wylye (Headwaters)	14	81	2	16	1	10
Wylye (Lower)		101				
Wylye (Middle)	39	93	11	46	5	15
Wylye Trib (The Were or Swab)		404		62		15
Grand Total	289	5841	44	469	33	114
Percentage	4.95%		9.38%		28.95%	

Total Building Completions by Sub-Catchment Area'. This is the total number of dwelling actually built, or where construction had started, during the sample period (2006-2014)

'Sum of Dwellings Permitted Through Applications by Sub-Catchment Area' – This is the total number of dwellings which the Council as permitted during the sample period, but where construction has not yet commenced (these may need to be considered in combination).

'Count of Permitted Applications by Sub-Catchment Area' – The number of housing permissions granted in the sample period which have not yet been implemented.

2.4.2 Climate Change

Climate change may result in a number of changes in the catchment including a rise in water temperatures and a change in recharge and flow within the catchment. This in turn may impact on the habitats and species the river supports.

Temperature: Changes in the temperature of rivers have already been observed in southern chalk rivers (Durance and Ormerod, 2008) and in the English Channel (Joyce, 2006; see Annex 1). Rising water temperature across the Hampshire Avon may result in designated species finding it harder to compete with other species more adapted to higher temperatures. For some species, such as Salmon, it could result in them not even entering the river system if river temperatures are too high.

Where nitrogen or phosphorus is not limiting, algal growth is likely to be increased by rising water temperatures (e.g. Lotze and Worm 2002). This can increase adverse effects on the river ecology by, for example reducing dissolved oxygen availability in the river, degrading the suitability of gravels for fish breeding and changing the abundance and composition of the aquatic macrophyte community.

Rainfall: Changes in rainfall pattern can have a number of impacts on phosphorus loads in the Avon and designated species. Increased rainfall intensities can result in more run-off and soil erosion, particulate P entering water courses, leaching of phosphorus in soils (Olsen-P), fertilisers and manure P both to surface and groundwater. An increase in rainfall recharge and river baseflow (at intensities that do not result in run-off) may in contrast provide some benefit to the river systems by providing a greater dilution of contaminants within the river and flushing out river sediment which contribute to high in river nutrient concentrations.

Reduced recharge or infiltration to ground will result in a reduction in baseflow volume to the river, reduce dilution and sediment flushing. This may result in an increased concentration of contaminants within surface and groundwater's. This effect is exacerbated at any point source discharges, which often rely on river dilution to bring in river chemical concentrations down. Low flows also result in a reduced area of wetted river bed and reducing flow velocity across the river bed. This impacts, for example, on river invertebrates and on spawning locations if a drought extends through spawning periods.

The frequency of "drought" events under certain climate change scenarios may also increase, putting further pressures on designated species. We have little control locally in changing the climate, but we do have the ability to improve the resilience of the river habitat and hence the ecology to climatic variables. Further discussion of available options is considered in Section 3.

2.4.3 Change in Land Use Practices

Climate change, population growth and changes in UK and international markets can result in land use changes, which can put further pressure of achieving SAC targets in the Avon.

In many cases it is not possible to forecast what these changes will be, but as with climate change, it will be essential that the impact of these changes are considered when observed or forecast and the NMP is updated to ensure that SAC objectives are met. A regular NMP review is therefore proposed that will fit in with Water Framework Directive review cycle every 6 years. Within each RBMP cycle there should be an interim assessment of progress towards NMP targets at agreed timescales/intervals.

Improvements in ecology and bio-diversity resulting from land use change and reduced point source loading to the Hampshire Avon may take years/decades to be fully realised.

2.5 Discussion: Current and Future Forecast Phosphorus Concentrations and Loading to the Avon

We have reasonable confidence in the phosphorus discharge concentrations and loading from Sewage Treatment Works and the larger point sources, that, pre phosphorus stripping made up over 98% of the point source loads to the Avon[23]. This is reflected in the close correlation of Wessex Water and SIMCAT model loadings results.

Total and OP loads to the Avon are however considered to be under estimated by the SIMCAT and PSYCHIC models. This is primarily because of an under estimation of diffuse loads. In SIMCAT this results from its use of average flow and average water quality data. The greatest diffuse loads are mobilised during times of high flow which are unlikely to be fully reflected in annual average water quality data.

PSYCHIC is also thought to under estimate phosphorus loads to the Avon. Davison (2014)[29], considers that again it is the diffuse element that is under-estimated by this approach.

Flow apportioned calculations of P loads within the Avon provide an improved directly observed estimate of phosphorus loading. Where possible hourly to daily water quality and flow data would be used to make this calculation. For the NMP, daily flow data was available but only weekly or monthly water quality data. Therefore average OP & TP loads for the Avon between 2009-2012 of 48 & 60 tonnes P yr (Table 2.3.1c), are still thought to be an underestimate of total loads, missing P loads at high flows (when significant proportion of diffuse loads generated from run-off) would enter the rivers through surface run-off pathways and not accounting for the uptake of phosphorus by plants (modelled in SIMCAT as 0.1/ day).

Note: OP loads in the Avon represent around 57-91% of TP loads for the Avon[29].

A combined PIT & Point Source Loading forecast should take into account our best point source loading estimate and modelled diffuse load, (Table 2.3.3:1a). However this approach takes no account of natural P loading from the UGS aquifer. When and whilst this combined approach for the whole catchments predicts a P load of 5-13% greater than calculated through flow apportioned methods[29], it under-estimates the phosphorus loads entering rivers that are fed by baseflow from the Upper Greensand, compared to flows from chalk catchments; forecast OP loads for Upavon East are under estimated by 35%, Upavon West by 24%, Nadder by 17%. The Wylye is over estimated by around 20%.

AMEC have looked to identify if this under estimation of P loads in UGS catchments could be explained by more intense agriculture in these areas. They concluded however that there was no substantial evidence of higher agricultural inputs in UGS areas compared to chalk.

Work commissioned by the Agency, identified a substantial natural source of phosphorus within the Upper Greensand aquifer and largely feeding reaches of the Avon where observed P exceeded PIT model forecast (Section 2.3.1).

EA work identified that where calcium concentrations within the water body are low, natural phosphatic minerals could dissolve in groundwater and flow as baseflow to the rivers. Modelled background phosphorus concentrations within the Avon are estimated under average flows to be around 28 ug/l at Knapp Mill at the bottom of the Avon, 97ug/l and 117ug/l in Upavon West and East 20ug/l on Lower Wylye and 31ug/l on Nadder Lower (Table 2.3.1:5). The concentration and proportionate input from the UGS reduce downstream of the UGS outcomes.

When these modelled background concentrations are calculated as a P load c13 tonnes/P/yr at Knap Mill for 2010/11 (Table 2.5:1) they can largely account for the missing sources of P, not considered within the PIT model. Considering these natural source of P improves the source apportionment estimations across the catchment, particularly when we remember that the calculated flow apportioned load are likely to be an under-estimation of total loads.

Table 2.5:1 Comparison of Calculated OP, TP and Modelled background loads.

Catchment	Calculated OP Load (2009-12; tonnes/yr)	Calculated TP Load Tonnes/yr)	Modelled OP Load (PIT) (Tonnes/yr)	% Difference (Modelled - calculated	Difference (t/yr)	Forecast Baseline natural 2010-11 (modelled background)	Natural + modelled OP tonnes/yr
Knapp Mill (Avon)	47.8	59.91	49.9	4.5	-2.10	12.86	62.76
Upavon East (Avon)	3.7		2.4	-35.3	1.30	3.24	5.64
Upavon West (Avon)	3.8		2.9	-23.8	0.90	1.78	4.68
Salisbury (Avon)	13.5	16.43	10.6	-21.7	2.90	3.50	14.10
South Newton (Wylye)	9	10.8	10.9	20.9	-1.90	1.52	12.42
Wilton (Nadder)	8.3		6.9	-17.4	1.40	4.47	11.37
Laverstock (Bourne)	2.3	2.59	3.3	40.8	-1.00	0.19	3.49
Nunton Bridge (Ebble)	2.6	4.6	2.4	-8.7	0.20	0.39	2.79

Following the installation of phosphorus stripping the point source loads to the Avon (STW+Fish Farm+Water Cress) have reduced from c80 tonnes/P yr to c17 tonnes TP yr (11 tonnes/yr from STW). With the uptake of headroom to 2035, STW loads are likely to increase to around 14 tonnes TP/yr in (Table 2.4.1:1- 2.4.1:2) Worst case forecasts from *SIMCAT Run1a_PR14_Full practical permit uptake*, assuming all STW permits operate at their full permit flow and at 0.7mg/l discharge quality forecast that STW loads would increase to c18 tonnes P/yr and point source loads will increase to 24 tonnes P/yr. The permitted point source load across the Avon were c22% of total loads (based on PIT modelling Figure 2.5:1) in 2011to 25% in 2035. This varies spatially with the highest proportionate loading c40% in Upper Avon East and lower totals 5% for Upper Avon West (assuming PR14 improvements are in place) Figure 2.3.3:1 a-c.

The implications of future development will need to be re-assessed, once it has been determined if the Favourable Status can be achieved in the Avon through the implementation of diffuse P reduction measures. The initial objective is to achieve the ambition target reductions for P. This is further considered in Section 3.0.

A summary source apportionment for the Avon is presented in Table 2.5.2:

Table 2.5:2 Summary Source Apportionment All Sources Using EA PIT Diffuse, SIMCAT Run 1a_PR14 Point Source Loads & Gross Un-sewered Forecast for catchment excluding Lower Avon (P kg/yr)

Water Body	Catchment Results	Ambition Target reduction P kg/yr	Point Sources (STW)	Fish Farm and Cress Farms	Diffuse (from PIT)	Urban	Modelled background	Un-sewered estimate*1	Total
GB108043022410	Upavon East	555	638	1029	2360	125	3242	119	7513
GB108043022370	Upavon West	733	237	0	2820	107	1777	119	5059
GB108043022352	Upper Avon	2007	1856	1101	11195	991	3499	280	18922
GB108043022510	Wylye	744	1356	578	13369	577	1522	114	17515
GB108043015880	Nadder	1421	361	1091	20669	979	3159	190	26448
GB108043022390	Bourne	191	693	0	3929	509	191	103	5424
GB108043015830	Ebble	0	110	666	3256	70	394	116	4614
GB108043015840	Lower Avon	9312	10564	6492	46862	3802	12860	689	81269

*1 Gross un-sewered figures from Murdoch March 2010, Upper Avon load divided equally between UAE, UAW and sum of all three inserted in Upper Avon, Gross Catchment Load included in the Lower Avon but excludes any calculation for this area

Figure 2.5:1 Summary Source Apportionment All Sources Using EA PIT Diffuse, SIMCAT Run 1a_PR14 Point Source Loads & Gross Un-sewered Forecast for catchment excluding Lower Avon[6]

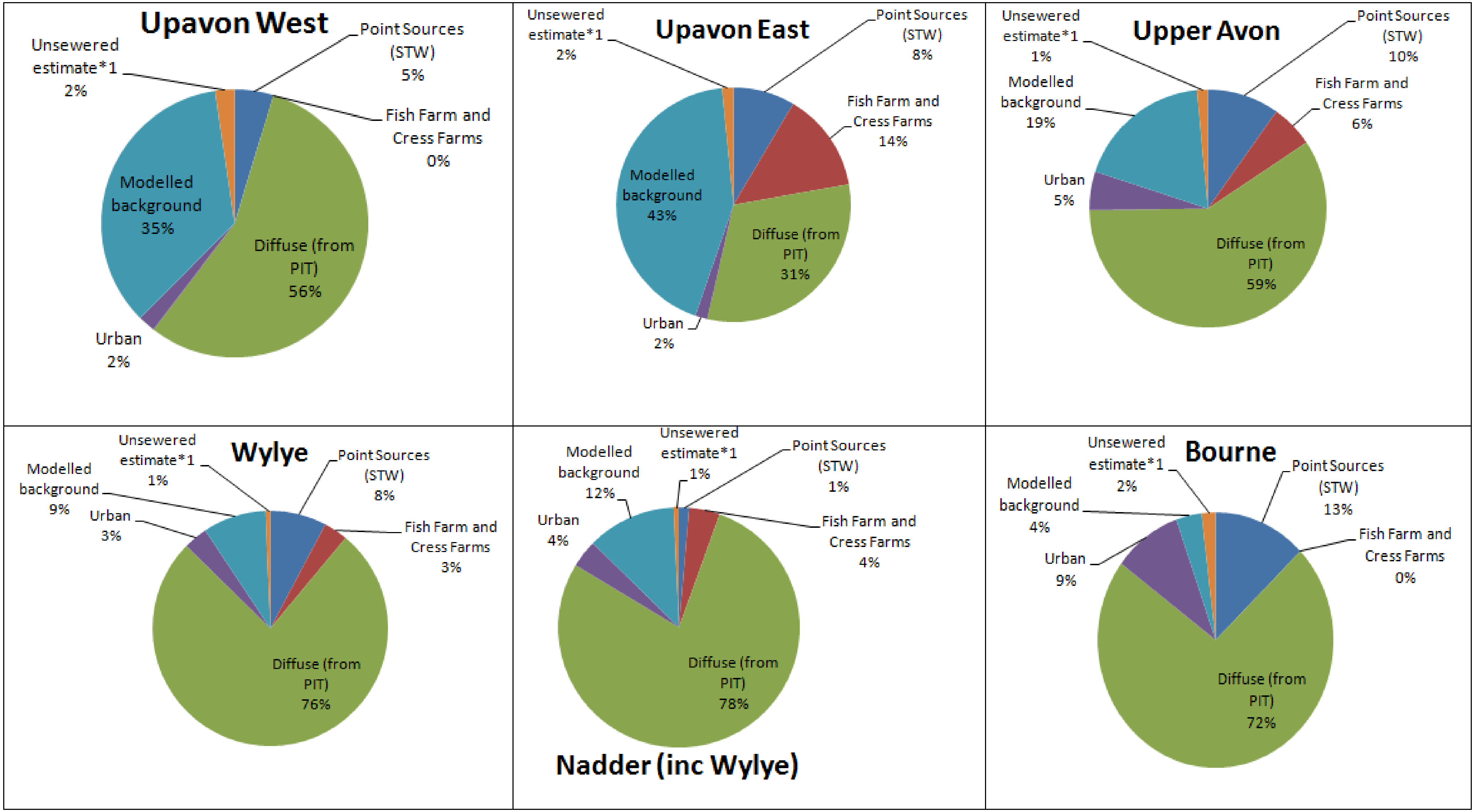
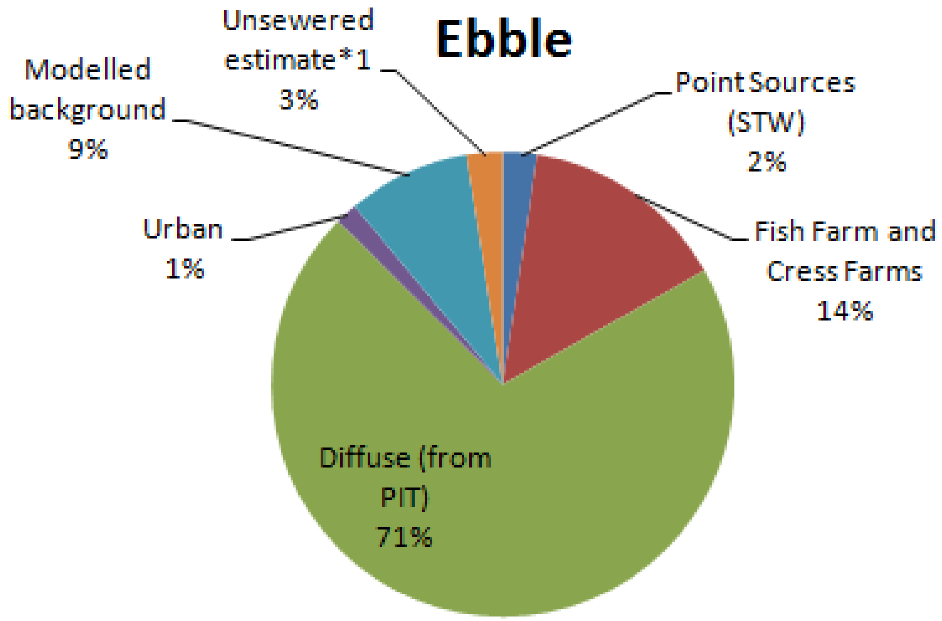
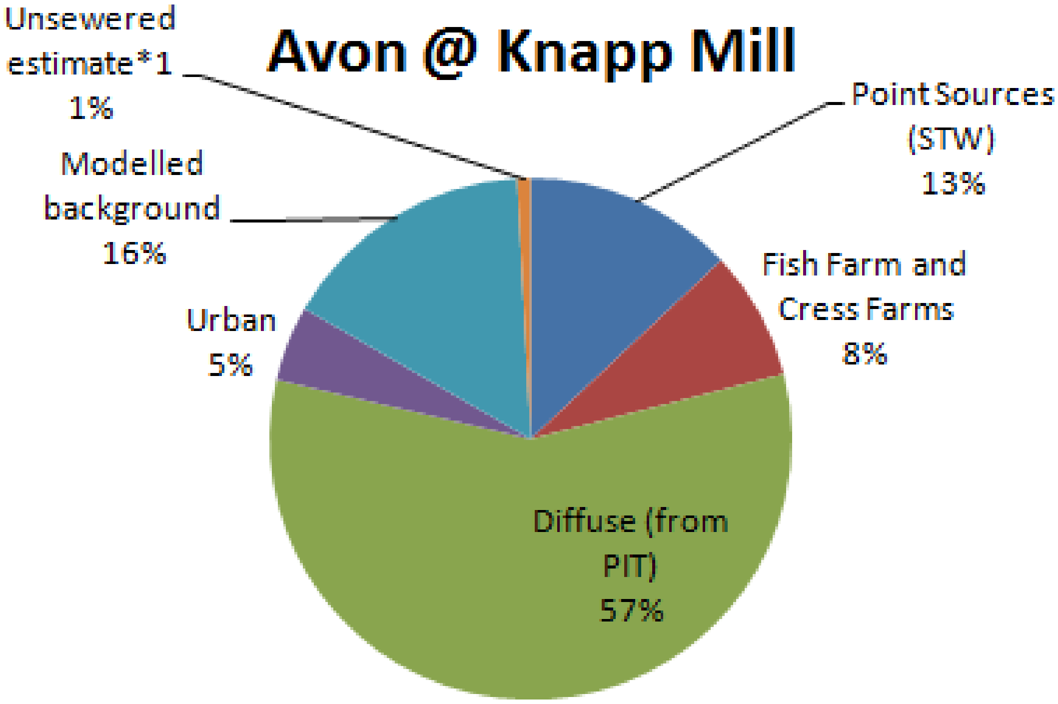


Figure 2.5.1 Continued





Summary

- Flow apportioned source apportionment, provides our best observed estimate of total phosphorus loads in the Avon. This method may still not fully account for all diffuse losses because they rely on weekly to monthly water quality sampling and this sampling may miss high flows events.
- Some reduction in phosphorus concentration will also occur as a result of settlement and uptake by plants. SIMCAT results include a loss factor or 0.1.
- PIT model results provide our best estimate of the diffuse source of P (excluding baseline). This data can be used in our interpretation of the P reduction that might be achieved through the implementation of agricultural measures.
- STW Loads to the Avon in 2011 are calculated to be c11 tonnes TP/yr and are forecast to increase to c13 tonnes TP/yr in 2035 following Wessex Water Growth forecasts following PR14 improvements (Table 2.4.1:2).
- Fish Farm and Water Cress loads are calculated in SIMCAT to be around 6.5 tonnes P/yr.
- Septic Tanks are thought to account for <c1 tonne/P yr.
- Point source loads to the Avon are likely to increase by c3 tonnes/yr to the year 2035 (assuming PR14 improvements are put in place) or c4 tonnes P yr if not (excluding Wylye improvements)
- Modelled background loads to the Avon are estimated to be c13 tonnes P/yr in 2010-11 increasing to around 17 tonnes P/yr under average flow conditions.
- The sum of PIT model forecast and natural baseline, loads are likely to replicate actual loads to the Avon reasonably well and are estimated to be c47 tonnes/P/yr Table 2.3.3:1c
- Total TP Loads to the Avon are likely to be in the range of 68-80 tonne TP/yr increasing during average and wetter years.

3.0 SOLUTIONS TO DELIVER OUTCOMES

As discussed in Section 2.0, phosphorus enters the catchment from natural sources (Upper Greensand aquifer, plant decomposition etc) and anthropogenic sources (fertilisers, animal manure, sewage etc).

To deliver the “ambition targets” set out in Table 2.3.1:5, a number of different approaches are considered below. The primary aim is to identify if they can be achieved through diffuse pollution reductions. If this is not however feasible, additional point source improvement measures are considered. Any such improvements if agreed are likely to be proposed under PR14 and installed under AMP7 from 2021.

With the exception of the sites that have already been put forward under PR14, it is not expected that further reduction in STW loads will be considered until PR19. The exception to this may be where the headroom to a STW is likely to be exceeded and improvements in performance of the STW may subsequently be required.

To assess the changes in diffuse and potentially a combination of diffuse and point source measures that are required to achieve SAC targets, a number of scenarios have been run and compared with the 2010-11SIMCAT base case. These scenarios are detailed below in Table 3.0:1. Results are presented in Figure 3.0:1 Scenario 3-13. Detailed results can be found in Appendix 3.0:1

This section will consider the water quality improvements that could be achieved through further STW improvements but will focus on diffuse reductions that could be achieved.

Table 3.0:1 Mitigation Scenarios Run for Baseline Model 2a and Full Practical Permit Uptake Scenario 2c

Scenario	Description	STW Load	Fish Farm and Water Cress Load	Diffuse Load
Source Apportionment Model Runs				
Run 1a	Compliance Against **WFD** Targets No Change in diffuse or point source	SIMCAT Historic (2010-11)	SIMCAT Historic (2010-11)	SIMCAT Historic (2010-11)
Run 1a_PR14	Compliance Against SAC Targets: No Change in diffuse or point source	Historic + All Canning and East Knoyle @ 1mg/l P	SIMCAT Historic (2010-11)	SIMCAT Historic (2010
Run 1a_PR14_Full practical permit uptake	Compliance Against SAC Targets: No Change in diffuse or point source	All STW @ 700ug/l	SIMCAT Historic (2010-11)	SIMCAT Historic (2010
Run 1a_no STW	Diffuse & non STW Loads	Non	SIMCAT Historic (2010-11)	SIMCAT Historic (2010
Run 1a_No Point Load	Diffuse Loads only	NON	NON	SIMCAT Historic (2010
Run 1a_WW PR14_FA	2010-11 source apportionment	Wessex Water 2011	SIMCAT (Historic 2010-11)	Flow Apportioned OP
Run 1a_WW_2025_PR14_FA	2010-11 source apportionment	Wessex Water 2025 forecast	SIMCAT (Historic 2010-11)	Flow Apportioned OP
Run 1a_WW_2035_PR14_FA	2010-11 source apportionment	Wessex Water 2035 forecast	SIMCAT (Historic 2010-11)	Flow Apportioned OP
Diffuse Reduction Scenarios				
PIT_CSF@Current	Pit model diffuse loads with reductions forecast assuming all CSF current = combined modelled impact of all measures recommended by CSF to date, including a factor representing the likelihood of the measures successful implementation.	NA	NA	Load reduction from PIT, assuming CSF_current
PIT_CSF@Optimum	Pit model diffuse loads with reductions forecast assuming all CSF @ Optimum = what we estimate a maximum benefit could be from a voluntary scheme like CSF. This includes the same factor limiting the likely implementation of measures via CSF. Note typical CSF is thought to deliver approximately 50% of Optimum on average.	NA	NA	Load reduction from PIT, assuming CSF_optimum
PIT_CSF@Maximum	Pit model diffuse loads with reductions forecast assuming all CSF @ Maximum = the total impact if all 86 measures in the DPI manual are applied to all farms and 95% measures are assumed to be implemented	NA	NA	Load reduction from PIT, assuming CSF_maximum

PIT_Farmscoper_Existing	PIT with Farmscoper measures			
PIT_Farmscoper_ALL Available	PIT			
Managed Grass and Arable Reversion to rough grazing	Based on the phosphorus loading (kg/ha) from combined managed grassland and arable activities (Arable & managed grass losses=total load-urban-point source loading)	NA	NA	Rough grazing and woodland P loading assumed to be zero.
Point Source Measures				
STW@0.5mg/l	Using WW Flow and Source Apportionment Data, Adjusting Loading Resulting from STW performing to 0.5mg/l P target	0.5 mg/l P	NA	NA
STW@0.2mg/l	Using WW Flow and Source Apportionment Data, Adjusting Loading Resulting from STW performing to 0.2mg/l P target	0.2 mg/P	NA	NA

Note: Options as detailed below have not been considered in this report but could have benefit in reducing phosphorus loads locally within the Avon

i. Reduce ingress of groundwater and input of surface rainwater in urban areas especially into STW sewer system. This will reduce discharge volume from STW, leaving more headroom within permit limits. It may also improve the efficiency of P removal processes at STW.

ii. Move STW discharge point downstream. Bigger flow in river hence increased dilution and less effect in raising P concentrations. Significant costs are likely to be associated with this option & may exacerbate low flow issues.

iii. Move discharge point to another catchment. This will remove the P input entirely (except for overflow). Involves pumping costs but that may be less than additional costs of P stripping to a higher standard than that required on the other catchment e.g. Warminster to Westbury?

iv. Connect STW to another STW further downstream for P stripping. This will move the discharge load downstream, where there may be a greater dilution volume and potentially improved treatment in operation. This option may however have an adverse impact on flows.

3.1 *Point Source Options*

3.1.1 Sewage Treatment Works

All Wessex Water larger STWs, which discharge directly to watercourses, with the exception of East Knoyle and All Cannings, Barford St Martin and Marden now have P stripping to 1mg/l, which was considered under the Review of Consents to be the Best Available Technology (BAT). The improvements were installed at a cost of approximately £30M and operational cost of c£2M/yr. Barford St Martin and Marden have stripping to 2mg/l (Table 2.3.2c). P stripping has typically resulted in an 8-10 fold reduction in point source phosphate loading.

Phosphate stripping at East Knoyle and All Cannings is proposed under PR14. When operating at 700ug/l this will result in a 0.7-0.8 tonne P yr reduction in the downstream water courses and at East Knoyle would improve water quality from 950ug/l (in the base model case (2010-11)) to 271 ug/l. At All Cannings it would result in a P reduction from 395ug/l to 197ug/l (Figure 3.1:1a and b).

P stripping will achieve an approximate 20-25% improvement in water quality over a 17km reach down stream of All Cannings, and a 40-50% improvement for 5km downstream of East Knoyle (Figure 3.1:1a&b).

Where it is unlikely that the ambition targets and favourable conservation status will not be achieved by diffuse measures alone, consideration will be given to further tightening existing STW discharges. The potential water quality improvements that would result from STW discharge quality reducing to 0.5mg/l and 0.2mg/l in 2011, 2025 and 2030 are modelled in Table 3.1:1. Tables 3.1:2-3 highlights if these measures alone could achieve firstly 50% of the ambition targets and then 100% of the ambition targets.

Current technologies used by Wessex Water are likely to allow for treatment at or near to a discharge quality of 0.5mg/l in many of their STW. There is not currently a phosphorus removal technology in use in the UK to achieve a <0.2mg/l total phosphorus consent (Per-Comms EA-Wessex Water August 2014).

Phosphorus technology trials to test a number of phosphorus removal technologies which purport to deliver a <0.1mg/l consent to understand the accuracy of these claims, costs, operation and benefits are proposed under AMP6. Results (and costs) from this work will be available at the end of 2017.

Uncertainty in delivering 0.2mg/l water quality standard is much greater than delivering a 0.5mg/l standard. This is reflected in the costs outlined in Section 4.1.

Figure 3.1:1a Forecast downstream water quality following P stripping at All Canning STW (Run 1a=green, Run 1a_PR14=blue)

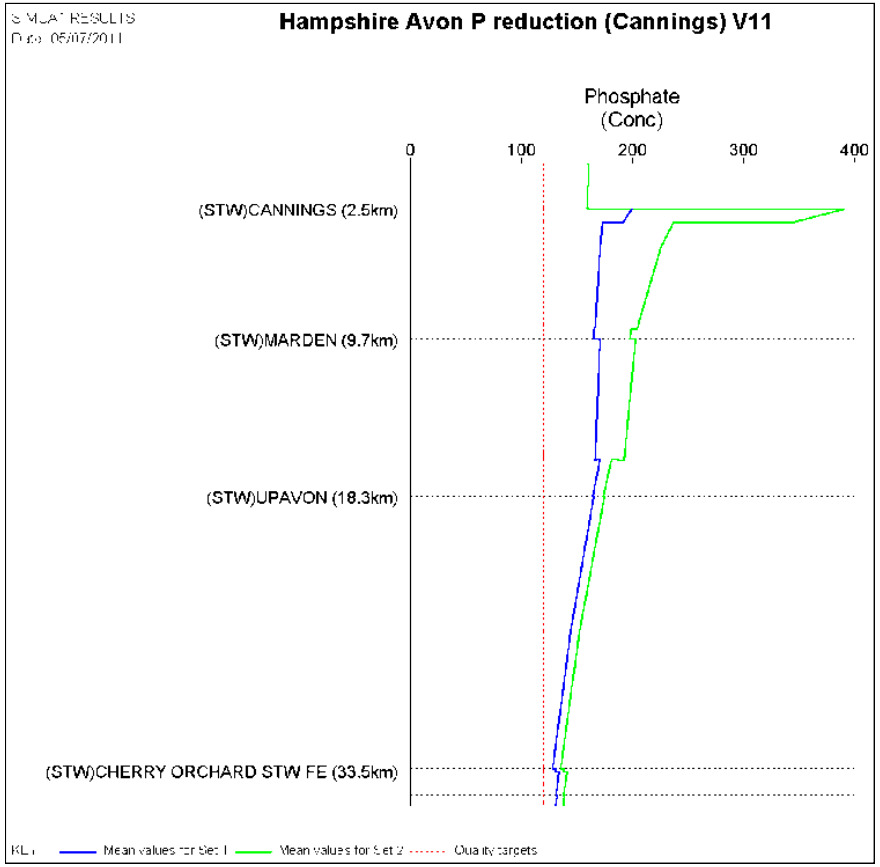


Figure 3.1:1b Forecast downstream water quality following P stripping at East Knoyle(Run 1a=green, Run 1a_PR14=blue)

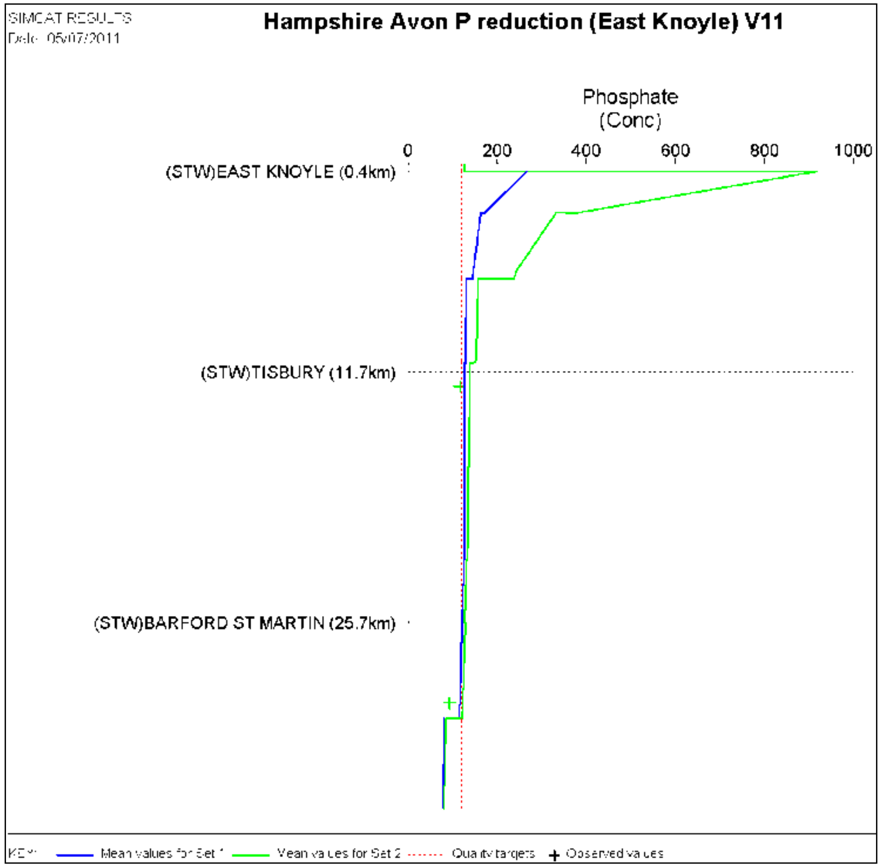


Table 3.1:1 STW P Reductions For Scenarios (from current operational concentrations)

Scenario PS 1: STW Load @500ug/l	Scenario PS 2: STW Load@200ug/l

POST PR14 Wessex Current and Forecast Future Phosphate Loads for discharges Wessex Water 21 largest STW in Avon (From "Point Source (SIMCAT & WW)" worksheet)

Site	Mean baseline discharge quality WW _PR14 (2011)Total P	WW Load (2011)with PR14 Improvements kg/yr	WW Forecast STW Load in 2025 inc PR14	WW Forecast STW Load 2030, inc PR14 improvements	WW Forecast STW Load 2035, inc PR14 improvements	Forecast STW Load WW_PR14 (2011) all STW @ 500ug/l*1	Forecast STW Load WW_PR14 in 2025 all STW @500ug/l	Forecast STW Load WW_PR14 in 2030 all STW @500ug/l	Forecast STW Load WW_PR14 (2011) all STW @ 200ug/l*1	Forecast STW Load WW_PR14 in 2025 all STW @200ug/l	Forecast STW Load WW_PR14 in 2030 all STW @200ug/l
	(ug/l)	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	(kg/yr)
SALISBURY STW FE	561	4,200	4,949	5,260	5,592	3743	4411	4688	1497	1764	1875
WARMINSTER STW	608	957	1,090	1,142	1,196	787	896	939	315	359	376
RINGWOOD STW	542	888	1,158	1,158	1,158	819	1069	1069	328	427	427
CANNINGS STW	700	102	112	121	133	73	80	86	29	32	34
HURDCOTT	575	537	551	560	568	467	480	487	187	192	195
COLLINGBOURNE DUCIS STW	5000	930	1,019	1,052	1,089	93	102	105	37	41	42
PEWSEY STW	683	463	495	503	511	339	362	368	136	145	147
FORDINGBRIDGE STW	542	457	474	481	488	422	437	443	169	175	177
DOWNTON	487	326	367	396	435	334	377	407	134	151	163
EAST KNOYLE STW	700	41	43	44	45	29	31	32	12	12	13
AMESBURY STW	606	265	379	408	440	219	313	337	88	125	135
SHREWTON	517	208	231	247	268	201	224	239	81	89	96
RATFYN STW	183	158	186	207	234	431	507	565	172	203	226
GREAT WISHFORD	342	144	165	179	197	210	242	262	84	97	105
FOVANT STW	700	102	118	133	154	73	85	95	29	34	38
MARDEN	1292	83	95	104	115	32	37	40	13	15	16
UPAVON	462	74	88	97	110	80	95	105	32	38	42
NETHERAVON STW	469	72	76	79	83	77	81	84	31	32	34
TISBURY	208	64	77	90	108	154	186	215	62	74	86

MAIDEN BRADLEY STW PRIOR TO SOAKAWAY	5000	64	67	69	70	6	7	7	3	3	3
BARFORD ST MARTIN	1552	47	51	55	61	15	17	18	6	7	7
Total		**10,182**	**11,792**	**12,384**	**13,054**	**8606**	**10035**	**10590**	**3442**	**4014**	**4236**

Figure 3.1:2 Phosphorus Reductions from STW Operating at 500ug/l and 200ug/l compared to WW 2011_PR14 Scenario. Ambition Targets Set at 50% Proposed

				POINT SOURCE Load Reduction For Scenarios						
					Scenario PS 1: STW Load @500ug/l			Scenario PS 2: STW Load@200ug/l		
					STW discharging at 500ug/l			STW discharging at 200ug/l		
				Forecast STW Load Reductions WW 2011 compared to WW 2011 with PR14 improvements WW_PR14	Forecast STW Load Reductions (in 2011)_pr14 Compared to WW Baseline WW_PR14 (2011) when all STW @ 500ug/l*1	Forecast STW Load Reductions (in 2025) Compared to WW Baseline WW_PR14 (2011) when all STW @ 500ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2030) Compared to WW Baseline WW_PR14 (2011) when all STW @ 500ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2011) Compared to WW Baseline (2011) when all STW @ 200ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2025) Compared to WW Baseline (2011) when all STW @200ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2030) Compared to WW Baseline (2011) when all STW @ 200ug/l*1
Catchment Results	Water Body	Ambition Target (ug/l)	Target Reduction (kg/yr)	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	(kg/yr)
Upavon East	GB108043022410	-20	277	0	124	101	95	327	318	316
Upavon West	GB108043022370	-40	366	626	80	69	59	143	139	135
Upper Avon	GB108043022352	-20	1003	626	-33	-257	-368	717	628	583
Wylye	GB108043022510	-10	372	0	167	4	-74	890	825	794
Nadder (excluding Wylye)	GB108043015880	-10	710	252	150	-59	-179	1036	953	905
Bourne*1	GB108043022390	-10	95	0	907	885	875	1243	1234	1230
Ebble	GB108043015830	0	0	0	0	0	0	0	0	0
Lower Avon	GB108043015840	-20	4656	879	1576	147	-407	6740	6168	5946

*1 Note Collingbourne Ducis discharge c500kg/yr is lost to ground over much of year and groundwater diverges east and west to the River Test and Avon respectively

*2 -ve values indicate that there is a deterioration in water quality compared to baseline, potentially due to scenario assuming poorer discharge quality than actual

Figure 3.1:3a Phosphorus Reductions from STW Operating at 500ug/l and 200ug/l compared to WW 2011_PR14 Scenario. Ambition Targets @ Full Proposed (note –ve number implies reduced quality and increased loading)

					Scenario PS 1: STW Load @500ug/l			Scenario PS 2: STW Load@200ug/l		
					STW discharging at 500ug/l			STW discharging at 200ug/l		
				Forecast STW Load Reductions WW 2011 compared to WW 2011 with PR14 improvements WW_PR14	Forecast STW Load Reductions (in 2011)_PR14 Compared to WW Baseline WW_PR14 (2011) when all STW @ 500ug/l*1	Forecast STW Load Reductions (in 2025) Compared to WW Baseline WW_PR14 (2011) when all STW @ 500ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2030) Compared to WW Baseline WW_PR14 (2011) when all STW @ 500ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2011) Compared to WW Baseline (2011) when all STW @ 200ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2025) Compared to WW Baseline (2011) when all STW @200ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2030) Compared to WW Baseline (2011) when all STW @ 200ug/l*1
Catchment Results	Water Body	Ambition Target (ug/l)	Target Reduction (kg/yr)	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	(kg/yr)
Upavon East	GB108043022410	-20	555	0	124	101	95	327	318	316
Upavon West	GB108043022370	-40	733	626	80	69	59	143	139	135
Upper Avon	GB108043022352	-20	2007	626	-33	-257	-368	717	628	583
Wylye	GB108043022510	-10	744	0	167	4	-74	890	825	794
Nadder (excluding Wylye)	GB108043015880	-10	1421	252	150	-59	-179	1036	953	905
Bourne*1	GB108043022390	-10	191	0	907	885	875	1243	1234	1230
Ebble	GB108043015830	0	0	0	0	0	0	0	0	0
Lower Avon	GB108043015840	-20	9312	879	1576	147	-407	6740	6168	5946

Figure 3.1:3b Phosphorus Reductions from STW Operating at 500ug/l and 200ug/l compared to WW 2011_PR14 Scenario. Ambition Targets @ Full Proposed

Source Apportionment For Sub Other Sub-catchments				0	Forecast STW Load Reductions (in 2011) Compared to WW Baseline WW_PR14 (2011) when all STW @ 500ug/l*1	Forecast STW Load Reductions (in 2025) Compared to WW Baseline WW_PR14 (2011) when all STW @ 500ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2030) Compared to WW Baseline WW_PR14 (2011) when all STW @ 500ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2011) Compared to WW Baseline (2011) when all STW @ 200ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2025) Compared to WW Baseline (2011) when all STW @2500ug/l*1	Forecast STW Load Reductions WW_PR14 (in 2030) Compared to WW Baseline (2011) when all STW @ 200ug/l*1
Water Body	**Catchment Results**	**Ambition Target Reduction (ug/l)**	**Target reduction kg/yr**	0	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	(kg/yr)
GB108043016200	Nadder Upper	-20	417	0	12	10	9	29	29	28
GB108043022470	Nadder Middle	-20	1270	0	-17	-63	-105	146	128	111
GB108043022520	Wylye Headwaters	-30	630	0	227	117	74	703	659	642
GB108043022550	Wylye Middle	-10	588	0	234	102	44	831	778	755
GB108043022570	Till Tributaries	0	0		7	-15	-31	128	119	113

Note: -ve number implies deterioration in quality and loading resulting with scenario exceeding baseline; often resulting from current operational water quality being similar to the scenario but growth results in deteriorating quality and load.

From this work it can be seen that tightening all STW permit condition to operate at a maximum discharge quality of 0.5mg/l, would have achieved 50% of the ambition target load reductions by 2030 in Upavon East, the Wylye, Nadder and Lower Avon. It would achieve 50% of the ambition target along the Bourne as soon as it was implemented and relative reductions would increase to 2030. In the Till there would be deterioration in quality as Shrewton STW currently operates close to 0.5mg/l and increased population in 2025 and 2030 will result in deterioration in quality and loading compared to the baseline.

A reduction in permit discharge quality to 0.2mg/l would deliver an improvement in water quality and decrease in P loading in all catchments. It would achieve 50% of the ambition targets from 2011_PR14 in all main sub catchments with the exception of Upavon West and Upper Avon.

Full ambition targets would only be achieved by a 0.2mg/l permit condition across the rivers Wylye, Bourne, Wylye Headwaters and Middle and Till. It would not achieve full ambition targets at any of the other catchments.

Practically, at this stage, a tightening of permit conditions to around 0.2mg/l P may be possible using improved technology as detailed in ‘Review of best practice in treatment and reuse/recycling of phosphorus at wastewater treatment works’. This report indicates that BAT could achieve 0.1mg/l P standard. In general the costs per unit of effluent treated to P levels less than 1 mg-P/l begin to rise significantly, doubling once they reach around 0.1 mg-P/l. The cost per unit of effluent treated at smaller works is also significantly more than at larger works, by a factor of around 2 for Wessex Water Treatment Works (WWTW) with a PE of 15,000 PE compared with one of 150,000 PE. However, once the effluent quality target becomes less than 0.1 mg-P/l the size of works seems to become of less relevant.

Whilst improving treatment to 0.1mg/l might practically be achievable, it would have significant capital cost in terms of investment in infrastructure and operational costs (OPEX) in terms of additional energy use (with commensurate carbon dioxide emissions and dis-benefits for climate change). For Warminster STW, as outlined above, the site does not achieve its proportionate targets, but has been operating at around 0.6 mg/l for a number of years.

Trials under AMP6 will assist in determining if tightening of permit conditions to 0.5 to 0.2 mg/l P limit is achievable and cost beneficial using existing infrastructure.

3.1.2: Cress Beds and Fish Farms

Modelling of Cress Beds and Fish Farms indicate that they could contribute c6.5 tonnes P/yr to the Avon (c20% of SIMCAT source apportionment & 8-10% of PIT/SIMCAT source apportionment: Table 2.3.2a & 2.3.3:1a respectively). Cress Beds and Fish Farms can also discharge significant phosphorus loads to the Avon, equivalent to some STW works for larger farms (Appendix 2.3.2:2). They therefore contribute to surface water bodies failing SAC target standards. Table 2.3.2a-c, estimates the load from the larger fish farms and water cress farms at a sub-catchment scale (Table 2.3.2e). However, the limited data collected to date would indicate that the load is close to 4 tonnes P/yr (Table 2.3.2h).

The greatest proportionate load from Fish Farms and Water Cress Farms are in the Ebble and Upavon East Catchment. Here they represent 86% and 62% of total point source loads respectively and 28 and 21% of total SIMCAT loads (which are considered low) and c 14 &10% of Pit Source Apportioned Loads.

Measures to reduce the phosphorus loading from fish farms and cress farms are primarily management related. These included reducing phosphate concentrations in fish food and managing more closely fertilizer application to cress beds by a) sampling water quality and ensuring fertilisers are only used when P concentrations are absolutely required b) applying the correct amount of fertilizer and c) managing flow through the beds so water flows through all beds before being discharged to the water course, maximising the opportunity of P uptake by plants. The overall benefits of these options is however thought to be low, as the data collected to date indicates that discharge quality is better than assumed in the SIMCAT model. Despite this, the farms should be expected to operate to appropriate standards, guidance and best farming practice. Where they do not, consideration should be given to tightening permit conditions to require such improvements.

Three scenarios have been modelled to see if 50% or 100% ambition targets could be achieved by 25%, 50% and 75% reduction in P loading at water cress and fish farms Table 3.1.4. These are highly theoretical scenarios and as detailed above, recent data indicates there may be limited opportunity for further reductions in loading from these sites. In the future however, fish farms and water cress farms should be implementing all reasonable measures to maximise their efficiency.

Table 3.1.4a MODELLED FISH FARM AND WATER CRESS MEASURE DELIVERY AS A PERCENTAGE OF 50% AMBITION TARGET

					Phosphorus reduction (P kg/yr) compared to 50% ambition target			Percentage of ambition targets achieved by each scenario		
Catchment Results	Water Body	Ambition Target (ug/l)	Target Reduction P kg/yr	Fish Farm & Water Cress Load P kg/yr	25% P reduction P kg/yr	50% P reduction kg/yr	75% P reduction kg/yr	25% P reduction	50% P reduction	75% P reduction
Upavon East	GB108043022410	-20	277	1029	257	515	772	93%	186%	278%
Upavon West	GB108043022370	-40	366	0	0	0	0	0%	0%	0%
Upper Avon	GB108043022352	-20	1003	1101	275	550	826	27%	55%	82%
Wylye	GB108043022510	-10	372	578	145	289	434	39%	78%	117%
Nadder (excluding Wylye)	GB108043015880	-10	710	1091	273	545	818	38%	77%	115%
Bourne*1	GB108043022390	-10	95	0	0	0	0	0%	0%	0%
Ebble	GB108043015830	0	0	666						
Lower Avon	GB108043015840	-20	4656	6492	1623	3246	4869	35%	70%	105%

Table 3.1.4b MODELLED FISH FARM AND WATER CRESS MEASURE DELIVERY AS A PERCENTAGE OF FULL AMBITION TARGET

					Phosphorus reduction (P kg/yr) compared to 50% ambition target			Percentage of ambition targets achieved		
Catchment Results	Water Body	Ambition Target (ug/l)	Target Reduction P kg/yr	Fish Farm & Water Cress Load P kg/yr	25% P reduction kg/yr	50% P reduction kg/yr	75% P reduction kg/yr	25% P reduction	50% P reduction	75% P reduction
Upavon East	GB108043022410	-20	555	1029	257	515	772	46%	93%	139%
Upavon West	GB108043022370	-40	733	0	0	0	0	0%	0%	0%
Upper Avon	GB108043022352	-20	2007	1101	275	550	826	14%	27%	41%
Wylye	GB108043022510	-10	744	578	145	289	434	19%	39%	58%
Nadder (excluding Wylye)	GB108043015880	-10	1421	1091	273	545	818	19%	38%	58%
Bourne*1	GB108043022390	-10	191	0	0	0	0	0%	0%	0%
Ebble	GB108043015830	0	0	666						
Lower Avon	GB108043015840	-20	9312	6492	1623	3246	4869	17%	35%	52%

Table 3.1.4c FISH FARM AND WATER CRESS MEASURE DELIVERY AS A PERCENTAGE OF FULL AMBITION TARGET

					Phosphorus reduction (P kg/yr) compared to 50% ambition target			Percentage of ambition targets achieved		
Catchment Results	**Water Body**	**Ambition Target Reduction (ug/l)**	**Target reduction P kg/yr**	Fish Farm & Water Cress Load P kg/yr	25% P reduction kg/yr	50% P reduction kg/yr	75% P reduction kg/yr	25% P reduction	50% P reduction	75% P reduction
Nadder Upper	GB108043016200	-20	417	140	35	70	105	8%	17%	25%
Nadder Middle	GB108043022470	-20	1270	539	135	269	404	11%	21%	32%
Wylye Headwaters	GB108043022520	-30	630	519	130	259	389	21%	41%	62%
Wylye Middle	GB108043022550	-10	588	575	144	288	431	24%	49%	73%
Till	GB108043022570	0	0	0	0	0	0	0	0	0

3.1.3 Other measures to tackle loading from point sources

As outlined in Table 3.0:1, other options to reduce point source loading & improve water quality could be considered and have not been included in this report. The focus of the NMP is to highlight and assess the benefit of key measures that may deliver the greatest water quality improvements at minimal cost. Where appropriate, further option appraisal should be undertaken outside the NMP.

Some additional options not considered in this report include:

- First time sewage networks where large number of septic tanks may be causing localised water quality problems.
- Tertiary treatment of discharge waters prior to discharge such as wetland/reed bed treatment.
- Reduce ingress of groundwater and input of surface rainwater in urban areas especially into STW sewer system. This will reduce discharge volume from STW, leaving more headroom within permit limits. It may also improve the efficiency of P removal processes at STW.
- Move STW discharge point downstream. Bigger flow in river hence increased dilution and less effect in raising P concentrations. Significant costs are likely to be associated with this option & may exacerbate low flow issues.
- Move discharge point to another catchment. This will remove the P input entirely (except for overflow). Involves pumping costs but that may be less than additional costs of P stripping to a higher standard than that required on the other catchment e.g. Warminster to Westbury?
- Connect STW to another STW further downstream for P stripping. Potential benefits economically for treatment and reducing point source loading upstream. This measure may however have a detrimental impact on flows, particularly where much of the water abstracted and used is derived from boreholes in the headwater catchments.

3.2 Diffuse Source Options

Phosphorus in the Avon is primarily derived from diffuse sources c56-78% but with significant modelled background loads (natural; 9-43%) (Figure 2.5:1). The greatest source of diffuse phosphorus is from Manure, Fertilisers and soils (Olsen P) (Table 2.3.3:1a&b). A smaller but significant load comes from Particulate P (silt and sediment entering rivers).

In order to reduce diffuse pollution, land owners should focus on:

1. **Reducing the source of pollution** from fields, infrastructure and chemical handling areas
2. **Breaking of slowing the pathway** for pollution
3. **Protecting the receptor** or waterway from pollutants

The main pathways for transferring diffuse source of phosphorus to rivers are surface (Table 3.2:1).

Table 3.2:1 Transport Pathways Predicted by PIT (excluding small discharges to ground)

	Surface	Subsurface
Manure	16.7%	12.1%
Fertilizer	19.9%	15.2%
Non Agriculture	36.2%	0.0%
Total	72.7%	27.3%

Measures to control/reduce P should focus on each of these factors.

The main controls that can be put in place across agricultural land to reduce phosphorus leaching and losses, have been captured in ADAS Report "Measures from Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution **",** often known as the DPI manual**.** The most effective of these measures in reduce P are highlighted in Table 3.2:2.

Catchment Sensitive Farming Initiatives have been operating in the Avon for some 10 years and Wessex Water Catchment Initiatives for a similar amount of time. A summary of the key initiatives put in place in the Avon up to around 2013 are outlined in Appendix 3.2:1.

An initial assessment of the effectiveness of Catchment Sensitive Farming and potential effectiveness of current and future measures nationally were highlighted in DEFRA, Catchment Change Matrix 2011 "Linking farm-scale improvements from ECSFDI to catchment water quality"[16]. This document highlights some of the main source and solutions to mitigating phosphorus loads.

A further assessment of Catchment Sensitive Farming effectiveness has been published in an Evaluation Report Phase 1-3 (2006-2014)[37]. As part of this, further modelling of the effectiveness of current and optimum and maximum CSF measures have been made for all River Basin Management Planning Cycle 2 catchments in the Hampshire Avon.

The model estimated CSF reductions were based on the combined impact of all measures in three scenarios applied to the relevant farms in the catchment. Reductions per measure were based on the typical reduction quoted in the DPI manual. Measure implementation rates, are derived from the continuous CSF audit process and will be available in the CSF Evaluation Report 2006-2014[37].

The Agency CCM (Catchment Change Matrix) database was used to identify the most effective OP/dissolved P measures for the Avon catchment. The order of these measures (in effectiveness) was prioritised within the modelling tool and multiple measures applied to the same farm source achieve a noticeable decrease in effectiveness (as the manageable loss per source is finite and less than the total loss from that source).

The Model effectiveness was modelled in accordance with Equation 1.

Me=Tfl*DPI*(1-Mp)*Cm*Ai*Nam ....Equation 1

Where

Me = Measure effectiveness

Tfl = Total farm loss addressed by measure

DPI	=	DPI manual reduction
Mp	=	Prior Mitigation
Cm	=	Coverage of mitigation*
Ai	=	likely implementation
Nam	=	number of antecedent measures

Consequently, this means that the measures the model addresses first will be attributed with a much greater benefit than all subsequent ones. The model is designed to predict catchment scale reductions and highlight the 'type' of measure that works best. The success of an individual measure is however based on many factors, each of which is uncertain. The model calculates the potential effectiveness of different measures at a catchment/sub catchment scale but will need agronomist interpretation and appropriate application.

The three scenarios modelled by the Environment Agency & their definitions are detailed below:

CSF current = combined modelled impact of all measures recommended by CSF to date, including a factor representing the likelihood of the measures success. This is therefore the estimated load reduction that will eventually be observed in the catchment following the advice given and considering likely %age uptake of measures.

CSF Optimum = what we estimate a maximum benefit could be from a voluntary scheme such as CSF. This includes the same factor limiting the likely implementation of measures via CSF and the maximum number of measures per farm (10 – approximately average number of recommendations per farm via CSF to date). As a rule of thumb, 50% of Optimum may readily be achieved by current CSF activities, but achieving reductions above this on average may require additional resources or very focused CSF approach with experienced officers focusing on the most effective measure at each farm for each contaminant.

Maximum = the total impact if all 86 measures in the DPI manual are applied to all farms and 95% measures are assumed to be implemented

The baseline diffuse loads used in the national assessment were from SIMCAT and SAGIS SIMCAT models. As detailed above these are considered to under-represent overall diffuse agricultural loads entering the Avon. Flow apportioned, source apportionment diffuse loads are also considered to under-estimate total loads. Results from the PIT model, present the most realistic estimates of total diffuse losses entering the Avon catchment, over high medium and low flows and have been multiplied against %age reductions for each scenarios to calculate reductions in load and so concentration that could be achieved. The PIT source apportionment undertaken in this report is based on Agricultural Census 2010 data.

The modelled phosphorus reduction that may be achieved by the above scenarios, based on SIMCAT and PIT are presented in Table 3.2:3 & 3.2:4 respectively. SIMCAT results represent the likely minimum achievable under each scenario.

Table 3.2:2 Diffuse Source Measures to Reduce Phosphorus Loading in the Hampshire Avon (Based on ADAS Report "Measures from Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution")

Measure	Maximum P Reduction For Given Land Use	Break Transport Pathway	Reduce P Input
1A: Convert arable land to unfertilised grass	50%		Y
1B: Arable reversion to low fertiliser input extensive grazing	50%		Y
2: Establish permanent woodlands	50%		Y
3: Grow biomass crops (willow, poplar, miscanthus)	50%		Y
4: Establish cover crops in the autumn	20-80%		Y
5: Early harvesting and establishment of crops in the autumn	20-50%		Y
6: Cultivate land for crops in spring rather than autumn	90%	Y	Y
7: Adopt reduced cultivation systems	90%	Y	
8: Cultivate compacted tillage soils	10-50%	Y	
9: cultivate and drill across the slope	40-80%	Y	
11: Manage over winter tram lines	20-50%	Y	
13: Establish in-field grass buffer strips	20-80%	Y	
14: Establish riparian buffer strips	20-80%	Y	
15: Loosen compacted soil layers in grassland fields	10-50%	Y	
32: Do not apply P fertiliser in high P index soils	50%		Y
35: reduce the length of the grazing day/grazing season	10%		Y
41: Reduce overall stocking rates on livestock farms	30%		Y
52: Increase the capacity of farm manure (slurry) stores to improve timing of slurry applications	20%	Y	Y
69: Do not spread slurry or poultry manure at high-risk times	50%	Y	Y
82: Establish new hedges	20%	Y	Y
81: Establish and maintain artificial wetlands	20-80%		Y
74: Transporting Manure to Neighbouring Farm	Not specified		Y
84: Irrigate crops to achieve maximum yield	20		Y

Table 3.2:3 Cumulative Diffuse Load Reduction Achieved By Application of EA CSF Measures Scenarios: Based on SIMCAT Source Apportionment

						Total CSF Reductions Achievable From EA National Modelling Including Based on PITT Source Apportionment including All Upstream Catchments			FARMSCOPER Reductions (Zhang etal 2012)	FARM-SCOPER EA Up scaling	Phosphorus Reductions (kg/yr)			FARMSCOPER Reductions all available
Water Body	Catchment Results	Total Cumulative Agri Diffuse load P kg/yr	Ambition Target Reduction (ug/l)	Target reduction kg/yr	Target reduction %age of total diffuse	Diffuse load % reduction - current CSF	Diffuse load % reduction - optimum CSF	Diffuse load % reduction - maximum	All Available Options General Cropping : (From Table 6)	Current improvements from baseline *1%age	Diffuse Load Reduction Current CSF P kg/yr	Diffuse Load Reduction Optimum CSF P kg/yr	Diffuse Load Reduction Maximum CSF P kg/yr	FARMSCOPER Reductions "all measures" P kg/yr
GB108043022410	Upavon East	3237	-20	555	17%	15.89%	26.48%	65.33%	57.30%	8.15	514	857	2115	1855
GB108043022370	Upavon West	2823	-40	733	26%	6.62%	21.29%	58.12%	57.30%	8.59	187	601	1641	1618
GB108043022352	Upper Avon	6555	-20	2007	31%	8.39%	25.15%	61.62%	57.30%	8.49	550	1649	4039	3756
GB108043022510	Wylye	2135	-10	744	35%	3.89%	24.03%	61.28%	57.30%	9.05	83	513	1308	1223
GB108043015880	Nadder	8499	-10	1421	17%	7.82%	24.77%	60.45%	57.30%	8.61	665	2105	5138	4870
GB108043022390	Bourne	311	-10	191	61%	14.99%	25.65%	60.11%	57.30%	7.69	47	80	187	178
GB108043015830	Ebble	1632	0	0	0%	5.90%	26.37%	65.69%	57.30%	8.46	96	430	1072	935
GB108043015840	Lower Avon	15070	-20	9312	62%	6.71%	25.69%	62.08%	57.30%	9.06	1011	3872	9356	8635

Table 3.2:4a Cumulative Diffuse Load Reduction Achieve By Application of EA CSF Measures Scenarios: Based on PIT Source Apportionment

	Source Apportionment: PIT					Total CSF Reductions Achievable From EA National Modelling Including Based on PITT Source Apportionment including All Upstream Catchments			FARMSC OPER Reductions (Zhang etal 2012)	FARMSC OPER EA Current	Phosphorus Reductions (kg/yr)			FARMSC OPER Reductions all available
Water Body	Catchment Results	Total Cumulative Agri Diffuse (P kg/yr)	Ambition Target Reduction (ug/l)	Target reduction kg/yr	Target reduction, %age of total diffuse	Diffuse load % reduction - current CSF	Diffuse load % reduction - optimum CSF	Diffuse load % reduction - maximum	All Available Options General Cropping : (From Table 6)	Current improvements from baseline *1	Diffuse Load Reduction Current CSF kg/yr	Diffuse Load Reduction Optimum CSF kg/yr	Diffuse Load Reduction Maximum CSF kg/yr	FARMSC OPER All measures kg/yr
GB108043022410	Upavon East	2360	-20	555	24%	15.89%	26.48%	65.33%	57.30%	8.15	375	625	1542	1352
GB108043022370	Upavon West	2820	-40	733	26%	6.62%	21.29%	58.12%	57.30%	8.59	187	600	1639	1616
GB108043022352	Upper Avon	11195	-20	2007	18%	8.39%	25.15%	61.62%	57.30%	8.49	939	2816	6898	6415
GB108043022510	Wylye	13369	-10	744	6%	3.89%	24.03%	61.28%	57.30%	9.05	520	3213	8192	7660
GB108043015880	Nadder	20669	-10	1421	7%	7.82%	24.77%	60.45%	57.30%	8.61	1616	5120	12494	11844
GB108043022390	Bourne	3929	-10	191	5%	14.99%	25.65%	60.11%	57.30%	7.69	589	1008	2362	2251
GB108043015830	Ebble	3256	0	0	0%	5.90%	26.37%	65.69%	57.30%	8.46	192	859	2139	1866
GB108043015840	Lower Avon*2	46862	-20	9312	20%	6.71%	25.69%	62.08%	57.30%	9.06	3144	12039	29092	26852

*1 *Based on average arable P reduction of 6% and grassland of 12% (average from Table5; Zhang etal)* ***2**: *Note total for Lower Avon represent the cumulative totals for the whole catchment.*

Table 3.2:4b Cumulative Diffuse Phosphorus Load Reduction Achieve By Application of EA CSF Measures Scenarios: Based on PIT Source Apportionment For Avon Sub catchments

Source Apportionment For Sub Other Sub-catchments

Water Body	Catchment Results	Total Cumulative Agri Diffuse (Manure, Fertilizer, Olsen, particulate & Direct) (kg/yr)	Ambition Target Reduction (ug/l)	Target reduction kg/yr	Target reduction, %age of total diffuse	Diffuse load % reduction - current CSF	Diffuse load % reduction - optimum CSF	Diffuse load % reduction - maximum	All Available Options General Cropping: (From Table 6)	Diffuse Load Reduction Current CSF P kg/yr	Diffuse Load Reduction Optimum CSF P kg/yr	Diffuse Load Reduction Maximum CSF P kg/yr	All Measures (Max) P kg/yr
GB108043016200	Nadder Upper	4893	-20	417	9%	13.41%	24.93%	57.92%	57.30%	656	1220	2834	2804
GB108043022470	Nadder Middle	6088	-20	1270	21%	12.07%	25.45%	59.51%	57.30%	735	1549	3623	3489
GB108043022520	Wylye Headwaters	2364	-30	630	27%	8.10%	22.18%	60.19%	57.30%	191	524	1423	1354
GB108043022550	Wylye Middle	7947	-10	588	7%	5.20%	24.58%	62.72%	57.30%	413	1953	4984	4554
GB108043022570	Till	4043	0	0	0	1.01%	22.54%	58.26%	57.30%	41	911	2356	2317

Table 3.2:5 Sources of Phosphorus Losses from EA National Modelling Across the Hampshire Avon (SAGIS_SIMCAT)

Method	Land Use	Form	P Loss (kg/yr)	Proportion of Total P
Soil	Arable	Particulate	7,299	29%
Void	Yards	Dissolved	3,954	16%
Soil	Grass	Particulate	2,534	10%
Fertiliser	Grass	Dissolved	2,427	10%
FYM	Field_Storage	Dissolved	1,868	7%
Void	Grass	Dissolved	1,379	5%
FYM	Grass	Dissolved	981	4%
Slurry	Grass	Dissolved	914	4%
Void	Tracks	Dissolved	891	4%
Fertiliser	Arable	Dissolved	730	3%
Void	Fords	Dissolved	671	3%
Soil	Arable	Dissolved	498	2%
Soil	Grass	Dissolved	399	2%
FYM	Arable	Dissolved	342	1%
Soil	Rough	Particulate	178	1%
Void	Rough	Dissolved	99	0%
Soil	Rough	Dissolved	81	0%
Slurry	Arable	Dissolved	34	0%
Litter	Grass	Dissolved	24	0%
Litter	Arable	Dissolved	12	0%
Dirty Water	Grass	Dissolved	9	0%
All	All	Total P	25,326	100%
		Total dissolved	15,315	60%

Definitions

Soil	Material generated within the soil profile, e.g. decomposition of organic material, weathering of minerals.
Fertiliser	Manufactured fertiliser applied to land on the farm
FYM	Farm yard manure; solid manure (mixture of straw and excreta) which can be stored in heaps before being applied to arable and grass land
Slurry	Liquid or semi-liquid livestock manure, stored in tanks or lagoons and applied to arable and grassland
Litter	Manure from poultry housing, consisting primarily of excreta and bedding material (e.g. sawdust). Can be stored in heaps before application to arable and grass land
Voided	Excretion by livestock in a specific location (as opposed to total excretion which includes material destined to become manure)
Dirty Water	Water derived from washing of equipment and floors in milking parlours, rainfall run-off from concrete area or hard-standings used by livestock and contaminated with faeces, urine, waste animal feed, etc... Contains organic matter and so poses a risk of water pollution but has negligible fertiliser value

The measures that achieve the greatest OP and TP reductions under EA National Maximum Scenario are detailed in Figures 3.2:1 & 3.2:2.

These results show that the measure that might achieve the greatest TP reduction is the adoption of reduced cultivation system and transporting manure to neighbouring farm (and so reduce the amount of imported nutrient load to the catchment and effectively utilising existing sources of nutrient in the catchment to meet crop nutrient requirements efficiently). The measures that achieve the greatest OP reduction are again transporting manure to neighbouring farm (or farms where additional nutrient is required to meet crop requirements) and fencing off rivers and streams from livestock (note the total TP and OP reductions modelled by these scenarios is c25 tonnes TP yr and c15 tonnes OP/yr respectively).

Figure 3.2:1a Total Phosphorus Reduction (kg/yr) Achieved By Top 20 "Maximum" Measures (which make up 65% of loading reductions) & Number of Times Each Measure is Recommended by EA National Modelling (from 26522437): note, both kg/yr and number of recommendations

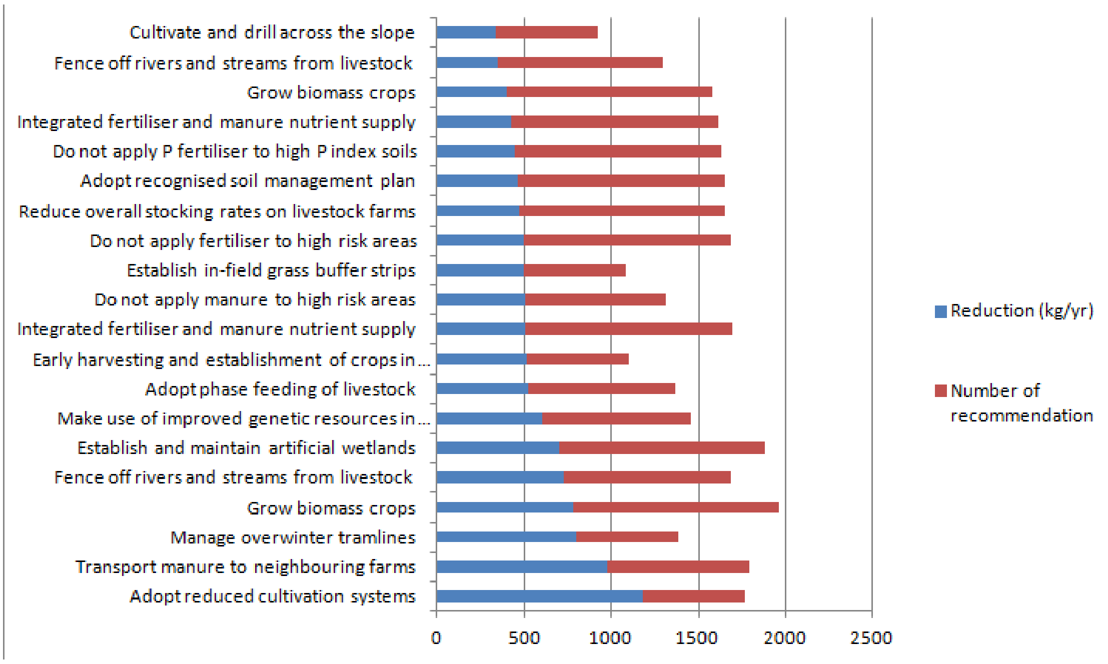


Figure 3.2:1b Orthophosphorus Reduction Achieved By Top 20 Maximum Measures (and which make up 84% of total load reductions) & Number of Recommendations by EA National Modelling (from 26522437)

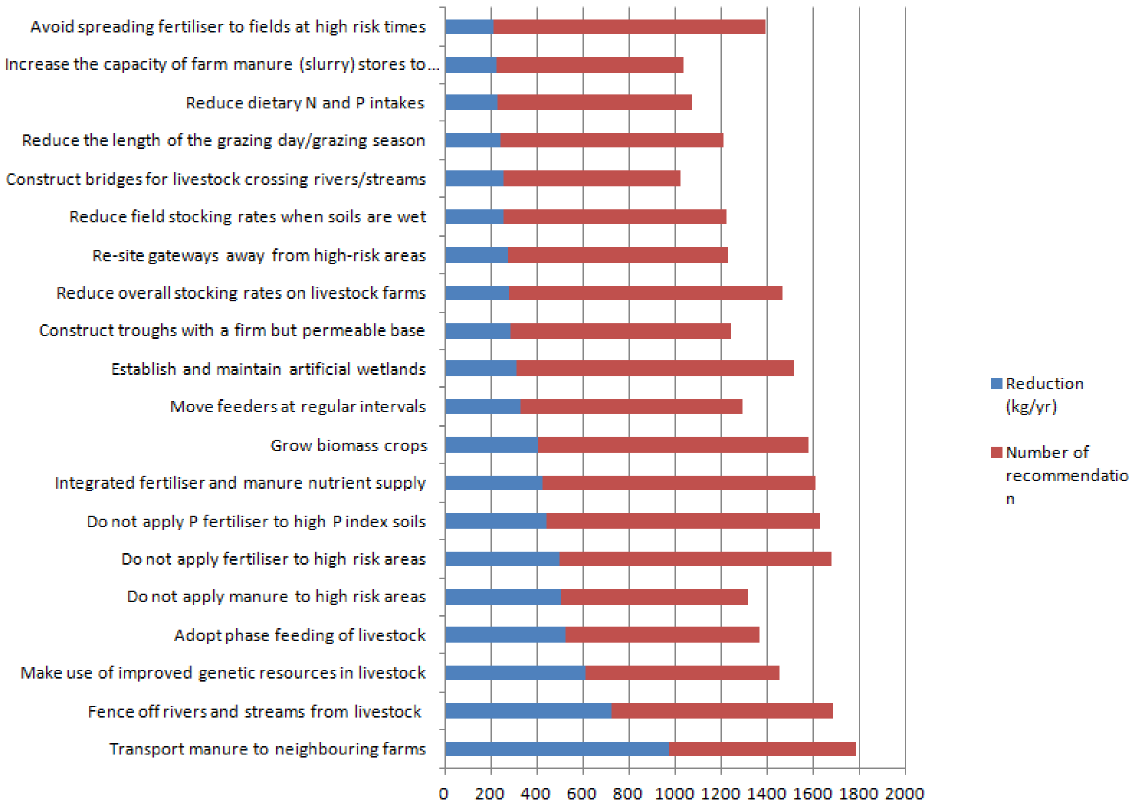


Figure 3.2:1c Total Phosphorus Reduction Achieved By Current Measures That Achieve 95% of Loading Reduction & Number of Recommendations by EA National Modelling (from 26522437)

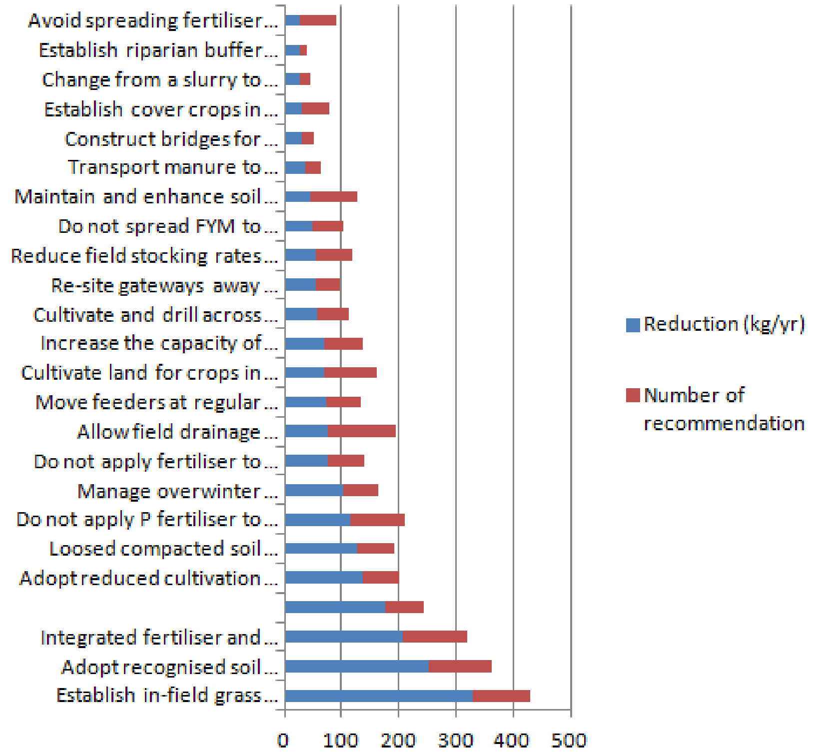
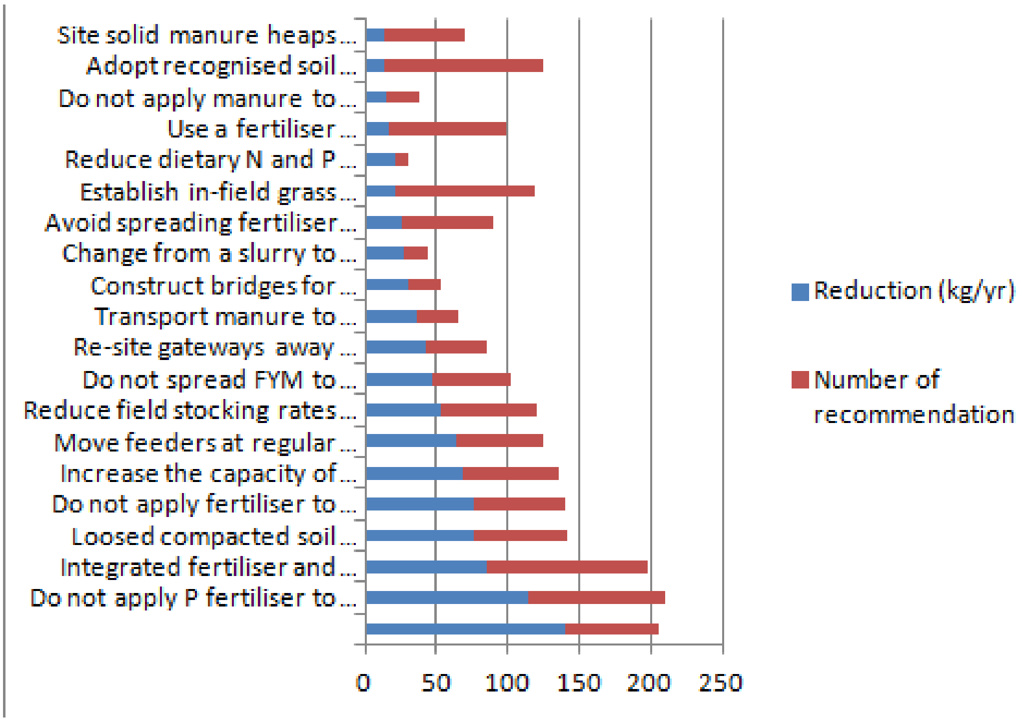


Figure 3.2:1d Ortho Phosphorus Reduction Achieved By Top 20 Current Measures & Number of Times Each Measure is Recommended by EA National Modelling & that make up 95% of the load reduction (from 26522437)



A further assessment of the possible reductions in phosphorus loading to the Avon was made, using figures presented by ADAS[35] report applying FARM Scale Optimisation of Pollutant Emission Reductions (FARMSCOPER) model, (Zhang Etal 2012[35]). Three scenarios have been modelled from this report to assess P loading as detailed below:

FARMSCOPER Baseline: No mitigation: Estimated baseline scenarios pollutant loadings (kg/ha/yr) for the Robust Farm Types across the Hampshire Avon (from Table 3 of Zhang etal[35])

FARMSCOPER: Current implementation of measures: The modelled impacts of the existing implementation of mitigation measures across the Hampshire Avon DTC (% reduction in the emissions of specific pollutants relative to the baseline scenario predictions for the DEFRA Robust Farm Types (from Table 5 of paper[35])

FARMSCOPER Maximum Reduction Scenario: The modelled reductions (%) in emissions of specific pollutants with all available mitigation methods implemented, relative to the corresponding "current emissions scenario" predictions shown in Taking average effectiveness of measures nationally (from Table 6 of Zhang etal[35])

Summary phosphorus loading from this report are detailed in Table 3.2:6. The percentage reduction from baseline that could be achieved by current measures is outlined in Table 3.2.7. The percentage P reduction that can be achieved by FARMSCOPER Maximum Reduction Scenario, is around

57.3% (general cropping). The reduction in diffuse P (kg/yr) entering the Avon when applied against PIT diffuse load are highlighted in Table 3.2:3 & 4. The P loading reduction achieved through current CSF measures are highlighted in Table 3.2:7.

Table 3.2:6: Baseline Phosphorus Loading Predicted by Zhang etal 2012 (Table 7)

	Average P Load Based on FARMSCOPER scenarios	Total Load
Baseline	0.21kg/ha	
Current emissions	0.19kg/ha	
Maximum reductions	0.1kg/ha	

Table 3.2:7 FARMSCOPER Reduction in P loading Based on Current Measures

Robust Farm Type	Phosphorus Reduction %	Generic Land use (from Table 1b)	Average
Cereals	6	Arable	6
General Cropping	6	Arable	
Horticulture	6.5	Arable	
Dairy	11.6	Grassland	
Lowland grazing	10.4	Grassland	12
Mixed	14.8	Grassland	

Table 3.2.8 P Reduction Potentially Achieved By Current Measures Applying FARMSCOPER P Reduction to PIT Loads

Water Body	Catchment Results	Proportioned P Reduction Based on Land Use	Current P Reduction FARMSCOPER applied to PIT Source Apportionment kg/yr
GB108043022410	Upavon East	8.15	192
GB108043022370	Upavon West	8.59	242
GB108043022352	Upper Avon	8.49	950
GB108043022510	Wylye	9.05	1210
GB108043015880	Nadder	8.61	1779
GB108043022390	Bourne	7.69	302
GB108043015830	Ebble	8.46	275
GB108043015840	Lower Avon	9.06	4247

Table 3.2:9 FARMSCOPER Maximum %age reduction in emissions with all available mitigation methods implemented relative to baseline (Zhang etal 2012)[35]

Robust Farm Type	Phosphorus Reduction %
Cereals	57
General Cropping	57.3
Horticulture	49.7
Dairy	61
Lowland grazing	58.3
Mixed	61.4

From the above tables, it can be seen that whilst some measures, such as the cultivating land for crops in spring rather than autumn(ADAS measure 6), can achieve a significant reduction in phosphorus leaching, when you consider the area of land over which any measure can be applied and the likely uptake, the overall effectiveness is often greatly reduced.

EA National Modelling and Farmscoper modelling indicate that c60% reduction in P loading from “current measures” can be achieved by applying all available measures. This represents the likely maximum load reduction that might be achieved however.

Reducing Phosphorus Sources

To maximise P reduction a mixture of measures are required to reduce the source of P and transport mechanisms.

Fundamental to reducing the source of phosphorus is ensuring that only the amount of nutrient that is required is actually applied and that it is applied at the right time, so it is available to the crop and P availability is reduced at high risk times, in autumn and winter with the onset of recharge and when soils may be saturated and run-off processes take place more frequently.

Preliminary results from baseline surveys from the Avon Demonstration Catchment indicate that many farmers are already applying some of these measures,

http://www.avondtc.org.uk/Literature.aspx

From the investigations into the natural source of P, preliminary soil testing results indicate that phosphorus concentrations and P Index may remain high, even in low input environments, due to presence of natural phosphatic minerals within certain Upper Greensand horizons. One of the key measures necessary across these areas is soil testing and the need to follow fertilizer recommendation systems (as updated by the P index results).

Other measures cited in CASCADE Frome Waste Water Nutrient Investigations for Wessex Water and originally from Dampney (2002) were:

1. Reduce stocking rates to reduce organic manure loadings per unit area.
2. Restrict livestock access to watercourses.
3. Reduce P inputs through animal feedstuffs where possible.
4. Reduce fertiliser and manure P inputs where possible.
5. Placement of P fertiliser in the soil has the potential to reduce inputs because of more efficient use and less vulnerability to surface run-off.

Reducing Phosphorus Transport Mechanisms

The key measures identified by Dampney (2002) related to Pathway Management as follows:

Pathway management
1. Incorporate manures into the soil soon after application.
2. Restrict manure application rates and timings to safe time windows, also avoiding periods of high rainfall when soils are excessively wet.
3. Introduce cropping that accommodates ploughing in the cycle.
4. In-field and riparian buffer strips (but also need complementary in-field control practices to control runoff).
5. Barrier ditch and reed-beds for trapping silt.
6. Adopt methods to minimise soil erosion.
7. Avoid liquid manure application on drained, cracking clay soils, especially grassland.

From PIT modelling, the pathway mobilising the greatest percentage of P are **surface pathways** (run-off) for Manure, Fertilizer and Non Agricultural Sources (Table 3.2:1).

Measures focusing on breaking this transport mechanism are essential and would include:

- improving soil permeability (and so infiltration rates)
- maintaining soil structure
- maximising ground cover to reduce the risk of capping of soils
- contour ploughing etc

Many of these measures and their effectiveness are listed in DEFRA DPI Manual.

Measures that could be implemented and for which grants may be available under CSF can be found in Natural England web site

http://publications.naturalengland.org.uk/publication/314101?category=45002

Other measure and case studies to reduce the mobilisation of sediment can be found on DEFRA website:

http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0H94GRCLYSC2A8H

LAND REVERSION

A more radical approach to achieving the ambition targets would be reversion of high P input land use activities such as arable and managed grassland, to lower/zero input land uses such as rough grazing and woodland.

Based on PIT & FARMSCOPER calculations, the average combined P loss from arable and managed grassland and required land area conversion to achieve the ambition targets are outlined in Table 3.2.10. This shows that an area of c23000 ha would need to be reverted from high to low input land use to achieve the ambition targets under PIT and Farmscoper source apportionment. This represents 21% of the current total arable and managed grassland area across the Avon.

Under Countryside Stewardship, farmers are expected to put 5% of their land area into an environmental scheme. If 5% of the total high input land was reverted to low input (c5590 ha) it would result in phosphorus loading reduction of around 2236 kg/yr assuming an average leaching/loss of 0.4 P kg/ha. This is 24% of a -20ug/l ambition reduction in the lower Avon and would be equal to a 48% of a -10ug/l reduction.

Implementation of Countryside Stewardship could result in a 2236 P kg/yr reduction if all farmers used this scheme to convert high input land use to a low input.

Table 3.2:10 Land Reversion Area Required To Achieve Ambition Targets Based on Converting High Input Land uses (Arable, Managed Grassland) to LOW input (rough grazing & woodland) based on PIT and SIMCAT source apportionment

Water Body	Catchment Results	Ambition Target reduction P kg/yr	Area of arable (ha)	Area of grassland (ha)	Total cumulative upstream arable and managed grassland area (ha)	Total Cumulative Agri Diffuse (Manure, Fertilizer, Olsen, particulate & Direct)	Diffuse Loss kg/P/ha for Upstream Catchment	FARMSCOPER Baseline (Mixed system)	Reversion Area to Achieve Ambition Targets (ha) (PIT)	Reversion Area to Achieve Ambition Targets (ha) (FARMSCOPER)
GB108043022410	Upavon East	554.8	3981	2228	6210	2360	0.38	0.4	1460	1387
GB108043022370	Upavon West	732.92	3772	2868	6641	2820	0.42	0.4	1726	1832
GB108043022352	Upper Avon	2006.77	9612	6796	12850	11195	0.38	0.4	5245	5017
GB108043022510	Wylye	743.87	16283	16855	33138	13369	0.40	0.4	1844	1860
GB108043015880	Nadder	1420.945	8000	6148	47287	20669	0.44	0.4	3251	3552
GB108043022390	Bourne	190.53	8254	3229	11483	3929	0.34	0.4	557	476
GB108043015830	Ebble	0	4852	3371	8224	3256	0.40	0.4	0	0
GB108043015840	Lower Avon	9311.88	7620	7948	111820	46862	0.42	0.4	22220	23280

3.3 Combined Point & Diffuse Measures

In some catchments where diffuse measures alone are not sufficient to achieve the ambition target reductions, a combination of diffuse and point source measures may be adopted/required. Table 3.3:1a & b below outline the benefits that can be achieved by a combination of these measures.

Table 3.3:1a Phosphorus Reduction (kg/yr) Achieved By Combined Diffuse and Point Source Reductions

Catchment Results	Water Body	Ambition Target (ug/l)	Target Reduction (kg/yr)	Current CSF +25% reduction in FF & WC	Optimum CSF + 25% reduction in FF & WC	Optimum CSF + FF&WC 25% reductions + WW STW @500ug/l (2011)	Optimum CSF + FF&WC 25% reductions + WW STW @500ug/l (2025)	Optimum CSF + FF&WC 25% reductions + WW STW @500ug/l (2030)
Upavon East	GB108043022410	-20	555	632	882	1006	983	977
Upavon West	GB108043022370	-40	733	187	600	681	669	660
Upper Avon	GB108043022352	-20	2007	1215	3091	3058	2833	2723
Wylye	GB108043022510	-10	744	665	3357	3525	3362	3283
Nadder (excluding Wylye)	GB108043015880	-10	1421	1889	5392	5543	5334	5214
Bourne*1	GB108043022390	-10	191	589	1008	1915	1893	1882
Ebble	GB108043015830	0	0	192	859	859	859	859
Lower Avon	GB108043015840	-20	9312	4767	13662	15239	13810	13255

Table 3.3:1b Phosphorus Reduction (kg/yr) Achieved By Combined Diffuse and Point Source Reductions from Sub-catchment

Catchment Results	Water Body	Ambition Target Reduction (ug/l)	Target reduction kg/yr	Current CSF +25% reduction in FF & WC	Optimum CSF + 25% reduction in FF & WC	Optimum CSF + FF&WC 25% reductions + WW STW @500ug/l (2011)	Optimum CSF + FF&WC 25% reductions + WW STW @500ug/l (2025)	Optimum CSF + FF&WC 25% reductions + WW STW @500ug/l (2030)
Nadder Upper	GB108043016200	-20	417	691	1255	1267	1265	1264
Nadder Middle	GB108043022470	-20	1270	870	1684	1667	1621	1694
Wylye Headwaters	GB108043022520	-30	630	321	654	527	771	664
Wylye Middle	GB108043022550	-10	588	557	2097	1976	2199	2106
Till Tributary	GB108043022570	0	0	41	911	791	896	921

The most effective point source options will be those that influence the greatest source loading of P along that reach. In Upavon East this would be CSF and potentially Fish Farm loads (where further nutrient management efficiencies are possible). Reasonable P reductions may also be achieved by tightening permit conditions in Wylye.

3.4 Mitigation for Future Urban Development

Future growth is likely to result in permit headroom being exceeded at a number of STW across the Avon (Table 2.4.1:2). This may result in the sites permitted loading (as summarise under the Review of Consents[11]), being exceeded. The main option to mitigate such impacts would be improved treatment so the STW has no greater impact on receiving waters than historic (or a net improvement) or some alternative mitigation method.

At the remaining sites, anticipated growth to 2035 can take place within current permit headroom without the proportionate loading being exceeded.

Alternative methods to reduce the impact of urban development could include:

- the installation of sediment traps in rural and urban areas,
- use of porous pavement to reduce run-off and flood risk
- land conversion and or reaching long term management agreements with farmers to change their land use practices from high to low input.

3.5 Mechanisms for Delivery

Measures that result in improved discharge quality to surface waters (such as improvements at Sewage Treatment Works) will result in a rapid improvement in water quality when implemented in the Avon and some marked improvements in water quality where the discharge volume and load are small compared to the receiving waters (as demonstrated by PR14 improvements at All Cannings and East Knoyle. Nevertheless, due to the relatively small overall contribution to the Avon coming from point sources (c13% for STW), there is more limited scope to deliver phosphorus reductions in this way. To achieve the strategy objective, significant savings must come from reducing agricultural sources (Figure 2.5:1).

Diffuse measures to reduce the transport of phosphorus along surface pathways, (such as by reducing run-off and erosion), will also be achieved rapidly. Measures designed to reduce phosphorus following groundwater pathways, will in contrast take much longer before the benefits of the measure are fully realised. Of these, measures applied on land with a shallow water table (such as in major river valleys), will result in more rapid improvement in surface water quality.

- Phosphorus reduction measures across the Avon catchment will need to be applied indefinitely to ensure the benefits of the measure are realised.
- This should be achieved by all farmers ensuring their phosphorus leaching along surface and subsurface pathways are minimised.
- Measures should be applied on a prioritised basis to achieve the most rapid water quality improvements (in river valleys floors, on tertiary geology and in lower permeability catchments), at the earliest opportunity.

In principle diffuse measures can be achieved on a voluntary approach, through regulation or a combination of the two.

3.5.1: Voluntary Approach to tackling diffuse agricultural pollution.

The greatest phosphorus load affecting the Avon is generated by agricultural activity across the catchment (c60%). Use of organic and inorganic fertilisers containing phosphorus by farmers has not historically been controlled under any legislation. Farmers are however required to operate within a Code of Good Agricultural Practice (CoGAP), the Nitrate Regulations (NR) and other relevant legislation.

Compliance with these baseline requirements is expected to ensure a minimum level of environmental performance. In broad terms, phosphorus pollution nationally has fallen over the last decade, though it is not clear to what extent this reflects regulatory compliance or the general reduction in use of phosphorus fertiliser that has occurred since the peak use of the early 1990's. It is clear that a basic level of regulatory compliance will not be sufficient to bring good status back to the whole of the Avon.

Farmers and land managers across the Avon can tap into a wide range of resources and organisations that provide advice on farm measures to reduce diffuse pollution and these include:

- advice programmes led by Government (England Catchment Sensitive Farming Delivery Initiative ECSFDI) (http://www.naturalengland.org.uk/ourwork/farming/csf/)
- the farming industry (http://www.nutrientmanagement.org)
- Non Government Organisations such as FWAG South West
- Water Company initiatives such as those run by Wessex Water.

In addition to addressing pollution concerns, a common theme emphasised by advice programmes is the benefit to the farm business that can come from conserving soils and minimising nutrient loss from the farm to the wider environment.

Capital grants are also available to farmers to support infrastructure improvements that reduce pollution. For example these have been available through ECSFDI, the Environmental Stewardship Scheme, and through some Water Company catchment initiatives. These schemes from 2015 have been replaced by Countryside Stewardship.

Annual Payments are also available to farmers and land managers through the New Environmental Stewardship Scheme for implementing measures (such as buffer strips or less intensive field management) that reduce diffuse pollution. Farmers must enter an agreement lasting 5-10 years to be eligible. These payments help to offset losses in agricultural productivity and any increased cost from implementing measures. For some options the payment rates will positively incentivise land management change.

Stewardship schemes from 2015 are to be replaced by Countryside Stewardship. Approximately 75% of the national budget for Countryside Stewardship will be assigned to deliver bio-diversity improvements (of which 25% must be aligned with improvements in water, quantity and quality) and 20% of the national budget directly aligned to water. Current Countryside Stewardship prioritisation mapping gives the Hampshire Avon the highest priority scoring for water quality because of the many overlapping drivers within the catchment. It is likely therefore that individual and groups of farmers will from 2015/16 be able to apply for Middle or Upper Tier Grants and Support to assist in implementing measures and capital works to improve water quality across the catchment. Results from this prioritisation exercise are likely to be published early in 2015.

The uptake of advice, capital grants and land management agreements by farmers and land managers is entirely voluntary. Consequently, a reliance on these measures to effectively tackle diffuse pollution from agriculture is often criticised because uptake can be variable, poorly targeted and the overall outcome uncertain. It is anticipated however that in the future a list of measures, all farmers will be expected to implement to prevent diffuse pollution will be published.

Experience of applying a voluntary catchment approach is building both in the UK and abroad. It remains difficult to predict with any certainty the degree to which pollution can be reduced on a voluntary basis although a feel for the scale of savings that could be made is beginning to emerge.

As assessment of the effectiveness of Catchment Sensitive Farming in delivering diffuse pollution reduction have been published in a number of reports looking at the historic uptake and effectiveness of measures [37]. These result indicated that historic CSF advice may have resulted in average in river P reduction of 7% with a maximum of around 25%. More recent Environment Agency modelling indicate that the current baseline vary from around a 3-5% reduction in the Wylye to13-16% in the Upper Nadder and Upper Avon East respectively. Overall larger reduction in TP has been achieved than OP because of the relative success of reducing sediment transport to rivers[37].

Implementation of Optimal measures may result in P reductions of 21-26% and maximum measures 58-65% (Table 3.2.4a & b).

It is increasingly recognised that successfully reducing diffuse pollution will require action by farms and land managers that goes beyond minimum regulatory requirements. To achieve this on a voluntary basis, experience indicates that success is most likely where certain key elements are in place:

- Good evidence linking agricultural activity to water quality concerns
- High degree of 1:1 support and advice for farms
- Approach is built on partnership, trust and openness
- Clear financial benefits to the farm business
- The right level of incentive is available.
- New methods of technology are accessible and trusted

A difficulty with securing reductions in farm nutrient losses through a voluntary approach is the durability of the improvements delivered if there is nothing to prevent improvements being abandoned at some future date. Measures delivered through agri-environment are only secure for the lifetime of that agreement which in the future through Countryside Stewardship is typically for 5 years. Furthermore there are changes to the 'base requirements' for the major part of the agricultural support budget and this can significantly influence farming practice and land use, much more so by area than agri-environment agreements. This is particularly problematic from the point of view of delivering development offsetting and ensuring Habitats Regulation and WFD compliance of new development where savings must be secured for the long term.

However, these issues may not be insurmountable. South West Water's 'Upstream Thinking' Project has sought to reduce agricultural pollution through the provision of advice and targeted investment in farm businesses. To protect that investment, farms involved are required to commit through a contractual agreement to continue to deliver the pollution reduction measures over a 25 yr period. A similar approach could be explored for the Avon catchment, with the aim however of achieving permanent offsetting.

3.5.2: Regulatory Approach to tackling diffuse agricultural pollution:

Phosphorus can now be considered as a "non hazardous pollutant". Where the Environment Agency have concerns and sufficient evidence that its use by farming activities is causing pollution, may be able to "control" or "prevent" its use, on a site by site basis using Environment Permitting Regulations (2010).

Indirectly the delivery of nitrate reduction measures within Safeguard Zones (SGZ) may also help to reduce phosphorus loading to groundwater, through the implementation on improved nutrient management measures, which typically would have a knock on benefit to P.

Water Protection Zones (WPZ's) are a regulatory tool which can be used by the Environment Agency to help meet WFD obligations, where additional legal powers are required to achieve these objectives. They require polluters to start or stop or limit certain activities, depending on the nature of the problem to tackle:

- point-source water pollution (from a single origin);
- diffuse water pollution (from dispersed sources which are collectively significant); or
- Physical damage to rivers.

A WPZ might cover a whole catchment or tackle more localized problems in England and Wales. Breaching the requirements of a WPZ would be an offence.

WPZs remain an additional tool that we can use as a last resort, where the Environment Agency existing powers are not sufficient to deliver the improvements required under the WFD. Where the Environment Agency has evidence to justify the use of a WPZ, the Environment Agency would approach DEFRA with a business case to demonstrate that additional measures are needed. If DEFRA ministers supported the introduction of a WPZ, we would draft a WPZ Order for public consultation and parliamentary approval.

3.4.3: Regulatory Approach to tackling point source pollution:

When considering point sources of pollution, Sewage Treatment Works and other discharges are permitted under the Environmental Permitting Regulations (EPR) 2010. Conditions are applied to these permits to reduce the risk of them having an adverse effect on the water environment. These permits can be reviewed, where they are thought to have a detrimental environmental impact or are considered to impact on the WFD classification of the water body.

Under the WFD, in addition to member states aiming to achieve good ecological status, good ecological potential or good chemicals status, the WFD requires member states to "implement the necessary measures to prevent deterioration of the status of all water bodies …" Article 4.1. At least equivalent requirements apply under the Habitats Directives for Special Areas of Conservation. Surface Water deterioration from one status to another is also not permitted under WFD.

Therefore, where there is sufficient scientific evidence to indicate a STW or other permitted discharges are adversely affecting the status of a European site, the permit can be reviewed and where necessary (and subject to appeal) conditions tightened. Changes in any such permit may have the effect of removing headroom from the permit, therefore preventing further connections to the STW without STW improvements. Typically, any required asset improvement to achieve new discharge quality would be submitted as part of the Periodic Review process for Water Company five year business plans.

Under the Urban Waste Water Treatment Directive (UWWTD), discharges from larger sewage treatment works into a Sensitive Areas, such as the Avon catchment, must meet the Directive's standards for the removal of nutrients. The size of the STW in the catchment will continue to be reviewed to identify when such thresholds are reached.

4.0 COST BENEFIT ASSESSMENT OF OPTIONS

The focus of the technical document is to identify the feasibility of achieving the Hampshire Avon Favourable Conservation Status through the proportionate reduction in diffuse pollution. Further action on point sources may be undertaken at a future point where diffuse measures are not “realistically available” or do not deliver sufficient reduction to achieve these targets. The cost benefits of these options are considered in Section 4.1 and 4.2.

4.1 Point Source Options

The P load reductions that could be delivered through tightening STW permit conditions from 1mg/l to 0.5 and 0.2mg/l (compared to current operational conditions) are outlined in Table 3.1.1. Table 4.1:1 outlines the absolute changes in load that would be achieved if the STW currently operated at their maximum permit conditions and were reduced to 0.5mg/l and 0.2mg/l scenarios using average flow data 2009 to 2013.

Trials under AMP6 are proposed to identify the feasibility of achieving a 0.1mg/l discharge quality and the costs and benefits. Results from this should be available by 2018 and will assist in a future review of the NMP.

A range of costs for making capital improvements to a site to achieve specific water quality objectives have been estimated by Wessex Water using a cost curve approach (Table 4.1:1). WW have greater confidence in the capital cost estimates for providing facilities to operate at 0.5mg/l discharge quality, as a number of their STW would already meet this condition. They have less confidence in the CAPITAL costs of improving STW to meet a 0.2 mg/l consent.

Wessex Water are currently unable to provide an indication of Operational Costs for running their STW at a 0.5 or 0.2mg/l consent, and therefore it is not possible at this stage to provide a full 50 year cost for these scenarios. The Capital costs alone as £/kg are however presented and convert to a cost £/kg in Table 4.1:2. This shows the average capital costs to be £68/kg P reported for 0.5mg/l P permit condition and £73 to £87 for a 0.2 mg/l P condition. This assumes an asset life of 40 years. Full costs will be greater than this.

The costs of alternative treatment using reed bed tertiary treatment were assessed by CASCAD for Wessex Water in the Frome Catchment[38]. This work identified costs for reducing discharge quality to 10mg/l consents and 2mg/l consents as £74/kg P at Maiden Newton to £164/kg P with a benefit cost ratio of 7:1 and 5:1 respectively. As STW across the Avon already operating beyond these lower levels, it is likely that costs would increase greatly for treating such discharges further. The Review of best practice in treatment and reuse/recycling of phosphate at wastewater treatment works[40], indicates that the cost of treatment can double when moving from 1 to 0.1mg/l permit condition. This would result in equivalent costs of £148-£328/kg P treated if Maiden Newton costs were adjusted to operate at 0.1mg/l P.

Table 4.1:1 Phosphorus Load Removal tonnes/P/yr & Capital Cost for Delivering STW Facilities to meeting 0.5 and 0.2mg/l Consent based on updated STW flow 2009-13, operating at maximum permit condition. Note costs represent additional CAPEX costs for tightening permit conditions at Wessex Water STW (£) and No OPEX costs are included. An Asset life of 40years can be assumed.

Site Name	Average flow 2009 / 13 m3/d	Existing P mg/L	P = 0.5mg/L t P removed per year	P = 0.2mg/L t P removed per year
Salisbury STW	22,310	1	4.07	6.51
Warminster STW	4,698	1	0.86	1.37
Ringwood STW	4,882	1	0.89	1.43
All Cannings STW	526	5	0.86	0.92
Hurdcott STW	2,995	1	0.55	0.87
Collingbourne Ducis STW	477	5	0.78	0.84
Pewsey STW	2,052	1	0.37	0.60
Fordingbridge STW	2,697	1	0.49	0.79
Downton STW	1,905	1	0.35	0.56
East Knoyle STW	174	5	0.29	0.30
Amesbury STW	1,405	1	0.26	0.41
Shrewton STW	1,253	1	0.23	0.37
Ratfyn STW	2,855	1	0.52	0.83
Great Wishford STW	1,135	1	0.21	0.33
Fovant STW	419	1	0.08	0.12
Marden STW	218	2	0.12	0.14
Upavon STW	465	1	0.08	0.14
Netheravon STW	492	1	0.09	0.14
Tisbury STW	1,138	1	0.21	0.33
Barford St Martin STW	119	2	0.06	0.08

Hampshire Avon - Phosphorus removal estimated costs

	Estimated Cost £m		
Site Name	P = 0.5mg/L	P 0.2mg/L range	
Salisbury STW	5.7	7.7	9.2
Warminster STW	2.9	3.9	4.7
Ringwood STW	2.9	3.9	4.6
All Cannings STW	1.8	2.4	2.8
Hurdcott STW	0.4	1.6	1.9
Collingbourne Ducis STW	1.6	2.2	2.6
Pewsey STW	0.4	2.5	3.0
Fordingbridge STW	2.2	2.9	3.5
Downton STW	1.4	1.9	2.3
East Knoyle STW	2.6	3.5	4.2
Amesbury STW	2.2	2.9	3.5
Shrewton STW	0.4	1.0	1.2
Ratfyn STW	0.4	3.1	3.7
Great Wishford STW	1.7	2.3	2.7
Fovant STW	0.4	0.8	0.9
Marden STW	1.1	1.5	1.8
Upavon STW	1.2	1.7	2.0
Netheravon STW	0.8	1.1	1.3
Tisbury STW	0.2	1.9	2.2
Barford St Martin STW	0.8	1.1	1.3

Table 4.1:2 CAPITAL Cost Estimate £/kg P removed Based on Table 4.1.1. Note No OPEX costs included

	P Removed Tonnes/yr (from 1mg/l permit)		CAPITAL Costs £M/40 year Asset Life			CAPITAL Costs £ kg P removed for 40 year asset life		
	P removed t/yr 0.5mg permit	P removed t/yr 0.2mg permit	0.5 permit	0.2mg l P	0.2mg/ l P	0.5 permit	0.2mgl P (average)	0.2mg/l P (high cost)
SALISBURY STW FE	4.07	6.51	5.7	7.7	9.2	35	30	35
WARMINSTER STW	0.86	1.37	2.9	3.9	4.7	84	71	86
RINGWOOD STW	0.89	1.43	2.9	3.9	4.6	81	68	80
CANNINGS STW	0.86	0.92	1.8	2.4	2.8	52	65	76
HURDCOTT	0.55	0.87	0.4	1.6	1.9	18	46	55
COLLINGBOURNE DUCIS STW	0.78	0.84	1.6	2.2	2.6	51	65	77
PEWSEY STW	0.37	0.6	0.4	2.5	3	27	104	125
FORDINGBRIDGE STW	0.49	0.79	2.2	2.9	3.5	112	92	111
DOWNTON	0.35	0.56	1.4	1.9	2.3	100	85	103
EAST KNOYLE STW	0.29	0.3	2.6	3.5	4.2	224	292	350
AMESBURY STW	0.26	0.41	2.2	2.9	3.5	212	177	213
SHREWTON	0.23	0.37	0.4	1	1.2	43	68	81
RATFYN STW	0.52	0.83	0.4	3.1	3.7	19	93	111
GREAT WISHFORD	0.21	0.33	1.7	2.3	2.7	202	174	205
FOVANT STW	0.08	0.12	0.4	0.8	0.9	125	167	188
MARDEN	0.12	0.14	1.1	1.5	1.8	229	268	321
UPAVON	0.08	0.14	1.2	1.7	2	375	304	357
NETHERAVON STW	0.09	0.14	0.8	1.1	1.3	222	196	232
TISBURY	0.21	0.33	0.2	1.9	2.2	24	144	167
BARFORD ST MARTIN	0.06	0.08	0.8	1.1	1.3	333	344	406
TOTAL	**11.37**	**17.08**	**31.1**	**49.9**	**59.4**	**68**	**73**	**87**

4.2 Diffuse Source Options

Less certainty can be ascribed to the amount of phosphorus that will be removed through the implementation of diffuse pollution measures compared to point source. Tables in Section 3.2 provide an initial estimation, based on a number of different approaches and models. A range of diffuse pollution reduction and costs are therefore reported in this section.

Zhang etal, using FARMSCOPER calculated the cost and benefit in terms of phosphorus reduction of implementing different combination of measures. Table 4.2:1 is taken from this paper and provides an estimate of the reduction in different pollutants that can be achieved at different cost to a farmer.

Table 4.2:1 Effect of the Minimum Cost Solutions That Achieve Minimum Target Pollution Reductions, For Mixed Farms (from Zhang etc (2012)

Table 8 – Effect of the minimum cost solutions that achieve minimum target pollutant reductions, for the mixed farm.

Target reduction (%)	Cost (£)	Reduction achieved (%)						Number of methods
		NO_3-N	P	SS	NH_3	CH_4	N_2O	
5	−15,712	8	7	13	6	3	14	9
10	−14,667	10	20	13	12	3	16	15
15	−13,054	16	24	20	16	3	15	18
20	−7407	20	31	26	21	4	16	29
25	−253	21	54	31	28	4	16	37
30	−85	21	44	39	33	4	17	38
35	1183	21	58	56	35	4	17	38
40	9388	21	47	51	36	4	17	43
45	10,034	21	51	58	36	4	17	44
50	10,433	21	62	61	36	4	17	46
55	10,708	21	59	57	36	4	17	42
60	12,509	21	60	61	36	4	17	46

These results show that potential phosphorus reductions of up to 54% could be achieved with a zero cost to a farm by applying a combination of 37 different measures. More typically however, reductions of 30-40% P loading might be achieved at zero cost[35]. A reduction of up to 60% might be achieved with a cost of £12,509 to a farmer (Table 4.2:1).

In influencing these changes in land use practice & implementation of measures, there is likely to be an operational cost to the government through the provision of agricultural advice. The objective would be for the adviser to work with the farmer to optimise the most effective measures that would be effective under a particular farming system. The cost of providing this advice is not discussed in the FARMSCOPER paper, but have been estimated in the NMP based on delivery costs under CSF, Wessex Water Catchment Initiatives, EA Economic Appraisal undertaken for RBMP2 and EA diffuse pollution bid submitted in 2014. These are further discussed below.

<u>Environment Agency Economic Appraisal: Cost of Agricultural Measures</u>

The Environment Agency CAM tool, allow the user to estimate the cost and effectiveness of measures that are commonly found in any waterbody / catchment that is failing from agricultural diffuse pollution. The tool was designed to undertake a high level Cost Benefit Analysis for the second cycle of River Basin Management Plan.

The CAM spreadsheet is based on the DEFRA Mitigation manual, with other information obtained from Agri-environment schemes, Catchment Sensitive Farming, pesticide evidence and expert judgement. Costs are based on a cost per farm holding applied to different farm types.

For the Avon, the number of farm holdings >20ha were calculated and percentage of the farms with livestock. Costs were then estimated as an annual cost per farm type. Table 4.2:2 gives an indication of the annual costs of all the measures that can be applied through “regulation, advice and incentives” for each farm type. The costs are cumulative depending on whether farms have livestock. The figure is given in "Thousands of Pounds".

From this analysis it is estimated that there are 629 farms that are >20ha across the Avon catchment and if advice was given to each farm to a cost of £3127/farm the annual cost would be c£1.9 Million/yr. An adjusted 50 year cost using a conversion factor of 24.495 would be £48M for 50yr cost.

This level of farm engagement may not be necessary to deliver the reductions in diffuse pollution required and typically farm visits should be prioritised according to risk. If 25% of farms were visited each year, these costs would reduce to £12M 50yr cost. Alternative adjustments to farm visit frequency could be made to try and maintain good delivery of measures but minimise costs. Further refinements of these costs were made as part of a submission to DEFRA for additional funding to deliver WFD objectives as outlined below.

Table 4.2:2: Cost of Achieving One level of WFD Status Change across the Hampshire Avon Operational Catchment

EA AREA	No. of Farms	% livestock	All farms without livestock supplement (£)	All farms with additional livestock supplement (£)	Total annual catchment OPEX cost (£K)	C% land surface in safeguard zones	Agri fair share	Agri diffuse fair share OPEX cost adjusted (£k)	cost per farm per year (£)	fair share cost per farm per year (£)
Hampshire Avon	629	10	1,966,770	1,969,495	1,969	5	0.50	976	3,127	1,551

Updated Diffuse Pollution Costs

A bid for additional funding to pay for farm advice and grants to achieve water quality improvements and deliver GOOD status under the WFD was submitted to DEFRA in 2014. The assumptions made to refine these costs are outlined below:

Advice Scheme Assumptions:

1. Each year farm advisers shall initiate visits 10% of farmers in the catchment and after 3 years 30% of farms will have some form of advice each year.
2. 3 days of advice shall be provided in the first year and then one day for the next two years (including preparation and reporting time) to identify key measures that shall be put in place to reduce diffuse phosphorus losses and to follow up on farm advice given in previous years.
3. Farm visits shall be prioritised in catchment areas that are most vulnerable to phosphorus losses and activities that present the highest risk.
4. 0.5FTE Project Manager and 0.5FTE Project Admin
5. After 5 years 75% of farms that present the highest risk will have engaged in phosphorus loss planning.

Grant Scheme Assumptions

1. Yr 1 grant £1459
2. Yr 2 grant £730
3. Yr3 grant £365
4. These grants could be made available alongside agricultural advice and have been
5. 2.5% inflation uplift in costs each year

Outline costs from this are outlined in Table 4.2:3a

Table 4.2:3a Estimated Cost of Farm Advice £/yr

Summary Diffuse Pollution Costs	**Advice £/yr**	**Time/days**	Project Management	Project Admin	Total Annual Cost*[1]
2015-16	75480	189	19658	12845	**107984**
2016-17	100659	252	20150	13167	**133975**
2017-18	125838	315	20653	13496	**159987**
2018-19	125857	315	21170	13833	**160860**
2019-20	125876	315	21699	14179	**161754**
2020-21	125894	315	22241	14533	**162669**
Total	**679603**	**1698**			**887228**

*[1] *including 2.5% inflation uplift/yr*

Table 4.2:3b Estimated Cost of Grants to Assist in Phosphorus Reductions

Summary Diffuse Pollution Costs	**No Farms**	**Total Cost*[1] £**
2015-16	63	**91801**

2016-17	126	**141144**
2017-18	189	**168785**
2018-19	189	**173005**
2019-20	189	**177330**
2020-21	189	**181763**
Total		**£933829**

***[1]** *including 2.5% inflation uplift/yr*

After 3 years, both schemes would be fully operational with 30% of the farms across the Avon being visited annually, with 10% receiving 3 days advice and 20%, 1 days advice as a follow up on a rolling/prioritised program. They would also receive/be able to apply for grants between £365-1459/yr to assist in delivery of measures.

Table 4.2.3c Total Annual and 50yr Costs of Providing Advice and Grants to 30% of farms Each Year (from full engagement in yr 3, 2017-18)

Activity	**Annual Cost**	**50yr Cost £**
Advice	£160,000	£3,919,000
Grants	£168,800	£4,134,756
Total	**£328,800**	**£8,054,000**

Based on the FARMSCOPER and the Environment Agency assumptions regarding advice and grant costs, advice could be given to a rolling program of 30% of farmers each year, along with grants at an annual cost of around half a million pounds. A 50year cost of c£8M would be incurred. Reductions in phosphorus of up to 52%, (but more likely 30-40%) might be achieved with a zero cost to farmers.

Based on the PIT source apportionment for the Avon, deliver of phosphorus reduction at or above the Optimum level (as indicated by FARMSCOPER) would achieve the ambition target reductions for all except Upavon West (Table 3.2:4a). Here P load reductions of slightly greater than the optimum (but less than FARMSCOPER estimated maximum) would deliver these.

If it were assumed that over the long term, this levels of support and advice would achieve the ambition targets, the cost in terms of £/kg/P removed can be estimated by dividing the P reduction achieved through optimal advice. Results for this are presented in Table 4.2:4.

Wessex Water Catchment Initiatives:

Wessex Water provide in their Safeguard Zones, a reasonably intense farm engagement/advisory service to farmers. This is funded through the periodic review process and the purpose is to prevent them having to install water treatment at specified abstraction sources. This is likely to represent a more “Optimum” service to farmers.

The cost of operating this service in the Poole Harbour Catchment was identified by Wessex Water and a cost benefit carried out in the Poole NMP[39]. These figures have been used in the Avon NMP and further scaled up from 800km^2 to 1700 km^2.

Advice	360,000	£/yr for 800km
Poole area	800	Km^2
Avon	1700	Km^2
Avon advice	765000	£/yr

Under PR14, Wessex Water has applied for further funding to deliver diffuse pollution reductions within their SGS.

The cost and benefits in P reduction applying Wessex Water diffuse reduction approach is also presented in Table 4.2:4.

Land Reversion: High Input to Low Input.

The “Catchment Sensitive Farming

The Catchment Sensitive Farming Initiative currently covers around 30% of the Avon catchment and provides advice to c300 farmers with engagement each year with c100 farms, through farm visits or events. To achieve this, resources of around 1.5 Full times Equivalent (FTE) are required to deliver current outcomes and assuming 10% regional Catchment Adviser salary.

From recent CLAD (Customer and Land Database) holdings polygons covering Catchment Sensitive Farming Priority Catchments and Partnerships and Target Areas data, there are 772 farm holdings across the Avon catchment of which c629 farms are greater than 20ha in size. If the current CSF coverage was scaled up to the whole catchment, it is estimated that around 3.9-4.5FTE of advice would be required.

The estimated staff costs of providing OPTIMUM CSF, are c£180,000 year. This includes 4.5FTE staff costs and an allowance of 0.2 FTE of a Regional Catchment Advisers, Table 4.2.4.

Table 4.2.4: Cost Benefit of Diffuse Advice Using P reduction predicted by EA CSF Modelling and FARMSCOPER Models. P load reductions based on PIT and SIMCAT source Apportionment and using EA, Wessex Water, CSF advice costs (assuming no cost to farmers for implementing measures)

	Diffuse Load Reduction Current CSF kg/P	Diffuse Load Reduction Optimum CSF kg/P	Diffuse Load Reduction Maximum CSF kg/P	FARMSCOPER Current	FARMSCOPER All measures
P Load Reduction (PIT) P kg/yr	3144	12039	29092	4247	26852
Estimated Diffuse Implementation Option Costs £/yr					
CSF costs for whole catchment*1	60000*1	180000*3	180000*3		
WW based costs (scaled up) *2	765000	765000	765000	765000	765000
EA Revised Bid Costs (advice & grants)	328000	328000	328000	328000	328000
EA RBMP2	1966500	1966500	1966500	1966500	1966500
Cost of P removal through advice & grants £/kg P removed					
CSF costs for whole catchment	19	15			
WW based costs (scaled up)	243	64	26	180	28
EA Revised Bid Costs (advice & grants)	104	27	11	77	12
EA RBMP2	625	163	68	463	73

**1; based on 2013-14 scaled up costs for the Avon, *2 Based on Poole Harbour estimated costs scaled up,*

	Diffuse Load Reduction Current CSF kg/P	Diffuse Load Reduction Optimum CSF kg/P	Diffuse Load Reduction Maximum CSF kg/P	FARMSCOPER All measures
P Load Reduction (SIMCAT)P kg/yr	1011	3872	9356	8635
Estimated Diffuse Implementation Option Costs £/yr				
CSF costs for whole catchment	60000*1	180000*3	180000*3	
WW based costs (scaled up)	765000	765000	765000	765000
EA Revised Bid Costs (advice & grants)	328000	328000	328000	328000
EA RBMP2	1966500	1966500	1966500	1966500
Advice costs £/kg P removed				
CSF costs for whole catchment	59	47	19	
WW based costs (scaled up)	757	198	82	89
EA Revised Bid Costs (advice & grants)	324	85	35	38
EA RBMP2	1945	508	210	228

Strategy for Managing Nitrogen in the Poole Harbour Catchment to 2035"[39], also undertook a full cost benefit analysis of a number of options to deliver nitrogen reduction across the catchment.

http://webarchive.nationalarchives.gov.uk/20140328084622/http://www.environment-agency.gov.uk/research/library/publications/148450.aspx

Two of the options considered were the purchase of high input agricultural land and its reversion to low input land. Figures from this work have been used to calculate the cost of converting 23,000 ha of high input land to low input land use (Table 4.2:5), as outlined in Section 3.2 may be required to achieve a -20ug/l ambition target.

Table 4.2:5 Land Reversion Costs (including land purchase)

Ha	Costs £/ ha		Costs (per ha/year)	Present Value costs over			PV Cost Effectiveness P £/kg		
	Land purchase*[1]	Establishment*[2]	Maintenance*[3]	50 years	100 years	200 years	50 years	100 years	200 years
23,000	16,496 Arable	2,500	11	£443,000,000	£301,000,000	£302,000,000	£47,573	£32,324	£32,431
23,000	16,496 Arable	660	50	£422,000,000	£236,000,000	£226,000,000	£45,318	£25,344	£24,270
23,000	13,701 Pasture	2,500	11	£379,000,000	£237,000,000	£237,000,000	£40,700	£25,451	£25,451
23,000	13,701 Pasture	660	50	£357,000,000	£226,000,000	£220,000,000	£38,338	£24,270	£23,625

*[1] *RICS Rural Land*2 Market Survey, H1 2011, arable land values £6,681 per acre & £5549 for pasture,* *[2] *Nix (2011), farmland woodland establishment >3ha (less than 3ha is £2,800/ha),* *[3] *Nix (2011)*

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Table 4.2:6 Annual Reduction in Gross Margin Assuming 50% Arable and 50% pasture is reverted to Woodland

		AVON		
Crop Type		**Low**	**Best Estimate**	**High**
Conversion from arable to woodland based on loss of gross margin for winter wheat				
Gross margin	a	£449	£673	£869
Gross margin lost due to reversion to woodland (£/ha)	b	£449	£673	£869
Area affected by change in gross margin (ha)	c	11,500	11,500	11,500
Reduction in gross margin under Option E	d=bxc	**£5,163,500**	**£7,739,500**	**£9,993,500**
Conversion from grassland to woodland based on loss of gross margin for intensive beef, sheep and dairy (weighted average based on no. each type and average stocking density)				
Gross margin	a	£879	£1,203	£1,509
Gross margin lost due to reversion to woodland (£/ha)	b	£879	£1,203	£1,509
Area affected by change in gross margin (ha)	c	11,500	11,500	11,500
Reduction in gross margin under Option	d=bxc	**£10,111,133**	**£13,834,977**	**£17,352,144**
Total Reduction in gross margin (arable and pasture)		**£15,274,633**	**£21,574,477**	**£27,345,644**

Assuming land area 43% dairy, 25% Beef, 32% Sheep (Agri Census 2010 & 2dairy animals/ha, 5.75 beef animals /ha, 10 sheep/ha)

4.3 Cost Benefit Discussion

There is greater confidence in the absolute phosphorus load reduction that would be achieved through the implementation of point sources improvements compared to diffuse measures. Wessex Water consider that tightening of permit conditions at most STW to 0.5ug/l is likely to be technically feasible, but the ability of delivering a maximum 0.2 mg/l P permit condition is less certain. The costs of delivering these improvements are also uncertain but awaiting trialling under AMP6.

The capital improvement costs alone across the Avon are estimated to be around £68-£87 £ P kg removed and for a full costing OPEX costs would need to be built in. Estimates from the Frome and Piddle Catchments for Maiden Newton STW indicates costs to deliver a 1mg/l permit condition might be between £74 and 164/kg P removed. These costs in the Avon are likely to be double[40] this to reduce existing permit conditions of 1mg/l down to around 0.1-0.2 and so for Maiden Newton could be estimated as £148 to £328 /kg/P reduction.

Diffuse Pollution reductions costs across the Avon for an Optimum modelled deliver (maximum P reduction likely given typical take up of measures; Table 4.2:4) are forecast to vary between £11-£163 kg P/yr. It is felt that the resource allocation under Wessex Water catchment initiative is most likely to deliver optimum P reduction. The estimated cost would be £64 kg/P reduction, comparable with the CAPITAL only costs for point source. When the full cost of delivering point source load reduction, diffuse measures are likely to be cheaper and would provide a much broader number of benefits to the catchment, such as reduced suspended sediment, reduced nitrogen leaching, with reduced CO_2 footprint (Annex 2, Poole Harbour Cost Benefit Assessment[39] and CASCADE[38]).

5.0 POTENTIAL ACTION PLAN

5.1 Point Source Measures

Substantial improvements in river water quality were achieved through the installation of phosphate removal at 17 of the largest water company Sewage Treatment Works (STW) in the Avon under AMP3 and 4 and one MOD discharge at Warminster Garrison. The impacts of the STW were subsequently assessed under the Habitats Regulations Review of Consents in 2010. The conclusion of this review was that phosphate removal undertaken under AMP3 and 4 had achieved an improvement at each STW proportionate to its contribution to unfavourable condition of the SAC.

For Warminster, its proportionate target for reduction had not been reached, but phosphate removal to the Best Available Technology (BAT) had been installed and following guidance from DEFRA Head of Water Quality to the Environment Agency Head of Water Quality (Chris Ryder to John Fraser; 27 August 2007) on “weight of evidence” the Review of Consents concluded that treatment beyond BAT would be considered if ecological evidence indicated this was required.

Based on these findings, where Wessex Water confirm that a development can be connected to one of their STWs within its permit headroom, then Environment Agency and Natural England shall not object to development within the catchment of the Hampshire Avon on the basis of its impact on phosphate concentrations within the river. It will be for the Council’s to determine planning approval.

Fish farms and Water Cress Farms are modelled to add c 6.5 tonnes/P/yr to the Avon and recent observation data indicate that this may be an over estimate and more likely loading of 4 tonnes P/yr is likely. It is clear however that these sources can have a significant local impact and these farms should implement all reasonable measures to maximise nutrient management efficiencies and reduce the release of phosphorus to downstream waters.

5.2 Diffuse Measures

To bring the Avon back into favourable status and to achieve ambition targets, it anticipated that an optimum level of P load reduction is required (Table 3.2.4). No indication of the level of effort (human resources) are available to identify how this might be achieved, but a range of costs of delivering diffuse pollution reduction have been presented in Section 4, based on different resource allocation models. Wessex Water would appear to provide the greatest staff costs per catchment with an estimated staff cost scaled to the whole Avon of c£500,000/yr based on the work they do across the Avon catchment. This compares with staff allocation resource if CSF were scaled up to the Avon of c£180 and Environment Agency cost estimates of £160K/yr assuming 30% of farms across the Avon are visited annually with between1-3 days of advice being given and £168K allocated for grants to these farmers.

The key however is not the resource allocation but the effectiveness in influencing farmers to implement measures to reduce soil erosion, SS mobilisation and Phosphorus leaching. Recommended approaches underpinning the effectiveness of CSF and ways that might enable optimisation or maximising delivery are summarised in “Catchment Sensitive Farming Evaluation Report (Phase 1 to 3 (2006-2014)37. These recommendations should be applied to the Avon catchment and all stakeholders should work together to maximise the efficiency of diffuse pollution measures across the catchment.

Wessex Are of the Environment Agency is due to produce a Diffuse Pollution Reduction Plan for Wessex in late 2014 early 2015. This document will identify how diffuse pollution reduction across Wessex will be prioritised and delivered. From risk mapping work already undertaken, the

Hampshire Avon catchment has already been identified as one of the highest priority areas where diffuse pollution reduction work needs to be prioritised. This document shall confirm this and identify how Wessex Water, CSF EA and other stakeholders shall work together to deliver common objectives. The document is likely to be similar to one recently drafted for the Poole Harbour catchment to deliver diffuse pollution reduction across this catchment.

5.3 Refining Water Quality Objective/Targets for the Hampshire Avon

The JNCC have proposed new conservation objective standards in designated rivers (Section 1.1) [36]. These standards do not however consider the ecology that would be native in phosphorus rich catchments where a significant proportion of the phosphorus loading to the river is naturally derived. Prior to the update of the NMP, Natural England and the Environment Agency, should try and secure the development of a new typology for UGS fed catchments, so future ecological and water quality targets can be identified. This should then be compared to the Ambition Targets outlined in the NMP to determine any further point source and diffuse pollution reduction that may be required in future years.

5.4 Monitoring & Review

Current WFD monitoring may not be sufficient to achieve these objectives and it is recommended the location, type and frequency of monitoring is reviewed to ensure the appropriate data is collected during the period of the NMP to enable the benefits of measures to be assessed and refined understanding of natural sources of P across the Avon gained. In undertaking this assessment, monitoring collected from research programs should be incorporated to maximise efficiency and prevent duplication. Natural England and the Environment Agency should agree who and how this will be delivered, where appropriate in consultation with other research institutes.

The type of monitoring that will be required will include:

- Changing Farming Practices: the uptake of measures by farmers and comparison with required uptake to achieve P load reduction and ambition targets.
- Land Use Change: Changing farming practices through Agricultural Census & CSF surveys.
- Water Quality: Surface and groundwater quality within key catchments and at strategic locations along the Avon and its tributaries to enable water quality along key reaches of the Avon to compare with land use/measure changes.
- Ecology: surveys should be undertaken to track the condition of designated species within the Avon and to be able to link this to water quality and other determining factors.

The recommendations of this plan should continue to be reviewed, as scientific knowledge improves. In particular some areas where a refinement in our understanding of natural processes would be of benefit would include:

1. Geographical and spatial understanding of natural phosphatic minerals in the Upper Greensand and its influence on river baseflow OP & TP concentrations. This will enable further refinement of water quality targets and ecological targets across the Avon.
2. Impact and link between nitrate and phosphate and SAC designated species
3. The impact of temperature change on eutrophication in the Avon & potential impact of climate change.
4. Refining list of measures for diffuse agricultural delivery.
5. Advances in phosphorus removal technologies for point source & cost benefit appraisal.

Suggested timescales for the implementation of this Phosphorus Management Plan is outlined in Table 5:1.

Table 5:1 Delivery Avon NMP

	2015/16		2016/17	2017/18	2018/19	2019/20
	Q1-2	Q3-4	Q1-4	Q1-4	Q1-4	Q1-4
1: Consult and Finalise NMP						
2: Agree Diffuse Pollution Reduction Plan						
3: Commence implementation of Diffuse Pollution Reduction Plan (See Table 5:2)						
4: Undertake Point Source Improvements Agreed Under PR14.						
5: Monitoring - develop plan (Catchment Initiative) - refine costs						
6: Funding Seek funding to assist in delivering nitrogen & Phosphorus reductions						
7: Install & undertake monitoring						
8: Deliver and Measure Implementation						
9: Reporting Annual reporting						
10. NMP update						

*[1] *Develop communication plan in consultation with NE, NFU, CLA, Experts in communication including Centre for Rural Policy Research*

Table 5.2: Diffuse Pollution Reduction Measures

	2015/16	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**
Farming High Risk Areas *1						
Understand the risk: Identify impact of your activities on N, P & SS losses (nutrient and soil management becomes daily decision making consideration)						
Plan to maximise efficiency: apply “apply all reasonable measures to reduce N, P and SS losses						
Implement best farming practice and land management measures						
Implement capital improvements						
All reasonable measures operational						
Review plans and measures and continue to deliver best farming practice						
Farming Intermediate Risk *1						
Understand the risk: Identify impact of your activities on N, P & SS losses (nutrient and soil management becomes daily decision making consideration)						
Plan to maximise efficiency: apply “apply all reasonable measures to reduce N, P and SS losses						
Implement best farming practice and land management measures						

Implement capital improvements						
All reasonable measures operational						
Farming Low Risk Areas *1						
Understand the risk: Identify impact of your activities on N, P & SS losses (nutrient and soil management becomes daily decision making consideration)						
Plan to maximise efficiency: apply “apply all reasonable measures to reduce N, P and SS losses						
Implement best farming practice and land management measures						
Implement capital improvements						
All reasonable measures operational						

***1 as defined by risk mapping undertaken as part of Wessex Diffuse Pollution Plan**

Table 5:2: Avon NMP Program

	2014/15	2019/20	2025/2026
1st Avon NMP			
2nd review			
3rd review			

5.2 Governance

The diffuse pollution reduction required to achieve the ambition targets is likely to be co-ordinated through Wessex Diffuse Pollution Reduction Project. This will bring all partners across Wessex, including Wessex Water, CSF, Environment Agency and other organisations, together to deliver diffuse pollution reduction work in a co-ordinated way. The key focus of this group shall be to:

- Prioritise diffuse pollution work across Wessex in a co-ordinated way.
- Agree
  - geographical areas each organisation shall operate and identify additional resources required (where available) to deliver catchment objectives.
  - common objectives & pollutants that advisers should focus on reducing across each catchment. Across the Avon this shall be nitrates within Safeguard Zones and Phosphorus across the wider catchment area.
  - Implementation & engagement plan for each year (farms that will be visited & outcomes sought).

Organisational Managers

⇩

Diffuse Pollution Steering Group (Wessex Wide: including Water Companies, Regulators, NFU, CLA and representatives, Local Authorities of nongovernmental organisations)

⇩

Catchment Based Partnership (Catchment Specific) & Task Groups

⇩

Delivery Group (Advisers from all organisations involved in this work)

The Wessex Diffuse Pollution Implementation plan shall be overseen by a Steering Board, comprising of the Environment Agency and Natural England, Local Authorities, Water Companies and landowner representative groups such as the National Farmers Union and Country Landowners Association.

Ultimately it will be the responsibility of each competent authority and individual within the catchment to follow guidance and best practice and achieve the outcomes required of them through legislation.

The Diffuse Pollution Steering Group shall meet biannually and receive guidance from a Catchment Based Partnership and Deliver Group.

6.0 CONCLUSIONS

The Hampshire Avon failed to achieve Good Ecological or Groundwater Chemical Status under the Water Framework Directive or Favourable Conservation Status under the Habitats Directive. This is in part due to failure of those elements indicative of eutrophication, such as phosphorus.

The main sources of phosphorus in order of significance are diffuse loads, baseline modelled background loads (largely natural), STW loads, Fish Farm and Water Cress and un-sewered discharges (Figure 2.5:1). However modelled Fish Farm and particularly Water Cress loads may be an over estimate.

Substantial reductions in stream ortho-phosphate concentrations across the Avon have been achieved through the installation of phosphate removal at 17 of the largest water company Sewage Treatment Works (STW) from the year 2000 and one MOD discharge at Warminster Garrison. Treatment on 7 STW that were thought to have the greatest impacts on water quality were undertaken under AMP3. Treatment on the remainder of sites was completed under AMP 4 (Table 2.3.2c)

In order for the Review of Consents to conclude no adverse effect and satisfy Regulation 64(3) of the Conservation of Habitats and Species Regulations 2010 for Warminster STW, it is necessary to implement a Nutrient Management Plan (NMP) which will identify, technically feasible "other action" to be taken to further reduce phosphate loading and secure the long term integrity of the SAC.

This document forms the technical annex to the NMP, produced by the Environment Agency and Natural England, in consultation with Wiltshire Unitary Authority and other stakeholders. The purpose of the technical document is to identify how sources of phosphorus can be reduced further, so, where technically feasible, the river meets its conservation objectives by 2027.

6.1 Background:

The Avon catchment is rural in nature (Table 1a & 1b), with approximately 65% of the catchment used for intensive agriculture (arable and managed grazing) and 22-30% in lower intensity agriculture such as grazing and woodland and c3-4% urban (Table 1a).
The Hampshire Avon is a large, predominantly groundwater fed river in Southern England. 86% of river flow is fed from the Chalk Aquifer and Upper Greensand aquifer in its headwaters.

Baseflow to the rivers follow two typical pathways, matrix flow and fracture flow. The first accounts for approximately 80% of the recharge in the chalk aquifer and the majority in sandstone catchments and moves through the rock matrix. Water following this pathway to the Avon is on average 55 years old by the time it enters the river (Figure 1.4) and infiltrates at a rate of approximately 1m/yr through the unsaturated zone (Figure 1.4). Fracture flow pathways in the chalk are initiated when the ground becomes saturated and recharge flows through any rock fractures. Recharge can reach the water table through these pathways within days or weeks. This pathway accounts for approximately 20% of recharge.

The flow pathway is important in influencing groundwater chemistry, as the slower the flow mechanisms, the more opportunity there will be for natural minerals within the rock to be dissolved into solution and for other chemicals within recharge water to undertake chemical changes as a result of oxidation and reduction processes (such as ammonia to nitrate) and the precipitation and adsorption of chemicals to the rock matrix. Water following the more rapid fracture pathways will have less time to pick up natural mineral content in the rock but are likely to be carrying more recent contaminants (Nitrate Phosphorus, Herbicides Pesticides etc) released from pollution sources. There will also be less time for these chemicals to be attenuated.

6.2 Chemical & Biological Status

Water Quality results from 2011-13 show compliance with WFD Good class in lower water bodies and also the Bourne. A few tributaries achieve High class (Dockens Water, Till and Nine Mile River). Non-compliance with Good status occurs on the whole of the Nadder in the SAC, the Middle and Headwater Wylye, and on the Avon upstream from the Nine Mile River. At some water bodies the scale of non-compliance is considerable, notably so on the Wylye and Hampshire Avon West. In these catchments there are however significant natural geological sources of phosphorus and anthropogenic sources that are likely to influence these results.

Only the lower Till fully complied with the more stringent SAC/SSSI standards. The Bourne came close to full compliance. The Dockens Water fully complied with the near-natural standard in the earlier 2009-11 period but the annual mean concentration increased in the 2011-13 period (15 µg/l to 29 µg/l) and the growing season mean increased even more (14 µg/l to 44 µg/l). Parts of the spine river Avon and Lower Wylye came close to compliance during the growing season (within 10 µg/l). This may be due to uptake of soluble phosphorus by the biology and lower input from the upstream catchment.

Biological results show that Macrophytes are failing to achieve WFD good status on both Eastern and Western arms of the Upper Hampshire Avon (very certain of less than good status), Wylye (very certain; Appendix A2:2:1) and Lower Hampshire Avon (uncertain).

Diatoms on the Ditchend, Dockens and Ripley Brook are currently achieving good status.

The Nine Mile River is achieving good status for Macrophytes.

6.3 Phosphorus Source Apportionment

In much of the upper reaches of the Avon (Upavon East and West and some tributaries of the Nadder and Wylye), 100% of the river baseflow is derived from the Upper Greensand Aquifer. This reduces in the Lower Avon at Knapp Mill to approximately 9% derived from the UGS, 76% from Chalk and 15% from run-off.

Work undertaken by the Environment Agency in 2012-13 has shown that there are significant natural sources of phosphorus entering the Avon, from minerals in the Upper Greensand Aquifer. Water quality analysis, borehole drilling coring and pore water analysis have demonstrated that modelled background groundwater phosphorus concentrations of c200ug/l from the UGS in the Wylye and Nadder catchments and c154ug/l from the UGS for the Avon and Upavon East and West can be supported by the evidence from surface and groundwater sampling. When the surface run-off component is considered (with an average quality of 25 g/l P), river water concentrations of between c115-181 ug/l P in UGS fed catchments and near natural concentrations of 10-13ug/l P in chalk fed catchments (Table 2.3.1:3a). Total modelled background loads entering the Avon in 2010-11 were estimated to be c13 tonnes P/yr and under average flow conditions could equate to 17 tonnes P/yr.

Total Phosphorus loads entering the Avon, measured from observed water quality and flow, have reduced significantly from >200 tonnes TP/yr in 2000 to c60-70 tonnes in 2012 (Figure 2.3:1) and averaging c60 tonnes/P/Yr for the period 2009-12. This reduction is largely the result of the installation of Phosphorus removal at the main STW across the Avon. These figures are thought however to be an under-representation of the true phosphorus loading entering the Avon, as they are based on daily flow data but only weekly to monthly water quality data. They are likely to miss peak phosphorus loadings going through the system at times of high flow and during and after heavy rainfall and do not account for P uptake by plants. The framework of surveillance and investigation monitoring across the Avon should therefore be reviewed to answer the outstanding scientific questions and improve our conceptual understanding of the processes impacting on water quality in the Avon. Future monitoring should incorporate that from research programmes, to improve knowledge on phosphorus concentrations and loads across the river system, to inform the targeting of measures on point and diffuse sources and to discern changes that arise with delivery of these measures

Different sources of P across the Avon and their potential sources were calculated using SIMCAT and PIT modelling. The PIT model is considered the most representative of the Avon and source apportionment results excluding natural outlined in Table 2.3:2b & 2.5:1. Phosphorus loads to the Avon from STW in 2011 are c11 tonnes P/yr or 10.5 tonnes P/yr with PR14 improvements installed at All Cannings and East Knoyle. Using Wessex Water Growth Forecast these are forecast to increase to 11.8 and 14.1 tonnes P/yr in 2025 and 2035 respectively.

Gross un-sewered loads are estimated to vary from 4.4 to 8.3 tonnes P/yr. The majority of these discharge to ground and following attenuation the load reaching surface and groundwater are likely to be <1 tonne/yr (Table 2.3:2f).

Phosphorus loads from Fish Farm and Water Cress farms are estimated from SIMCAT modelling (and assumed discharge quality) to be c6.5 tonnes P/yr. Recent monitoring data at a number of these sites would indicate that this is an over-estimate and average loads may closer to 4 tonnes P/yr. The apportionment of this diffuse source is outlined in Figures 2.3.3:1a-c.

The greatest source of phosphorus now entering the Avon is considered to be baseline natural sources c13 tonnes P/yr (Table 2.5:1) and diffuse sources c47 tonnes [Olsen p (from soil leaching), fertilisers, manure and then point sources] (Figure 2.3.3:1c)

6.4 Water Quality Targets

The JNCC new conservation objective standards in designated rivers (Section 1.1) [36] take no considerations of potential natural sources of phosphorus. It will therefore be necessary for work to be carried out during the period of the NMP to identify the ecology that would be expected in a phosphorus rich natural environment (in the upper reaches of the Avon) and to set appropriate water quality objectives to meet Favourable Conservation Status. This is likely to require the development of a new typology for Upper Greensand fed catchments.

Until these revised targets are developed in the short term (2021) the measures recommended by the NMP are intended to achieve the **ambition phosphorus reduction targets** outlined in Table 2.3.1.5. These may not reflect the full improvement in water quality that may be required but will work towards the targets that are likely to be necessary to achieve Favourable Conservation Status. It is intended these ambition targets will primarily be achieved through actions on diffuse sources and where necessary further point source measures. Any point source improvements to water company assets would be implemented under AMP7 (2020-25).

6.5 Future Pressures on the Catchment

Future population growth will result in increased phosphorus loading to the Avon and some STW reaching their permit headroom (Table 2.4.1:2). Wessex Water estimate that loads may increase from c11 tonnes P/yr in 2011 (when modelled to include proposed PR_14 improvements), to c14 tonnes/P/yr in 2035.

Climate change may also result in increased temperatures within rivers, which could result in species more tolerant to higher temperatures, out competing less tolerant species. This may result in more pressure on designated species. Rising temperatures may also put pressure on fish populations such as for Salmon. Research indicates that rising river temperatures may result in Salmon not even entering the river at all.

Changes in rainfall may also impact on the catchment. Greater rainfall totals and or intensity may result in increased run-off and erosion (transporting more soil and particulate P to rivers).This will therefore increase particulate and dissolved P loadings. Lower rainfall totals would result in lower baseflow concentrations in the river and a reduced amount of water available for dilution of point source inputs/loads.

6.6 Solutions to Deliver Water Quality Improvements

Proportionate reductions in point source loading from STW to the Avon have already been achieved. No further point source improvements, beyond those submitted under PR14 are proposed. Where STW reach their permit headroom, the impact of any permit changes should be re-assessed in light of the current scientific evidence, including the NMP. Where further permit headroom is required for flow, it would be recommended that conditions are varied so that the STW has no greater impact on receiving waters than historic (or a net improvement).

Modelling carried out to consider the phosphorus reduction that could theoretically be achieved by tightening current permit conditions to a 0.5mg/l P target and 0.2mg/l (compared with current operation and WW PR14 improvements at All Cannings and East Knoyle), indicate that 0.2mg/l permit would achieve the ambition targets in the Wylye, Wylye Middle, Wylye Headwaters and the Bourne catchment, but none of the others (Table 3.1.3a). It would however deliver 50% of the ambition targets on the Upper Avon, Nadder and Lower Avon (Table 3.1.2).

A 50% reduction in Fish Farm Loading in Upavon East (there is no Water Cress Farms here) and 75% on the Wylye, Nadder and Lower Avon would result in 50% of the ambition targets being achieved (Table 3.1.4a) and a reduced loading of c3250 & 4870 kg/P/yr respectively. Model results may however currently over estimate the fish farm and water cress loading and so forecast load reductions may themselves be over-estimated.

To reduce phosphorus losses from fish farms and water cress farms, they should all implement all reasonable measures to maximise nutrient efficiency and reduce the loading (and impact on water quality) to downstream waters.

The focus for any phosphorus reduction measures should however be achieving the proportionate reduction in diffuse loads. This can be achieved by reducing the source of pollution, breaking the pathway and or protecting the receptor. The main pathway for diffuse pollutants is the surface water pathway (Table 3.2:1).

Environment Agency modelling of CSF options, based on the PIT source apportionment model, indicate that Optimum CSF delivery could achieve ambition targets within all catchments with the exception of Upavon West and the Wylye Headwaters (Table 3.2:4a & b). Maximum CSF measures would achieve the ambition targets at Upavon West. FARMSCOPER forecasts indicate that “all available” measures would achieve the ambition targets. EA interpretation of this model data however would indicate that 50% of Optimum CSF may on average be achieved by a typical CSF scheme.

A combination of the Optimum diffuse CSF measures and point source reductions (to 0.2mg/l permit condition) would also deliver ambition targets on Upavon West. The type of measures and effectiveness recommended through the EA modelling are outlined in Figures 3.2.1a-d.

Approximately 24% of the ambition targets on the Lower Avon could be delivered if ALL FARMERS implementing nutrient reduction measures under Countryside Stewardship.

To achieve the ambition targets in the Lower Avon through land reversion, over c23000 ha of land would need to be converted from high input to low input.

6.7 Cost Benefit

High level cost benefit assessment, indicate that the CAPITAL costs alone of implementing 0.5mg/l permit options would be approximately £68/kg P reduction and 0.2mg/l permit condition of £73 to £87 kg/P reduction, based on a 40 year asset life. This includes no OPEX costs and so the actual cost would be greater than this. A full cost benefit of P reduction from 10mg/l P to 1mg/l across the Frome catchment (less stringent than already implemented in the Avon), indicate that the full cost would be c£74-£164/kg/P reduction at Maiden Newton using traditional wastewater treatment to reed bed treatment. This is likely to double when load reductions from 1mg/l to 0.1mg/l are required[40] to around £148 to £328 kg/P

FARMSCOPER modelling indicates that a 30-40% reduction in P loading and up to 54% can be delivered at zero cost to farmers. It will however take time and farm advice on the ground to achieve this level of P loading reduction. The costs of providing farm advisers in a catchment have been estimated to vary from £19 kg/P reduction under current CSF or £15/kg P if current CSF resources could deliver Optimum P reductions (Table 4.2.4). If Optimum P reductions were achieve by applying the level of catchment support provided by Wessex Water across the Poole Harbour catchment, the cost/delivery would be £64/kg/P reduction, reducing to £26/kg/P reduction if maximum P reduction was achieved. This would reduce further to £27/kg/P and £11/kg/P for Optimum and Maximum reductions based on EA Revised Diffuse Pollution Bid costs.

Land reversion costs to achieve P reduction are considerable when land has to be purchased (Table 4.2:5) and unlikely to be cost effective for delivering wider scale diffuse phosphorus reductions required. They may however be appropriate to secure long term mitigation for future urban development, when mitigation for c100 years may be required and particularly when land does not have to be purchased.

Diffuse pollution options are likely to deliver reduction in phosphorus loads at lower cost than point source measures. They are also likely to deliver wider benefits, such as reduced run-off and suspended sediment loading to catchment, Nitrate leaching reductions as well as phosphorus reduction.

6.8 Mechanisms for Delivery

Phosphorus reduction measures will need to be implemented indefinitely to ensure the benefits of the measure are realised. Where possible this should be achieved through farmers and landowners implementing “all reasonable measures” on a voluntary basis. Where this is not however feasible, legislative/regulatory powers may be required,

Measures should be applied on a prioritised basis to achieve the most rapid water quality improvements (in river valleys floors, on tertiary geology and in lower permeability catchments), at the earliest opportunity. The Environment Agency and Wessex Area are drafting a Diffuse Pollution Reduction Implementation Plan outlining how this will be delivered across the Wessex Area.

Government policy on the delivery of diffuse pollution reduction through Countryside Stewardship is also currently being prioritised. Current mapping indicates that the Hampshire Avon has been assigned the highest priority areas for delivery of grants and advice through Countryside Stewardship because of the many overlapping drivers within the catchment. It is likely therefore that individual and groups of farmers will from 2015/16 be able to apply for Middle or Upper Tier Grants and Support to assist in improving water quality across the catchment. Results from this prioritisation exercise are likely to be published early in 2015.

7.0 RECOMMENDATIONS

1. Surface and groundwater quality across the Avon should continue to be sampled and analysed to refine our understanding of the spatial and temporal influence of Upper Greensand and Chalk mineralogy on surface and groundwater quality and in particular phosphorus concentrations.
2. The framework of surveillance and investigation monitoring across the Avon should be reviewed to answer the outstanding scientific questions and improve our conceptual understanding of the processes impacting on water quality in the Avon. Future monitoring should incorporate that from research programmes, to improve knowledge on phosphorus concentrations and loads across the river system, to inform the targeting of measures on point and diffuse sources and to discern changes that arise with delivery of these measures
3. A new typology for Upper Greensand Fed catchments and revised conservation objective standards for the Hampshire Avon should be developed, taking into account the ecology that would be expected in a naturally phosphorus rich environment such as the upper reaches of the Hampshire Avon. This will supplement or provide a local refinement of JNCC conservation standards published in 2014 [36.]
4. Stakeholders across the Avon should work together to deliver ambition phosphorus reduction targets outlined in Table 2.3.1:5. These are challenging target water quality reductions at different points across the Avon, required to work towards favourable status. They take into consideration current water quality and modelled background water quality.
5. Ambition targets will be superseded when this NMP is updated in line with the WFD River Basin Management Planning Cycle (RBMP3) by locally refined conservation objective standard following the development of this new typology.
6. Ambition targets should largely be achieved through the implementation of measures to reduce diffuse pollution across the whole of the Hampshire Avon,
7. The improvement in water quality should be monitored against a baseline dataset (2010/11) so that any changes that occur can be compared with flow and other climatic variable that may impact on water quality. WQ should also be collected using WFD and JNCC reporting methodologies and compared against WFD & SAC targets to monitor progress towards these.
8. Work undertaken by CSF, Water Company Catchment Initiatives and other stakeholders should be prioritised in accordance to risk. Their work should be co-ordinated to deliver shared outcomes of each organisation so reduction in the loading of the chemicals presenting the highest risk across the Avon (Phosphorus and Nitrate & suspended sediment). This will help to maximise benefits realised by agricultural advice across the catchment (see Wessex Diffuse Pollution Reduction Plan: in draft).

9. Sewage Treatment Works should be allowed to accept further connections without the need for an appropriate assessment, where proportionate phosphorus reductions have been achieved at full pull permit flows and where permit headroom remains and development can be delivered without compromising the deliverability of the NMP as set out in D.5 & D.6 of the NMP.
10. Where a STW reaches its full permit headroom, any change in permit condition should be re-assessed in accordance with current permitting regulations and practice and in light of current scientific understanding of the catchment and proportionality continue to be achieved. Permit flow headroom could potentially be increased by improving treatment at the site (tightening permit water quality standards) and maintaining the principles of "proportionality", or any additional P load will need to be offset by another means and the STW should have no greater impact than the historic permit (or a net improvement).
11. New point source discharges large enough to meet the criteria to require a permit, (as identified by the Environment Agency) and which do not connect to a main sewerage network with phosphorus reduction in place, will require phosphorus removal or offsetting unless a risk assessment can identify the discharge will not result in an adverse impact on the water environment. The level of offsetting shall be determined by the P load (kg) that will enter surface waters. Groundwater discharges to chalk aquifer may require a lower level of offsetting where the attenuation of phosphorus loads can be demonstrated.
12. Fish Farms and Cress Farms should introduce all reasonable measures to improve nutrient efficiency and prevent pollution of downstream waters. This may include adjusting food types for fish to low N & P sources and in water cress providing more control in flow and quality when fertilizing the crop.
13. The NMP should be update in line with WFD planning cycle and in light of new science, growth projections, water quality target and typology information.

8.0 GLOSSARY

ADAS	Agricultural Development and Advisory Service
AMP	Asset Management Plan. Five year planning cycle for water companies and the
Baseline Modelled background	The concentration, on the basis of information currently available and which requires further refinement, that likely to be **near natural** but with an uncertain component of anthropogenic influence and error margin in functioning of the model.
BFI	Baseflow Index
BGS	British Geological Survey
CCM	Catchment Change Matrix
CSF	Catchment Sensitive Farming
CLAD	Customer and Land **Database** (**CLAD**) holdings polygons covering Catchment Sensitive **Farming** Priority Catchments and Partnerships and Target Areas CLAD
CoGAP	Code of Good Agricultural Practice
DEFRA	Department for Environment Food and Rural Affairs
EA	Environment Agency
ECSFDI	England Catchment Sensitive Farming Delivery Initiative
EPA (2006)	Environment Protection Act 2006
FARMSCOPER	FARM Scale Optimisation of Pollutant Emission Reductions (FARMSCOPER),
JNCC	Joint Nature Conservation Committee
LTA	Long Term Average
Mg/l	Milligrams per litre
MOD	Ministry of Defence
NE	Natural England
NMP	Nutrient Management Plan
OFWAT	Water Services Regulation Authority
Olen P	Concentration of available P in soil determined by a standard method (developed by Olsen) involving extraction with Sodium bicarbonate solution at pH 8.5. The main method used in the England, Wales and Northern Ireland and the basis for the **Soil Index** for P.
OP	Orthophosphate
P	Phosphorus
PE	Population Equivalent
PR14/19	Periodic Review 2014 or 2019
Q95	The flow that occurs 95% of the time (low flows)
SAC	Special Area of Conservation
SRP	Soluble Reactive Phosphorus
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
TP	Total phosphorus
Ug/l	Micro grams per litre
UGS	Upper Greensand
WC	Water Cress
WBGM	Wessex Basin Groundwater Model
WFD	Water Framework Directive
WPZ	Water Protection Zone
WW	Wessex Water

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APPENDIX 2.3.1:1 AN INTERPRETATION OF UPPER GREENSAND PORE AND MINERAL DATA FROM ENVIRONMENT AGENCY CORED UPPER GREENSAND BOREHOLES INVESTIGATION

Technical Note From Paul Withers Considering the Chemical Results from the Environment Agency Upper Greensand Core Investigation and considering Phosphorus Profiles in the Upper Greensand

Introduction

Phosphorus (P) concentrations in the tributaries and main stem of the R. Avon, Hampshire are well above target levels to control eutrophication. The Avon is a groundwater-dominated catchment underlain by Lower Chalk(LC) together with much smaller areas of Upper Greensand (UGS) and Gault clay lithology. In an analysis of nutrient (nitrogen (N) and P) hydrochemistry of groundwater and river water in the Avon catchment based on a 10-year dataset held by the Environment Agency (EA), Jarvie*et al*. (2005) concluded that, in direct contrast to N, P inputs to the catchment surface (fertilisers, manures and septic tank discharges) were effectively buffered by soil adsorption and calcite co-precipitation processes within both the unsaturated zone and the chalk aquifer. Groundwater P concentrations were therefore very low (0.02-0.03 mg/L), except in boreholes in the UGS, where concentrations were >0.1 mg/L. Jarvie*et al*. (2005) suggested that the higher concentrations of P in the UGS may be due to both increased fissure flow (i.e. reduced opportunity to interact with the sub-strata matrix) and a lack of calcite co-precipitation sites within the UGS. These authors highlighted sewage discharges from sewage treatment works (STW) as the main source of P to the river.

However, more recent modelling of P export to two intensively monitored headwater streams (East and West Avon) draining the UGS indicated that the annual average river P concentrations of over 0.2 mg/L could not be fully accounted for by point and diffuse source inputs to the catchment area (Defra, 2008). Longer-term public water supply data available for the Avon area also show elevated P concentrations (ca. 0.1-0.3 mg/L) in UGS groundwaters relative to eutrophication thresholds set under the Water Framework Directive (WFD). These data indicate that the groundwaters that feed the river in catchment areas underlain by UGS are high in P, but it is unclear whether this enrichment is natural or anthropogenically-derived. If the P in the groundwater is derived from P-rich geological seams within the Greensand rather than from anthropogenic activities, then this will have a large influence on P reduction strategies adopted within the catchment. Incorrect source attribution will mean that river P targets will not be met and unwarranted pressure put on rural communities and farming.

An investigation was undertaken in 2013 to help determine the origin of P in the groundwater draining the UGS. This brief technical note covers the preliminary analysis and interpretation of the data generated within the context of supporting geological, soil, river and public water supply data available for the catchment and adjacent area.

Methods and data analysis procedures

Four boreholes were sunk at locations with UGS lithology: Urchfont, Wellhead, Divers Bridge and Cannfield Farm. Borehole cores were 100 mm wide and drilled using air flush and where necessary air mist, using water obtained from a nearby hydrant. At Urchfont, core collapse at 52 m necessitated the re-drilling of a nearby borehole (Urchfont A) with samples removed within the UGS at 36m and below. At Wellhead, Divers Bridge and Cannfield Farm, boreholes were drilled to 10-12 m depth only, due to the difficulty in preventing borehole collapse, using an air or air mist technique alone. To overcome problems of core collapse in the UGS at the first drilling site, Urchfont, a polymer was used at Urchfont A (second drill hole), but this was subsequently found to contain P and contaminate the sample porewaters and was not subsequently used in any of the other holes.

Site	Hole	Drill Method	Depth (m)
Urchfont	Urchfont	Hand dug Rotary coring with air flush Rotary coring with air/mist flush	0 – 1.00 1.00 – 8.00 8.00 – 52.50
Urchfont	Urchfont A	Hand dug Open hole drilling Rotary coring using polymer (mud) flush Open hole drilling Rotary coring using polymer (mud) flush	0 – 1.20 1.20 – 35.00 35.00 – 43.50 43.50 – 50.50 50.50 – 70.00
Wellhead		Hand dug Rotary coring with air flush Rotary coring with air/mist flush	0 – 1.20 1.20 – 8.15 8.15 – 12.00
Divers Bridge		Hand dug Rotary coring with air flush Rotary coring with air/mist flush Rotary coring with air flush	0 – 1.20 1.20 – 7.60 7.60 – 12.85 12.85 – 13.20
Cannfield Farm		Hand dug Rotary coring with air flush Rotary coring with air/mist flush	0 – 1.20 1.20 – 6.75 6.75 – 15.00

Core solid samples were taken at 1m intervals with an additional sample at 0.5 m. At Urchfont, where there was an overlying layer of LC, a detailed geological profile was also undertaken. This identified that the transition from LC to UGS occurred at 33 m depth below the surface. A groundwater table was recorded at 29 m depth at Urchfont and at 6 m depth at Wellhead. There was no groundwater detected at the Divers Bridge and Cannfield Farm sites.

Samples were extracted and transported wet to the laboratory where they were centrifuged to remove porewater. All water extracted from each sample went into the same nalgene bottle and was then separated off for (a) total (TP) and soluble reactive P (SRP) by colorimetry,(b) anion chemistry (Cl, Br, NO_2, NO_3, SO4, PO_4 and F) by ion chromatogarphy (Dionex) and (c) metal analysis by inductively coupled plasma – optical emission spectroscopy (ICP-OES) with different filtration and acidification depending on analysis type. Not all determinands were analysed due to small sample size. SRP was determined after filtering through 0.45µm. TP was determined after acid digestion with persulphate. Elemental analysis by ICP-AES was undertaken on unfiltered porewater samples so these are not dissolved element concentrations, and this should be noted in the interpretation. Solid cores were analysed for Olsen-extractable P (Olsen-P) and Total P (TP), TFe, TAl, TCa, TMg and TK.

Data on total oxidised N (overwhelmingly nitrate-N) and total reactive P (TRP) concentrations in groundwater at various boreholes in the UGS and LC from public water supply records dating back to 1980 were also made available and analysed for trends.

A number of potential nutrient ratio indicators were used to help determine whether the measured P concentrations within the borehole samples were anthropogenically-derived or not. However many of these ratios have not been widely tested within this context. These included:

1. P:Cl ratios –Cl is a widely used indicator of agricultural and sewage inputs and is conservative in its behaviour (i.e. not attenuated at all in its passage from the catchment surface to the groundwater). Jarvie*et al*. (2005) found that Cl concentrations in the Avon groundwaters were generally less than 20 mg/L and the TRP:Cl ratios were < 0.007. However data for UGS groundwaters are not specifically given.
2. Cl:Br ratio –both Cl and Br are conservative elements whose relative abundance varies in different source types (Katz *et al*., 2011).Rainfall and groundwater have values up to those of seawater of 290, whereas values of 400-900 are typical of sewage-derived inputs.
3. Rb:Sr ratio – Rubidium is diet-derived constituent of biological matrices (sewage, manures) whilst Strontium is a natural constituent of calcareous parent materials. The ratio of dissolved Rb:Sr is therefore naturally very low in calcareous strataand elevated ratios >0.01 have successfully been used to indicate sewage sources to groundwaters and rivers (Nirel and Revaclier, 1999).
4. Ba:TP ratio – Based on an analysis of the difference in chemical signatures between catchments subjected to different anthropogenic pressures, Ahlgrenet al. (2012) identified a Ba:TP ratio in river water >22 indicated an anthropogenic influence.

Results and Interpretation

Public water supplies

TON and TRP concentrations in drinking water abstracted at four sites in solely UGS lithology were analysed for temporal trends over a 30-year period from 1982-2011. At all sites, there was a significant trend in N concentrations, but TRP concentrations remained stable (Figure 1). At Divers Bridge, Dunkerton Springs and Fovant, nitrate concentrations increased up to ca. 2001 and remained stable or declined slightly thereafter. The largest rate of increase in N was at Dunkerton Springs. The lack of any further increase after 2001 is consistent with the general overall reductions in fertiliser N use in the UK around the turn of the century. At Boyne Hollow, N concentrations have declined steadily since 1987 when measurements started. As intensification of agriculture (i.e. greater use of N fertiliser and recycling of organic manures) is the main source of increased nitrate concentrations in drinking water, these data suggest that changes in agricultural practices over the last 30 years are not the cause of the elevated TRP concentrations in these water supplies. Any intensification in N use is likely to have been accompanied by an increase in P use, either as fertiliser of manure.

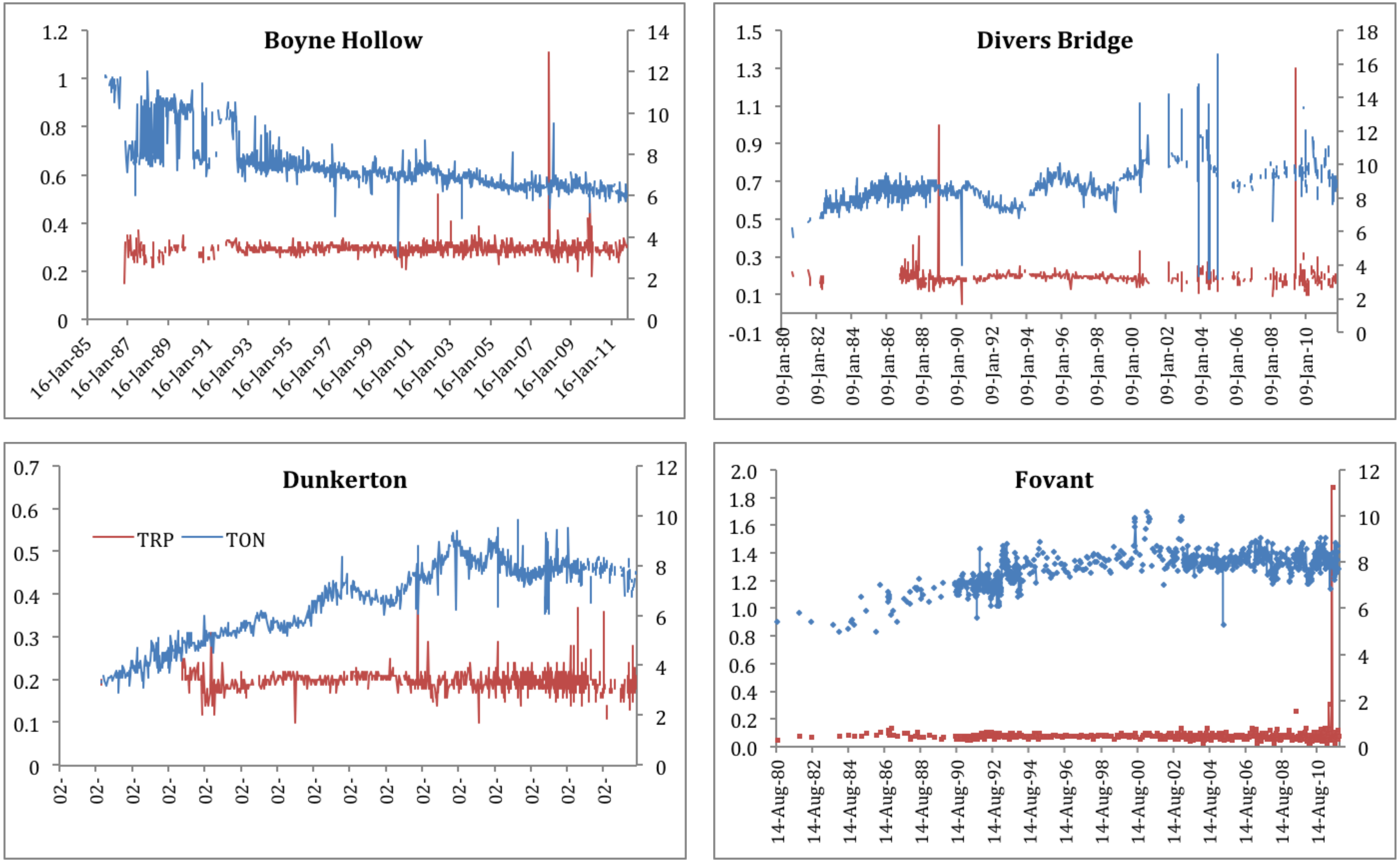


Figure 1.

Temporal trends in total oxidised N (TON; >99% nitrate-N) and total reactive P (TRP) in four boreholes in UGS lithology.

In contrast to N, which is highly mobile in soils and leaches through readily the unsaturated zone, P is rapidly immobilised and only leaches to groundwater if (a) the P sorption capacity of the sub-strata is very low, (b) there are substantial preferential flow pathways (fissures) in the unsaturated zone and (c) the form of P in solution is organic and colloidal.

A comparison of the average TRP concentrations in a number of public water supplies within the study area suggests that those in UGS lithology are generally greater than those in predominantly Chalk lithology.

Phosphorus distribution in boreholes

Analysis of the solid matrix indicted that all boreholes are slightly different in their lithological make-up and much of the variation is associated with variation in Ca levels down the profile. At Urchfont, TP, TFe and TK concentrations increased very markedly, and Ca concentrations decreased very markedly, when LC passed to UGS at 33 m. Data for TP are shown in Figure 2. The large increase in TP is consistent with P-rich geological layers associated with 'phosphorus pebbles' that are present within the UGS, either as distinct bands within the Greensand (e.g. Potterne sandstone, Cann sandstone, Boyne Hollow Chert), or at the junction between the UGS and glauconitic chalk marl (Melbury sandstone, Bookham Conglomerate) of the overlying LC formation (Woods *et al*., 2008).

At Wellhead, Divers Bridge and Cannfield Farm, TP concentrations also fluctuated, especially at Cannfield Farm (Figure 2). However, in contrast to Urchfont, TP tended to increase when Ca concentrations increased. This is perhaps to be expected since the proximity of the UGS to the LC strata suggests various influxes of Ca and P (as apatite) would have occurred when the UGS was laid down. There was a notable separation between depths that contained low Ca concentrations(<10,000 mg/kg) and those that contained close to 100,000 mg/kg within each of these three boreholes, although at Wellhead intermediate concentrations up to 40,000 mg/kg were also measured. The Ca concentrations in the LC at Urchfont were well over 200,000 mg/kg. Where Ca concentrations were low, TP concentrations were linked most often with TK concentrations reflecting the glauconitic nature of the UGS.

Olsen-P is a measure of the potential availability of P and the relationship between OP and TP within the solid matrix provides an indication of the ease with which P might be released into the porewater. A clear distinction was apparent in the OP:TP ratio between depths with low Ca concentrations and those with much higher Ca concentrations as separated above for Wellhead, Divers Bridge and Cannfield Farm sites (Figure 3a). Outliers from this general pattern were samples from the surface at Wellhead and Divers Bridge where accelerated accumulation of P from fertilisers and manures might be expected. However, surface samples from Cannfield Farm did not behave differently. Olsen-P concentrations at Urchfontand Urchfont A were uniformly low (<7 mg/kg) down the borehole, even where Ca concentrations were low. In this respect Urchfont behaved very differently to the other sites.

The relationship between OP and SRP in the porewater extracted at each depth for the Wellhead, Divers Bridge and Cannfield Farm sites is shown in Figure 3b. As expected there is a significant positive relationship for all samples, although some higher SRP values than expected do occur, especially at Cannfield Farm which as yet remain unexplained.

A notable feature of the Divers Bridge and especially the Cannfield Farm sites is the large amount of OP accumulation within the top 2 m of UGS.

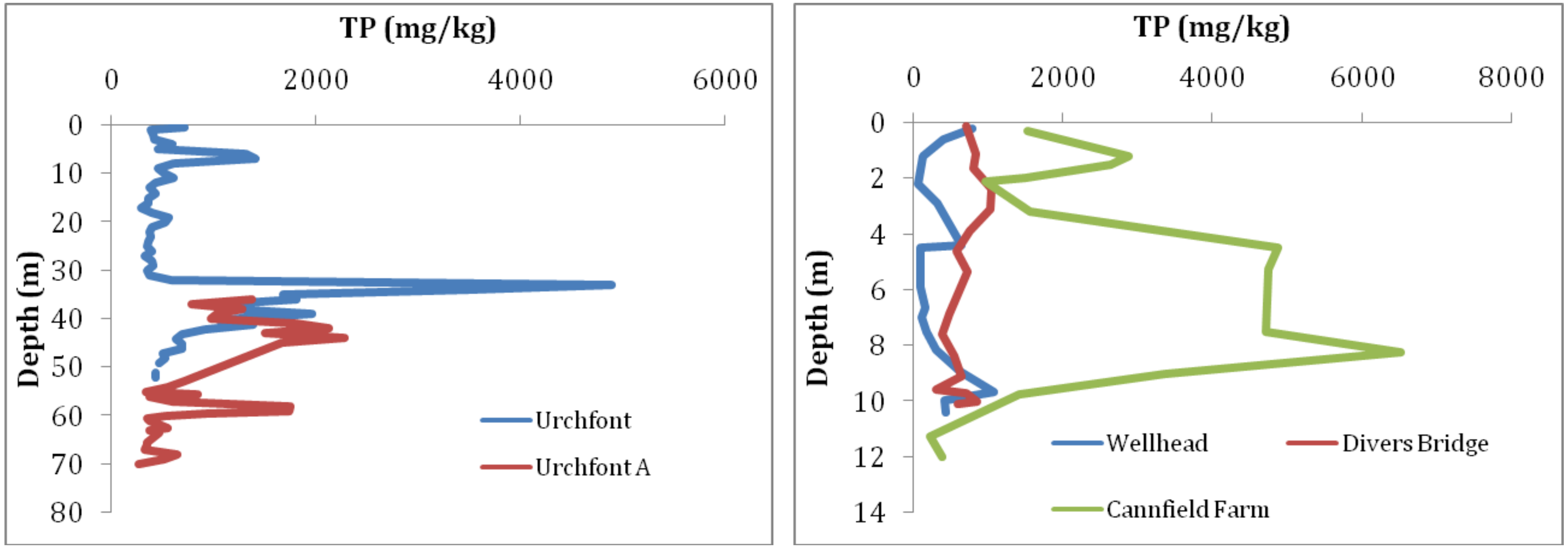
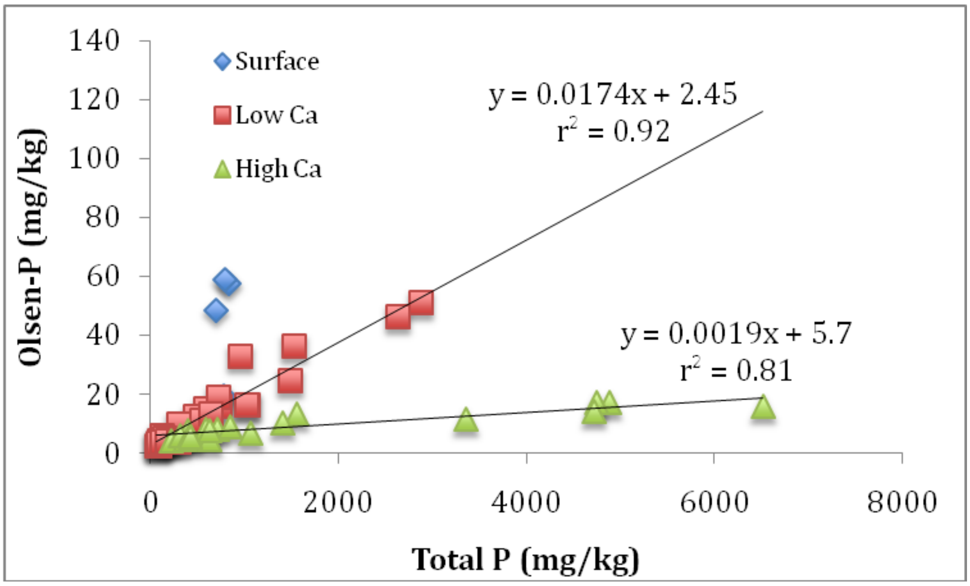


Figure 2. Depth distribution profiles of Total P (TP) at the four sites. At Urchfont, UGS occurs at 33m and is marked by a large increase in TP concentration.

(a)



(b)

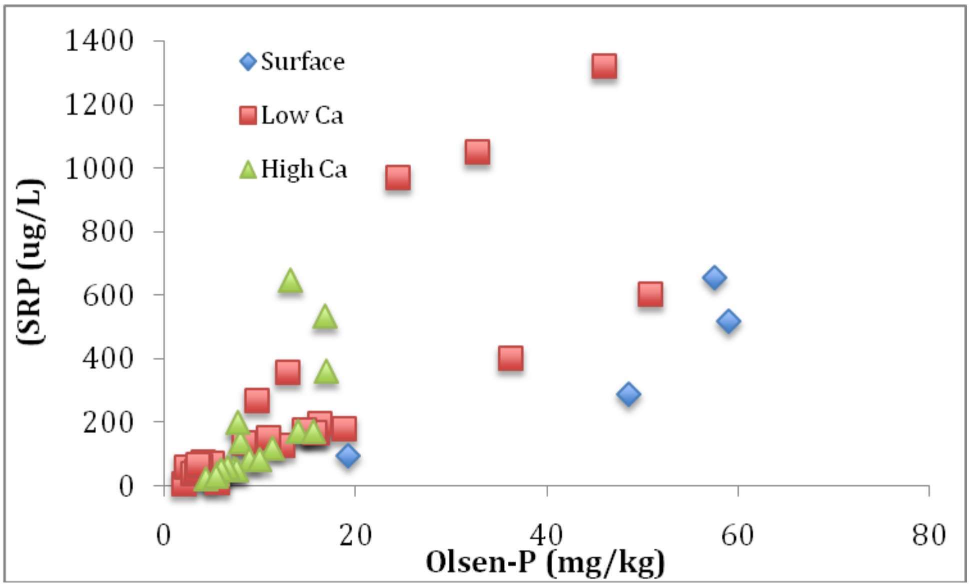


Figure 3. Calcium concentrations govern (a) the relationship between Olsen-P (OP) and total P (TP) concentrations in the solid matrix , but (b) further factors are affecting the concentration between OP and soluble reactive P concentrations in the extracted porewaters at the same depths.

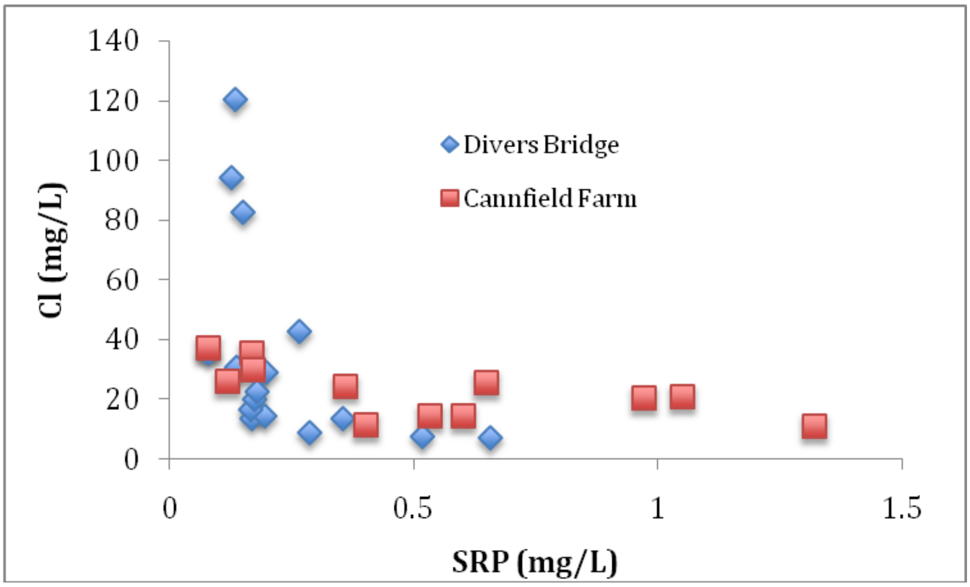
Anthropogenic indicators

The concentrations of Cl and the different anthropogenic element indicator ratios did not consistently demonstrate that the P enrichment down the borehole profile was related to nutrient inputs at the land surface. There was also no general agreement between the indicator ratios used, except at the surface at some sites.

At Wellhead, the higher concentrations of Olsen-P and porewater P in the surface 0.2 m, and a declining P concentration gradient below this depth, were also reflected in slightly greater Cl(>20 mg/L) concentrations and higher Rb:Sr (>0.02)and Cl:Br ratios (ca. 800).Excluding this enrichment zone, SRP concentrations down this Ca-dominated borehole profile averaged 0.05 mg/L, which is fairly typical of groundwater concentrations where Ca concentrations are relatively high.

At Divers Bridge and Cannfield Farm there was a highly significant negative correlation between porewater SRP concentrations and Cl concentrations indicating that there are other natural sources of Cl within these UGS profiles or that P concentrations at these two sites are not anthropogenically derived (Figure 4a).Similarly there was a negative correlation between SRP and nitrate.

(a)



(b)

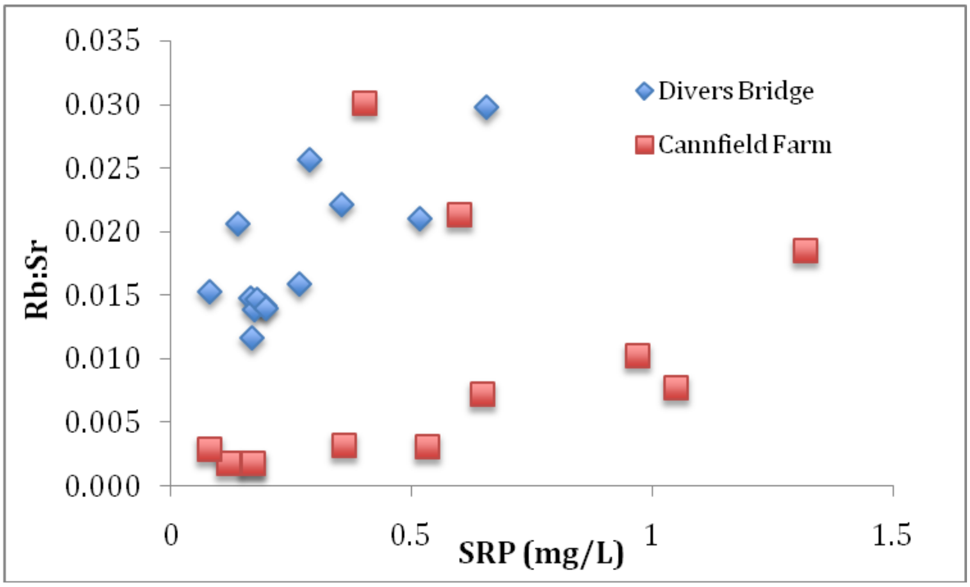


Figure 4. Relationships between porewater soluble reactive P (SRP) concentrations and two indicators of anthropogenic activity (a) chloride concentrations and (b) Rubidium to Strontium (Rb:Sr) ratios. Note the Rb and Sr values are not dissolved concentrations as used by Nirel, and Revaclier(1999).

However, there were statistically significant positive correlations between porewater SRP and Rb:Sr ratios at both sites, with the exception of two elevated ratio values from the two surface samples at Cannfield Farm (Figure 4b). Greater Rb concentrations might be expected at the surface due to inputs of organic manures and biosolids. At Cannfield Farm, SRP started to increase more consistently above a ratio value of 0.003. Average porewater SRP concentrations below 0.003 were 0.135 mg/L suggesting this might be the background P derived from natural sources within the UGS. This also indicates there has been substantial migration of P down the profile to 7m. However, this is also the transition zone to much higher Ca concentrations in the porewater due to rising Ca in the core matrix. Hence, Rb:Sr showed a highly negative correlation to Ca concentrations because Sr is known to geologically linked to Ca. It is therefore Ca concentrations that are probably governing the Rb:Sr concentrations rather than an indication of anthropogenic enrichment. At Divers Bridge, Rb:Sr values are much higher that an Cannfield Farm for an equivalent porewater SRP concentration, and SRP values start to increase when Rb:Sr exceeds 0.02. Average porewater SRP concentrations relating to values below 0.02 are 0.167 mg/L.

Although there is considerable doubt over the usefulness of the specific anthropogenic elemental indicators to discriminate from natural sources, what is clear at both Divers Bridge and CannfieldFarm sites is that there is considerable accumulation of Olsen-P within the surface 1.6-2m depth which can only be from additional P inputs at the surface. At Divers Bridge, there is a very sharp change below 1.6 m, which suggest that porewater SRP concentrations below 1.6m are more likely to represent natural sources within the UGS parent material. At Cannfield Farm, the gradient in OP is much more gentle and the SRP concentrations are consequently higher suggesting more significant enrichment to depth at this site, with SRP concentrations decreasing sharply when Ca concentrations increase at 7m depth.

At Urchfont, there are large discrepancies between the different estimates of porewater SRP concentrations that preclude an analysis of potential contributions. At Urchfont A, the contamination from the polymer used also precludes any analysis. At both sites, OP concentrations were also uniformly low.

There was no indication that the presence of a water table at Urchfont or Wellhead was influencing matrix or porewater P concentrations, although nitrate concentrations decreased presumably due to denitrification.

Preliminary Conclusions

A thin zone of considerable total P enrichment was observed at the junction of the UGS and LC lithologies at the Urchfont borehole. This is consistent with the known occurrence of ‘phosphatic pebbles’ in UGS sub-strata. However, analyses of porewater P concentrations in the UGS at Urchfont by different methods were highly variable and no conclusions could be drawn on the impact of this P enrichment on porewater P. There was only a slight increase in Olsen-P concentrations in the UGS compared to the LC. A large increase in concentrations of Fe at the LC/UGS boundary maybe buffering the effect of increased TP concentrations on release of P into solution.

Wellhead, Divers Bridge and Cannfield Farm boreholes provided much more robust datasets with which to assess the degree of natural versus anthropogenic enrichment in the UGS. Fluctuations in total P down the borehole profile were related to two factors: surface accumulation of P at the surface from anthropogenic inputs and natural enrichment at deeper depths as Ca concentrations increased, most probably as apatite. UGS profiles generally contained considerably less Ca (<10,000 mg/kg), but zones of Ca (and P) enrichment up to 100,000 mg/kg were frequently found, although still appreciably lower than those in LC (>250,000 mg/kg).

Concentrations of porewater P were positively correlated to Olsen-P concentrations in the solid matrix, although some of the variation has yet to be explained. Olsen-P and porewater P were greatest where there was accumulation of TP at the surface. However, relatively high porewater P concentrations were also observed where Ca concentrations were low (<10,000 mg/kg) at deeper borehole depths.

A range of previously used elemental indicators of anthropogenic enrichment were not useful in identifying the influence of agricultural or wastewater P inputs other than to confirm accumulation of P at the surface. All three UGS boreholes showed marked surface P accumulation but to varying depths: 0.2 m at Wellhead, 1.6m at Divers Bridge and at least 2m at Cannfield Farm. Average porewater P concentrations below these zones of enrichment were ca. 0.05 mg/L at Wellhead (higher Ca concentrations in the borehole profile) and 0.2 mg/L at Divers Bridge and 0.3 mg/L at Cannfield Farm. However, the more gradual decline in P at Cannfield Farm suggests this site was influenced by additional P sources from the surface.

For Divers Bridge, Wellhead and Cannfield Farm there is excellent agreement between SRP porewater concentrations in the core profile and borehole 30-yr averages if the surface accumulation horizons are excluded. The Urchfont groundwater seems much more contaminated than its borehole characteristics would suggest.

The results indicate that it is reasonable to assume a background porewater P concentration of about 0.15 mg/L in UGS profiles, but that the actual contribution will vary due to the natural variation in the lithological make-up of the UGS (and hence profile average TP and Olsen-P).

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Appendix 2.3.1:2 *Estimation of Baseline Phosphorus Concentrations in Run-off in the Hants Avon*

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Estimation of Baseline Phosphorus Concentration in Runoff in the Hants Avon

1. Background

Recent investigations undertaken by the Environment Agency have established evidence for elevated orthophosphate (OP) concentrations occurring naturally in the Upper Greensand in the Hants Avon. The River Avon is substantially (about 85%) baseflow fed, and hence high natural OP concentrations in baseflow will lead to elevated naturally occurring phosphorus concentrations in the river.

This has led to a proposed revision of water quality objectives for the river, recognising that observed elevated P concentrations in many of the headwaters of the river may not be anthropogenic in origin. However, in order to establish "baseline" P concentrations for the river (i.e. the concentration of phosphorus that would occur naturally in the absence of any anthropogenic influence), there is a need to consider the P concentration that would occur naturally in the runoff to the river that comprises the remaining 15% or so of the total flow.

This memo draws together previous observations and modelling approaches to estimating P concentrations in surface runoff in the Hants Avon, with a view to deriving an appropriate value for the "baseline" P concentration that can be used to inform water quality objectives.

2. Conceptual Understanding

In rivers which are predominantly baseflow-fed such as the Hants Avon, phosphorus (P) transfer to surface waters in runoff is likely to be highly episodic. Observed river water quality will be dominated by P in baseflow with occasional "spikes" reflecting higher flow runoff events, during which the concentration of P in runoff will dominate. Because of the relative lack of attenuation of surface water pathways (compared with groundwater pathways), concentrations of P in runoff are likely to be substantially greater than those in baseflow. However, observed river water quality at most sites will include a "natural" component (resulting from the dissolution of P from soil and contribution from particulate P, and P occurring naturally in groundwater) and an anthropogenic component (P from organic and inorganic fertiliser, plus some elevation of P loadings from soil resulting from increased soil P index in cultivated soils).

The aim of this note is to provide an estimate of the P concentrations that result in groundwater and surface runoff in the Hants Avon, from "natural" and anthropogenic sources. Sections 3 and 4 review observed groundwater and surface water quality, respectively. Section 5 provides an estimate of natural P concentrations in runoff based on these data.

3. Observed Groundwater Quality in the Hants Avon

Previous work by AMEC (ref 30530rr089i2, 2013) has reviewed measurements of groundwater quality at a number of sites in the Hants Avon with differing geology. These measurements will include a "natural" component which will vary according to the geology of the monitoring site, and an anthropogenic component which will vary according to land use and other management factors in the area contributing recharge to the groundwater being monitored or abstracted, as well as the degree of attenuation of phosphorus in the unsaturated zone.

Table 3.1 shows time-averaged orthophosphate (OP) concentrations at a number of PWS abstractions in the Hants Avon operated by Wessex Water (data supplied by Wessex Water).

Based on these data, the time averaged OP concentrations, averaged by geology type, are as follows:

- Chalk 0.039 mg/l
- Chalk/UGS 0.079 mg/l
- UGS 0.154 mg/l

Compton Durville in the Limestone is excluded from the analysis. These values represent the averages across a number of sites, are time-averaged (rather than flow-weighted) concentrations, and will include both natural and anthropogenic sources of OP.

The data review also noted that:

- Chalk groundwater OP concentrations are generally much lower than in surface water, and below Special Area of Conservation (SAC) targets;
- The majority of data values lie below the limit of detection, with occasional periods of elevated OP concentrations;
- OP concentrations at some sources in the UGS are much higher, and exceed SAC targets;
- There is no apparent trend or seasonality in groundwater OP concentrations, in contrast to surface water OP concentrations.

These points are further discussed in Section 4.

Table 3.1 Average Orthophosphate Concentration at Wessex Water PWS Abstractions

Site Name	Geology	Easting	Northing	Date From	Date To	Average Orthophosphate P (mg/l)
Bulbridge	Unconfined Upper Chalk	408800	130100	16-Nov-81	02-Nov-11	0.042
Chitterne	Unconfined Upp & Mid Chalk	399807	144873	29-Sep-88	04-Oct-11	0.034
Clarendon BH1	Upper Chalk Formation (undivided)	417500	130200	22-May-84	01-Nov-11	0.038
Clarendon BH2	Upper Chalk Formation (undivided)	417500	130200	10-Jul-84	01-Nov-11	0.052
Deans Fm	Upper Chalk Formation (undivided)	414800	130700	29-Jan-85	14-Oct-11	0.044
Devizes Rd	Upper Chalk Formation (undivided)	413305	130823	13-Jul-83	11-Nov-11	0.033
Durrington	Unconfined Upper Chalk	415300	143700	23-May-84	01-Nov-11	0.035
Easterton	Unconfined Chalk	402611	154825	02-Apr-80	22-Sep-11	0.041
Fonthill	Unconfined Upp & Mid Chalk	394100	134100	31-Jul-85	04-Nov-11	0.042
Newton Toney	Chalk Group (undivided)	421192	139610	18-Jul-84	13-Sep-11	0.043
Shepherds Shore BH1	Chalk	404800	166800	28-Sep-92	28-Oct-11	0.035
Shrewton	Chalk Group (undivided)	408204	143478	23-May-84	07-Oct-11	0.033
Bourton	Middle/Lower Chalk & Upper Greensand	404548	164859	29-Aug-84	30-Sep-11	0.032
Brixton Deverill	Lower Chalk/Upper Greensand	385669	138026	21-Nov-96	08-Nov-11	0.086
Chirton	Chalk/Upper Greensand	408700	155700	29-May-84	03-Nov-11	0.059
Codford	Chalk/Upper Greensand	395508	140110	31-Oct-90	10-Nov-11	0.048
Compton	Unconfined Mid & Lower Chalk (& UGS)	412728	151981	17-May-84	28-Jul-11	0.107

Table 3.1 (continued)

Site Name	Geology	Easting	Northing	Date From	Date To	Average Orthophosphate P (mg/l)
Heytesbury	Chalk/Upper Greensand	392729	144699	19-Apr-82	28-Oct-11	0.187
Upton Scudamore	Chalk/Upper Greensand	386353	148348	15-Oct-80	07-Nov-11	0.037
Upton Scudamore springs	Unconfined Lower Chalk & UGS	386317	148282	02-Jan-80	07-Nov-11	0.079
Compton Durville	Inferior Oolite Group (undivided)	341744	117073	07-Jan-80	03-Nov-11	0.079
Barton Hill	Upper Greensand Formation	386498	123203	02-Jan-80	10-Jan-11	0.266
Bishop Cannings	Upper Greensand Formation	403632	163535	11-Jul-84	10-Nov-11	0.050
Boyne Hollow	Unconfined Upper Greensand	387448	121441	16-Jan-85	11-Nov-11	0.296
Dunkerton	Unconfined Upper Greensand	380256	139869	02-Jan-80	07-Nov-11	0.196
Forston	Unconfined Upper Greensand	401266	128598	26-May-82	11-Nov-11	0.037
Fovant	Upper Greensand Formation	401300	128500	20-Feb-80	08-Nov-11	0.082

4. Observed Surface Water Quality in the Hants Avon

In contrast to concentrations in groundwater, concentrations of OP in surface water show a strong seasonal signal with peaks generally occurring in the summer or autumn, and are in general much higher. Figure 4.1 shows monitored OP concentrations at the Western Avon at Upavon. There is a clear seasonality in the signal which is indicative of diffuse or, more likely in this case, point source impacts. Recent monitoring data lie roughly in the range 0.1 mg/l to 0.4 mg/l.

Figure 4.2 shows monitored OP concentrations from the Nine Mile River at Bulford. This site drains from Salisbury Plain and is unlikely to demonstrate significant anthropogenic impacts, either point source or diffuse. Nonetheless, clear spikes in OP concentration are evident, which probably correspond with runoff events and the influence of elevated OP concentrations in runoff. Apart from these events, OP concentrations at this site are generally low (often reported at the limit of detection, typically 0.02 mg/l to 0.05 mg/l), reflecting the low level of anthropogenic inputs and high baseflow contribution.

Figure 4.1 Observed Orthophosphate Concentration (Avon at Upavon)

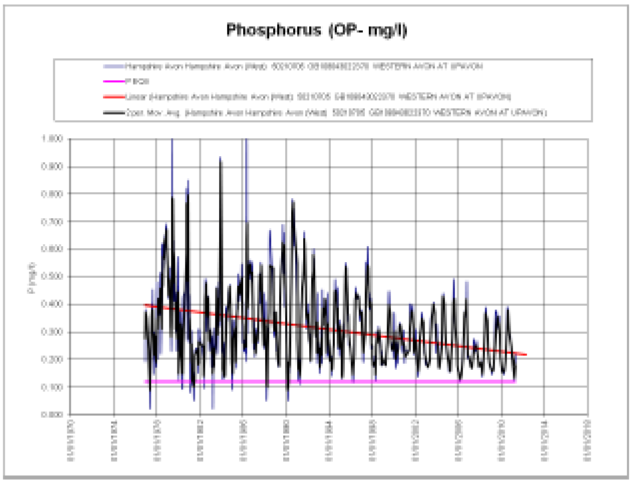


Figure 4.2 Observed Orthophosphate Concentration (Nine Mile River at Bulford)

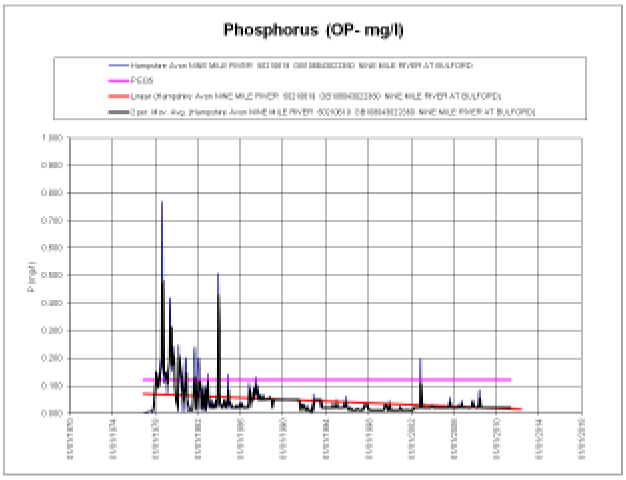
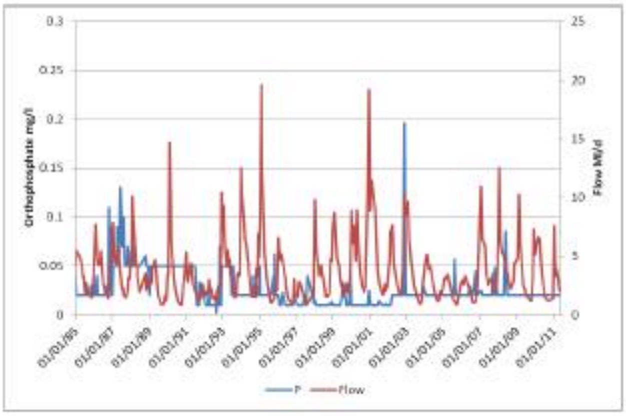


Figure 4.3 shows observed OP concentrations at Nine Mile River at Bulford, overlain with monitored flow. Many of the peaks in the (irregular) OP monitoring data coincide with increases in flow.

Figure 4.3 Monitored flow and OP Concentration (Nine Mile at Bulford)



5. Estimation of Baseline Phosphorus Concentrations in Runoff

5.1 Summary of conceptual understanding

Based on the previous review, it is postulated that observed surface water OP concentrations are made up of the following components:

- OP in baseflow, which displays little or no seasonality and which includes natural and anthropogenic components; and
- OP in runoff, which also includes both natural and anthropogenic components and displays a marked seasonality (at some sites).

The natural and anthropogenic components in groundwater (i.e. baseflow) will show some variability between sites, depending on geology and hence the magnitude of the natural source, but the relative proportions of each are likely to show little temporal variation.

The concentration of OP in runoff is likely to be seasonal, and will include point source impacts (mainly sewage treatment works) and sources from soil, organic and inorganic fertilisers. Where the former dominate this is likely to result in seasonal variation in OP concentrations caused by seasonal variations in flow.

Where the latter dominate, observed SW quality is likely to show "spikes" caused by episodic runoff events during which both flow and OP concentration are elevated.,

The "baseline" OP concentration in surface waters will therefore, represent the combination of the natural baseflow contribution and the natural runoff contribution (i.e. dissolution from soil and particulate P), with the runoff contribution showing as "spikes" in observed OP concentration correlated with high flow events. The magnitude of these spikes will be elevated by the anthropogenic component of OP in runoff at some sites (principally from organic and inorganic fertilisers in rural catchments). In addition, at point source impacted sites, there may be a seasonal signal superimposed on the baseline.

5.2 Modelling Baseline Orthophosphate Inputs in Runoff

The PIT (Phosphorus Indicators Tool) model (Heathwaite et al, 2003) has previously been used as part of source apportionment calculations in the Hants Avon (AMEC ref 30530rr089i2, 2013). The same model spreadsheet has been used to estimate the concentration of phosphorus in runoff from non-anthropogenic sources.

All manure and fertiliser sources were removed from the spreadsheet. Soil P index was set to zero, indicative of uncultivated soil. All other soil parameters were left unchanged from the original model.

Based on soil type, the PIT model predicts that 10% of hydrologically effective rainfall (HER) becomes surface runoff and 90% recharge to groundwater. The total phosphorus concentration in runoff is predicted to be 0.1 mg/l. Of this, approximately 50% was dissolved P from soil and 50% was particulate P. Depending on the degree to which particulate P influences OP concentrations in-stream (i.e. P cycling), this suggests an OP concentration in runoff of 0.05 to 0.1 mg/l.

5.3 Baseline Orthophosphate Concentrations

Taking monitoring data from the Nine Mile River at Bulford as representative of a site unimpacted by anthropogenic inputs of OP, the baseline OP concentration in Chalk baseflow is estimated at around 0.02 mg/l. This is lower than the 0.04 mg/l regional average observed OP concentration in Chalk groundwater, due to the absence of significant anthropogenic inputs and also probably due to variability within the Chalk aquifer.

During runoff events, concentrations increase to 0.05 to 0.08 mg/l. Assuming that during runoff events 85% of flow is runoff and 15% baseflow, this suggests a "natural" concentration of OP in runoff of 0.055 to 0.09 mg/l. This is consistent with PIT modelling (Section 5.2), therefore we suggest a typical range in concentration is assumed of 0.05 mg/l to 0.1 mg/l.

5.4 Discussion

The simplest approach to estimating "baseline" orthophosphate concentrations in surface waters would be to calculate a flow weighted average of the estimated concentrations in baseflow and runoff.

Assuming 85% baseflow at 0.04 mg/l (the regional average figure for the Chalk) and a concentration in runoff of 0.05 to 0.1 mg/l, this would result in a baseline annual average concentration in the range 0.042 mg/l to 0.049 mg/l, or approximately 0.04 mg/l to 0.05 mg/l.

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Alternatively, using the lower value for orthophosphate concentration in baseflow of 0.02 mg/l (derived from data from the Nine Mile River at Bulford), an estimated baseline annual average concentration (catchment specific) would lie in the range 0.025 mg/l to 0.032 mg/l.

The corresponding figure for the Upper Greensand, assuming 0.2 mg/l orthophosphate in baseflow, would lie in the range 0.178 mg/l to 0.185 mg/l.

However, the highly episodic nature of runoff events and the corresponding increases in OP concentration would probably result in transient exceedances of this threshold, even at sites with little or no anthropogenic orthophosphate input. The time-average of all measurements of orthophosphate concentration is likely to be significantly influenced by the proportion of samples which are taken during runoff events.

It may be more appropriate to consider a water quality objective which recognises that "spikes" are, to some extent, inevitable and beyond management control. One possibility would be to set a water quality target as a percentile, i.e. a certain percentile of all water quality measurements over a period must not exceed a specified value. This is an approach which has been used in the past to set water quality objectives for surface waters.

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APPENDIX 2.3.1:3A OBSERVED PHOSPHATE CONCENTRATIONS 2010-12 & 2010-11 FOR THE HAMPSHIRE AVON (AS USED IN SIMCAT & MODEL INTERPRETATION)

The following sampling points have results for ortho-phosphate concentrations.

	Water Body	SMPT_Code	SMPT_NAME	Average Water Quality (WFD) 2010-12 data	90%ile (indicitive max) (WFD) 2010-12 data	10%ile (indicitive Minimum) (WFD) 2010-12 data	SIMCAT Model 2010-11 Flow Scenario 1a
Ripley Brook	GB108043011010	50280808	RIPLEY BROOK U/S CONFLUENCE	11	15	7	30
Clockhouse Stream	GB108043011011	50280726	CLOCKHOUSE STREAM	#VALUE!	0	0	30
Bisterne Stream	GB108043011012	50280911	BISTERNE STREAM AT A338	#VALUE!	0	0	30
Linford Brook:	GB108043015720	50281106	LINFORD BROOK U/S CONFLUENCE	16	29	2	30
Sleep Brook:	GB108043015730	50281619	SLEEP BROOK AT TURMER	15	28	2	30
Dockens Water:	GB108043015740	50281314	DOCKENS WATER AT A338	25	78	0	29
Huckles Brook:	GB108043015750	50281811	HUCKLES BROOK D/S GARAGE A338	23	55	0	29
Ditchend Brook:	GB108043015770	50281905	DITCHEND BROOK	12	17	6	29
Ashford Water (Allen River):	GB108043015800	50270104	ASHFORD WATER U/S CONFLUENCE WITH HAMPS	26	62	0	36
Sweatford Water:	GB108043015810	50270207	SWEATSFORD WATER U/S CONFLUENCE	15	26	4	29
Ebble	GB108043015830	50250102	RIVER EBBLE DOWNSTREAM LONGFORD FISH FA	40	62	19	61
Hampshire Avon (Lower)	GB108043015840	50280271	HAMPSHIRE AVON AT KNAPP MILL	71	100	43	70
EBBLE TRIB (Chalke Valley Stream)	GB108043015860	50250326	RIVER EBBLE D/S CHALKE VALLEY FISH FARM	81	115	48	67
EBBLE (Upper)	GB108043015870	50250291	RIVER EBBLE AT BROADCHALKE	60	94	26	60
NADDER (Lower)	GB108043015880	50220110	RIVER NADDER AT BEMERTON	69	99	38	82
Nadder (Headwaters)	GB108043016160	50220329	RIVER NADDER AT WARDOUR	175	222	129	125
Nadder Tribs (Swallowcliff)	GB108043016180	50221210	SWALLOWCLIFFE STREAM U/S CONFLUENE	156	232	80	124
Fovant Brook	GB108043016190	50220854	FOVANT BROOK D/S FOVANT FISH FARM	137	170	103	137
Nadder (upper)	GB108043016200	C0235000	NADDER AT TISBURY	146	184	107	122
Sem	GB108043016210	c0268000	SEM WARDOUR	179	267	91	249
Hampshire Avon (Upper) u/s Nine Mile River confl	GB108043022351	50210411	HAMPSHIRE AVON AT BULFORD	#N/A	#N/A	#N/A	99

Hampshire Avon (Upper) d/s Nine Mile River confl	GB108043022352	50210209	HAMPSHIRE AVON AT STR SUB CASTLE	65	103	27	99
Nine Mile River	GB108043022360	50210619	NINE MILE RIVER AT BULFORD	13	27	0	20
Hampshire Avon (West)	GB108043022370	50210705	WESTERN AVON AT UPAVON	240	345	135	154
BOURNE	GB108043022390	50240116	RIVER BOURNE AT LAVERSTOCK	49	79	19	53
Hamp Avon East and Woodborough Stream	GB108043022410	50211468	EASTERN AVON AT SWAN BRIDGE PEWSEY	161	205	118	177
Deane Water	GB108043022420	50211720	DEANE WATER AT KNOWLE (PREVIOUSLY AVON	144	185	102	159
Etchilhampton Water	GB108043022430	50210770	WESTERN AVON AT PATNEY BRIDGE	309	460	158	156
Nadder (middle)	GB108043022470	50220284	RIVER NADDER AT UPPER CHICKSGROVE	116	185	46	121
Teffont	GB108043022471	50220926	TEFFONT STREAM AT TEFFONT MANOR	44	70	17	
FONTHILL STREAM	GB108043022500	50221110	FONTHILL STREAM U/S CONFLUENCE	35	79	0	124
Wylye (Lower)	GB108043022510	50230111	RIVER WYLYE AT QUIDHAMPTON	72	116	28	55
Wylye (Headwaters)	GB108043022520	50250634	RIVER WYLYE AT B3095 BRIDGE	77	121	32	90
Wylye Trib (Heytesbury Stream)	GB108043022530	50231202	HEYTESBURY BROOK AT HEYTESBURY	211	370	53	60
Wylye Trib (The Were or Swab)	GB108043022540	50231604	RIVER WERE AT CALVESWATER PUMPING STATI	532	1510	0	60
Wylye (Middle)	GB108043022550	50230245	RIVER WYLYE AT STEEPLE LANGFORD BRIDGE	92	128	56	57
Chitterne Brook tributary	GB108043022560	50231121	CHITTERNE BROOK AT CODFORD	35	57	13	20
Till Tributary	GB108043022570	50231010	RIVER TILL AT STAPLEFORD	34	62	5	40

APPENDIX 2.3.1:3B SUMMARY PHOSPHATE DATA 2000 – 2011 FOR THE LOWER HAMPSHIRE AVON

The following sampling points have results for ortho-phosphate concentrations.

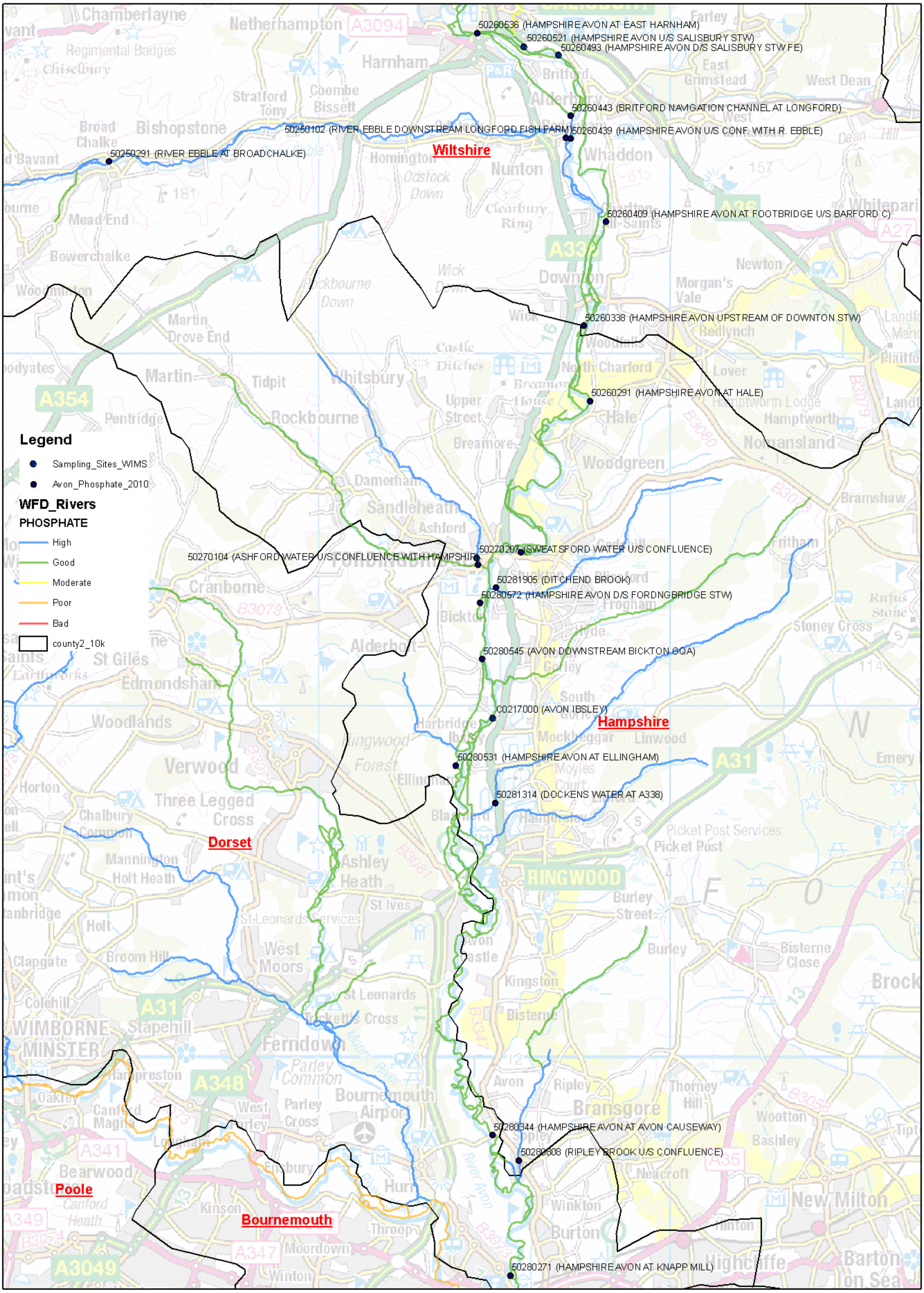
Sampling Point Reference	Sampling Point Name	SSSI Unit Number	Phosphate Target mg/l	Page	Compliance 2010/2012
50260338	HAMPSHIRE AVON U/S DOWNTON STW	11	0.06	3	N
50260439	HAMPSHIRE AVON U/S CONF. WITH R. EBBLE	11	0.06	4	N
50260536	HAMPSHIRE AVON AT EAST HARNHAM	9	0.06	5	N
50280344	HAMPSHIRE AVON AT AVON CAUSEWAY	35	0.10	6	Y
50250102	RIVER EBBLE D/S LONGFORD FISH FARM	n/a		7	
50260291	HAMPSHIRE AVON AT HALE	11	0.10	8	Y
50260409	AVON AT F/B U/S BARFORD CARRIER	11	0.06	9	N
50260443	BRITFORD NAVIGATION CHANNEL AT LONGFORD	9	0.06	10	N
50260493	HAMPSHIRE AVON D/S SALISBURY STW FE	9	0.06	11	No data
50260521	HAMPSHIRE AVON U/S SALISBURY STW	9	0.06	12	N
50280271	HAMPSHIRE AVON AT KNAPP MILL	35	0.10	13	Y
50280531	HAMPSHIRE AVON AT ELLINGHAM	34	0.10	14	Y
50280545	AVON D/S BICKTON GQA	34	0.10	15	Y
50280572	HAMPSHIRE AVON D/S FORDNGBRIDGE STW	34	0.10	16	Y
50280585	HAMPSHIRE AVON AT FORDINGBRIDGE	34	0.10	17	Y
C0217000	AVON IBSLEY	34	0.10	18	No data
50270104	ASHFORD WATER U/S CONFLUENCE WITH AVON	n/a		19	
50270207	SWEATSFORD WATER U/S CONFLUENCE	n/a		19	
50281314	DOCKENS WATER AT A338	12	0.04	19	Y

The data has been processed using Aardvark software supplied by WRc.

The following pages show the trends in phosphate concentration over time, the seasonality and a statistical summary of the annual data.

G Brown
Senior Environment Planning Officer 23 August 2012

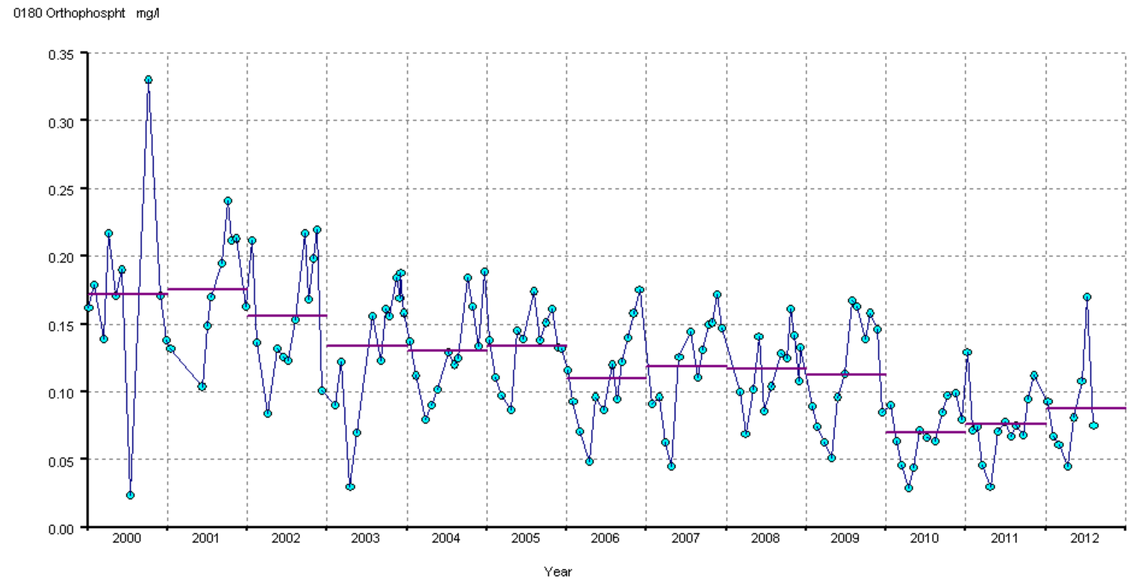
Lower Hampshire Avon Sampling Points



Time Series Plot - 0180 Orthophospht mg/l

06-01-2000 to 07-08-2012

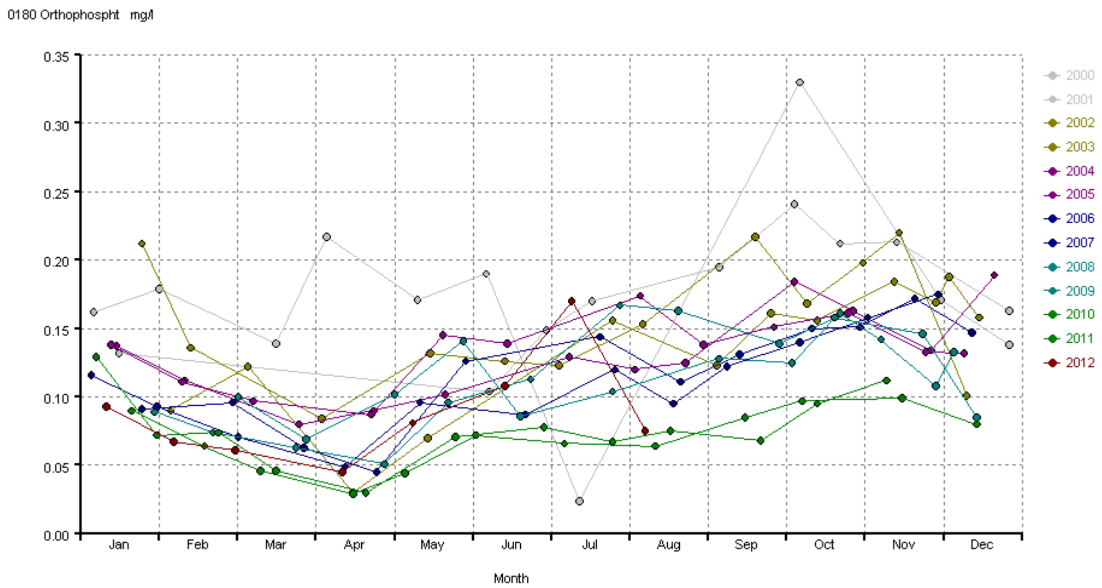
50260338; HAMPSHIRE AVON UPSTREAM OF DOWNTON STW



Year-on-Year Plot - 0180 Orthophospht mg/l

06-01-2000 to 07-08-2012

50260338; HAMPSHIRE AVON UPSTREAM OF DOWNTON STW



50260338; HAMPSHIRE AVON UPSTREAM OF DOWNTON STW

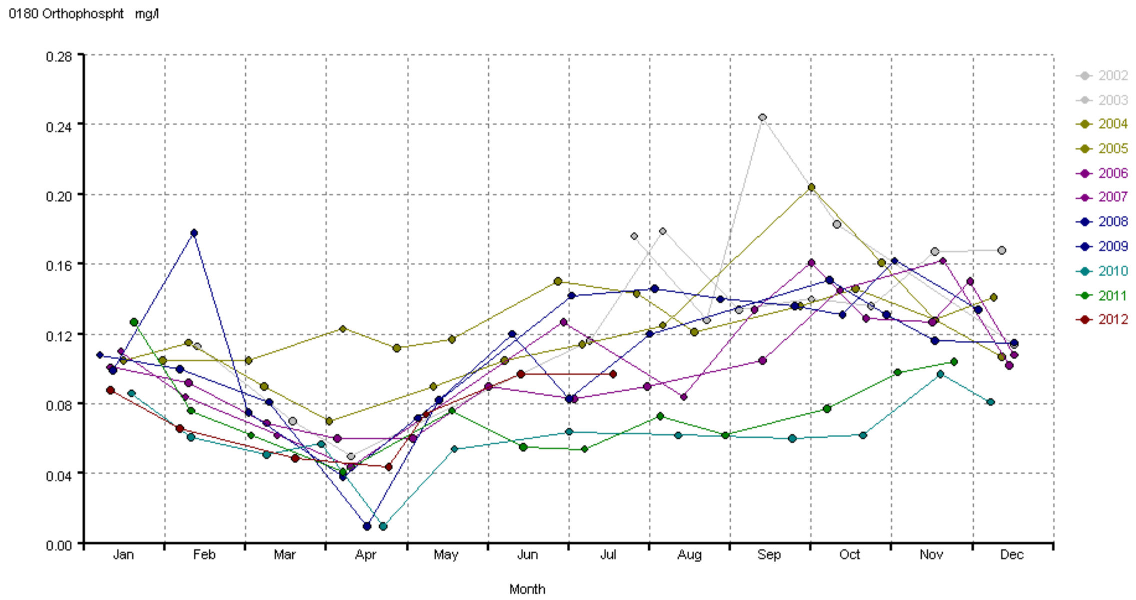
Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	06-01-2000	27-12-2000	10	0.17	0.076	0.024	0.330
2001	16-01-2001	27-12-2001	9	0.18	0.044	0.104	0.241
2002	25-01-2002	10-12-2002	12	0.16	0.047	0.084	0.220
2003	05-02-2003	30-12-2003	12	0.13	0.049	0.030	0.188
2004	15-01-2004	21-12-2004	12	0.13	0.034	0.080	0.189
2005	13-01-2005	09-12-2005	12	0.13	0.025	0.087	0.174
2006	05-01-2006	29-11-2006	12	0.11	0.036	0.049	0.175
2007	25-01-2007	12-12-2007	12	0.12	0.039	0.045	0.172
2008	29-02-2008	05-12-2008	12	0.12	0.026	0.069	0.161
2009	30-01-2009	14-12-2009	12	0.11	0.041	0.051	0.167
2010	21-01-2010	14-12-2010	12	0.07	0.022	0.029	0.099
2011	07-01-2011	09-11-2011	12	0.08	0.026	0.030	0.129
2012	11-01-2012	07-08-2012	8	0.09	0.039	0.045	0.170

Time Series Plot - 0180 Orthophospht mg/l 26-07-2002 to 18-07-2012

50260439; HAMPSHIRE AVON UPSTREAM CONFLUENCE WITH RIVER EBBLE

Year-on-Year Plot - 0180 Orthophospht mg/l 26-07-2002 to 18-07-2012

50260439; HAMPSHIRE AVON UPSTREAM CONFLUENCE WITH RIVER EBBLE



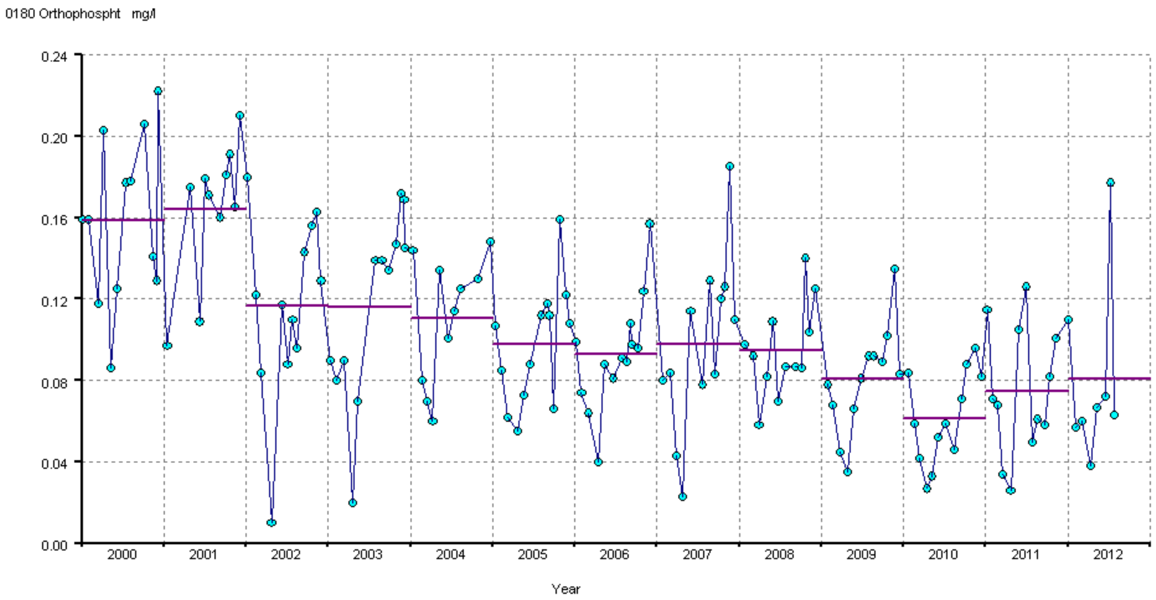
Yearly Summary - 0180 Orthophospht mg/l 26-07-2002 to 18-07-2012

50260439; HAMPSHIRE AVON UPSTREAM CONFLUENCE WITH RIVER EBBLE

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2002	26-07-2002	17-12-2002	5	0.17	0.051	0.114	0.244
2003	12-02-2003	12-12-2003	10	0.13	0.042	0.050	0.179
2004	16-01-2004	09-12-2004	12	0.12	0.036	0.070	0.204
2005	31-01-2005	12-12-2005	12	0.12	0.016	0.105	0.150
2006	11-01-2006	15-12-2006	12	0.10	0.031	0.060	0.162
2007	15-01-2007	17-12-2007	12	0.11	0.035	0.044	0.161
2008	07-01-2008	17-12-2008	12	0.10	0.036	0.010	0.151
2009	12-01-2009	03-12-2009	12	0.12	0.041	0.038	0.178
2010	19-01-2010	08-12-2010	12	0.06	0.022	0.010	0.097
2011	20-01-2011	24-11-2011	12	0.08	0.024	0.041	0.127
2012	11-01-2012	18-07-2012	7	0.07	0.022	0.044	0.097

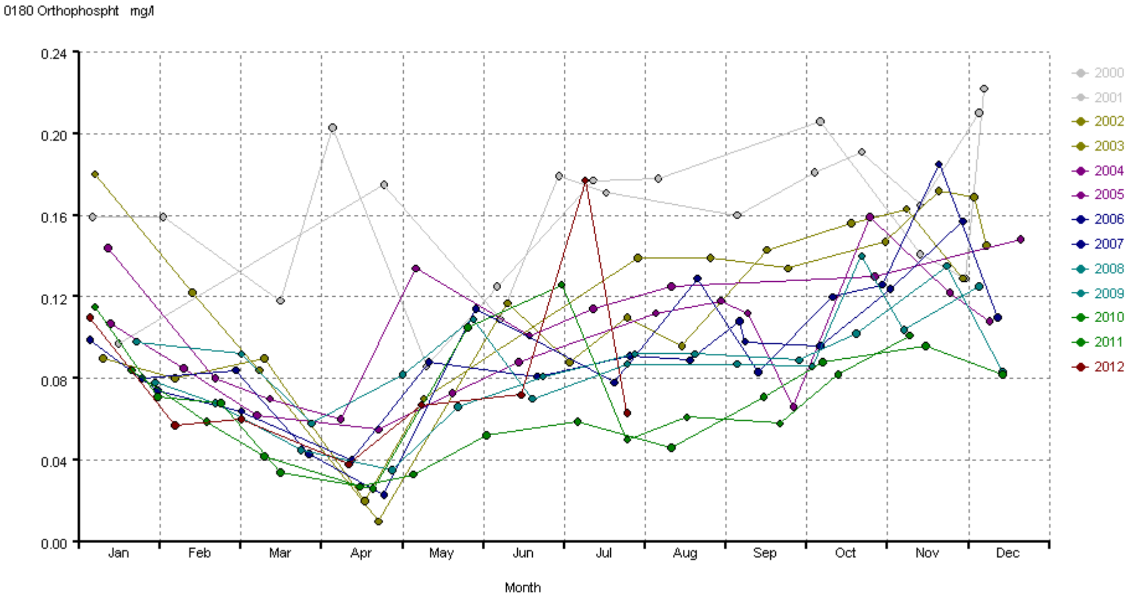
Time Series Plot - 0180 Orthophospht mg/l 06-01-2000 to 25-07-2012

50260536; HAMPSHIRE AVON AT EAST HARNHAM



Year-on-Year Plot - 0180 Orthophospht mg/l 06-01-2000 to 25-07-2012

50260536; HAMPSHIRE AVON AT EAST HARNHAM



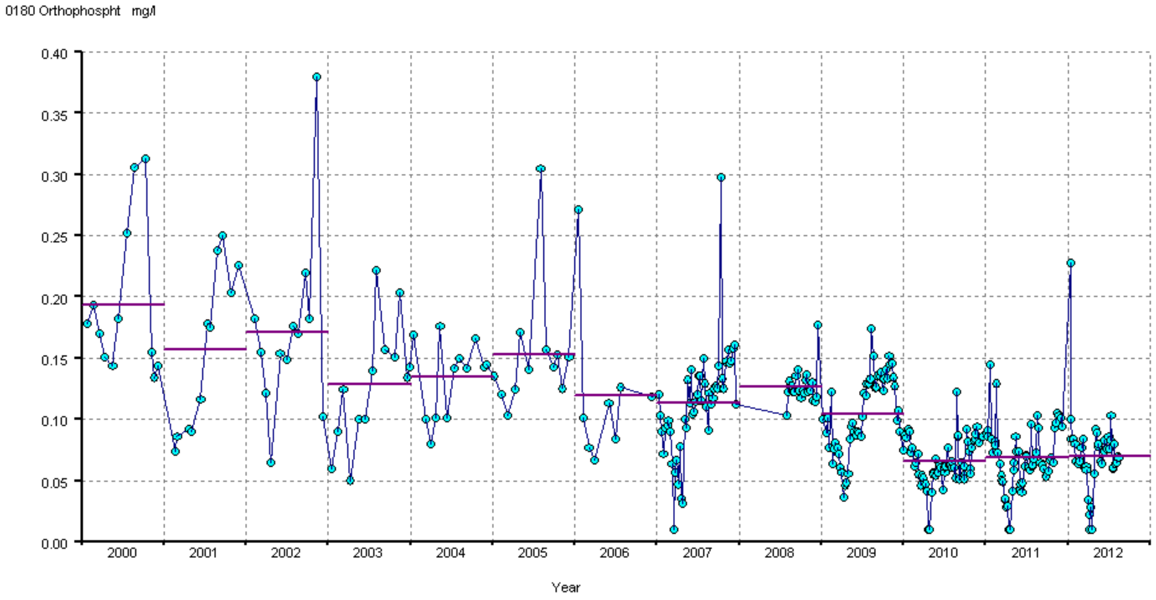
Yearly Summary - 0180 Orthophospht mg/l 06-01-2000 to 25-07-2012

50260536; HAMPSHIRE AVON AT EAST HARNHAM

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	06-01-2000	07-12-2000	12	0.16	0.041	0.086	0.222
2001	16-01-2001	19-12-2001	10	0.16	0.035	0.097	0.210
2002	07-01-2002	29-11-2002	12	0.12	0.045	0.010	0.180
2003	10-01-2003	08-12-2003	12	0.12	0.046	0.020	0.172
2004	12-01-2004	21-12-2004	10	0.11	0.031	0.060	0.148
2005	13-01-2005	09-12-2005	13	0.10	0.029	0.055	0.159
2006	05-01-2006	29-11-2006	13	0.09	0.028	0.040	0.157
2007	25-01-2007	12-12-2007	12	0.10	0.043	0.023	0.185
2008	23-01-2008	10-12-2008	12	0.09	0.023	0.058	0.140
2009	30-01-2009	14-12-2009	12	0.08	0.026	0.035	0.135
2010	21-01-2010	14-12-2010	12	0.06	0.023	0.027	0.096
2011	07-01-2011	09-11-2011	12	0.07	0.032	0.026	0.126
2012	05-01-2012	25-07-2012	8	0.08	0.044	0.038	0.177

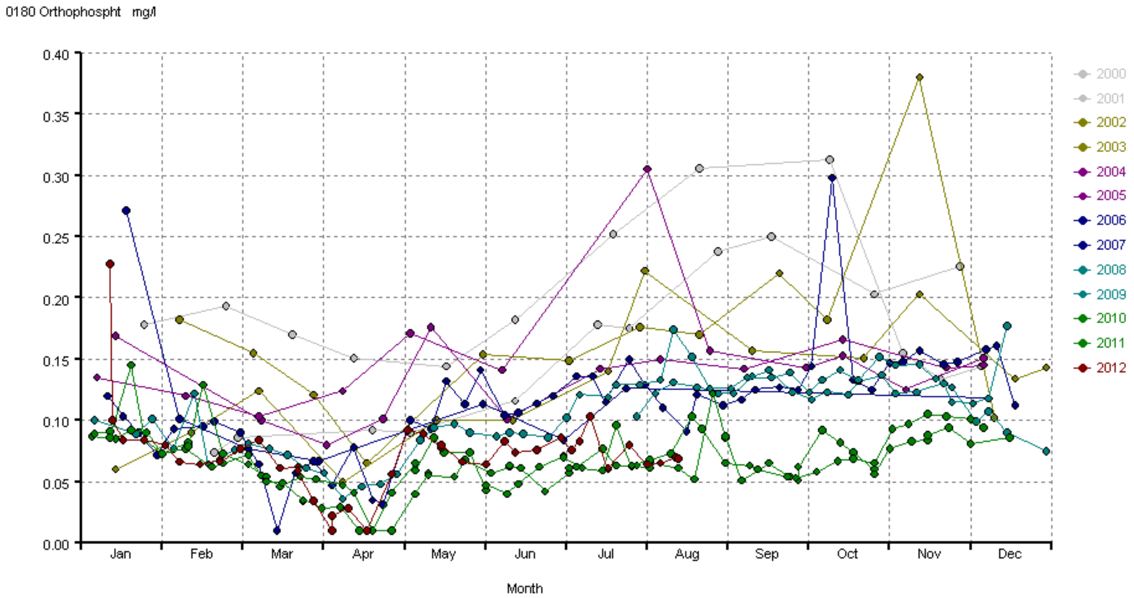
Time Series Plot - 0180 Orthophospht mg/l 25-01-2000 to 13-08-2012

50280344; HAMPSHIRE AVON AT AVON CAUSEWAY



Year-on-Year Plot - 0180 Orthophospht mg/l 25-01-2000 to 13-08-2012

50280344; HAMPSHIRE AVON AT AVON CAUSEWAY



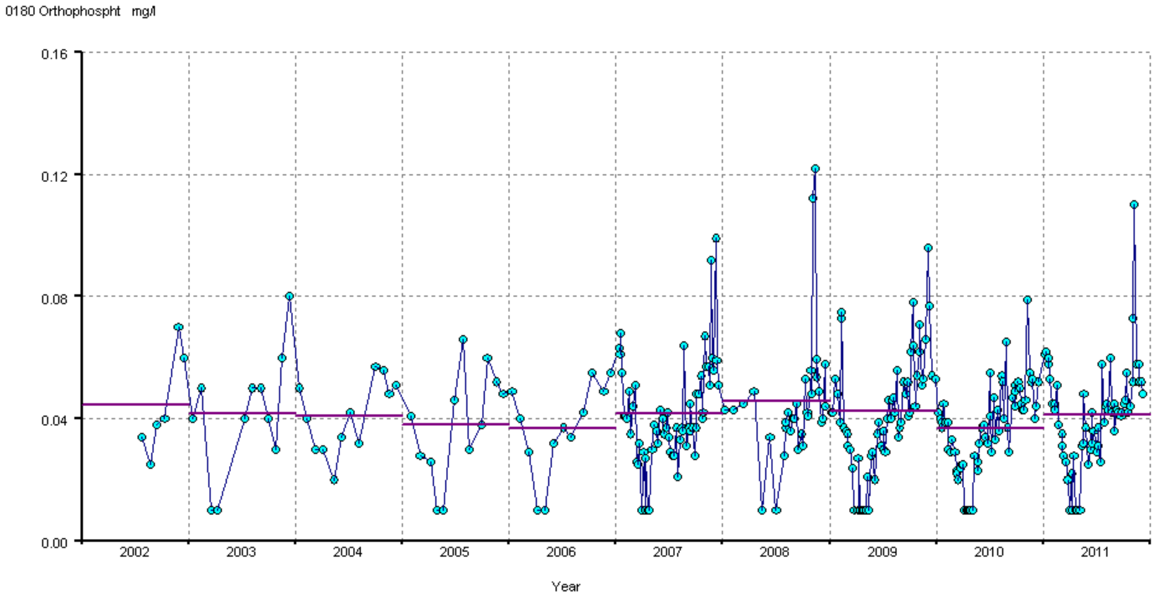
Yearly Summary - 0180 Orthophospht mg/l   25-01-2000 to 13-08-2012

50280344; HAMPSHIRE AVON AT AVON CAUSEWAY

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	25-01-2000	05-12-2000	12	0.19	0.063	0.134	0.313
2001	19-02-2001	27-11-2001	11	0.16	0.067	0.074	0.250
2002	07-02-2002	10-12-2002	12	0.17	0.077	0.065	0.380
2003	14-01-2003	30-12-2003	13	0.13	0.050	0.050	0.222
2004	14-01-2004	06-12-2004	12	0.13	0.031	0.080	0.176
2005	07-01-2005	06-12-2005	12	0.15	0.052	0.103	0.305
2006	18-01-2006	08-12-2006	8	0.12	0.065	0.067	0.271
2007	11-01-2007	18-12-2007	50	0.11	0.044	0.010	0.298
2008	28-07-2008	15-12-2008	21	0.13	0.014	0.103	0.177
2009	06-01-2009	30-12-2009	50	0.10	0.032	0.036	0.174
2010	05-01-2010	16-12-2010	57	0.07	0.019	0.010	0.122
2011	06-01-2011	06-12-2011	61	0.07	0.026	0.010	0.145
2012	12-01-2012	13-08-2012	41	0.07	0.034	0.010	0.228

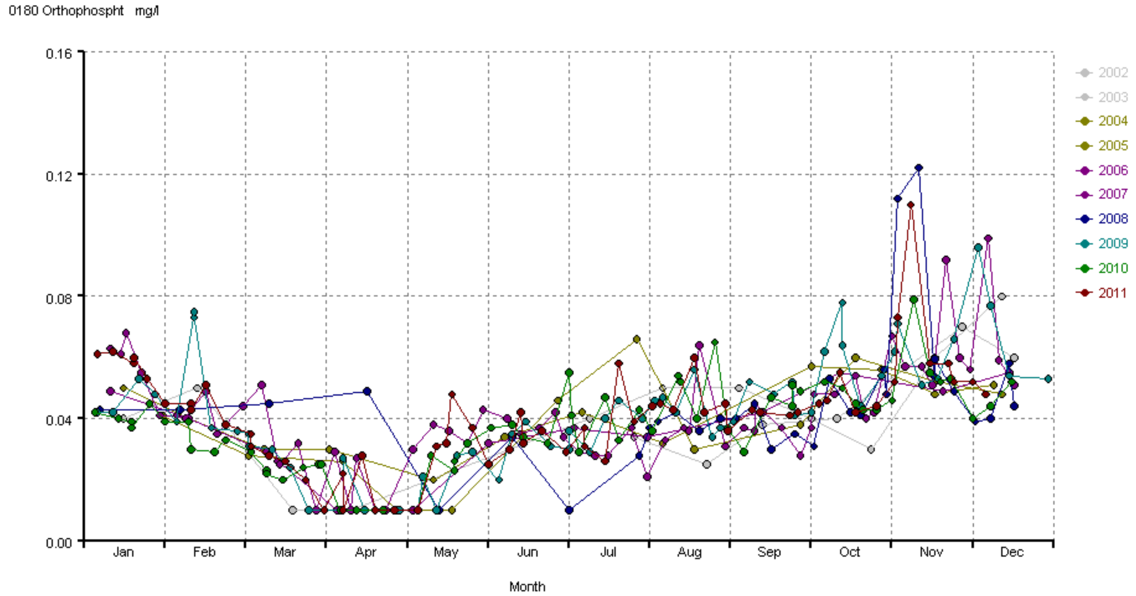
Time Series Plot - 0180 Orthophospht mg/l   26-07-2002 to 06-12-2011

50250102; RIVER EBBLE DOWNSTREAM LONGFORD FISH FARM



Year-on-Year Plot - 0180 Orthophospht mg/l 26-07-2002 to 06-12-2011

50250102; RIVER EBBLE DOWNSTREAM LONGFORD FISH FARM



Yearly Summary - 0180 Orthophospht mg/l 26-07-2002 to 06-12-2011

50250102; RIVER EBBLE DOWNSTREAM LONGFORD FISH FARM

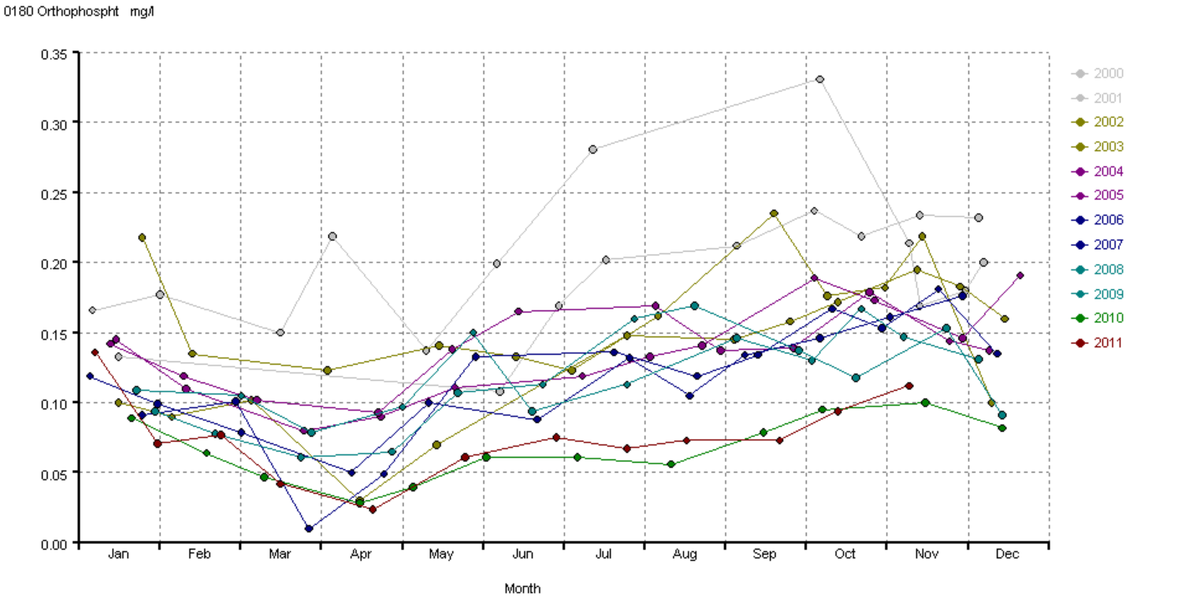
Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2002	26-07-2002	17-12-2002	6	0.04	0.017	0.025	0.070
2003	16-01-2003	12-12-2003	11	0.04	0.020	0.010	0.080
2004	16-01-2004	09-12-2004	12	0.04	0.012	0.020	0.057
2005	31-01-2005	12-12-2005	12	0.04	0.018	0.010	0.066
2006	11-01-2006	15-12-2006	12	0.04	0.015	0.010	0.055
2007	11-01-2007	17-12-2007	61	0.04	0.017	0.010	0.099
2008	07-01-2008	17-12-2008	33	0.05	0.022	0.010	0.122
2009	06-01-2009	30-12-2009	61	0.04	0.020	0.010	0.096
2010	05-01-2010	16-12-2010	61	0.04	0.014	0.010	0.079
2011	06-01-2011	06-12-2011	61	0.04	0.017	0.010	0.110

Time Series Plot - 0180 Orthophospht mg/l 06-01-2000 to 09-11-2011

50260291; HAMPSHIRE AVON AT HALE

Year-on-Year Plot - 0180 Orthophospht mg/l 06-01-2000 to 09-11-2011

50260291; HAMPSHIRE AVON AT HALE



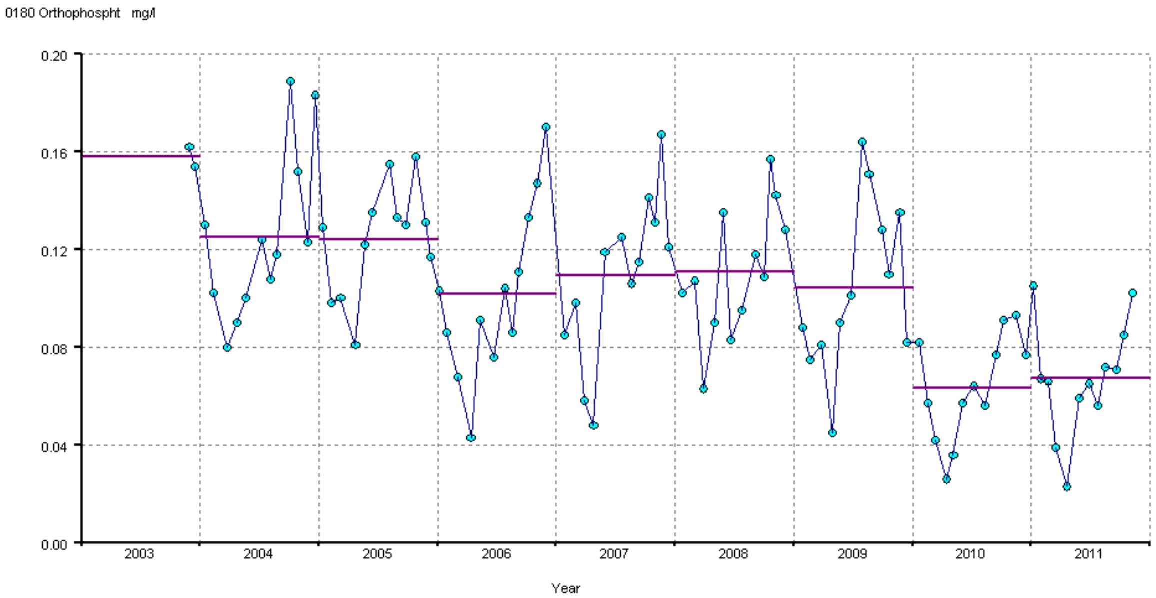
Yearly Summary - 0180 Orthophospht mg/l 06-01-2000 to 09-11-2011

50260291; HAMPSHIRE AVON AT HALE

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	06-01-2000	07-12-2000	12	0.20	0.055	0.137	0.331
2001	16-01-2001	19-12-2001	9	0.19	0.047	0.108	0.237
2002	25-01-2002	10-12-2002	12	0.16	0.044	0.100	0.235
2003	16-01-2003	15-12-2003	12	0.13	0.050	0.030	0.195
2004	15-01-2004	21-12-2004	12	0.14	0.036	0.080	0.191
2005	13-01-2005	09-12-2005	12	0.14	0.025	0.093	0.179
2006	05-01-2006	29-11-2006	12	0.12	0.036	0.050	0.176
2007	25-01-2007	12-12-2007	12	0.12	0.049	0.010	0.181
2008	23-01-2008	05-12-2008	12	0.12	0.027	0.079	0.167
2009	30-01-2009	14-12-2009	12	0.11	0.036	0.061	0.169
2010	21-01-2010	14-12-2010	12	0.07	0.023	0.028	0.100
2011	07-01-2011	09-11-2011	12	0.08	0.029	0.024	0.136

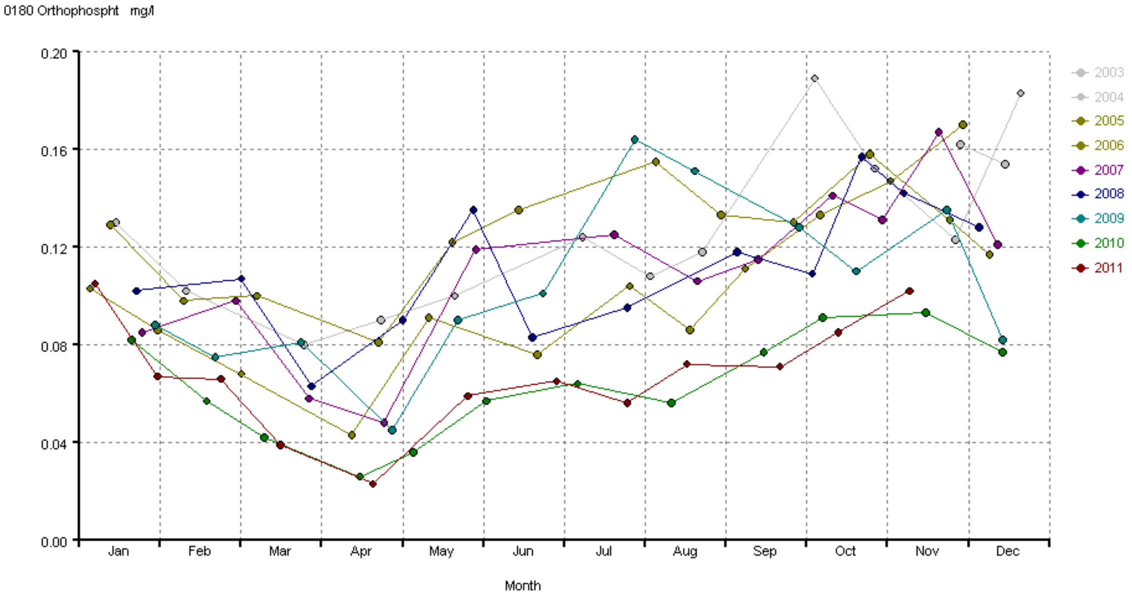
Time Series Plot - 0180 Orthophospht mg/l 28-11-2003 to 09-11-2011

50260409; HAMPSHIRE AVON AT FOOTBRIDGE U/S BARFORD CARRIER



Year-on-Year Plot - 0180 Orthophospht mg/l 28-11-2003 to 09-11-2011

50260409; HAMPSHIRE AVON AT FOOTBRIDGE U/S BARFORD CARRIER



Yearly Summary - 0180 Orthophospht mg/l 28-11-2003 to 09-11-2011

50260409; HAMPSHIRE AVON AT FOOTBRIDGE U/S BARFORD CARRIER

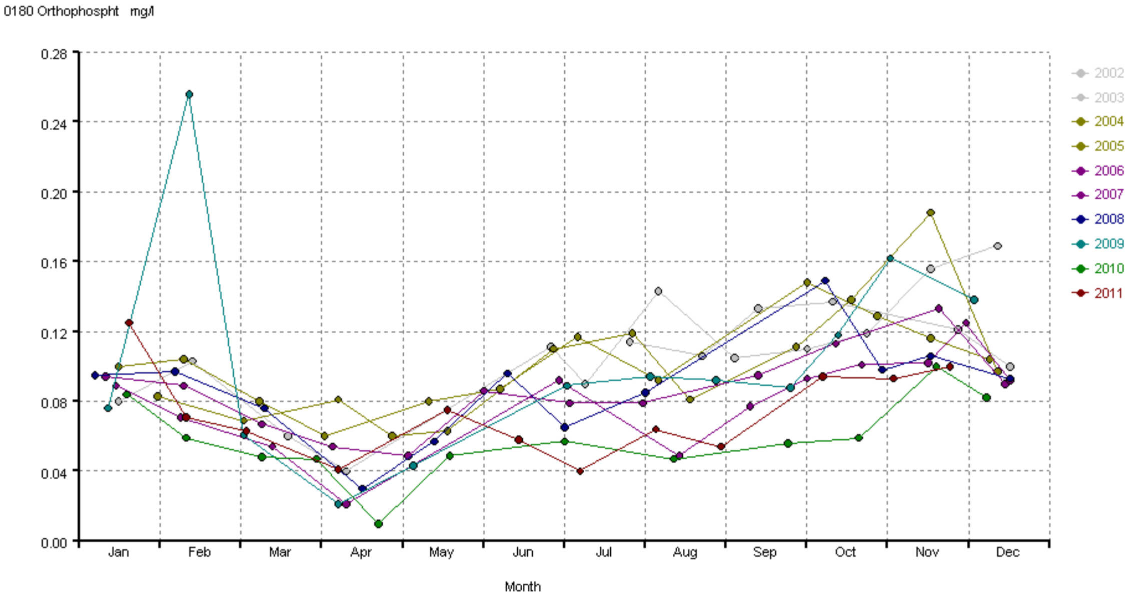
Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2003	28-11-2003	15-12-2003	2	0.16	0.006	0.154	0.162
2004	15-01-2004	21-12-2004	12	0.12	0.034	0.080	0.189
2005	13-01-2005	09-12-2005	12	0.12	0.023	0.081	0.158
2006	05-01-2006	29-11-2006	12	0.10	0.035	0.043	0.170
2007	25-01-2007	12-12-2007	12	0.11	0.034	0.048	0.167
2008	23-01-2008	05-12-2008	12	0.11	0.027	0.063	0.157
2009	30-01-2009	14-12-2009	12	0.10	0.035	0.045	0.164
2010	21-01-2010	14-12-2010	12	0.06	0.022	0.026	0.093
2011	07-01-2011	09-11-2011	12	0.07	0.023	0.023	0.105

Time Series Plot - 0180 Orthophospht mg/l 26-07-2002 to 24-11-2011

50260443; BRITFORD NAVIGATION CHANNEL AT LONGFORD

Year-on-Year Plot - 0180 Orthophospht mg/l 26-07-2002 to 24-11-2011

50260443; BRITFORD NAVIGATION CHANNEL AT LONGFORD



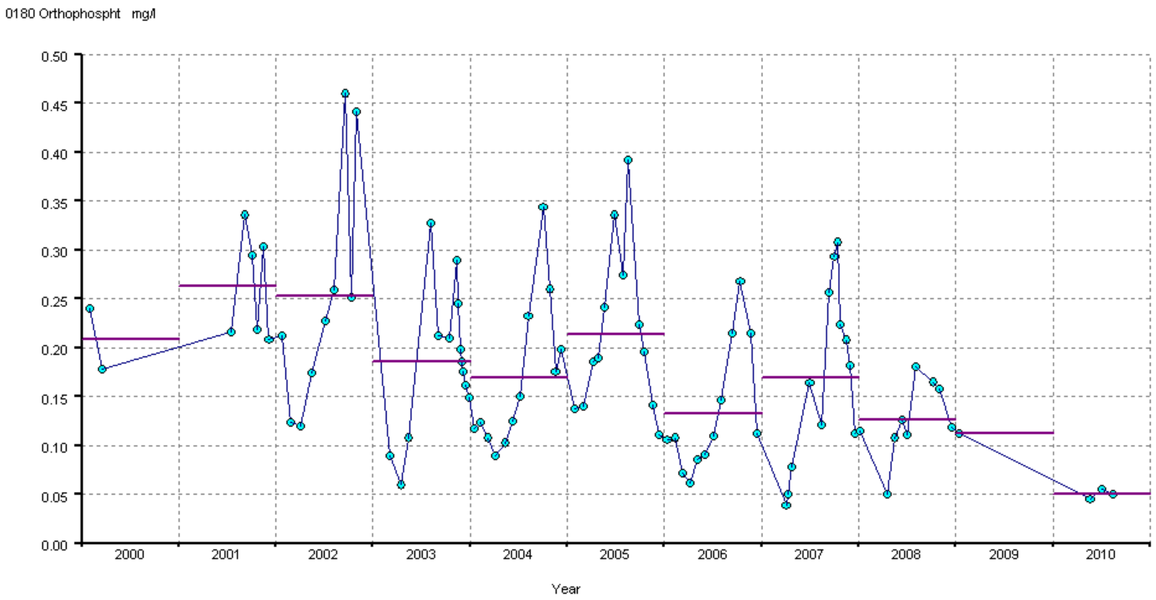
Yearly Summary - 0180 Orthophospht mg/l 26-07-2002 to 24-11-2011

50260443; BRITFORD NAVIGATION CHANNEL AT LONGFORD

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2002	26-07-2002	17-12-2002	6	0.12	0.015	0.100	0.137
2003	16-01-2003	12-12-2003	12	0.11	0.037	0.040	0.169
2004	16-01-2004	09-12-2004	12	0.10	0.024	0.060	0.148
2005	31-01-2005	12-12-2005	12	0.10	0.037	0.060	0.188
2006	11-01-2006	15-12-2006	12	0.09	0.023	0.049	0.133
2007	15-01-2007	17-12-2007	12	0.08	0.028	0.021	0.125
2008	07-01-2008	17-12-2008	12	0.09	0.029	0.030	0.149
2009	12-01-2009	03-12-2009	12	0.10	0.062	0.021	0.256
2010	19-01-2010	08-12-2010	12	0.06	0.023	0.010	0.100
2011	20-01-2011	24-11-2011	12	0.07	0.026	0.040	0.125

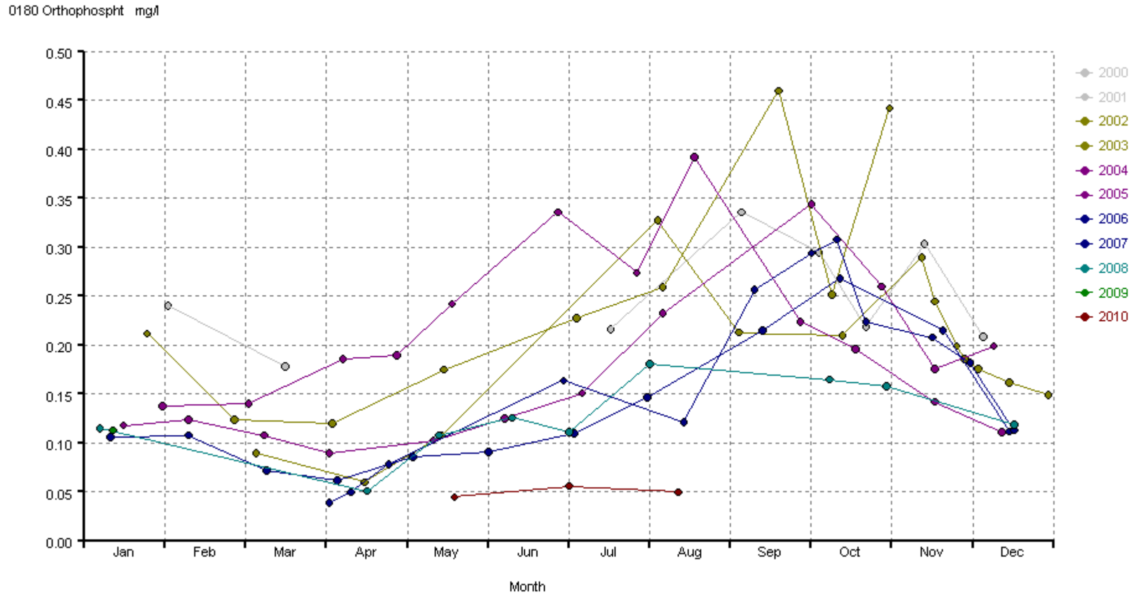
Time Series Plot - 0180 Orthophospht mg/l 02-02-2000 to 12-08-2010

50260493; HAMPSHIRE AVON DOWNSTREAM OF SALISBURY STW FINA EFFLUENT



Year-on-Year Plot - 0180 Orthophospht mg/l 02-02-2000 to 12-08-2010

50260493; HAMPSHIRE AVON DOWNSTREAM OF SALISBURY STW FINA EFFLUENT



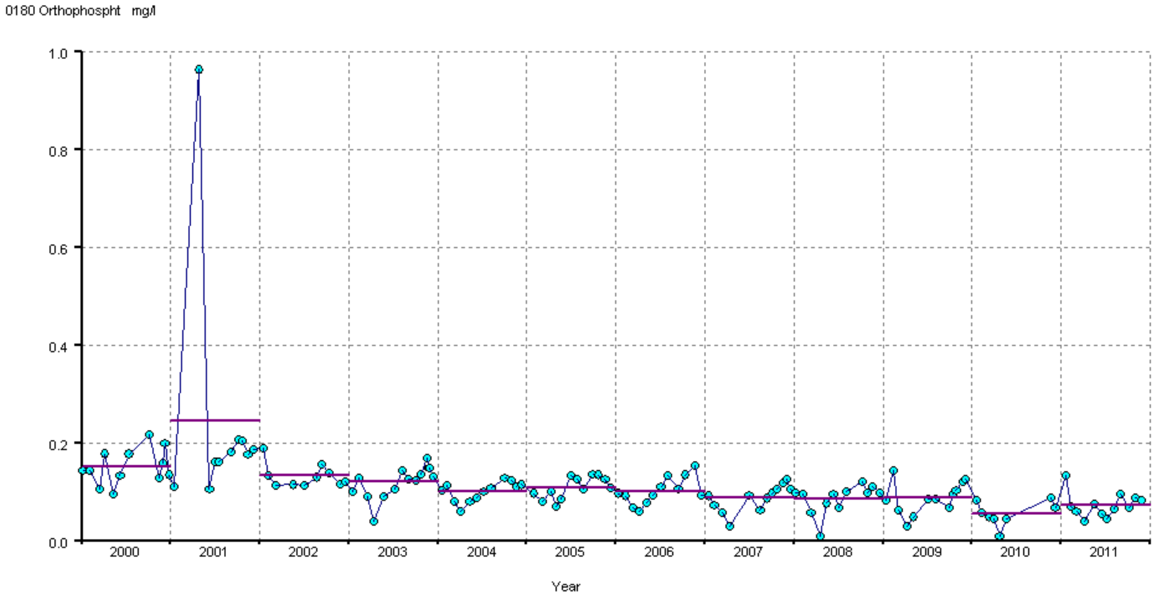
Yearly Summary - 0180 Orthophospht mg/l 02-02-2000 to 12-08-2010

50260493; HAMPSHIRE AVON DOWNSTREAM OF SALISBURY STW FINA EFFLUENT

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	02-02-2000	16-03-2000	2	0.21	0.044	0.178	0.240
2001	17-07-2001	19-12-2001	6	0.26	0.055	0.209	0.336
2002	25-01-2002	31-10-2002	9	0.25	0.123	0.120	0.460
2003	05-03-2003	30-12-2003	13	0.19	0.076	0.060	0.328
2004	16-01-2004	09-12-2004	12	0.17	0.077	0.090	0.344
2005	31-01-2005	12-12-2005	12	0.21	0.085	0.111	0.392
2006	11-01-2006	15-12-2006	12	0.13	0.065	0.062	0.268
2007	02-04-2007	17-12-2007	12	0.17	0.092	0.039	0.308
2008	07-01-2008	17-12-2008	9	0.13	0.039	0.051	0.181
2009	12-01-2009	12-03-2009	1	0.11		0.113	0.113
2010	19-05-2010	12-08-2010	3	0.05	0.006	0.045	0.056

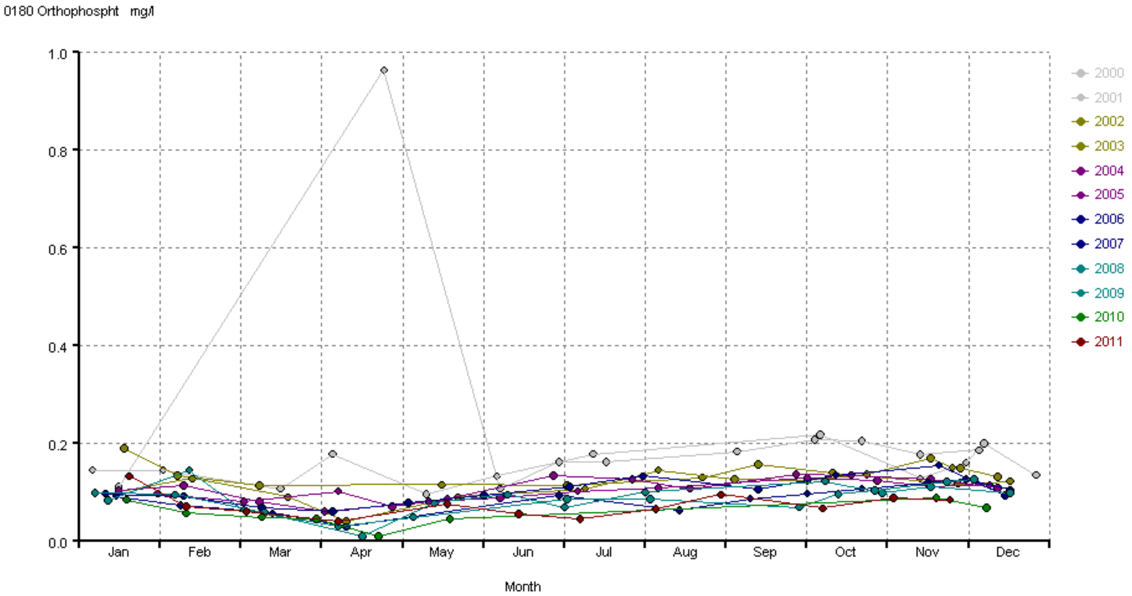
Time Series Plot - 0180 Orthophospht mg/l 06-01-2000 to 24-11-2011

50260521; HAMPSHIRE AVON UPSTREAM OF SALISBURY STW



Year-on-Year Plot - 0180 Orthophospht mg/l 06-01-2000 to 24-11-2011

50260521; HAMPSHIRE AVON UPSTREAM OF SALISBURY STW



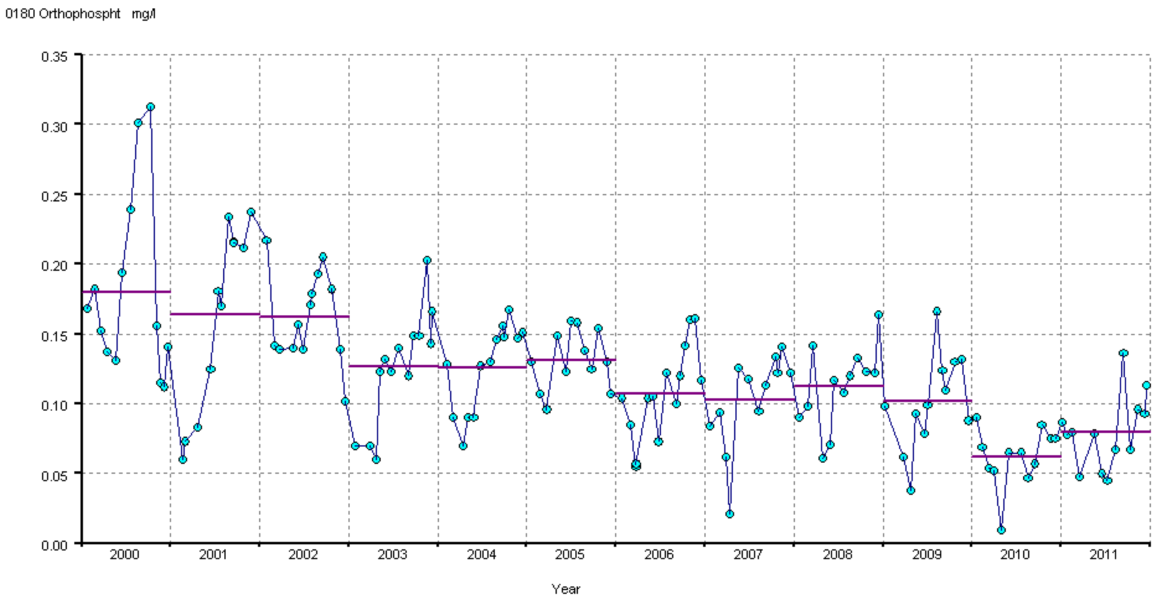
Yearly Summary - 0180 Orthophospht mg/l 06-01-2000 to 24-11-2011

50260521; HAMPSHIRE AVON UPSTREAM OF SALISBURY STW

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	06-01-2000	27-12-2000	12	0.15	0.036	0.096	0.218
2001	16-01-2001	19-12-2001	10	0.25	0.254	0.107	0.963
2002	18-01-2002	17-12-2002	10	0.13	0.024	0.113	0.190
2003	16-01-2003	12-12-2003	14	0.12	0.033	0.040	0.170
2004	16-01-2004	09-12-2004	12	0.10	0.020	0.060	0.129
2005	31-01-2005	12-12-2005	12	0.11	0.023	0.071	0.137
2006	11-01-2006	15-12-2006	12	0.10	0.028	0.061	0.155
2007	15-01-2007	17-12-2007	12	0.09	0.028	0.029	0.126
2008	07-01-2008	17-12-2008	12	0.09	0.030	0.010	0.122
2009	12-01-2009	03-12-2009	12	0.09	0.033	0.030	0.145
2010	19-01-2010	08-12-2010	8	0.06	0.025	0.010	0.088
2011	20-01-2011	24-11-2011	12	0.07	0.025	0.040	0.133

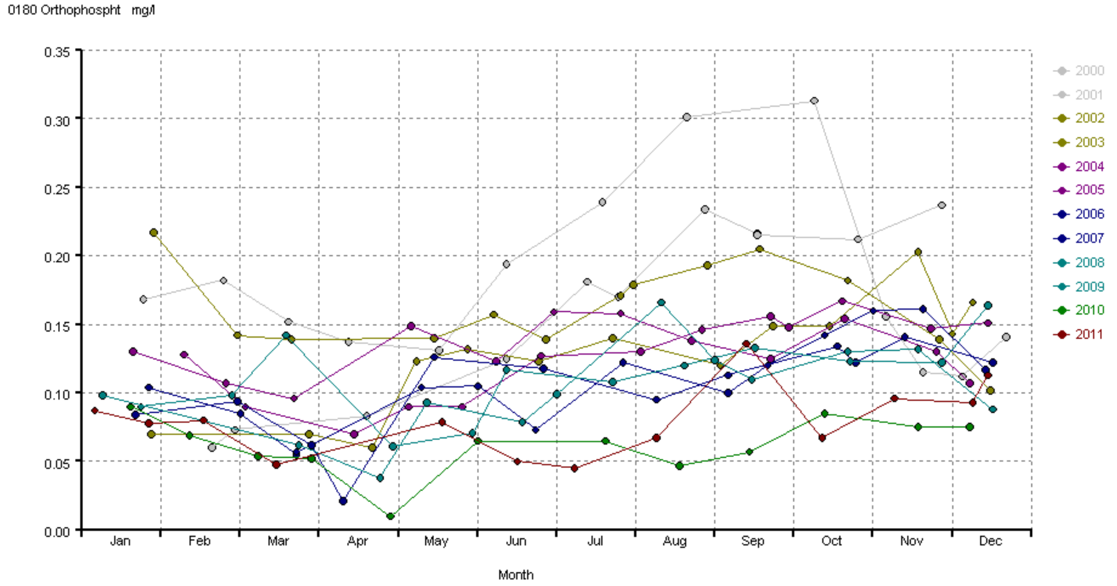
Time Series Plot - 0180 Orthophospht mg/l 25-01-2000 to 15-12-2011

50280271; HAMPSHIRE AVON AT KNAPP MILL



Year-on-Year Plot - 0180 Orthophospht mg/l 25-01-2000 to 15-12-2011

50280271; HAMPSHIRE AVON AT KNAPP MILL



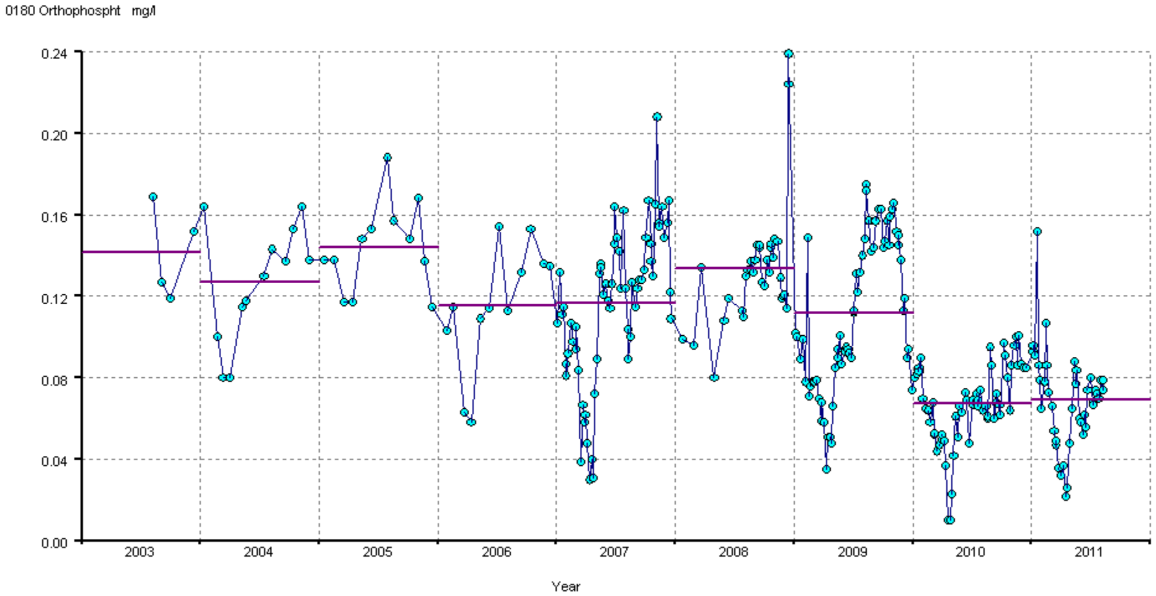
Yearly Summary - 0180 Orthophospht mg/l 25-01-2000 to 15-12-2011

50280271; HAMPSHIRE AVON AT KNAPP MILL

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	25-01-2000	22-12-2000	13	0.18	0.066	0.112	0.313
2001	19-02-2001	27-11-2001	11	0.16	0.067	0.060	0.237
2002	29-01-2002	16-12-2002	13	0.16	0.033	0.102	0.217
2003	28-01-2003	17-12-2003	13	0.13	0.041	0.060	0.203
2004	09-02-2004	15-12-2004	13	0.13	0.031	0.070	0.167
2005	21-01-2005	08-12-2005	12	0.13	0.021	0.096	0.159
2006	27-01-2006	14-12-2006	14	0.11	0.033	0.055	0.161
2007	22-01-2007	17-12-2007	12	0.10	0.034	0.021	0.141
2008	24-01-2008	15-12-2008	12	0.11	0.029	0.061	0.164
2009	06-01-2009	17-12-2009	12	0.10	0.034	0.038	0.166
2010	20-01-2010	08-12-2010	12	0.06	0.021	0.010	0.090
2011	06-01-2011	15-12-2011	13	0.08	0.026	0.045	0.136

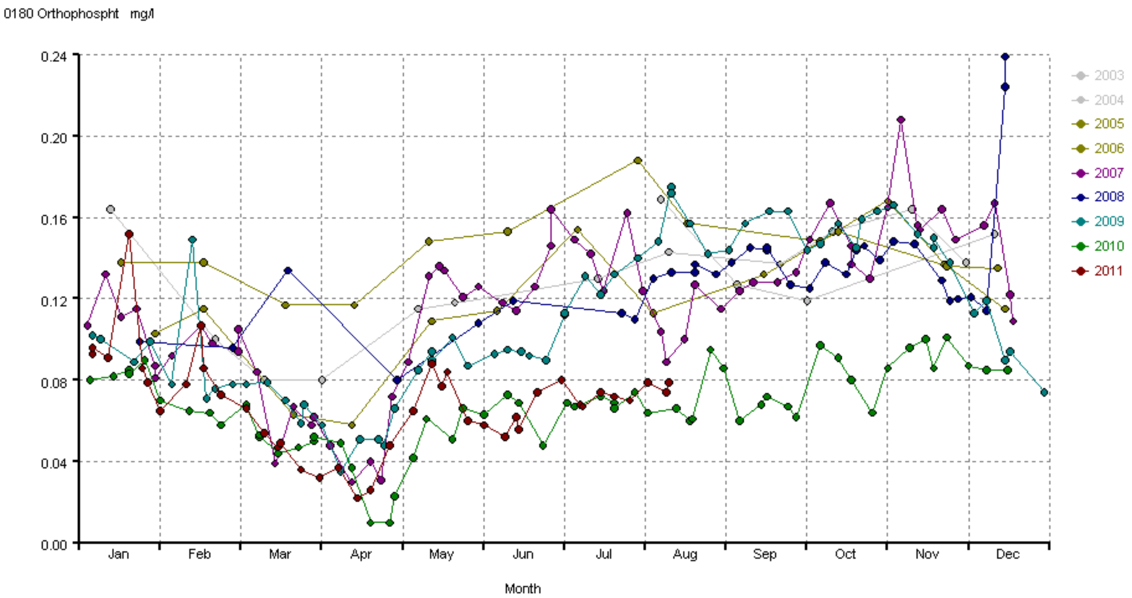
Time Series Plot - 0180 Orthophospht mg/l 07-08-2003 to 10-08-2011

50280531; HAMPSHIRE AVON AT ELLINGHAM



Year-on-Year Plot - 0180 Orthophospht mg/l 07-08-2003 to 10-08-2011

50280531; HAMPSHIRE AVON AT ELLINGHAM



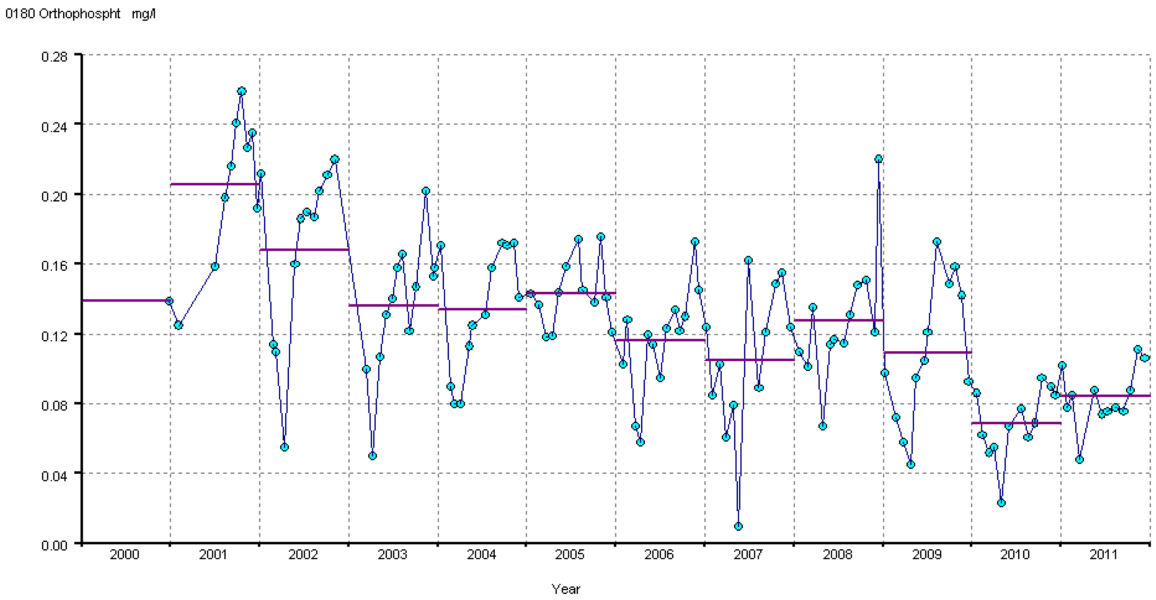
Yearly Summary - 0180 Orthophospht mg/l — 07-08-2003 to 10-08-2011

50280531; HAMPSHIRE AVON AT ELLINGHAM

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2003	07-08-2003	11-12-2003	4	0.14	0.023	0.119	0.169
2004	13-01-2004	30-11-2004	12	0.13	0.029	0.080	0.164
2005	17-01-2005	15-12-2005	12	0.14	0.022	0.115	0.188
2006	30-01-2006	12-12-2006	12	0.12	0.030	0.058	0.154
2007	04-01-2007	18-12-2007	62	0.12	0.037	0.030	0.208
2008	24-01-2008	15-12-2008	33	0.13	0.030	0.080	0.239
2009	06-01-2009	30-12-2009	62	0.11	0.038	0.035	0.175
2010	05-01-2010	16-12-2010	61	0.07	0.020	0.010	0.101
2011	06-01-2011	10-08-2011	40	0.07	0.024	0.022	0.152

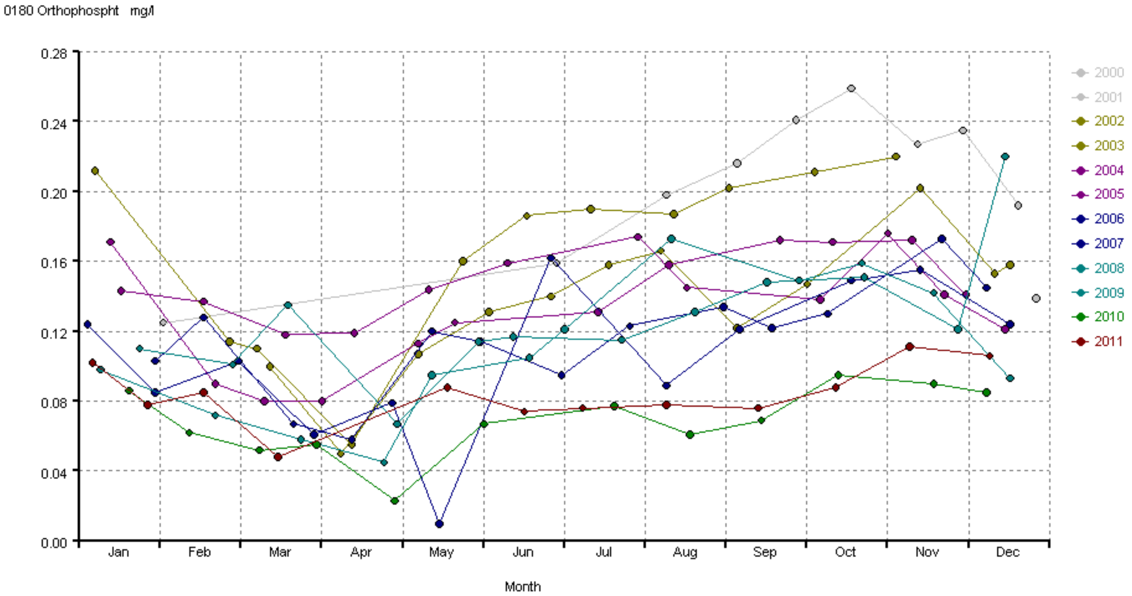
Time Series Plot - 0180 Orthophospht mg/l — 27-12-2000 to 09-12-2011

50280545; AVON DOWNSTREAM BICKTON GQA



Year-on-Year Plot - 0180 Orthophospht mg/l 27-12-2000 to 09-12-2011

50280545; AVON DOWNSTREAM BICKTON GQA



Yearly Summary - 0180 Orthophospht mg/l 27-12-2000 to 09-12-2011

50280545; AVON DOWNSTREAM BICKTON GQA

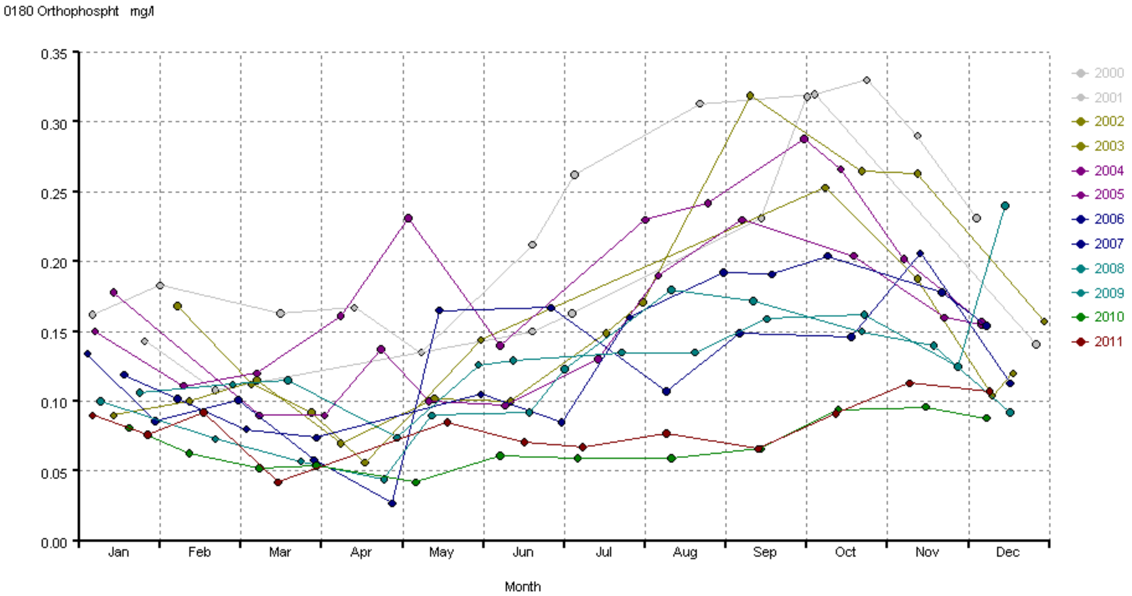
Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	27-12-2000	27-12-2000	1	0.14		0.139	0.139
2001	02-02-2001	20-12-2001	9	0.21	0.042	0.125	0.259
2002	07-01-2002	22-11-2002	11	0.17	0.053	0.055	0.220
2003	12-03-2003	17-12-2003	12	0.14	0.039	0.050	0.202
2004	13-01-2004	30-11-2004	12	0.13	0.036	0.080	0.172
2005	17-01-2005	15-12-2005	12	0.14	0.019	0.118	0.176
2006	30-01-2006	08-12-2006	13	0.12	0.031	0.058	0.173
2007	04-01-2007	17-12-2007	12	0.11	0.044	0.010	0.162
2008	24-01-2008	15-12-2008	12	0.13	0.037	0.067	0.220
2009	09-01-2009	17-12-2009	12	0.11	0.041	0.045	0.173
2010	20-01-2010	08-12-2010	12	0.07	0.020	0.023	0.095
2011	06-01-2011	09-12-2011	12	0.08	0.017	0.048	0.111

Time Series Plot - 0180 Orthophospht mg/l 06-01-2000 to 09-12-2011

50280572; HAMPSHIRE AVON D/S FORDNGBRIDGE STW

Year-on-Year Plot - 0180 Orthophospht mg/l 06-01-2000 to 09-12-2011

50280572; HAMPSHIRE AVON D/S FORDNGBRIDGE STW



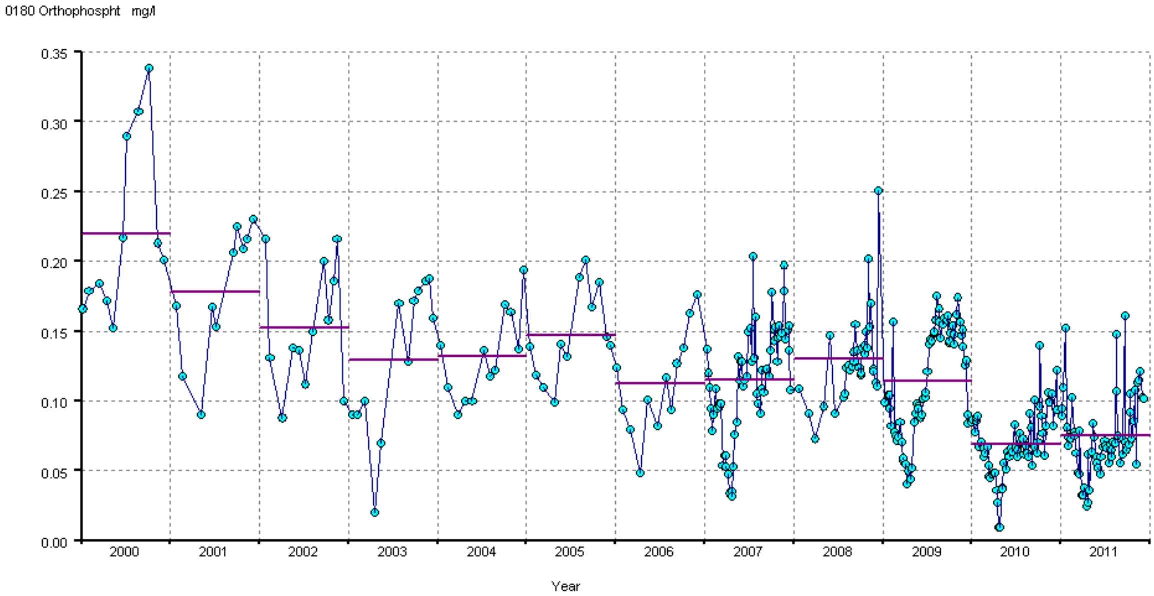
Yearly Summary - 0180 Orthophospht mg/l 06-01-2000 to 09-12-2011

50280572; HAMPSHIRE AVON D/S FORDNGBRIDGE STW

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	06-01-2000	27-12-2000	10	0.21	0.069	0.135	0.320
2001	26-01-2001	04-12-2001	9	0.22	0.082	0.108	0.330
2002	07-02-2002	18-12-2002	9	0.14	0.059	0.056	0.253
2003	14-01-2003	30-12-2003	12	0.16	0.081	0.070	0.319
2004	14-01-2004	06-12-2004	12	0.15	0.047	0.090	0.230
2005	07-01-2005	06-12-2005	12	0.19	0.059	0.111	0.288
2006	18-01-2006	08-12-2006	12	0.14	0.048	0.074	0.204
2007	04-01-2007	17-12-2007	12	0.12	0.050	0.027	0.206
2008	24-01-2008	15-12-2008	12	0.13	0.040	0.074	0.240
2009	09-01-2009	17-12-2009	12	0.11	0.044	0.044	0.180
2010	20-01-2010	08-12-2010	12	0.07	0.018	0.042	0.096
2011	06-01-2011	09-12-2011	12	0.08	0.019	0.042	0.113

Time Series Plot - 0180 Orthophospht mg/l 06-01-2000 to 06-12-2011

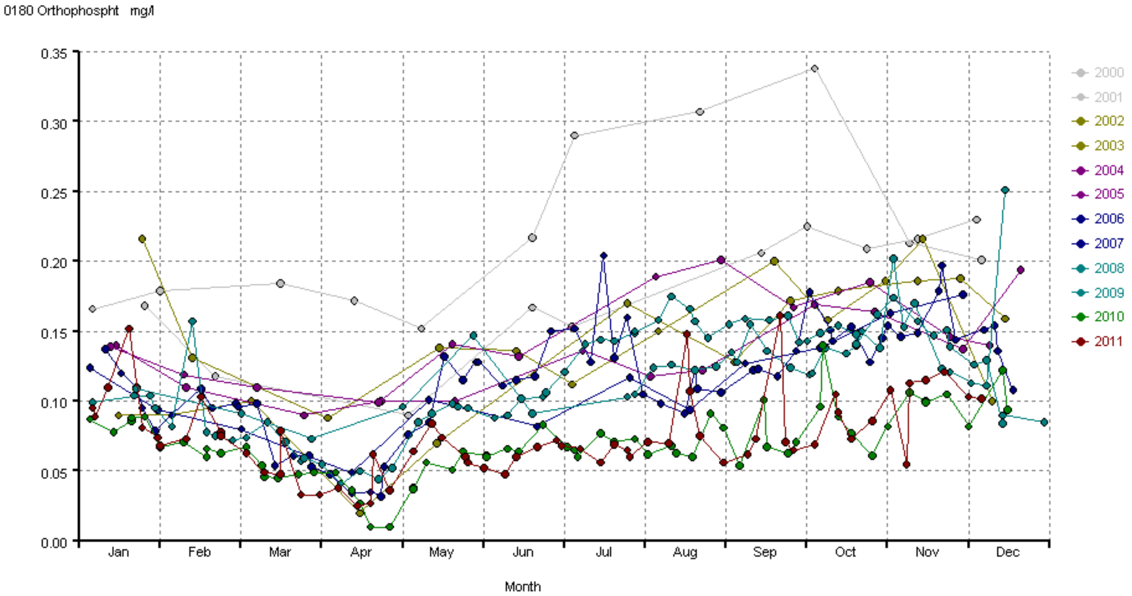
50280585; HAMPSHIRE AVON AT FORDINGBRIDGE



Year-on-Year Plot - 0180 Orthophospht mg/l

06-01-2000 to 06-12-2011

50280585; HAMPSHIRE AVON AT FORDINGBRIDGE



Yearly Summary - 0180 Orthophospht mg/l

06-01-2000 to 06-12-2011

50280585; HAMPSHIRE AVON AT FORDINGBRIDGE

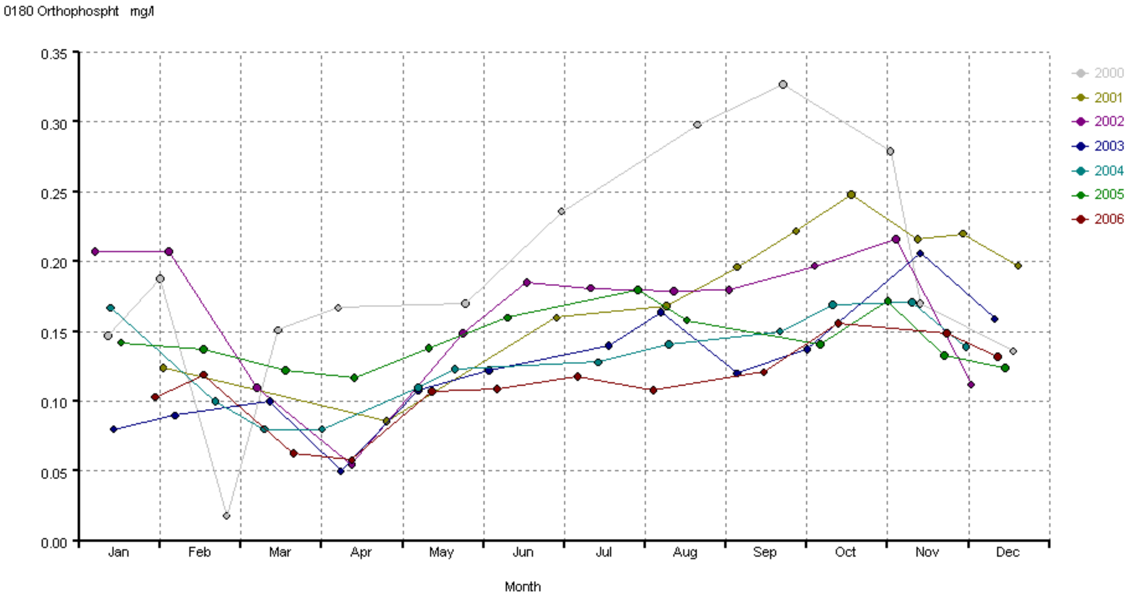
Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	06-01-2000	06-12-2000	11	0.22	0.063	0.152	0.338
2001	26-01-2001	04-12-2001	10	0.18	0.047	0.090	0.230
2002	25-01-2002	10-12-2002	12	0.15	0.044	0.088	0.216
2003	16-01-2003	15-12-2003	12	0.13	0.055	0.020	0.188
2004	15-01-2004	21-12-2004	12	0.13	0.032	0.090	0.194
2005	13-01-2005	09-12-2005	12	0.15	0.032	0.099	0.201
2006	05-01-2006	29-11-2006	12	0.11	0.036	0.049	0.176
2007	11-01-2007	18-12-2007	61	0.12	0.039	0.032	0.204
2008	23-01-2008	15-12-2008	33	0.13	0.033	0.073	0.251
2009	06-01-2009	30-12-2009	62	0.11	0.039	0.041	0.175
2010	05-01-2010	16-12-2010	61	0.07	0.024	0.010	0.140
2011	06-01-2011	06-12-2011	61	0.08	0.028	0.025	0.161

Time Series Plot - 0180 Orthophospht mg/l 12-01-2000 to 12-12-2006

C0217000; AVON IBSLEY

Year-on-Year Plot - 0180 Orthophospht mg/l 12-01-2000 to 12-12-2006

C0217000; AVON IBSLEY



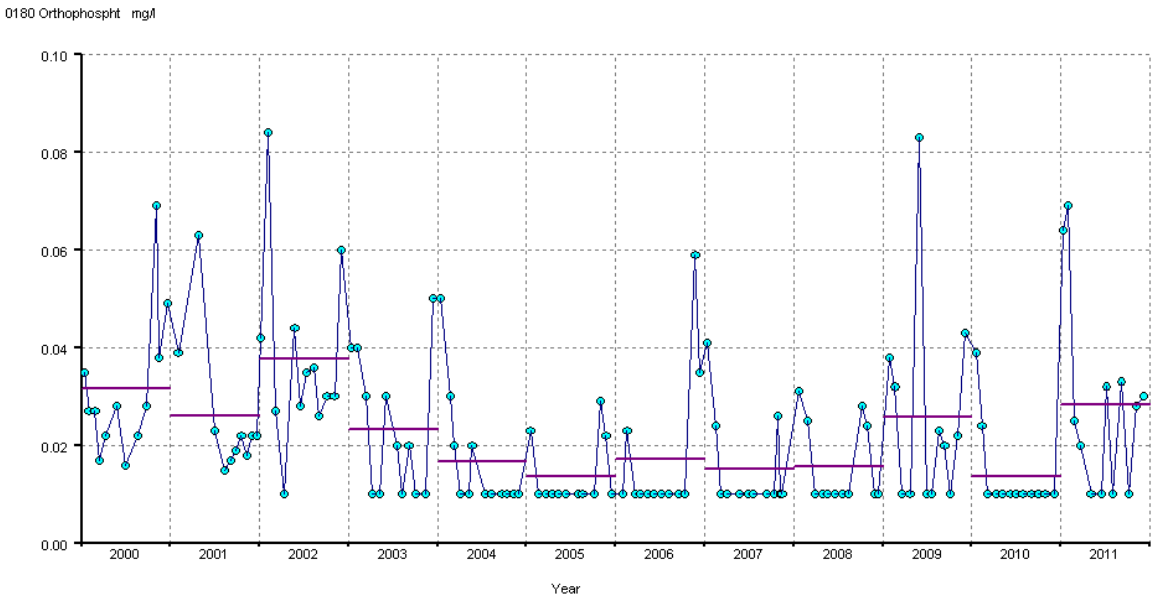
Yearly Summary - 0180 Orthophospht mg/l 12-01-2000 to 12-12-2006

C0217000; AVON IBSLEY

Year	Start Date	End Date	N	Mean	Std Dev	Min	Max
2000	12-01-2000	18-12-2000	12	0.19	0.084	0.018	0.327
2001	02-02-2001	20-12-2001	10	0.18	0.050	0.086	0.248
2002	07-01-2002	02-12-2002	12	0.16	0.049	0.055	0.216
2003	14-01-2003	17-12-2003	12	0.12	0.042	0.050	0.206
2004	13-01-2004	30-11-2004	12	0.13	0.032	0.080	0.171
2005	17-01-2005	15-12-2005	12	0.14	0.020	0.117	0.180
2006	30-01-2006	12-12-2006	12	0.11	0.029	0.058	0.156

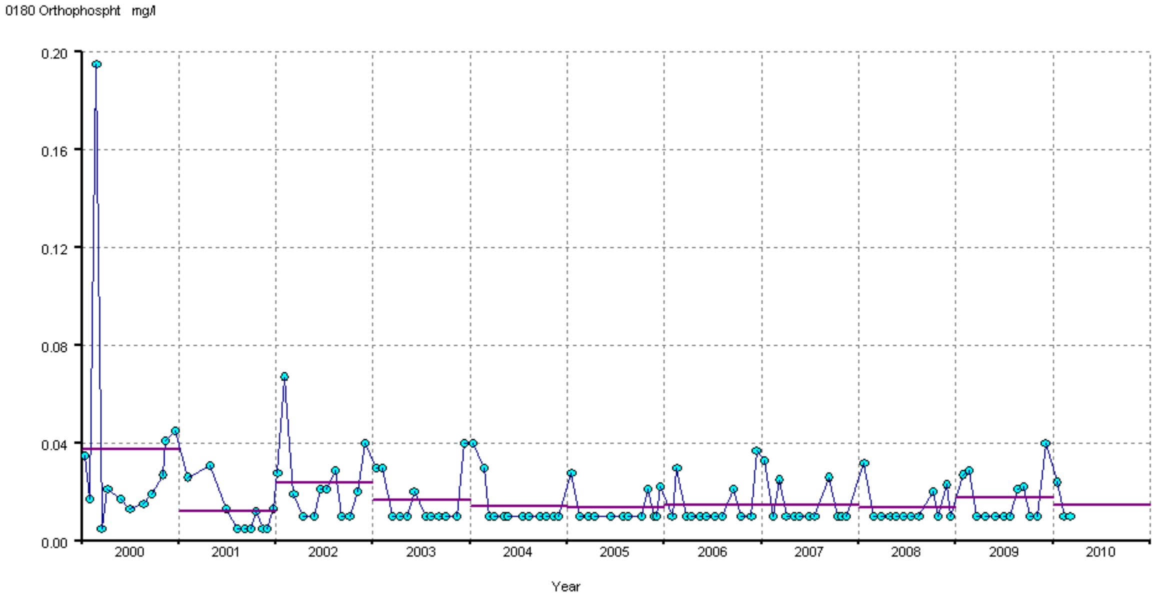
Time Series Plot - 0180 Orthophospht mg/l 12-01-2000 to 08-12-2011

50270104; ASHFORD WATER U/S CONFLUENCE WITH HAMPSHIRE AVON



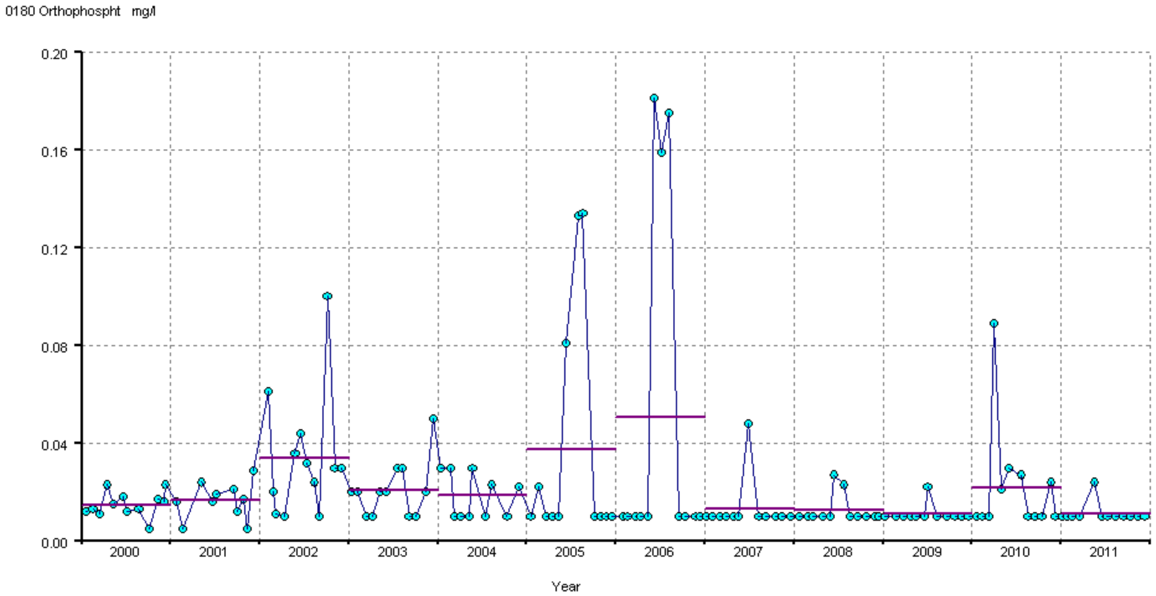
Time Series Plot - 0180 Orthophospht mg/l 12-01-2000 to 05-03-2010

50270207; SWEATSFORD WATER U/S CONFLUENCE



Time Series Plot - 0180 Orthophospht mg/l 18-01-2000 to 09-12-2011

50281314; DOCKENS WATER AT A338



ANNEX 3.2:1: CURRENT DEPLOYMENT OF RELEVANT AGRI-ENVIRONMENT OPTIONS WITHIN THE HAMPSHIRE AVON SAC CATCHMENT WITH NOTES ON EFFECTIVENESS AT REDUCING AGRICULTURAL POLLUTION

Draft Effectiveness of Agri-environment schemes

The effectiveness of agri-environment options, in particular Environmental Stewardship (ES) in reducing/preventing sediment movement, nutrient losses and their delivery to watercourses will depend on the options selected, their extent and exact location within the catchment.

Outlined below is a discussion of how groups of options can contribute to addressing P pollution arising from agriculture. Details on options and areas within the River Avon corridor can be found in Table 1 below.

Buffer strips and Management of Field Corners

Currently a total of 28.67 ha are entered into these options. Buffer strips can act as a sediment trap by slowing down overland flow as well as helping to reduce nutrient transfers. However, the effectiveness of these options is dependent whether they are located adjacent to watercourses and whether under drainage is present. Only 7.81 ha are specifically recorded adjacent to watercourses. The remaining 20.86 ha have not been specifically identified and therefore it must be assumed that these buffer strips/field corners have been established for purposes other than to intercept potential pollutants.

Permanent grassland/rush pastures with low or very low inputs

Permanent grassland options prevent grassland intensification and help to maintains existing stocking rates or potentially reduces stocking rates. It also prevents the risk of ploughing. The removal of livestock during the winter period will also reduce the risk of poaching and hence sediment and nutrient delivery to watercourses. The overall impact is difficult to assess as these areas are likely to have been present rather than arising from arable reversion or intensificationt. Currently within the river corridor there are 520.05 ha in the low or very low input grasslands. 20 ha of the Former Habitat Scheme (water fringe option) in the riparian zone are still present in the catchment. This usually took the form of 10 m – 20 m buffer strip adjacent to a watercourse.

Maintenance/restoration HLS Grassland options for species

These grassland options primarily aim to provide suitable habitat for species e.g. species rich grassland, breeding or over wintering waders. These options have the capability to intercept, capture sediment and absorb nutrients and will therefore have some impact on mitigating sediment and P delivery to watercourses.

Maintenance/restoration of fens, woodland and traditional water meadows

24.2 ha have been entered into these options. As above, in general these options have the capability to intercept and capture sediment and absorb nutrients and will therefore have some impact on mitigating sediment and P delivery to watercourses

Resource protection options

Resource protection options appear to be poorly represented with catchment, with only 0.74 ha been reverted from arable cropping. 80.86 ha have been entered into the seasonal livestock removal on a grassland option. Seasonal livestock removal will reduce the risk of soil compaction during the late autumn/winter period when soils are wet and therefore help to reduce the risk of surface run-off and transport of pollutants to watercourses. Maintenance of 1.8 km of watercourse fencing will exclude livestock from watercourses, preventing pollutants, principally FIO's and sediment derived from eroded banks from directly entering watercourses.

The effectiveness of the above agri-environment options will dependent on the proportion of pollution contributing areas of the catchment that have been entered into specific options that capable of reducing/preventing sediment P loss (source options), reduced connectivity (pathways options) and receptor (water protection options) .

An assessment/modelling exercise needs to be carried out so as to assist in the estimation of how effective the current deployment of ES options are at reducing sediment and P loss and delivery to watercourses.

Subsequently a further modelling exercise needs to be undertaken so as to help determine the coverage and specific areas where appropriate ES options should be deployed. The suite of ES options that would be suitable will be dependent upon the farming systems e.g. arable, livestock, infrastructure etc that could be contributing to problem. This approach should help to improve option effectiveness and therefore help reduce agriculture's sediment and P loading to the River Avon.

Table 1 Agri-environment options and areas within River Avon corridor

	WA of UA (Units 1 & 2)	E of UA	U A (Unit 3)	U A (Unit 4)	Nadder to Avon (Unit 9)	Nadder (Unit 8)	Wylye (Unit 5)	Wylye (Unit 6)	Wylye (Unit 7)	Bourne (Unit 10)
EE3 6m buffer strips on cultivated land	2.22	1.48	10.72							
O/EF1 Management of field corners	2.66									
EE/OE/HE6 6m buffer strips on intensive grassland								3.78		
O/EE/HE10 6 m buffer strip on intensive grassland next to watercourse		0.2			3.56					
O/EE9 6 m buffer strip on cultivated land next to a watercourse	4.05									
O/EK2/HK2 Permanent grassland with low inputs	12	12.78	57.92		39.82	29.6	0.75	12.79		41.63
O/EK3/HK3 Permanent grassland with very low inputs outside the SDA	11.88	14.78	31.36	30.25	68.13	86.36	11.41	7.7 20 in habitat scheme	2.29	12.48
EK4 Management of Rush pastures						3.59	1.17			
HK6 Maintenance of species-rich grassland					27.45	3.65		4.2		
HK 7 Restoration of species – rich grassland			1.7			7.34				10.07
HK8 Creation of species rich grassland								0.75		

HK11 Restoration of wet grassland for breeding wader					59.66					
HK 12 Restoration of wet grassland for wintering waders			2.78			37.82		9.03		
HK15 Maintained for target features		0.47	19.53	7.5	6.38	32.91			15.43	
HK16 Restoration of grassland for target features			4.69							
HQ 6 Maintenance of Fen		4.36								
HQ 7 Restoration of Fen								2.21		0.74
HD 10 Maintenance of traditional water meadows				14.04						
HJ5 Arable reversion to grassland with low fertiliser input to prevent erosion or run-off						0.74				
HJ 7 Seasonal livestock removal on grassland with no input restriction						34.52			46.34	
HJ11 Manteca of watercourse fencing						1800 m				
HC15 Maintenance of succession areas and scrub								0.38		
HC 7 Maintenance of woodland								2.06		0.41
Totals	32.81	34.07	128.7	51.79	232.45	202	13.33	62.9	64.06	65.33

Total in river corridor 687.64 ha

Key

WA of UA (Units 1 & 2) WA of UA – Western arm of Upper Avon (Units 1 & 2) c. 12 km
E of UA Eastern arms of Upper Avon (Pusey & Manningford Bruce – non SSSI) 25 km
U A (unit 3) Upper Avon (Unit 3 Rushall to Woodford Bridge, Upper Woodford) c.45km
U A (Unit 4) Upper Avon (Unit 4 Woodford Bridge, Upper Woodford to confluence with Nadder, Longbridge Salisbury) c.8.5km
Nadder (Unit 9) Nadder – Avon (Unit 9 Quidhampton to confluence with Avon through Salisbury to Longford Boat House) c. 26km
Nadder (Unit 8) Nadder (Unit 8 top to Quidhampton, confluence with the Wylye) c.35kmWylye
Wylye (Unit 5) (Unit 5 top of unit to Codford St Mary) c. 25km
Wylye (Unit 6) Wylye (Unit 6 Codford St Mary to Serrington) c.26km
Wylye (Unit 7 Serrington to Quidhampton) c. 12km
Bourne (Unit 10) c. 9km

APPENDIX 3.0:1 WATER QUALITY RESULTS FROM MITIGATION SCENARIOS AND COMPARISON WITH WFD (SCENARIO 1) AND SAC STANDARDS SCENARIOS

		SIMCAT FLOW 2010-11 m3/d	Model Run 1a (Cannings & East Knoyle @ 1mg/l P)	Model• Run 1a+PR14+growth (growth scenario at permit flow and STW @ 0.7mg/l P)	Model Run 1a but No STW	Run 1a_Zero Point Source (STW, FF, Cress)	WQ Run 1a BASELINE (2010-11 average WQ) 1a (ug/l)	Run 1a + PR14 (ug/l)	Run 1a_PR14_ Growth (ug/l)	Run 1a_Zero STW ug/l	Run 1a_Zero Point Source (STW, FF, Cress) ug/l	Total P load Run 1a P/kg/yr	Total P load Run 1a_PR14 P/kg/yr :	Total P load Run 1a_PR14 + Growth P/kg/yr :	Total P Load Run 1a no STW	Total P load Run 1a_No Point Source P/kg/yr :
Ripley Brook	GB108043011010	2520	2520	2520	2520	2520	30	30	30	30	30	27	27	27	27	27
Clockhouse Stream	GB108043011011					2520						0	0	0	0	0
Bisterne Stream	GB108043011012					2520						0	0	0	0	0
Linford Brook:	GB108043015720	2610	2610	2610	2610	2610	30	30	30	30	30	28	28	28	28	28
Sleep Brook:	GB108043015730	1960	1960	1960	1960	1960	30	30	30	30	30	21	21	21	21	21
Dockens Water:	GB108043015740	2990	2990	2990	2990	2990	29	29	29	29	29	32	32	32	32	32
Huckles Brook:	GB108043015750	3350	3350	3350	3350	3350	29	29	29	29	29	36	36	36	36	36
Ditchend Brook:	GB108043015770	2030	2030	2030	2030	2030	30	30	30	30	30	22	22	22	22	22
Ashford Water (Allen River):GB108043015800	GB108043015800	22800	22800	22800	22800	22800	37	37	37	30	9	306	306	306	249	76
Sweatford Water:	GB108043015810	4690	4690	4690	4690	4690	30	30	30	30	30	50	50	50	50	50
Ebble	GB108043015830	108000	108000	108000	108000	108000	61	61	61	58	41	2409	2409	2409	2298	1632
Hampshire Avon (Lower)	GB108043015840	1275600	1275600	1292400	1270400	1270400	71	69	83	47	33	32824	32126	39200	21562	15070
EBBLE TRIB (Chalk Valley Stream)	GB108043015860	24100	24100	24100	24100	24100	67	67	67	60	20	588	588	588	530	179

EBBLE (Upper)	GB108043015870	23400	23400	23400	23400	23400	59	59	59	59	59	507	507	507	507	507
NADDER (Lower)	GB108043015880	389300	389300	391000	388100	388100	82	80	89	68	60	11709	11297	12673	9590	8499
Nadder (Headwaters)	GB108043016160	29200	29200	29200	29200	29200	125	125	125	124	113	1330	1330	1330	1321	1203
Nadder Tribs (Swallowcliff)	GB108043016180	9280	9280	9280	9280	9280	124	124	124	124	124	421	421	421	421	421
Fovant Brook	GB108043016190	17800	17800	17800	17700	17700	139	139	144	123	66	900	900	933	793	425
Nadder (upper)	GB108043016200	57100	57100	57100	57100	57100	152	129	127	122	116	3176	2680	2645	2547	2407
Sem	GB108043016210	19700	19700	19700	19700	19700	249	146	139	121	121	1793	1050	997	868	868
Hampshire Avon (Upper) u/s Nine Mile River confluence	GB108043022351	180600	180600	182000	180000	180000	140	133	138	112	95	9248	8780	9187	7365	6215
Hampshire Avon (Upper) d/s Nine Mile River confluence	GB108043022352	274900	274900	280500	274200	274200	99	95	113	77	66	9954	9512	11600	7656	6555
Nine Mile River	GB108043022360	24800	24800	24800	24800	24800	20	20	20	20	20	179	179	179	179	179
Hampshire Avon (West)	GB108043022370	50200	50200	50200	50100	50100	194	167	163	154	154	3562	3060	2979	2823	2823
BOURNE	GB108043022390	52200	52200	52100	52000	52000	53	53	59	16	16	1004	1004	1116	311	311
Hampshire Avon East and Woodborough Stream	GB108043022410	76000	76000	76000	75600	75600	177	177	176	155	117	4904	4904	4882	4266	3237
Deane Water	GB108043022420	25300	25300	25300	25300	25300	159	159	159	159	159	1466	1466	1466	1466	1466
Etchilhampton Water	GB108043022430	33700	33700	33700	33700	33700	206	165	163	156	156	2533	2033	2006	1920	1920
Nadder (middle)	GB108043022470	174000	174000	174300	173700	173700	121	115	118	109	101	7691	7278	7513	6917	6378
Teffont	GB108043022471	174000	174000	174300	173700	173700	121	115	118	109	101	7691	7278	7513	6917	6378
FONTHILL STREAM	GB108043022500	30000	30000	30000	30000	30000	124	124	124	124	124	1355	1355	1355	1355	1355

Wylye (Lower)	GB108043022510	203800	203800	205300	203100	203100	55	55	70	37	29	4069	4069	5223	2713	2135
Wylye (Headwaters)	GB108043022520	57500	57500	59900	57100	57100	90	90	137	55	30	1893	1893	3004	1148	629
Wylye Trib (Heytesbury Stream)	GB108043022530	7460	7460	7460	7460	7460	60	60	60	60	60	163	163	163	163	163
Wylye Trib (The Were or Swab)	GB108043022540	4180	4180	4180	4180	4180	60	60	60	60	60	91	91	91	91	91
Wylye (Middle)	GB108043022550	161200	161200	163500	160800	160800	58	58	76	42	32	3383	3383	4518	2459	1884
Chitterne Brook tributary	GB108043022560	26400	26400	26400	26400	26400	20	20	20	20	20	190	190	190	190	190
Till Tributary	GB108043022570	39800	39800	39100	39500	39500	39	39	32	19	19	571	571	460	275	275

APPENDIX 2.3.2:1 WESSEX WATER CURRENT AND FORECAST FUTURE SEWAGE TREATMENT LOADS AT THEIR SEWAGE TREATMENT WORKS IN THE AVON

Wessex Water Current and Forecast Point Source Loads to the Hampshire Avon: From Worksheet DM-#1504533-V3-Hamsphire_Avon_SIMCAT_reporttable"

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Project:

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	Units	2011		2015	2020	2025	2030	2035
13258 Salisbury STW								
Resident	nr	50,859		52,507	55,646	59,265	63,126	67,244
Non resident, commercial	nr	5,994		7,008	7,365	7,724	8,084	8,447
Total Population (excluding Trade & Tankered)	nr	56,853		59,515	63,011	66,989	71,210	75,691
Consented DWF	m3/d	23,500						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	16,989		17,784	18,829	20,018	21,279	22,618
Measured Average Flow	m3/d	20,511		21,471	22,732	24,168	25,690	27,307
Measured Average Flow: DWF ratio		1.21						
Crude Total Phosphorus	mg P/L	**6.9**	**Spot Samples**					
Crude Ortho Phosphorus	mg P/L	**4.7**	**Spot Samples**					
Predicted Total Phosphorus Load	tpa	51.7		54.1	57.3	60.9	64.7	68.8
Predicted Ortho Phosphorus Load	tpa	35.2		36.8	39.0	41.5	44.1	46.8
Measured Average Effluent Total Phosphorus	mg P/L	**0.56**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.561	0.561	0.561	0.561	0.561
Effluent Predicted Load Total Phosphorus	tpa	4.2		4.4	4.7	4.9	5.3	5.6
Total Phosphorus removed	tpa	47.5		49.7	52.6	55.9	59.4	63.2
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.28**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.282	0.282	0.282	0.282	0.282
Effluent Predicted Load Ortho Phosphorus	tpa	2.1		2.2	2.3	2.5	2.6	2.8
Total Ortho Phosphorus removed	tpa	33.1		34.6	36.7	39.0	41.4	44.0
	Units	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
13255 Ringwood STW								
Resident	nr	14,242		14,284	14,424	14,637	14,853	15,072
Non resident, commercial	nr	1,095		5,716	5,576	5,363	5,1	4,9

							47	28
Total Population (excluding Trade & Tankered)	nr	15,337		20,000	20,000	20,000	20,000	20,000
Consented DWF	m3/d	4,564						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	3,740		4,877	4,877	4,877	4,877	4,877
Measured Average Flow	m3/d	4,490		5,855	5,855	5,855	5,855	5,855
Measured Average Flow: DWF ratio		1.20						
Crude Total Phosphorus	mg P/L	**5.1**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**5.0**	**No Data**					
Predicted Total Phosphorus Load	tpa	8.4		11.0	11.0	11.0	11.0	11.0
Predicted Ortho Phosphorus Load	tpa	8.1		10.6	10.6	10.6	10.6	10.6
Measured Average Effluent Total Phosphorus	mg P/L	**0.54**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.542	0.542	0.542	0.542	0.542
Effluent Predicted Load Total Phosphorus	tpa	0.9		1.2	1.2	1.2	1.2	1.2
Total Phosphorus removed	tpa	7.5		9.8	9.8	9.8	9.8	9.8
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.25**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.254	0.254	0.254	0.254	0.254
Effluent Predicted Load Ortho Phosphorus	tpa	0.4		0.5	0.5	0.5	0.5	0.5
Total Ortho Phosphorus removed	tpa	7.7		10.0	10.0	10.0	10.0	10.0

	Units	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
13325 Warminster STW								
Resident	nr	16,771		17,292	18,138	19,119	19,987	20,898
Non resident, commercial	nr	5,102		5,179	5,483	5,794	6,114	6,441
Total Population (excluding Trade & Tankered)	nr	21,873		22,471	23,621	24,913	26,101	27,339
Consented DWF	m3/d	5,500						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	3,704		3,806	4,000	4,219	4,420	4,630
Measured Average Flow	m3/d	4,312		4,430	4,656	4,911	5,145	5,389
Measured Average Flow: DWF ratio		1.16						
Crude Total Phosphorus	mg P/L	**16.5**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**13.3**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	26.0		26.7	28.0	29.6	31.0	32.5
Predicted Ortho Phosphorus Load	tpa	20.9		21.5	22.6	23.8	25.0	26.2
Measured Average Effluent Total Phosphorus	mg P/L	**0.61**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.608	0.608	0.608	0.608	0.608
Effluent Predicted Load Total Phosphorus	tpa	1.0		1.0	1.0	1.1	1.1	1.2
Total Phosphorus removed	tpa	25.0		25.7	27.0	28.5	29.8	31.3

Measured Average Effluent Ortho Phosphorus	mg P/L	**0.47**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.468	0.468	0.468	0.468	0.468
Effluent Predicted Load Ortho Phosphorus	tpa	0.7		0.8	0.8	0.8	0.9	0.9
Total Ortho Phosphorus removed	tpa	20.2		20.7	21.8	23.0	24.1	25.2

13158 Hurdcott STW	**Units**	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	3,358		3,367	3,398	3,445	3,494	3,542
Non resident, commercial	nr	57		58	61	65	68	72
Total Population (excluding Trade & Tankered)	nr	3,415		3,425	3,459	3,510	3,562	3,614
Consented DWF	m3/d	2,034						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	**2,102**		2,108	2,129	2,160	2,192	2,224
Measured Average Flow	m3/d	**2,556**		2,564	2,589	2,627	2,666	2,705
Measured Average Flow: DWF ratio		1.22						
Crude Total Phosphorus	mg P/L	**3.3**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**1.7**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	3.1		3.1	3.2	3.2	3.3	3.3
Predicted Ortho Phosphorus Load	tpa	1.6		1.6	1.6	1.6	1.7	1.7
Measured Average Effluent Total Phosphorus	mg P/L	**0.58**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.575	0.575	0.575	0.575	0.575
Effluent Predicted Load Total Phosphorus	tpa	0.5		0.5	0.5	0.6	0.6	0.6
Total Phosphorus removed	tpa	2.6		2.6	2.6	2.7	2.7	2.7
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.31**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.309	0.309	0.309	0.309	0.309
Effluent Predicted Load Ortho Phosphorus	tpa	0.3		0.3	0.3	0.3	0.3	0.3
Total Ortho Phosphorus removed	tpa	1.3		1.3	1.3	1.3	1.4	1.4

13107 East Knoyle STW	**Units**	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	603		608	619	631	644	657
Non resident, commercial	nr	55		56	60	62	66	69
Total Population (excluding Trade & Tankered)	nr	658		664	679	693	710	726
Consented DWF	m3/d	205						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	109		110	112	115	117	120
Measured Average Flow	m3/d	161		162	166	169	174	177
Measured Average Flow: DWF ratio		1.48						
Crude Total Phosphorus	mg P/L	**8.0**	**No data**					
Crude Ortho Phosphorus	mg P/L	**5.0**	**No data**					
Predicted Total Phosphorus Load	tpa	0.5		0.5	0.5	0.5	0.5	0.5
Predicted Ortho Phosphorus Load	tpa	0.3		0.3	0.3	0.3	0.3	0.3
Measured Average Effluent Total Phosphorus	mg P/L	**5.00**	**No Data**					
Assumed Future Effluent P concentration	mg			5.000	5.000	5.000	5.0	5.0

	P/L						00	00
Effluent Predicted Load Total Phosphorus	tpa	0.3		0.3	0.3	0.3	0.3	0.3
Total Phosphorus removed	tpa	0.2		0.2	0.2	0.2	0.2	0.2
Measured Average Effluent Ortho Phosphorus	mg P/L	**4.11**	**Spot Samples**					
Assumed Future Effluent P concentration	mg P/L			4.111	4.111	4.111	4.111	4.111
Effluent Predicted Load Ortho Phosphorus	tpa	0.2		0.2	0.2	0.3	0.3	0.3
Total Ortho Phosphorus removed	tpa	0.1		0.1	0.1	0.1	0.1	0.1
	Units	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
13237 Pewsey STW								
Resident	nr	6,957		7,239	7,311	7,420	7,531	7,644
Non resident, commercial	nr	329		337	352	367	384	400
Total Population (excluding Trade & Tankered)	nr	7,286		7,576	7,663	7,787	7,915	8,044
Consented DWF	m3/d	1,596						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	1,486		1,545	1,563	1,588	1,614	1,641
Measured Average Flow	m3/d	1,857		1,931	1,953	1,984	2,017	2,050
Measured Average Flow: DWF ratio		1.25						
Crude Total Phosphorus	mg P/L	**7.2**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**5.0**	**No data**					
Predicted Total Phosphorus Load	tpa	4.9		5.1	5.2	5.2	5.3	5.4
Predicted Ortho Phosphorus Load	tpa	3.4		3.5	3.6	3.6	3.7	3.8
Measured Average Effluent Total Phosphorus	mg P/L	**0.68**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.683	0.683	0.683	0.683	0.683
Effluent Predicted Load Total Phosphorus	tpa	0.5		0.5	0.5	0.5	0.5	0.5
Total Phosphorus removed	tpa	4.4		4.6	4.7	4.8	4.8	4.9
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.43**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.430	0.430	0.430	0.430	0.430
Effluent Predicted Load Ortho Phosphorus	tpa	0.3		0.3	0.3	0.3	0.3	0.3
Total Ortho Phosphorus removed	tpa	3.1		3.2	3.3	3.3	3.4	3.4
	Units	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
13128 Fordingbridge STW								
Resident	nr	8,803		8,828	8,912	9,039	9,168	9,299
Non resident, commercial	nr	514		522	563	607	622	638
Total Population (excluding Trade & Tankered)	nr	9,317		9,350	9,475	9,646	9,790	9,937
Consented DWF	m3/d	2,751						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	1,705		1,711	1,734	1,765	1,791	1,818
Measured Average Flow	m3/d	2,312		2,320	2,351	2,394	2,429	2,466
Measured Average Flow: DWF ratio		1.36						
Crude Total Phosphorus	mg P/L	**7.5**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**4.1**	**Composite samples**					

Predicted Total Phosphorus Load	tpa	6.4		6.4	6.5	6.6	6.7	6.8
Predicted Ortho Phosphorus Load	tpa	3.5		3.5	3.6	3.6	3.7	3.7
Measured Average Effluent Total Phosphorus	mg P/L	**0.54**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.542	0.542	0.542	0.542	0.542
Effluent Predicted Load Total Phosphorus	tpa	0.5		0.5	0.5	0.5	0.5	0.5
Total Phosphorus removed	tpa	5.9		5.9	6.0	6.1	6.2	6.3
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.31**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.313	0.313	0.313	0.313	0.313
Effluent Predicted Load Ortho Phosphorus	tpa	0.3		0.3	0.3	0.3	0.3	0.3
Total Ortho Phosphorus removed	tpa	3.2		3.2	3.3	3.3	3.4	3.4
	Units	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
13008 Amesbury STW								
Resident	nr	8,423		9,555	10,658	11,969	12,916	13,952
Non resident, commercial	nr	689		728	887	1,048	1,101	1,158
Total Population (excluding Trade & Tankered)	nr	9,112		10,283	11,545	13,017	14,017	15,110
Consented DWF	m3/d	1,811						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	1,096		1,237	1,389	1,566	1,686	1,818
Measured Average Flow	m3/d	1,199		1,353	1,519	1,713	1,844	1,988
Measured Average Flow: DWF ratio		1.09						
Crude Total Phosphorus	mg P/L	**12.5**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**6.2**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	5.5		6.2	6.9	7.8	8.4	9.1
Predicted Ortho Phosphorus Load	tpa	2.7		3.1	3.4	3.9	4.2	4.5
Measured Average Effluent Total Phosphorus	mg P/L	**0.61**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.606	0.606	0.606	0.606	0.606
Effluent Predicted Load Total Phosphorus	tpa	0.3		0.3	0.3	0.4	0.4	0.4
Total Phosphorus removed	tpa	5.2		5.9	6.6	7.4	8.0	8.6
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.28**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.282	0.282	0.282	0.282	0.282
Effluent Predicted Load Ortho Phosphorus	tpa	0.1		0.1	0.2	0.2	0.2	0.2
Total Ortho Phosphorus removed	tpa	2.6		2.9	3.3	3.7	4.0	4.3
	Units	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
13099 Downton STW								
Resident	nr	4,525		4,606	4,709	4,779	4,850	4,922
Non resident, commercial	nr	275		284	297	313	329	345
Total Population (excluing Trade & Tankered)	nr	4,800		4,890	5,006	5,092	5,179	5,267
Consented DWF	m3/d	1,075						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	1,496		1,524	1,560	1,587	1,614	1,642
Measured Average Flow	m3/d	1,832		1,866	1,946	2,065	2,2	2,4

							28	45
Measured Average Flow: DWF ratio		1.22						
Crude Total Phosphorus	mg P/L	**10.2**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**5.2**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	6.8		6.9	7.2	7.7	8.3	9.1
Predicted Ortho Phosphorus Load	tpa	3.5		3.5	3.7	3.9	4.2	4.6
Measured Average Effluent Total Phosphorus	mg P/L	**0.49**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.487	0.487	0.487	0.487	0.487
Effluent Predicted Load Total Phosphorus	tpa	0.3		0.3	0.3	0.4	0.4	0.4
Total Phosphorus removed	tpa	6.5		6.6	6.9	7.3	7.9	8.6
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.27**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.268	0.268	0.268	0.268	0.268
Effluent Predicted Load Ortho Phosphorus	tpa	0.2		0.2	0.2	0.2	0.2	0.2
Total Ortho Phosphorus removed	tpa	3.3		3.4	3.5	3.7	4.0	4.4

13275 Shrewton STW	**Units**	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	1,750		1,781	1,798	1,824	1,851	1,878
Non resident, commercial	nr	68		78	81	86	90	95
Total Population (excluing Trade & Tankered)	nr	1,818		1,859	1,879	1,910	1,941	1,973
Consented DWF	m3/d	660						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	238		243	246	250	254	258
Measured Average Flow	m3/d	1,104		1,129	1,167	1,226	1,309	1,420
Measured Average Flow: DWF ratio		4.64						
Crude Total Phosphorus	mg P/L	**7.1**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**4.9**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	2.9		2.9	3.0	3.2	3.4	3.7
Predicted Ortho Phosphorus Load	tpa	2.0		2.0	2.1	2.2	2.3	2.5
Measured Average Effluent Total Phosphorus	mg P/L	**0.52**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.517	0.517	0.517	0.517	0.517
Effluent Predicted Load Total Phosphorus	tpa	0.2		0.2	0.2	0.2	0.2	0.3
Total Phosphorus removed	tpa	2.7		2.7	2.8	3.0	3.2	3.4
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.37**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.373	0.373	0.373	0.373	0.373
Effluent Predicted Load Ortho Phosphorus	tpa	0.2		0.2	0.2	0.2	0.2	0.2
Total Ortho Phosphorus removed	tpa	1.8		1.9	1.9	2.0	2.2	2.3

13253 Ratfyn STW	**Units**	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	10,014		10,037	10,118	10,240	10,364	10,489
Non resident, commercial	nr	552		733	1,034	1,336	1,404	1,477
Total Population (excluing Trade & Tankered)	nr	10,56		10,770	11,15	11,57	11,	11,

		6			2	6	768	966
Consented DWF	m3/d	4,546						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	2,167		2,209	2,287	2,374	2,414	2,454
Measured Average Flow	m3/d	2,359		2,404	2,538	2,780	3,096	3,507
Measured Average Flow: DWF ratio		1.09						
Crude Total Phosphorus	mg P/L	**10.7**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**5.7**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	9.2		9.4	9.9	10.9	12.1	13.7
Predicted Ortho Phosphorus Load	tpa	4.9		5.0	5.3	5.8	6.4	7.3
Measured Average Effluent Total Phosphorus	mg P/L	**0.18**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.183	0.183	0.183	0.183	0.183
Effluent Predicted Load Total Phosphorus	tpa	0.2		0.2	0.2	0.2	0.2	0.2
Total Phosphorus removed	tpa	9.1		9.2	9.7	10.7	11.9	13.5
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.21**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.206	0.206	0.206	0.206	0.206
Effluent Predicted Load Ortho Phosphorus	tpa	0.2		0.2	0.2	0.2	0.2	0.3
Total Ortho Phosphorus removed	tpa	4.7		4.8	5.1	5.6	6.2	7.0
	Units	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
13353 Great Wishford STW								
Resident	nr	1,819		1,879	1,898	1,927	1,956	1,985
Non resident, commercial	nr	204		208	217	225	235	244
Total Population (excluing Trade & Tankered)	nr	2,023		2,087	2,115	2,152	2,191	2,229
Consented DWF	m3/d	791						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	1,063		1,096	1,111	1,131	1,151	1,171
Measured Average Flow	m3/d	1,153		1,190	1,244	1,323	1,433	1,579
Measured Average Flow: DWF ratio		1.09						
Crude Total Phosphorus	mg P/L	**8.2**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**5.2**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	3.5		3.6	3.7	4.0	4.3	4.7
Predicted Ortho Phosphorus Load	tpa	2.2		2.3	2.4	2.5	2.7	3.0
Measured Average Effluent Total Phosphorus	mg P/L	**0.34**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.342	0.342	0.342	0.342	0.342
Effluent Predicted Load Total Phosphorus	tpa	0.1		0.1	0.2	0.2	0.2	0.2
Total Phosphorus removed	tpa	3.3		3.4	3.6	3.8	4.1	4.5
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.22**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.216	0.216	0.216	0.216	0.216
Effluent Predicted Load Ortho Phosphorus	tpa	0.1		0.1	0.1	0.1	0.1	0.1
Total Ortho Phosphorus removed	tpa	2.1		2.2	2.3	2.4	2.6	2.9

13196 Marden STW	**Units**	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	799		819	833	850	867	884
Non resident, commercial	nr	21		21	23	24	26	26
Total Population (excluing Trade & Tankered)	nr	820		840	856	874	893	910
Consented DWF	m3/d	190						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	97		100	102	104	106	108
Measured Average Flow	m3/d	177		182	190	202	220	244
Measured Average Flow: DWF ratio		1.82						
Crude Total Phosphorus	mg P/L	**6.3**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**3.7**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	0.4		0.4	0.4	0.5	0.5	0.6
Predicted Ortho Phosphorus Load	tpa	0.2		0.2	0.3	0.3	0.3	0.3
Measured Average Effluent Total Phosphorus	mg P/L	**1.29**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			1.292	1.292	1.292	1.292	1.292
Effluent Predicted Load Total Phosphorus	tpa	0.1		0.1	0.1	0.1	0.1	0.1
Total Phosphorus removed	tpa	0.3		0.3	0.3	0.4	0.4	0.4
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.90**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.902	0.902	0.902	0.902	0.902
Effluent Predicted Load Ortho Phosphorus	tpa	0.1		0.1	0.1	0.1	0.1	0.1
Total Ortho Phosphorus removed	tpa	0.2		0.2	0.2	0.2	0.2	0.3

13220 Netheravon STW	**Units**	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	1,749		1,754	1,771	1,798	1,825	1,853
Non resident, commercial	nr	284		286	288	290	292	294
Total Population (excluding Trade & Tankered)	nr	2,033		2,040	2,059	2,088	2,117	2,147
Consented DWF	m3/d	1,500						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	321		322	325	330	335	339
Measured Average Flow	m3/d	423		425	430	442	460	486
Measured Average Flow: DWF ratio		1.32						
Crude Total Phosphorus	mg P/L	**8.8**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**5.8**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	1.4		1.4	1.4	1.4	1.5	1.6
Predicted Ortho Phosphorus Load	tpa	0.9		0.9	0.9	0.9	1.0	1.0
Measured Average Effluent Total Phosphorus	mg P/L	**0.47**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.469	0.469	0.469	0.469	0.469
Effluent Predicted Load Total Phosphorus	tpa	0.1		0.1	0.1	0.1	0.1	0.1
Total Phosphorus removed	tpa	1.3		1.3	1.3	1.4	1.4	1.5
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.21**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.213	0.213	0.213	0.213	0.213
Effluent Predicted Load Ortho Phosphorus	tpa	0.0		0.0	0.0	0.0	0.0	0.0
Total Ortho Phosphorus removed	tpa	0.9		0.9	0.9	0.9	0.9	1.0

13320 Upavon STW	Units	2011		2015	2020	2025	2030	2035
Resident	nr	977		1,016	1,034	1,054	1,076	1,097
Non resident, commercial	nr	38		40	41	43	46	48
Total Population (excluding Trade & Tankered)	nr	1,015		1,056	1,075	1,097	1,122	1,145
Consented DWF	m3/d	416						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	314		326	332	339	347	354
Measured Average Flow	m3/d	438		456	483	522	577	651
Measured Average Flow: DWF ratio		1.40						
Crude Total Phosphorus	mg P/L	**4.9**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**3.0**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	0.8		0.8	0.9	0.9	1.0	1.2
Predicted Ortho Phosphorus Load	tpa	0.5		0.5	0.5	0.6	0.6	0.7
Measured Average Effluent Total Phosphorus	mg P/L	**0.46**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.462	0.462	0.462	0.462	0.462
Effluent Predicted Load Total Phosphorus	tpa	0.1		0.1	0.1	0.1	0.1	0.1
Total Phosphorus removed	tpa	0.7		0.7	0.8	0.8	0.9	1.1
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.27**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.271	0.271	0.271	0.271	0.271
Effluent Predicted Load Ortho Phosphorus	tpa	0.0		0.0	0.0	0.1	0.1	0.1
Total Ortho Phosphorus removed	tpa	0.4		0.5	0.5	0.5	0.6	0.6

13129 Fovant STW	Units	2011		2015	2020	2025	2030	2035
Resident	nr	1,239		1,259	1,297	1,340	1,384	1,430
Non resident, commercial	nr	53		54	58	60	64	67
Total Population (excluding Trade & Tankered)	nr	1,292		1,313	1,355	1,400	1,448	1,497
Consented DWF	m3/d	345						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	274		278	287	297	307	317
Measured Average Flow	m3/d	401		408	427	463	519	601
Measured Average Flow: DWF ratio		1.46						
Crude Total Phosphorus	mg P/L	**9.6**	**Composite samples**					
Crude Ortho Phosphorus	mg P/L	**5.8**	**Composite samples**					
Predicted Total Phosphorus Load	tpa	1.4		1.4	1.5	1.6	1.8	2.1
Predicted Ortho Phosphorus Load	tpa	0.8		0.9	0.9	1.0	1.1	1.3
Measured Average Effluent Total Phosphorus	mg P/L	**0.70**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			0.700	0.700	0.700	0.700	0.700
Effluent Predicted Load Total Phosphorus	tpa	0.1		0.1	0.1	0.1	0.1	0.2
Total Phosphorus removed	tpa	1.3		1.3	1.4	1.5	1.7	2.0
Measured Average Effluent Ortho Phosphorus	mg	**0.35**	**Composite samples**					

	Units	2011	2015	2020	2025	2030	2035
Assumed Future Effluent P concentration	mg P/L		0.348	0.348	0.348	0.348	0.348
Effluent Predicted Load Ortho Phosphorus	tpa	0.1	0.1	0.1	0.1	0.1	0.1
Total Ortho Phosphorus removed	tpa	0.8	0.8	0.8	0.9	1.0	1.2

13313 Tisbury STW	**Units**	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	4,011	4,082	4,225	4,393	4,569	4,752
Non resident, commercial	nr	320	339	377	421	449	479
Total Population (excluding Trade & Tankered)	nr	4,331	4,421	4,602	4,814	5,018	5,231
Consented DWF	m3/d	525					
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	479	489	509	532	555	579
Measured Average Flow	m3/d	844	862	915	1,018	1,179	1,424
Measured Average Flow: DWF ratio		1.76					
Crude Total Phosphorus	mg P/L	**8.3**	**Composite samples**				
Crude Ortho Phosphorus	mg P/L	**4.0**	**Composite samples**				
Predicted Total Phosphorus Load	tpa	2.5	2.6	2.8	3.1	3.6	4.3
Predicted Ortho Phosphorus Load	tpa	1.2	1.2	1.3	1.5	1.7	2.1
Measured Average Effluent Total Phosphorus	mg P/L	**0.21**	**Composite samples**				
Assumed Future Effluent P concentration	mg P/L		0.208	0.208	0.208	0.208	0.208
Effluent Predicted Load Total Phosphorus	tpa	0.1	0.1	0.1	0.1	0.1	0.1
Total Phosphorus removed	tpa	2.5	2.5	2.7	3.0	3.5	4.2
Measured Average Effluent Ortho Phosphorus	mg P/L	**0.22**	**Composite samples**				
Assumed Future Effluent P concentration	mg P/L		0.223	0.223	0.223	0.223	0.223
Effluent Predicted Load Ortho Phosphorus	tpa	0.1	0.1	0.1	0.1	0.1	0.1
Total Ortho Phosphorus removed	tpa	1.1	1.2	1.2	1.4	1.6	1.9

13015 Barford St Martin STW	**Units**	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	379	382	389	397	405	413
Non resident, commercial	nr	25	25	27	28	30	32
Total Population (excluding Trade & Tankered)	nr	404	407	416	425	435	445
Consented DWF	m3/d	83					
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	47	47	48	49	51	52
Measured Average Flow	m3/d	83	84	86	91	98	107
Measured Average Flow: DWF ratio		1.77					
Crude Total Phosphorus	mg P/L	**10.0**	**Composite samples**				
Crude Ortho Phosphorus	mg P/L	**5.7**	**Composite samples**				
Predicted Total Phosphorus Load	tpa	0.3	0.3	0.3	0.3	0.4	0.4
Predicted Ortho Phosphorus Load	tpa	0.2	0.2	0.2	0.2	0.2	0.2
Measured Average Effluent Total Phosphorus	mg P/L	**1.55**	**Composite samples**				
Assumed Future Effluent P concentration	mg P/L		1.552	1.552	1.552	1.552	1.552

Effluent Predicted Load Total Phosphorus	tpa	0.0		0.0	0.0	0.1	0.1	0.1
Total Phosphorus removed	tpa	0.3		0.3	0.3	0.3	0.3	0.3
Measured Average Effluent Ortho Phosphorus	mg P/L	**1.41**	**Composite samples**					
Assumed Future Effluent P concentration	mg P/L			1.407	1.407	1.407	1.407	1.407
Effluent Predicted Load Ortho Phosphorus	tpa	0.0		0.0	0.0	0.0	0.1	0.1
Total Ortho Phosphorus removed	tpa	0.1		0.1	0.1	0.1	0.2	0.2

13004 All Cannings STW	**Units**	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	1,090		1,100	1,120	1,142	1,165	1,189
Non resident, commercial	nr	73		75	79	83	88	91
Total Population (excluding Trade & Tankered)	nr	1,163		1,175	1,199	1,225	1,253	1,280
Consented DWF	m3/d	240						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	254		257	262	268	274	280
Measured Average Flow	m3/d	399		403	416	438	472	519
Measured Average Flow: DWF ratio		1.57						
Crude Total Phosphorus	mg P/L	**8.0**	**No data**					
Crude Ortho Phosphorus	mg P/L	**5.0**	**No data**					
Predicted Total Phosphorus Load	tpa	1.2		1.2	1.2	1.3	1.4	1.5
Predicted Ortho Phosphorus Load	tpa	0.7		0.7	0.8	0.8	0.9	0.9
Measured Average Effluent Total Phosphorus	mg P/L	**5.00**	**No Data**					
Assumed Future Effluent P concentration	mg P/L			5.000	5.000	5.000	5.000	5.000
Effluent Predicted Load Total Phosphorus	tpa	0.7		0.7	0.8	0.8	0.9	0.9
Total Phosphorus removed	tpa	0.4		0.4	0.5	0.5	0.5	0.6
Measured Average Effluent Ortho Phosphorus	mg P/L	**4.11**	**Spot samples**					
Assumed Future Effluent P concentration	mg P/L			4.109	4.109	4.109	4.109	4.109
Effluent Predicted Load Ortho Phosphorus	tpa	0.6		0.6	0.6	0.7	0.7	0.8
Total Ortho Phosphorus removed	tpa	0.1		0.1	0.1	0.1	0.2	0.2

13191 Maiden Bradley STW	**Units**	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	284		287	292	298	304	310
Non resident, commercial	nr	43		44	47	49	52	54
Total Population (excluing Trade & Tankered)	nr	327		331	339	347	356	364
Consented DWF	m3/d	57						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	13		13	13	14	14	14
Measured Average Flow	m3/d	35		35	36	37	38	39
Measured Average Flow: DWF ratio		2.70						
Crude Total Phosphorus	mg P/L	**8.0**	**No data**					
Crude Ortho Phosphorus	mg P/L	**5.0**	**No data**					
Predicted Total Phosphorus Load	tpa	0.1		0.1	0.1	0.1	0.1	0.1
Predicted Ortho Phosphorus Load	tpa	0.1		0.1	0.1	0.1	0.1	0.1

Measured Average Effluent Total Phosphorus	mg P/L	**5.00**	**No Data**					
Assumed Future Effluent P concentration	mg P/L			5.000	5.000	5.000	5.000	5.000
Effluent Predicted Load Total Phosphorus	tpa	0.1		0.1	0.1	0.1	0.1	0.1
Total Phosphorus removed	tpa	0.0		0.0	0.0	0.0	0.0	0.0
Measured Average Effluent Ortho Phosphorus	mg P/L	**4.00**	**Spot samples**					
Assumed Future Effluent P concentration	mg P/L			4.000	4.000	4.000	4.000	4.000
Effluent Predicted Load Ortho Phosphorus	tpa	0.1		0.1	0.1	0.1	0.1	0.1
Total Ortho Phosphorus removed	tpa	0.0		0.0	0.0	0.0	0.0	0.0

13071 Collingbourne Ducis STW	**Units**	**2011**		**2015**	**2020**	**2025**	**2030**	**2035**
Resident	nr	1,246		1,280	1,318	1,361	1,405	1,451
Non resident, commercial	nr	83		85	89	95	99	105
Total Population (excluing Trade & Tankered)	nr	1,329		1,365	1,407	1,456	1,504	1,556
Consented DWF	m3/d	227						
Measured DWF (Q80 Flow April 2010 to Mar 2011)	m3/d	168		173	178	185	191	197
Measured Average Flow	m3/d	318		327	337	349	360	373
Measured Average Flow: DWF ratio		1.89						
Crude Total Phosphorus	mg P/L	**8.0**	**No data**					
Crude Ortho Phosphorus	mg P/L	**5.0**	**No data**					
Predicted Total Phosphorus Load	tpa	0.9		1.0	1.0	1.0	1.1	1.1
Predicted Ortho Phosphorus Load	tpa	0.6		0.6	0.6	0.6	0.7	0.7
Measured Average Effluent Total Phosphorus	mg P/L	**5.00**	**No Data**					
Assumed Future Effluent P concentration	mg P/L			5.000	5.000	5.000	5.000	5.000
Effluent Predicted Load Total Phosphorus	tpa	0.6		0.6	0.6	0.6	0.7	0.7
Total Phosphorus removed	tpa	0.3		0.4	0.4	0.4	0.4	0.4
Measured Average Effluent Ortho Phosphorus	mg P/L	**4.00**	**No data**					
Assumed Future Effluent P concentration	mg P/L			4.000	4.000	4.000	4.000	4.000
Effluent Predicted Load Ortho Phosphorus	tpa	0.5		0.5	0.5	0.5	0.5	0.5
Total Ortho Phosphorus removed	tpa	0.1		0.1	0.1	0.1	0.1	0.1

Notes

Q80 flows are based on the period April 2010 to Mar 2011 which was a wet period, lower DWF flows were seen in 2009 and 2011.
DWF figures are increased on a pro rata basis based on population increases.
Loads are calculated on average flow and average composite strengths. Actual loads would be better calculated from matched daily flow and daily strength.
Wessex Water are investigating infiltration into sewer system at Great Wishford and Downton STW.

Example Assumptions for Salisbury Forecast

Assumptions:

1.Planning & Asset Management [PAM] June Return 2012 [JR12] population data is used as the base

2.Housing growth 1.50% per annum is forecast throughout (see notes)

3.PAM's JR12 data is adjusted by +1,177 for the numerous care homes within the catchment (see note

4.PAM's JR12 data is further adjusted by +100 for boarders and live-in staff at two independent schools (see notes)

5.PAM's JR12 non-resident population is reduced from 4,797 to 2,622 (see notes)

6.Non-resident population is forecast to grow at 0.50% per annum throughout from this revised base

7.A baseline commercial growth of 58 PE per annum is forecast throughout (see notes)

8.An arbitrary additional adjustment of 800 PE is made at 2015 for the prospective development of a foodstore and filling stati adjacent to the STW (see notes)

9.Trade effluent PE is forecast to remain static but, as ever, this ought to be discussed with local trade effluent officer Nicola Marshall (see notes)

10.Any existing sites under construction and sites identified for future development are expected to progress at planned and even rates between landmark dates

11.A downward trend in average household size 2012-2020 is derived from DCLG 2002-based regional projections 2001-202 adjusted to PAM's JR12 base

12.That downward trend in average household size is extended 2020-2035 with a slower rate of reduction

Notes:

There was major capital investment in this works during AMP4 under the project D9096 Salisbury STW Additional Phosphoru Removal & Effluent Pipeline [£4.3m]

which followed AMP3 project D1220 Salisbury STW Phosphorus Removal [£892k]. The scope of AMP2 projects D7445 and D7546 [£956k] has not been confirmed.

The STW serves Salisbury and all or parts of the surrounding parishes of Alderbury, Britford, Clarendon Park, Laverstock, Netherhampton, Quidhampton and Wilton,

each of which falls within the defunct Salisbury District Council [SDC] area and its successor the Wiltshire Council [WC] area. Some villages beyond the catchment

are served by a variety of private sewerage and sewage treatment arrangements but no consideration has been given to any catchment enlargement to absorb these.

WC adopted the South Wiltshire Core Strategy [SWCS] for the former SDC area in February 2012 and this makes provision f at least 6,060 dwellings in Salisbury

and Wilton during the period 2006-26 together with 29 hectares of employment land and a separate retail-led mixed use development to deliver 40,000 m^2 floorspace.

More than 1,000 dwellings were completed and occupied during 2006-11 and it is assumed these are reckoned into the JR12 figures on which this forecast is based.

Therefore, another 5,000 or so dwellings are expected in Salisbury and Wilton by 2026 together with some more in Alderbury which is designated in the SWCS as a

secondary village and capable of sustaining a modest amount of development. The SWCS makes provision for a front end loaded build trajectory, as a mechanism to

ensure that the requisite number of new dwellings are delivered within the period, but this is overlooked in the forecast above recognition of the prevailing economic

climate and the difficulties facing the housing market. An economic recovery in the short term might have the effect of advanc development a little although it may

ultimately be that the SWCS targets are proven to be undeliverable and this forecast should be revisited at appropriate interva with that in mind.

A review of care homes and sheltered units not separately billed identified 1,207 places which, at an arbitrary occupancy rate 97½%, merits a +1,107 adjustment.

No future growth is forecast in this adjustment but more care provision, particularly for the elderly, may be reasonably expecte to go hand in hand with development.

Various schools in the catchment have a total approaching 9,000 pupils, teachers and ancillary staff which, at 18% of the resident population, is at the upper end of

the expected range but the only adjustment made is for the "guesstimated" 100 boarders and live-in staff at Chafyn Grove School and Godolphin School in Salisbury.

The JR12 dataset significantly overestimates non-resident population in this catchment. No detailed review has been undertaken but it is noted that 2,700 of the JR12

total of 4,797 is attributed to the Salisbury Camping & Caravanning Club site which, in fact, has 150 touring pitches for an assumed 525 bedspaces. Added to various

other addresses identified in the JR12 dataset which total 2,097 bedspaces that gives the revised figure of 2,622. Neither figu includes an allowance for daytrippers.

Commercial growth conversion: 0.3 litres/second/hectare x 8 hours / estimated per capita domestic use of 150 litres/day [i.e. 0 x 60 x 60 x 8 / 150 = 58 PE per ha]

An additional adjustment of 800 PE assumes that a prospective Sainsbury foodstore and filling station next to the works will have significantly longer opening hours.

Any commercial growth may result in new trade effluent agreements and load but there is no reliable basis upon which to predict any population equivalents for these.

A long term decline in average household size [as derived from SDC/WC statistics] may or may not be sustained in future and figures used above should be taken to

represent only the onward projection of a trend. If this downward trend were to be arrested then a forecast growth in the catchment population would be accentuated.

It is noted that the validity of assumptions made on average household size will be reviewed once 2011 census data is available.

Further guidance should be sought from Developer Services if trigger points for capital investment are identified between landmark dates in the short or medium term.

APPENDIX 2.3: 1 P SOURCE APPORTIONMENT IN THE HAMPSHIRE AVON CATCHMENT: KEY CONCLUSIONS AND RECOMMENDATIONS FROM BEWES ET AL (2011)

The following conclusions and recommendations are provided for each source of P.

Consented point sources

Conclusions:

- None of the studies identified includes a complete, up-to-date inventory of consented point source discharges, but considered the key sources of phosphorus contributing the greatest proportion of P to the Avon.
- Two approaches have been used to estimate loads from consented point sources: an export coefficient approach using human population data and explicit identification of consented point source discharges from the Environment Agency register and estimation of loads from these sources using estimated or measured effluent P concentrations and effluent flow. The latter approach is more rigorous and better suited to the characterisation of P loads from these sources in a NMP because it provides estimates on a source-by-source basis that is most appropriate for the application of control measures.
- The application of this approach has been implemented both within the context of a SIMCAT model and independently (i.e. Jarvie *et al.* 2005). The application of the approach as part of a SIMCAT model offers the all the advantages of a predictive model that allows future scenarios of control measures to be identified and their potential effectiveness assessed.
- The estimation of P loads from consented point sources in the studies identified has been undertaken either from estimated or measured effluent P concentrations and effluent flow. In the majority of cases, the more rigorous approach is to use measured effluent P concentrations and effluent flows where these are available.
- The National SIMCAT model is currently (March 2011) being updated to include the latest effluent P concentration and flow data for each consented point source and in-river P monitoring data from Environment Agency routine and enhanced ECSFDI monitoring. The model reach network is also being updated to use the EA detailed river network (DRN). These developments will also include the creation of a standardised procedure for model calibration. This updating is being undertaken as part of an EA national initiative. National SIMCAT models for other RBDs have been updated and used for regional investigations.

Recommendations:

- The National SIMCAT model that provides coverage of the whole Hampshire Avon catchment should be further updated to include all consented point source discharges with associated contemporary treatment and with P loads calculated using available measured effluent P concentrations and effluent flows.

Unconsented point sources

Conclusions:

- P load estimates for the Hampshire Avon were obtained from two main studies; May *et al.* (in press) and Murdoch (2010). Both studies used an export coefficient approach to calculate P loads though the details of the approaches differed.

- The approach adopted by May *et al.* (in press) included the identification of households not connected to the sewer network in the two sub-catchments studied and identified many more potential sources than were indicated on existing Environment Agency registers. This approach is better suited to a PMP because potential individual sources can be identified and targeted with control measures.

- The export coefficient approaches adopted did not take into account on-site treatment system type and condition and location with respect to watercourses. These factors are important in the functioning of the systems and should ideally be accounted for. The spatial distribution of unconsented discharges is often overlooked when calculating P loads. For example, a discharge located in close proximity to a water course on impermeable soils is likely to contribute a greater P load than a discharge further away located in areas with permeable soils. Recent work by WRc (2009) for SNIFFER has built upon the per capita export coefficient approach in order to develop a tool which takes into consideration the distribution and condition of unconsented on-site systems. The tool, which could be adapted to represent any catchment, was designed to look at the aggregated impact of pollutant loads and generate concentrations at given 'assessment points' in the catchment. The methodology is based on a 'pressure-pathway-receptor' model. The unconsented discharges represent the 'pressures' and the Assessment Points represent the 'receptors' in the model. Each of the unconsented discharges were assumed to comprise a treatment plant and a drainage field or reed bed – pollutant loads are routed through these units in turn, with potential load reductions based on the type and condition of the units. Pathways in terms of overland flow and sub soil drainage were also modelled with pollutants reducing, depending on the subsoil and aquifer characteristics, pollutant type and distance. The tool includes literature values for key parameters but is not validated. Empirical studies are required to provide the required validation information. For example, Withers *et al.* (2011) undertook a 1-year monitoring programme in a ditch and stream network around a village in the Welland catchment (Leicestershire) receiving discharges from a large (but unknown) number of septic tanks. Significant concentrations of P (<1 – 14 mg L^{-1}) were measured in the effluent of one system with soluble fractions comprising 70 - 85% of the total. Stream concentrations of soluble P downstream of the village were enhanced by 4 to 10-fold compared to upstream concentrations as a result of septic tank discharges. Studies such as this, enhanced with information on the type and condition of the system, will provide valuable data to enhance estimates of P loads from these sources.

- The geographical coverage of the estimates for unconsented point sources did not extend to the whole Hampshire Avon catchment. The Environment Agency has a national GIS layer for unconsented discharges (Environment Agency, pers. comm.) that has been used in risk assessment work in support of the development of the WFD River Basin Management Plans. This information source should be considered when taking forward work on unconsented discharges in the Hampshire Avon.

- SIMCAT is currently being further developed in work funded jointly by the Environment Agency and UKWIR (UKWIR Project reference WW02) to include a source apportionment tool. This tool will facilitate the derivation of explicit estimates of diffuse pollution loads for P from 7 different source types including septic tanks. An export coefficient approach is under development for this source. The SIMCAT software is being updated to deliver results on a monthly time step in addition to the annual time step currently available. This tool is due to be available in September 2011 and is intended to be the tool of choice for water quality planning for the Environment Agency and water companies. As part of this process the models will be validated using selected test catchments.

Recommendations:

- The potential importance of unconsented discharges in some of the sub-catchments of the Hampshire Avon strongly indicates that an approach to the estimation of P loads from this source should be developed. The approach should include a mechanism to identify specific source locations perhaps using the approach developed by May *et al.* (in press) but taking into consideration the available information on the Environment Agency's GIS layer and the approach under development for the SIMCAT source apportionment tool.

- Once the individual unconsented source locations are identified, an approach to estimating P loads should be developed that takes into account the type, condition and location of the on-site treatment system. In the future this might be informed by the information arising from the implementation of the Environmental Permitting Regulations that came into force on 1 April 2010.

Agricultural diffuse sources

Conclusions:

- The PSYCHIC model output for the Hampshire Avon catchment provides the most up-to-date estimates of agricultural diffuse P loads in soluble and particulate forms.

- While scope for improved estimates was identified by ADAS (2005), little work has been done to implement this. The underlying land use data is based on the 2000 agricultural census and further census updates are now available.

- The PSYCHIC results are amenable to inclusion in a SIMCAT model providing explicit estimates of agricultural diffuse P loads as inputs to the SIMCAT model. The estimates for the Hampshire Avon (ADAS 2005) can be used for this purpose.

- Agricultural diffuse pollution from livestock and arable land use are two of the 7 sectors of diffuse pollution to be included in the source apportionment tool under development in UKWIR project WW02. This tool will use the national PSYCHIC estimates as a basis.

Recommendations:

- The available results for the Hampshire Avon from PSYCHIC (ADAS 2005) should be used to provide explicit estimates of diffuse agricultural P loads in a further refinement of the National WFD SIMCAT model.

- The outcomes of the proposed approach to the estimation of diffuse P loads from livestock and arable sources as part of the Environment Agency UKWIR WW02 project should be compared with the PSYCHIC estimates already available for the Hampshire Avon to determine any differences and relative strengths and weaknesses in the context of the requirements of a PMP.

Agricultural point sources

Conclusions:

- The provisional estimates of P loads from agricultural point sources in PSYCHIC (ADAS 2005) are the only available estimates for this source in the Hampshire Avon. However, the provisional estimates appear to be in the same order as P loads from agricultural diffuse sources, suggesting that this source is potentially significant.

- A recent study by Withers and Jarvie (2008) suggests that runoff from impervious surfaces such as farmyards, and slurry stores show a large degree of temporal variability depending on the precise source. Storm runoff in farmyards has been shown to contain P concentrations as high as > 200 mg L^{-1} (Edwards *et al.* 2007), with the majority of the P in soluble form. Other studies have shown concentrations of 15 mg L^{-1} in farmyard runoff (Withers *et al.* 2009), and 51 mg L^{-1} in farmyard drains (Edwards and Hooda 2007), while concentrations from cowpath runoff were much lower, at 0.99 mg L^{-1} (Hively *et al.* 2005), and mostly in particulate form. As runoff from farmyards contains high proportions of SRP, it is likely to have a more significant ecological impact if the runoff is directed to a watercourse. Farmyard areas have also been estimated to contribute 25-30% of downstream P loads in some areas (Edwards and Hooda 2007), making it an ecologically significant source in these locations.

Recommendation:

- Further research into the sources and concentrations of these types of runoff in the Hampshire Avon specifically could indicate whether this is a significant source of P which needs to be addressed. In particular, the precise location of farmyards in the vicinity of watercourses should form part of the observations recorded in any catchment walkovers followed up with empirical studies to establish contributions from this source.

Road and urban runoff

Conclusions:

- No Hampshire Avon specific information was found for P loads from this source.

- However, work elsewhere suggests that P from vehicles, gardens and parks (WRc 2011) could be a significant source of P. A project funded by SNIFFER (2006) 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. EMCs for total and soluble P have been derived by Mitchell (2001) for general urban land use (0.34 mg L^{-1} total P and 0.5 mg L^{-1} soluble P) and for main roads and motorways (0.18 mg L^{-1} for both total and soluble P).

- Roads and urban runoff are two of the 7 sectors of diffuse pollution to be included in the Environment Agency UKWIR source apportionment tool and export coefficient approaches are under development for these sources.

- Despite the findings detailed above, urban P pollution is probably likely to be limited in the Hampshire Avon catchment, as there are few major urban centres and the land use is dominated by agriculture.

Recommendations:

- While the P loads from road and urban runoff is likely to be small in relation to other sources in the Hampshire Avon catchment, there is no available evidence to confirm this. The export coefficient approach proposed for the Environment Agency UKWIR source apportionment tool is recommended as a starting point for some limited investigation.

Groundwater

Conclusions:

- No Hampshire Avon specific information was found for P loads from this source.

- Jarvie *et al.* (2005a) concluded that groundwater is not a significant source of P in the Hampshire Avon based on a comparison of P concentrations in groundwater samples compared to river water samples. More than 60% of groundwater samples had TRP concentrations below 0.05 mg L^{-1} with highest concentrations in the Nadder sub-catchment due to its greensand geology.
- Holman *et al.* (2010) conducted a national assessment of groundwater P levels, finding slightly higher concentrations of P in England and Wales than in Scotland and Northern Ireland. The areas with the highest concentrations were found in the south east of England, with concentrations often above 0.05 mg L^{-1}. Concentrations in the Hampshire Avon were mostly below 0.03 mg L^{-1}, but some downstream areas may have concentrations between 0.03 and 0.05 mg L^{-1}.
- The Environment Agency UKWIR source apportionment tool does not include a sector for groundwater though 'background' is one of the sectors included.

Recommendations:

- The balance of available evidence suggests that groundwater P levels are low. However, this evidence is limited and an assessment based on current local groundwater monitoring data linked to connectivity with the river system would be worthwhile.

Key recommendations

The following key recommendations are made on the basis of the review and assessment of the existing information in the context of the requirements of a PMP:

- The National WFD SIMCAT model should be further refined to include <u>all</u> consented point sources on the Environment Agency register with up-to-date information on the level of treatment and with P loads calculated using available measured effluent P concentrations and effluent flows where available. The PSYCHIC estimates of agricultural diffuse P should be included as explicit inputs to the refined SIMCAT model. All other relevant features should be updated to produce a functional tool to support the development and implementation of a PMP.

- Further work should be undertaken to determine an approach to the identification of the location of unconsented point sources using the approach developed by May *et al.* (in press) but taking into account new information arising from the implementation of the Environmental Permitting Regulations and from the Environment Agency septic tank GIS layer.

- Further work should be undertaken to establish more robust estimates of P loads from agricultural point sources to determine their relative importance to other sources. This could include catchment walkovers to locate farmyards within each subcatchment and their proximity to watercourses.

- Further monitoring, including that carried out by the Defra Demonstration Test Catchments (DTC) project, could be useful to improve estimates from particular sources. The current monitoring network has good coverage due to enhanced monitoring under the ECSFDI programme, and should be maintained to aid further investigations. The enhanced monitoring network could also be beneficial if investigations into the effectiveness of measures to reduce P are planned.

- The Environment Agency UKWIR SIMCAT source apportionment tool is developing approaches to the estimation of P loads from diffuse agricultural sources (livestock and arable), urban and road runoff, septic tanks and ‘background’, using the results of studies including the PSYCHIC model. Where no Hampshire Avon specific estimates of P load are available, the approaches developed for this tool should be assessed and, if appropriate, used to derive P load estimates

Table 4.1 Summary of estimates of annual P loads from different sources to the of sub-catchments of the Hampshire Avon (From Bewes et al, 2011). Percentage contributions from different sources are given in parentheses where provided in the original study; they are not based on an integrated analysis across studies.

Subcatchment	Character summary	Annual P load t a^{-1} (% of total from each study where available)						Interpretation and comments
		Point sources			Diffuse sources			
		Consented point sources[1]	Unconsented point sources[2]		Agricultural diffuse sources[3]	Agricultural point sources[4]	Total diffuse sources[5]	
Reference		Murdoch (2010)	Murdoch	May et al	ADAS	ADAS	Murdoch	
Wylye	The Wylye rises near Kingston Deverill, south of Warminster on the Upper Greensand springs although most of the river flows over the Lower, Middle and Upper Chalks to join the Nadder at Wilton. The catchment is characterised by chalklands and chalk valleys containing aquifers, which provide a major source of water for domestic, agricultural and industrial purposes. The aquifer also results in spring lines and surface water flows on the	3.16 2.43 (25)	0.85 0.57 (6)	2.70	1.74 (8)	3.94 (18)	6.65 (69)	Based on Murdoch (2010) annual P loads are dominated by diffuse sources (69%) calculated by difference from the estimated in-river load and calculated loads from consented and unconsented point sources taking into account the most recent P stripping at STWs. However, these estimates are not based on measured effluent concentration and flow data at STWs. However, PSYCHIC estimates (ADAS 2005) also indicate that the contribution from farmyards could be significant.
Till	The River Till is wholly within a narrow sinuous chalk valley, the upper reaches a winterbourne channel that flows in winter and early spring. The perennial head is at Winterbourne Stoke. It is predominantly grazed improved grasslands							

Subcatchment	Character	Annual P load t a^{-1} (% of total from each study where available)						Interpretation and comments
		Point sources			Diffuse sources			
		Consented point sources[1]	Unconsented point sources[2]		Agricultural diffuse sources[3]	Agricultural point sources[4]	Total diffuse sources[5]	
Reference		**Murdoch (2010)**	**Murdoch (2010)**	**May et al (in**	**ADAS (2005)**	**ADAS (2005)**	**Murdoch (2010)**	
Nadder	The River Nadder is sourced near Ludwell rises on the clays and greensands of the Vale of Wardour and drains the escarpment of the South Wiltshire Downs and the clays of	0.98	0.63	1.60	2.44 (23)	1.8 (17)	Nd	PSYCHIC estimates (ADAS 2005) suggest that annual P loads from diffuse agricultural sources are greater than other sources. The estimates for point sources are not based on measured
Upper and Mid Avon	The Upper Avon (Units 3, 4, 9 and 11) is the second largest subcatchment rising at a number of locations on the upper greensands. The headwaters to the east flow from Dean Water between the Kennet & Avon Canal (to the North) and Pewsey (to the South). To the West,	3.79 2.35 (18)	1.05 0.65 (5)	nd	2.95 (20)	2.77 (19)	10.4 (78)	Annual P loads are dominated by diffuse sources (78%) calculated by difference from the estimated in-river load and calculated loads from consented and unconsented point sources taking into account the most recent

Bourne	The River Bourne is sourced near Burbage on the Chalk of Salisbury Plain and is a winterbourne upstream flowing due	1.52	0.86	nd	0.70 (6)	0.87 (7)	nd	Annual P load estimates are low compared with other sub-catchments. Current estimates suggest that point sources contribute a
Ebble	The River Ebble is sourced near Ebbesbourne Wake and stretches out for 22 km	0.01	0.97	nd	0.83 (31)	0.95 (36)	nd	Annual P load estimates are very low compared with other subcatchments. There are
Ashford and Lower Avon	Below Downton to Christchurch the river course is within Tertiary geology, of sands, gravels and clay with the	Nd	nd	nd	3.47 (15)	2.11 (9)	nd	No annual estimates of P loads from point sources are available for this subcatchment and so the relative contribution of point and diffuse
Total to catchment[6]		9.47	4.36	nd	12.13 (14)	12.44 (15)	nd	

nd = no data

<u>Notes:</u>

1 Estimates of annual P loads from consented point sources are taken only from Murdoch (2010) as these are the only available estimates which include the reductions in effluent P concentrations resulting from AMP4 P stripping at STWs. Estimates from Parr *et al.* (1998), Jarvie *et al.* (2005a) and ADAS (2005) were excluded on this basis. However, these estimates are not calculated from measured STW effluent P concentrations and measured effluent flow data and, with the exception of the Wylye and Upper and Mid Avon sub-catchments have not been compared with measured in-river P loads. Percentage values quoted are taken from Murdoch (2010) for the Wylye and Mid Avon sub-catchments and can be compared directly with those for total diffuse sources also provided by this study.

2 Estimates of annual P loads from unconsented point sources are taken from Murdoch (2010) and May et al (in press). The estimation methods differ (see Section 2.3) and those from May et al. (in press) can be considered as representing a ‘worse case’ scenario.

3 Estimates of annual P loads from agricultural diffuse sources are derived from the PSYCHIC model (ADAS 2005) and are calculated using measures of soil erosion, runoff and incidental losses of P.

Percentage values quoted are taken from ADAS 2005) and are not directly comparable with percentage values quoted from other studies.

[4] Estimates of annual P loads from agricultural point sources are derived from the PSYCHIC model (ADAS 2005) and are calculated based on the time spent by animals in open yards and the frequency of yard cleaning. Percentage values quoted are taken from ADAS 2005) and are not directly comparable with percentage values quoted from other studies.

[5]. Estimates of annual P loads from total diffuse sources are derived by Murdoch (2010) and calculated by difference from the estimated in-river load and calculated loads from consented and unconsented point sources taking into account the most recent P stripping at STWs. These estimates can be compared with the sum of the estimates from ADAS (2005) though they are not calculated in the same way. Other estimates of diffuse pollution from agriculture (Parr *et al.* (1998) and Ash *et al.* (2006)) were excluded because the land-use data used was out of date.

[6] Total values and percentages, where quoted, are taken directly from the component studies and do not necessarily represent sums of the sub-catchment loads.