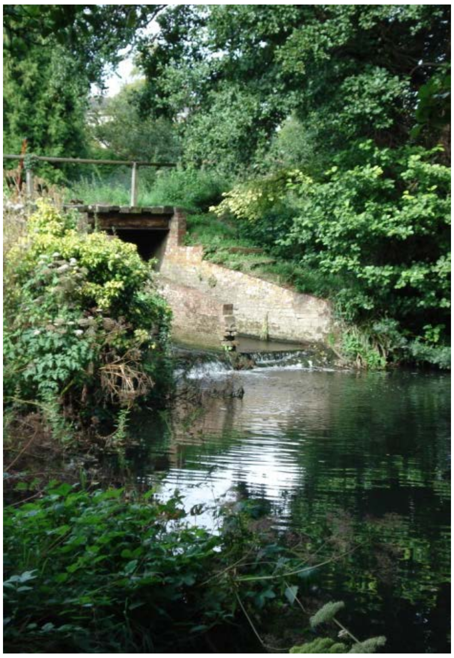
Portsmouth Water

PIM and WFD Investigations

Water Framework Directive Final Report



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Contents

1. Introduction

This report presents the results of the programme of investigations undertaken by AMEC for Portsmouth Water, from 2011 to 2013, to assess the impact of Portsmouth Water's abstractions on the environment. The over-arching driver for the studies is the Environment Agency's 'Restoring Sustainable Abstraction' programme, but with two distinct parts to the investigation:

- In-river investigations into the impact of a number of Portsmouth Water's abstractions on rivers highlighted through the Environment Agency's River Basin Management Planning (RBMP) process, in relation to the implementation of the Water Framework Directive (WFD);
- 'Post-implementation' monitoring (PIM) of European designated sites that were assessed under the Review of Consents but where the Environment Agency was not able to conclude 'no adverse effect' without further monitoring.

These have been considered as part of the same over-arching project, due to geographical similarities and overlaps in some of the data collection and analysis requirements. However due to the separate drivers, separate project reports are required. The purpose of this report is to present the findings of the Water Framework Directive study. The findings of the PIM study are reported separately in report reference 30206C121.

1.1.1 Background to the project

In 2009 the Environment Agency provided Portsmouth Water with a scope of work to be investigated in AMP5 under the driver of the WFD. The Environment Agency identified the scope of WFD investigations based on their water resource assessments. The first cycle RBMPs (published December 2009) divide main rivers in to reaches that are identified as individual waterbodies. For each waterbody, the ecological status is defined based on a range of biological and physiochemical criteria, with the aim of bringing all waterbodies to 'Good Ecological Status' (GES) by 2015. The impact of abstraction on flows is a supporting criterion in the achievement of GES: i.e. an impact on flows does not constitute a failure of GES in itself, but if biological parameters that could be related to flow also fail, it may be determined that reductions in flow are contributing to the failure. On this basis, the Environment Agency has identified waterbodies requiring further investigation with respect to Portsmouth Water's abstractions where:

- The waterbody combined ecological status is less than Good, and this correlates with the failure of a biological element;
- The influenced flow statistic at Q95 is estimated to be below 50 per cent of the Environmental Flow Indicator (EFI);
- The deficit in the Q95 is greater than 2Ml/d; and
- At least 50 per cent of the impact on flows is from water company abstractions (Environment Agency, 2009).

This resulted in the identification of waterbodies requiring assessment in four catchments: the Hamble, Wallington, Ems and Lavant (as shown in Figure 1.1).

In 2010, AMEC (then Entec) worked with Portsmouth Water to refine the scope of work proposed by the Environment Agency and integrate it with the proposed PIM investigation programme. This included a review of all proposed monitoring and the drivers for each aspect, and discussions with the Environment Agency. During this process, some aspects of the scope were reduced or omitted entirely. The results of the scoping study were presented in Entec (2010). AMEC were commissioned to undertake the scope of work from the Entec (2010) scoping study, with some revisions, in June 2011.

1.2 Project aims

The Environment Agency has identified specific waterbodies in each catchment that require assessment. However, the project has taken the aim of understanding the impacts of abstraction on the catchment as a whole, and then focussing back in on the specific waterbodies, in order to be able to put any localised impacts in the catchment context to understand their significance.

Impacts on flow are a 'supporting standard' under WFD. This means that a failure of a flow target should only contribute towards reducing the status of a waterbody if it is resulting in deterioration of a biological or physic-chemical element. For this reason, site-specific hydro-ecological investigations are required rather than relying on a purely hydrological assessment.

The focus of WFD water resource investigations has primarily been in relation to evidence of existing or historic impact: i.e. considering whether the existing abstraction regime is having an impact on the river. Despite this, the project has also considered the potential effects of abstraction increasing to its fully licensed rates, since this is considered more likely to lead to conclusions that will remain sustainable in to the future. This approach fits in with recent developments in the Environment Agency's approach to WFD assessments, as they are now moving towards greater consideration of "no deterioration". Although the Environment Agency's approach towards "no deterioration" is still evolving, it is expected that it will require greater consideration of fully licensed abstraction rates, to prevent any future increases in abstraction, even within existing licence limits, contributing to a reduction in status of a waterbody.

The aims of this project are therefore to:

- Confirm the extent of impact of Portsmouth Water's abstractions on river flows in the identified waterbodies and the downstream catchment, at both existing and fully licensed abstraction regimes;
- Investigate whether there are any failures of biological or physico-chemical elements that could be a result of, or partly contributed by, impacts on the flow regime; and
- Understand the relevance of other pressures in the waterbodies and wider catchments, in influencing the biology of the river and potentially interacting with flow impacts.

1.3 Introduction to the sites

Table 1.1 shows the catchments and designated sites that have been included in the scope of work.

Table 1.1 Summary of scope of the WFD investigations

Catchment	Waterbodies	Waterbody status (2009)	Portsmouth Water sources
Hamble	107042016290 107042016240	Moderate Ecological Potential Moderate Ecological Status	Northbrook Lower Upham
Wallington	GB107041016410 GB107042016360	Moderate Ecological Status Moderate Ecological Status	Newtown Worlds End Maindell Lovedean
Ems	GB107041012370	Poor Ecological Potential	Walderton Woodmancote
Lavant	GB107041012360	Good Ecological Status	Lavant Brickkiln

Text in grey denotes sources that do not require investigation in AMP5. Lower Upham does not require consideration because its impact on flows in the Hamble catchment was determined by the Environment Agency to be minor. Lovedean is not included because previous studies (Entec, 2006) have found it to be predominantly linked to Havant and Bedhampton springs rather than the Wallington

1.4 Report structure

The remainder of this report includes:

- Section 2 describes the work that has been undertaken to contribute to the WFD investigation, including monitoring and analytical approaches;
- The assessments of impact have been presented on a catchment-by-catchment basis. The catchments are reported in:
  - Section 3: Impacts of abstraction on the River Hamble;
  - Section 4: Impacts of abstraction on the River Wallington;
  - Section 5: Impacts of abstraction on the River Ems;
  - Section 6: Impacts of abstraction on the River Lavant.
- Section 7 summarises the conclusions of the study, including both waterbody-specific and catchment-specific conclusions.

Sections 3-6 present the main results and findings from the assessments. More detailed assessments are included for relevant aspects in appendices, which can be referred to for more detail.

2. Approach

2.1 Overview

An overview of the scope of monitoring undertaken as part of this project is presented in Table 2.1, with more detail on specific aspects provided in the rest of this section.

Table 2.1 Scope of work

Subject area	Intended scope of work	Actual work undertaken
WFD investigations		
Hydrometric monitoring: gauging	Monthly gauging at a number of locations through each catchment, tied in to biology sampling sites.	Monthly gauging July 2011 to January 2013, and will be continued to March 2013. All gauging locations coincide with agreed biology sampling points. Locations in ephemeral reaches were also visited when there was no flow, to maintain a continuous photographic record.
Hydrometric monitoring: ephemeral reaches	During the winter re-wetting and summer drying of the ephemeral reaches, more frequent walkover visits to be made to the relevant river reaches	Weekly visits to the Ems and Lavant from January-May 2012. Occasional visits through summer 2012. Flow has been continuous at all locations since then. Visits were mainly to gauging sites, although some walkovers were carried out along Lavant with agreement of landowners. Occasional visits to head of Hamble.
Water quality monitoring	Spot monitoring of temperature, electrical conductivity (EC) and dissolved oxygen (DO) with flow gaugings. One continuous DO logger on each river.	Spot measurements of water quality taken on all gauging visits. Includes temperature, pH, DO and EC. DO loggers installed on Hamble, Wallington and Ems (not on Lavant since often completely dry).
River Habitat Surveys	River Habitat Surveys to be carried out at 2km intervals along the length of all rivers. GeoRHS was also proposed.	Hamble, Wallington and lower Ems surveyed in September 2011. Upper Ems and all Lavant sites surveyed in May 2012 (although some sites still did not have flow at that time). Surveys were carried out at invertebrate sampling locations. This averaged out to approximately every 2km as planned, but it was more appropriate to focus on the exact biology locations. GeoRHS surveys at two locations per catchment – a representative sub-set of the sampling locations was selected.
Macroinvertebrate surveys	Three-minute kick-samples to be taken in autumn 2011, spring 2012 and autumn 2012. Sampled at agreed sites on all rivers, all of which had been sampled on at least one occasion previously by EA.	Samples in all catchments taken in three seasons, whenever there was flow at the survey location (no autumn 2011 or spring 2012 surveys from most of Lavant, upper Ems or upper Hamble). Samples collected by EA in autumn 2010 were also analysed by AMEC. Additional samples were collected from the Lavant approximately monthly over summer 2012, to assess recovery of invertebrate community with flow.

Table 2.1 (continued) Scope of work

Subject area	Intended scope of work	Actual work undertaken
Macrophyte surveys	Surveys in each summer, focussed on the same locations as the invertebrate surveys, using LEAFPACs method (UKTAG, 2008).	Surveys completed in all catchments in September 2011 and 2012. Where there was no flow, vegetation in channel was still recorded.
Fish surveys	Electrofishing to be carried out on a single occasion along the River Hamble.	Agreed with EA that this was not required.
Groundwater investigations		
Pumping tests	Pumping tests for Ems and Lavant sources. Approach agreed between AMEC and Portsmouth Water and documented in AMEC (2011c).	Pumping tests completed at Walderton, Lavant and Brickkiln as planned. Results have been documented in AMEC (2011c). Test at Woodmancote was not possible because the source was out of use at the time and could not be re-started.

2.2 Monitoring

2.2.1 Overall approach and monitoring locations

Macro-invertebrate sample locations had been selected by the Environment Agency before the project started. This included some locations in each catchment that had long-term biology records (extending back through the 1990s in the Hamble and Wallington, and to around 2000 in the Ems and Lavant), as well as a wider distribution of sites where monitoring had only commenced in 2010. The sites selected by the Environment Agency were reviewed to confirm whether they were of an appropriate distribution to inform the assessment of impact of Portsmouth Water's abstractions in each catchment. No obvious gaps in the site frequency or distribution were discovered, so all of the Environment Agency's proposed sites were retained for consistency and to increase the number of samples available at each site. The monitoring locations in each catchment are identified in Figures 2.1 (Hamble), 2.2 (Wallington), 2.3 (Ems) and 2.4 (Lavant), and the grid references of each site are specified in Table 2.2.

Data from all surveys have been collated in a database (Appendix O).

Table 2.2 Monitoring locations for the 2011-12 investigations

River	Site ref	Site name	Grid ref	Equivalent EA biology site ref	Sampling
Hamble	H1	Upstream of Abbey Ponds	SU 55444 17791	152830	Flow, invertebrates, macrophytes, RHS
	H2	Abbey Ponds north	SU 55160 17550	81918	Invertebrates, macrophytes
	H3	Abbey Ponds south	SU 55057 17456	97196	Invertebrates, macrophytes
	H4	Upstream of Brooklands Farm	SU 54268 16806	82199	Flow, invertebrates, macrophytes, RHS, GeoRHS
	H5	Wintershill tributary	SU 54258 16810	82198	Flow, invertebrates, macrophytes, RHS
	H6	Moors Stream	SU 54300 16000	42933	Flow, invertebrates, macrophytes, RHS
	H7	Durley Mill	SU 52510 15140	43174	Flow, invertebrates, macrophytes, RHS
	H8	Maddoxford Farm	SU 51800 14400	43125	Flow, invertebrates, macrophytes, RHS, GeoRHS, DO
	H9	Horton Heath Stream	SU 51720 14370	42285	Flow, invertebrates, macrophytes, RHS
Wallington	W1	Worlds End tributary	SU 62220 11350	83718	Flow, invertebrates, macrophytes, RHS
	W2	Newtown tributary	SU 62200 11340	83717	Flow, invertebrates, macrophytes, RHS, GeoRHS
	W3	Newmans Bridge	SU 62130 08750	42879	Flow, invertebrates, macrophytes, RHS
	W4	Spurlings Farm	SU 58600 07900	42017	Flow, invertebrates, macrophytes, RHS, GeoRHS, DO
	W5	Upstream of M27	SU 58775 07433	152937	Flow, invertebrates, macrophytes, RHS
	W6	Downstream of M27	SU 58593 07058	152936	Flow, invertebrates, macrophytes, RHS
Ems	E1	Walderton	SU 78883 10643	78499	Flow, invertebrates, macrophytes, RHS
	E2	Lordington Manor	SU 78240 09742	95452	Flow, invertebrates, macrophytes, RHS
	E3		SU 77220 08594	96645	Flow, invertebrates, macrophytes, RHS, GeoRHS
	E4	Downstream of augmentation	SU 76102 07909	82657	Flow, invertebrates, macrophytes, RHS
	E5	Rivers Street tributary	SU 75941 08179	96641	Flow, invertebrates, macrophytes, RHS
	E6	Upstream of Westbourne gauging station	SU 75500 07450	75936	Flow, invertebrates, macrophytes, RHS, GeoRHS, DO

Table 2.2 (continued) Monitoring locations for the 2011-12 investigations

River	Site ref	Site name	Grid ref	Equivalent EA biology site ref	Sampling
Lavant	L1	Fox Goes Free	SU 88891 12991	78398	Flow, invertebrates, macrophytes, RHS
	L2	Upstream of West Dean (a)	SU 87511 13020	n/a	Flow only
	L3	Upstream of West Dean (b)	SU 87123 12964	96681	Invertebrates, macrophytes, RHS
	L4	Downstream of West Dean	SU 85850 12086	75938	Flow, invertebrates, macrophytes, RHS, GeoRHS
	L5	Hayes Down	SU 85200 09950	96663	Flow, invertebrates, macrophytes, RHS
	L6	Downstream of Lavant abstraction	SU 85620 09607	79836/ 96682	Flow, invertebrates, macrophytes, RHS, GeoRHS
	L7	Mid Lavant	SU 85830 08436	97301	Flow, invertebrates, macrophytes, RHS

2.2.2 Flow and water quality

There is one permanent gauging station in each catchment, as listed in Table 2.3.

Table 2.3 Permanent gauging stations in the study catchments

Catchment	Gauging station	Grid ref	Period of record
Hamble	Frogmill	SU 523 149	1972-present
Wallington	North Fareham	SU 587 075	1951-present
Ems	Westbourne	SU 755 074	1967-present
Lavant	Graylingwell	SU 871 064	1970-present

Spot flow surveys have been carried out by Hydro-Logic in all catchments once a month from July 2011 to March 2013. These have been undertaken at all of the biology survey locations, as shown in Table 2.2, so that site-specific flow data are available to tie-in more directly to the biology data (compared to the gauging station data alone). All spot flow surveys have been carried out by wade gauging with a current meter, repeated at the same location on each occasion. Use of a consistent location means that the cross-section and velocity information can be used for analysis as well as the flow data.

From the start of the survey period in July 2011 until spring 2012, some of the survey locations were dry. This included sites H1, W1, W2, E1-E3 and L1-L7. All of these sites were still visited monthly by Hydro-Logic, and a photograph taken of the channel.

The main ephemeral reaches were visited more frequently around the time when they may have been expected to start flowing. The intention had been to do this over two autumn and one spring season (i.e. to capture the wetting up of the catchment twice, and the drying once), but the climatic conditions (as described further in Section 2.4) over the project duration have been such that only a single period of wetting up has been experienced. Regular visits were made to the key monitoring locations on the Lavant through winter-spring, and a photo-record kept of key sites. In addition, walkover surveys of the upper Lavant were carried out occasionally, when some flow commenced around West Dean, to confirm the exact locations where flow started and stopped. The upper Ems and Hamble were also visited occasionally.

The data from all of the flow surveys can be found in the project monitoring database (Appendix O). A summary of the ephemeral reach visits, including maps of the changing extent of flow in the Lavant in early 2012, is presented in Appendix P.

2.2.3 River Habitat Surveys

RHS

Flow and channel morphology are closely related in terms of hydro-ecological effect, since it is in general not the flow volume that is important, but the range of depths and velocities occurring as a result of a particular flow, which will depend on the channel cross-section. The effect of the interaction between altered morphology and flow is considered in the DRIED-UP analysis approach (Dunbar *et al.*, 2006, 2008, 2009), which has been employed in the perennial reaches of these catchments. In order to provide the information required for DRIED-UP, River Habitat Surveys (RHS) have been carried out by accredited surveyors at all macroinvertebrate monitoring locations, using the methodology specified in Environment Agency (2003).

The intention was for all RHS to be completed in 2011 so the results were available for use in interim analysis. However full RHS requires water to be present in the catchment which, as noted above, was not the case at all sites in 2011 and early 2012. Locations with flow were surveyed in September 2011 (including the Hamble below Abbey Ponds, the Wallington and lower Ems). The remaining locations were surveyed in May 2012, at which point all sites on the Lavant had flow but E1-E3 and H1 were still dry. For the latter, the survey was still carried out but some sections are incomplete due to the lack of flow.

The results of the RHS were input to the RAPID database (Davy-Bowker *et al.*, 2008), from which were automatically calculated the Habitat Modification Scores (HMS) and sub-scores, and the Habitat Quality Assessments (HQAs). These scores have been used in the general characterisation of each river, as well as being used quantitatively in DRIED-UP, which specifically uses the re-sectioning and poaching sub-scores.

The scores and sub-scores from the RHS surveys are included in Appendix J and are recorded in the project database, as well as being mapped for each catchment in the relevant catchment chapters.

GeoRHS

In addition to RHS, the use of GeoRHS had been discussed during the scoping project (Entec, 2010) to assist with identifying and recording wider pressures, particularly relating to sediment input (which had been identified in Holmes, 2007 as being relevant in the Ems and Lavant catchments). Geo-RHS is an expanded version of RHS that involves a more extensive assessment of the geomorphology of the river, floodplain and catchment (Branson *et al.*, 2005), so has the potential to allow further assessment of any wider pressures relating to morphology and sediment.

In the first few months of this project, the catchment characterisation and knowledge was developed extensively as a result of the regular site-visits that were being undertaken, and this gave a reasonable qualitative understanding of pressures acting on the catchment. Partly as a result of this, it was felt that carrying out GeoRHS at all of the sample locations in Table 2.2 was unnecessary. Instead, two representative sites were selected in each catchment, and GeoRHS was carried out in September 2012 using the methodology specified in Branson *et al.* (2005).

A summary of the findings of the GeoRHS is presented in Appendix K.

2.2.4 Macroinvertebrate surveys

As noted in Section 2.2.1, macroinvertebrate surveys have been continued at locations already identified by the Environment Agency. Spring and autumn surveys were planned for 2011 and 2012 at all locations, which would replace the Environment Agency's monitoring in all four catchments, However since the project did not in the end get underway until June 2011, the spring surveys were carried out by a separately commissioned contractor. The analysis provided by that contractor unfortunately did not include abundance data, which means that not all biotic indices could be calculated and as a result no LIFE scores are available for spring 2011.

Autumn 2011 and 2012 samples and spring 2012 samples were collected and analysed by AMEC for all sites with flow, as identified in Table 2.4.

Table 2.4 Summary of macroinvertebrate samples collected for this project

Catchment	Autumn 2011	Spring 2012	Autumn 2012
Hamble	H3 to H9	H3 to H9	H3 to H9
Wallington	W1 to W6	W1 to W6	W1 to W6
Ems	E5, E6	E4 to E6	E1 to E6
Lavant	-	L4, L4	L1, L3 to L7

In addition to the routine spring and autumn sampling, extra samples were collected from the River Lavant through the summer 2012 as flow developed, to allow the development of the invertebrate community to be observed.

A record of the results from all monitoring in this project is included in the project database in Appendix O, with all of the biotic indices also presented in Appendix E. The biotic indices have been combined with all historic data collected by the Environment Agency to show a full historic record for each site.

2.2.5 Macrophyte surveys

Rivers

Macrophyte surveys used the standard LEAFPACS survey method as set out in Water Framework Directive - United Kingdom Advisory Group (2008). Each survey section covered 100 metres of river, and aquatic macrophytes and macroalgae within the zone flooded for at least 50% of the year were recorded with their abundance scored on a 10 point scale. As the upper limit of survey is usually quite difficult to estimate, recording often extended higher up the bank than this, and as a result, a significant number of non-aquatic species have been included in the lists. However, this does not affect the LEAFPACS scores as these are based on a shortlist of strictly aquatic species.

Several scores are used in the LEAFPACS method to summarise the macrophyte data (WFD-TAG 2008). These comprise River Macrophyte Nutrient Index (RMNI), River Macrophyte Hydraulic Index (RMHI), Number of aquatic taxa (N_ATAXA-R), Number of functional groups (N_RFG) and Algal cover (ALG-COV). Additionally, although it is not one of the standard LEAFPACS metrics the cover of macrophytes, including algae, is also recorded. These scores are defined below.

- **River Macrophyte Nutrient Index (RMNI)** -Each aquatic species has a score between 0-10 based on their mean nutrient tolerance. This is combined with the abundance in each section to produce a mean nutrient score, with the higher scores indicating higher nutrient levels;

- **River Macrophyte Hydraulic Index (RMHI) -** Each aquatic species has been allocated a score between 0-10 based on their mean association with flow rates. Species with high scores are associated with low energy flow environments. This is combined with the abundance in each section to produce a mean hydraulic score, with the lower scores indicating a macrophyte community with a higher proportion of high flow species;

- **Number of aquatic taxa (N_ATAXA-R) -** This score is the number of aquatic macrophytes based on a set checklist of taxa used in the LEAFPACS survey;

- **Number of functional groups (N_RFG) -** This score is based on the life forms of the aquatic species present (e.g. group 1 covers duckweeds and other small free-floating species, group 2 covers stoneworts, group 3 covers blue-green algae, group 4 covers stiff rosette-type vascular plants such as *Littorella uniflora*, etc);

- **Algal cover (ALG-COV) -** This is the percentage cover of macro-algae.

A number of physical parameters were also recorded. Unlike the plant survey, these were assessed in relation to the actual water level at the time of survey. All of the LEAFPACS results are recorded in Appendix M.

Ponds

Abbey North and South ponds at Bishop's Waltham on the River Hamble were surveyed using variations of the standing water LEAFPACS survey method as set out in Water Framework Directive - United Kingdom Advisory Group (2009). The Abbey North Pond was dry at the time of both surveys and this was surveyed by a 20 point transect along the south side of the foot bridge which crosses the pond. This was an adaptation of the boat transect element of the LEAFPACS method, except that the transect was from shore to shore irrespective of the lack of standing water and DAFOR abundances were recorded at each sample point rather than just presence/absence. The location of the transect along the bridge means that the transect can be repeated when the pond is full without the need of a boat.

The Abbey South Pond was surveyed using a wader transect. This involved 4 sample points at 25 cm, 50 cm, 75 cm and >75 cm depths at five equally spaced points along 100 metres of the northern shore. At each sample point the DAFOR abundance of any species encountered was recorded. In addition, a perimeter transect was surveyed at the same location as the wader transect. This involved recording the shoreline species present in 5 x 20 metre stretches of the 100 metre transect.

In both ponds a full species list was recorded for the whole pond and an overall DAFOR abundance given to all of the wetland and aquatic species.

2.3 Analysis and Modelling

2.3.1 Hydrological modelling

The hydrological impacts of abstraction on all sites have been investigated using the East Hampshire-Chichester Chalk (EHCC) groundwater model.

The EHCC groundwater model was developed by Entec for the Environment Agency from 2005-7. Phases 1 and 2 of the EHCC project produced a conceptual and numerical model, as described in Entec (2006) and Entec (2007). Model predictions of the impacts of groundwater abstractions on river flows and freshwater inflows to Portsmouth, Chichester and Langstone Harbours were summarised in Entec (2008). Recommendations were also made for Phase 3 monitoring and investigations to improve hydrogeological understanding and refine the performance of the eastern (Sussex) half of the model.

The EHCC has recently been updated and refined by AMEC for the Environment Agency (AMEC, 2012), including updates to the runoff and recharge and groundwater components of the model. This included updating the model to September 2011, and undertaking some refinements to improve the model calibration. The main priorities for re-calibration included: River Meon; Aldingbourne Rife; River Ems; River Lavant; Swanbourne Lake and Park Bottom springs; and Bosham Stream. The model refinements were made by calibration of the historic simulation to observed historic data, and subsequently updated predictions were produced of the in-combination impacts of standard Environment Agency abstraction and discharge scenarios (Recent Actual and Fully Licensed, compared against Natural). Details of the new standard model runs are provided in Table 2.5.

Table 2.2 Flow scenarios and corresponding model run numbers

Scenario	Summary of definition	Run used for modelled flow impact assessment
Naturalised	This represents the 'natural' flow condition if there were no abstractions, discharges or main leakages. In the EHCC model the naturalised period is from 1965 to 2011.	124
Historic	This scenario uses actual historical levels of abstractions and discharges obtained from the Environment Agency's National Abstraction Licensing Database (NALD) and previous databases. In some cases where no abstraction returns are available infilling of datasets is carried out using the licence quantity and a typical uptake factor.	127
Recent Actual	Abstractions and discharges operating at rates derived from averaging monthly historic rates 2006-2010. The average excludes any non-typical shutdowns etc.	128
Fully Licensed	This scenario is derived from maximum licensed quantities taken from the CAMS ledger. For licences with an abstraction period of 365 days an average daily abstractions rate is assumed based on the maximum annual licence quantity distributed across the licensed abstraction period, proportionate to the distribution of the recent actual quantity.	151

The EHCC groundwater model provides spatially-distributed outputs including groundwater levels and river flows, on a 10-day time-step covering a period from 1965 to 2011. Outputs of modelled flows at specific locations in the relevant catchments have been extracted from the standard scenarios mentioned above. In addition, a number of runs have been undertaken as part of this project to understand the influence of individual licences within the overall abstraction impact. These have generally been undertaken using the Recent Actual scenario as the baseline, with a single abstraction either 'turned up' to its Fully Licensed rate, or 'turned down' to zero.

2.3.2 Macroinvertebrate analysis

Biotic Indices

Biological Monitoring Working Party (BMWP) scores, Number of Taxa (NTAXA), Average Score per Taxon (ASPT) and LIFE(F) scores have been calculated for all samples. LIFE(F) scores have been calculated using the PISCES Conservation computer programme (Species Diversity and Richness version 4.1.2). These indices were also available for historic samples.

ASPT and NTAXA scores are used to determine the ecological status of rivers for WFD. This relies upon derivation of an Ecological Quality Ratio (EQR) that compares expected scores for the ASPT index with observed scores. The expected scores are calculated based on physical and physico-chemical parameters of the river, as calculated in the River Invertebrate Classification Tool (RICT, UKTAG 2008). The Expected scores in this assessment were received from the Environment Agency. For sites with long-term records, the Expected scores were calculated from 1995 site environmental data, whereas for new sites they have been based on 2009 data (Phillip Rudd, EA, pers. comm. 21 February 2012). If an EQR of one is achieved, this means that the ASPT scores are as would be expected in a river in good condition, based on the local conditions. If the ratio is significantly less than one it may be taken as an indication of water quality pressures on the waterbody (although other pressures such as physical habitat availability may also have an influence). The Ecological Quality Ratios (EQRs) for ASPT, used to indicate the biological status of watercourses, are calculated using the boundary values indicated in Table 2.6 below.

Although not officially forming part of the ecological status assessment for rivers, the biotic index of LIFE (Lotic Invertebrate Index for Flow Evaluation, originally developed by Extence *et al*., 1999) is widely used by the Environment Agency to indicate whether flows are limiting the invertebrate populations, in contrast to other indices such as ASPT and NTAXA which have been used more for water quality purposes. If LIFE is being considered, a ratio of significantly less than one for the EQR probably indicates a measure of flow stress on the fauna present. Potential LIFE (f) EQR values have been proposed during other work for the Environment Agency and are increasingly being used in the analysis of whether flows are limiting the invertebrate fauna. The proposed EQR values are presented in Table 2.6 below (for LIFE, only an indicative value that may indicate 'Good' status is included, at 0.945), again using Expected scores provided by the Environment Agency.

Table 2.6 Biological Status Boundary Values (existing ASPT and NTAXA values and proposed LIFE)

Index	High	Good	Moderate	Poor	Bad
ASPT (used to determine biological status)	0.97	0.86	0.75	0.63	<0.63
NTAXA (used to determine biological status)	0.85	0.71	0.57	0.47	<0.47
LIFE(F) (proposed- not currently used in ecological status determination)		0.945			

Use of DRIED-UP

The DRIED-UP projects (Dunbar *et al.*, 2006, Dunbar and Mould, 2008, Dunbar *et al.*, 2009a, Dunbar *et al.*, 2009b) have created a series of statistical models that describe the relationship between family LIFE score and two types of explanatory variables:

- Time-varying: seasonal daily mean flow statistics (high flows – Q10 and low flows – Q95), time(year); and
- Time-static River Habitat Survey sub-scores.

Flow statistics are normalised to allow comparison between different catchment sizes and flow regimes. The model includes a linear time trend component to describe ongoing linear changes (typically increases) in LIFE score not relating to the flow variables used in DRIED-UP, which are seen across many rivers. The version of the model used here (DRIED-UP4) uses the flow variables described in Table 2.7.

Table 2.7 Flow variables used in the DRIED-UP 4 model

Flow variable abbreviation	Description
Q95z	Normalised Q95 flow in six month standard period prior to sampling, i.e. summer (April to September) for autumn samples, winter (October to March) for spring samples
Q10z	As above, but Q10 statistic
Q95zLS1	Normalised Q95 statistic for summer prior to year of biology sample, i.e. if sample taken in 2010, Q95zLS1 would be Q95z flow for summer 2009
Q95zLS2	Normalised Q95 statistic for two summers prior to year of biology sample, i.e. if sample taken in 2010, Q95zLS1 would be Q95z flow for summer 2008
Q10zLS2	As for Q95zLS2, but Q10 statistic
Q95z:Q10z	Interaction between Q95z and Q10z. This has the effect that where Q95z and Q10z are both low, the combined effect is more negative than would be expected from simply adding the two effects.

The DRIED-UP model is based on a dataset of around 140 biology monitoring sites, with around 3,000 data points (each point is a match of a macroinvertebrate sample, the flow statistics and RHS scores). Lowland sites are matched to flow gauging stations, while some upland sites are matched to gauging stations and others to synthetic natural daily mean flow series. The model is based on spring and autumn macroinvertebrate sample data. It can be used to predict LIFE score response at a new site to flow given only flow and River Habitat Survey data, although when used in this way, the predictions are relatively uncertain. Where local biological data are available for new sites of interest, these can be incorporated into the model (with accompanying flow and RHS survey data).

Assessment of flow-LIFE relationships and impacts of abstraction

The assessment for the Hamble and Wallington has considered the impacts of flow on macroinvertebrate communities, based on the biotic index LIFE (Extence *et al*., 1999). The assessment has been undertaken in three stages:

- The Environment Agency approach to Hydro-Ecological Validation (HEV) is used, by which LIFE scores as well as ASPT and NTAXA are plotted up as a time series along with a representative flow time series for the location in question. This allows a qualitative consideration of apparent relationships between those indices and flow. The LIFE, ASPT and NTAXA scores are plotted as EQRs, which also allows assessment of the status of the biology at this location;

- Relationships between LIFE and flow are investigated by plotting one against the other and fitting a regression line to the data, to see whether there is a relationship with a good fit, i.e. with a high R^2 (assuming a linear relationship) . This considers the spring and autumn LIFE scores separately and together, and compares them against a range of flow statistics. Flow statistics are calculated throughout the flow duration curve, taking in to account either the full year's worth of flow data, or considering only summer (April-September) or only winter flows (October-March). Flow statistics using only the previous year of data, and the previous two years', are both calculated. Different rivers (and different sites within the same river) can respond to flow over varying timescales, so it is important to consider a variety of statistics in making this assessment. Where high R^2 values are achieved, the nature of the relationship (e.g. the slope) is considered. The strength and type of these relationships informs the assessment of the influence of flow on LIFE scores;

- In order to consider the impact of different flow scenarios, and the combined influence of habitat modification, LIFE scores have also been modelled using DRIED-UP (as described above) (This approach also allows a more extensive time series to be modelled at sites where there is limited data). Time series of LIFE scores for under each abstraction scenario are plotted and compared. This is an important additional step to the analysis, because it predicts the extent to which different abstraction scenarios might be expected to actually influence LIFE scores, and also shows the extent to which habitat modification may be contributing to reduced LIFE scores or causing greater sensitivity to changes in flow. This provides evidence rather than automatically assuming that low LIFE scores are attributable to abstraction.

Carrying out these three steps together allows a good picture to be built up regarding the impacts of flow on macroinvertebrate communities, which is taken as an indicator of the health of the aquatic system overall. In each catchment the assessment has been undertaken for each monitoring location individually, with overall conclusions then being drawn regarding the river as a whole.

Assessment of ephemeral watercourses

For ephemeral rivers (the whole of the Lavant and the upper Ems), the biotic indices discussed above have been given some consideration, to provide some consistency between catchments, but are not designed for intermittently-flowing watercourses and do not necessarily provide a good overall picture of the quality of ephemeral streams. The assessment for the Ems and Lavant has therefore considered the invertebrate species data directly. The approach to this is described further in Appendices H and I, and in the relevant parts of Sections 5 and 6, since it is a more site-specific approach. This has included use of a wider range of metrics describing invertebrate species diversity: Simpson’s index (a diversity index), Shannon index (also a diversity index but downweighs rare species), Margalef richness (which standardises the number of species by the total number of individuals to adjust for passive increases in diversity expected with bigger samples) and Berger-Parker index (which is a species dominance index i.e. an inverse of diversity indices. Principal Components Analysis (PCA) has also been undertaken using all available data.

2.3.3 Velocity assessments

Assessments of the velocities experienced in each river have been carried out to consider how the physical habitat availability compares to expected preferences of the biota found in the rivers, including macrophytes (mainly *Ranunculus* species) and macroinvertebrates.

Velocity requirements for macroinvertebrates can be taken from the basis of the LIFE index (Extence *et al*, 1999), which assigns invertebrate families/ species to particular LIFE flow groups as indicated in Table 2.8 below. The velocity assessment has used 20 cm/s as a lower threshold to indicate whether flow is likely to be suitable for taxa preferring faster flows (i.e. those in LIFE flow groups I and II).

Table 2.8 LIFE flow groups (From Extence *et al*, 1999)

Group	Ecological Flow Association	Mean Current Velocity
I	Taxa primarily associated with rapid flows	Typically >100cm/s
II	Taxa primarily associated with moderate or fast flows	Typically 20-100 cm/s
III	Taxa primarily associated with slow or sluggish flows	Typically <20cm/s
IV	Taxa primarily associated with flowing (usually slow) and standing waters	-
V	Taxa primarily associated with standing waters	-
VI	Taxa frequently associated with drying or drought impacted sites	-

Other studies that have investigated the flow requirements of Chalk river habitats have focused primarily on *Ranunculus* spp. Flow is known to be one of the most important variables governing *Ranunculus* cover, with declining summer mean discharge, minimum flows and lower frequencies of summer flushing negatively correlated with *Ranunculus* cover (Wilby *et al*, 1992) and positively correlated with filamentous algae cover. Chalk river *Ranunculus* spp. also preferentially colonise faster flowing water, and prefer deeper water, (Flynn *et al*, 2002) that provides a continuous nutrient and carbon dioxide supply. Relatively high flow velocities also prevent algae smothering *Ranunculus*, which would impede photosynthesis and its role in oxygenating Chalk Rivers.

Ranunculus often grows as part of a cycle of macrophyte growth, which may be influenced by flow and velocity. As flow rates drop silt is deposited around the *Ranunculus*, facilitating colonisation by marginal macrophytes such as fool's watercress and watercress (Giles *et al*, 1991) and by filamentous algae. The *Ranunculus* dies back, after a period of peak biomass during late summer, leaving relatively unstable watercress/ fool's watercress beds, which are subsequently washed away by elevated winter flows (Giles *et al*, 1991). Hence, flow velocity can influence the proportion of *Ranunculus* relative to marginal, emergent macrophytes.

Acceptable velocity ranges for *Ranunculus* were derived by Scott Wilson (2004) and used by Atkins (2005) to consider macrophyte habitat on the River Kennet. The velocity ranges, which are presented in Table 2.9, are considered to be representative of preferred *Ranunculus* habitats in chalk streams.

Table 2.9 Ranunculus Velocity Requirements (applicable April-November, from Atkins, 2005)

Velocity	Suitability
<10 cm/s	Below optimum
10-30 cm/s	Acceptable, but may make *Ranunculus* vulnerable to other stresses
30-50 cm/s	Optimal range
>50 cm/s	*Ranunculus* grows in velocities greater than 50cm/s but may be subject to mechanical stresses

The velocity assessment is based on flow-velocity relationships derived using a combination of cross-section details and total flows from spot flow data, and flows from the groundwater model. It has been undertaken at all locations where there has been flow for the majority of the project duration.

Relationships between flows and velocities were derived using the spot flow surveys undertaken between July 2011 and September 2012. The approach can be summarised as:

1. Derive linear relationships between flow and velocity using the spot flow data. Maximum and median velocities were considered: this gives an idea of both the overall habitat suitability in the channel (median velocity) as well as whether there is any suitable habitat available at all (maximum velocity);

2. Develop daily flow time series at each location. This has been achieved by using flow data from the gauging station in the catchment, combined with modelled accretion (from the EHCC groundwater model) between the location of interest and the gauging station at each model stress period. This was done for each of the standard scenarios in the EHCC model (naturalised, historic, recent actual and fully licensed);

3. Calculate median and maximum velocity time series at each interest location and for each flow scenario by converting the flow time series from step 2 using the relationships from step 1.

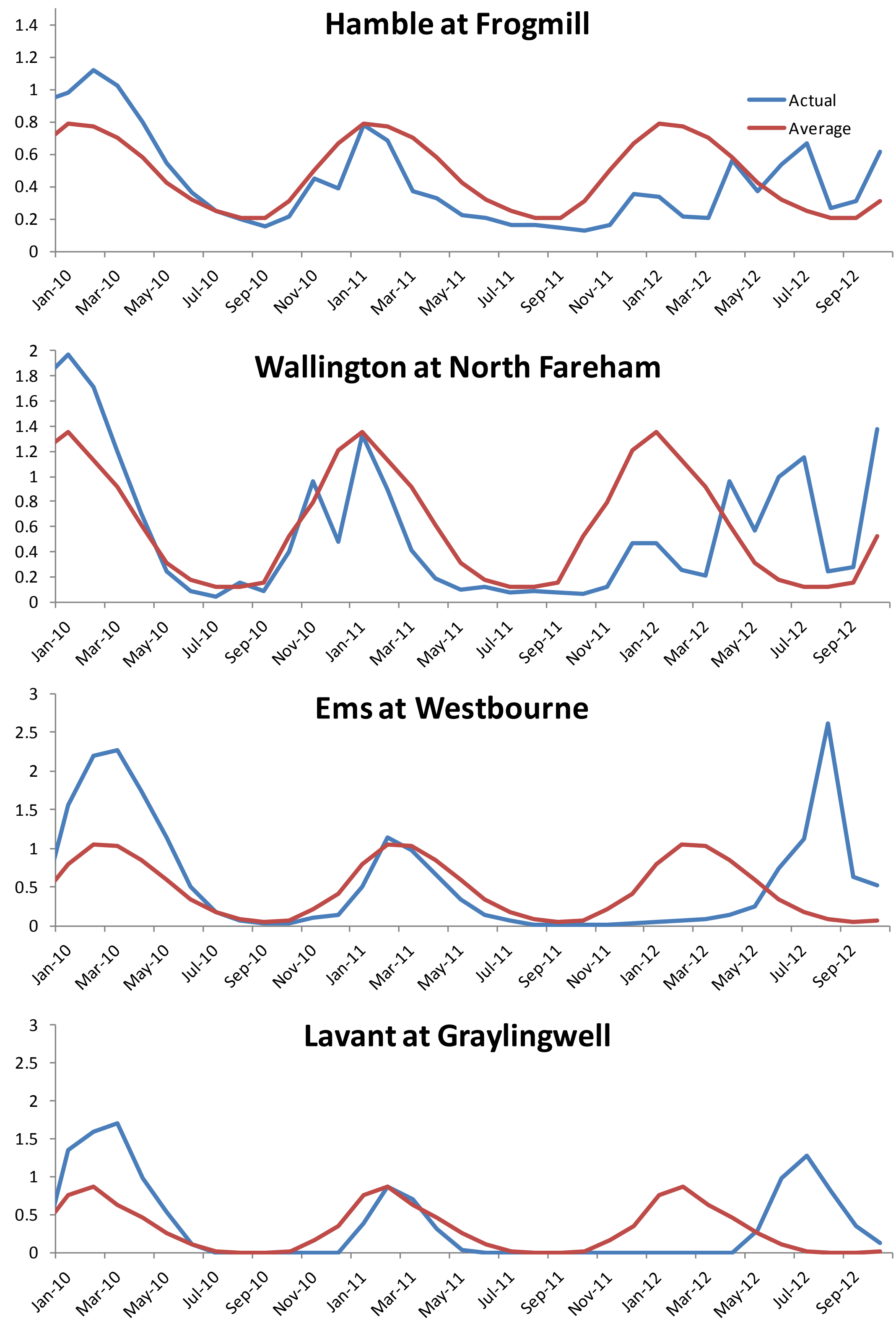
This approach gives a set of velocity time series for each location, which can be compared visually as an indication of the change in physical habitat suitability between flow scenarios, and quantitatively by comparison to the standards identified above in Tables 2.8 and 2.9.

2.4 Climatic conditions during the study

The study has been carried out over a period of atypical weather conditions. For the first nine months of the project, conditions were relatively dry; with a dry winter from 2011-12. Since this followed a dry winter in 2010-11, it was widely assumed that this would cause low groundwater levels and low flows to persist through the summer of 2012, and hosepipe bans were introduced in April 2012 in much of the south of England (although not by Portsmouth Water). However, the summer and autumn of 2012 then proved to be exceptionally wet, to the extent that groundwater levels recovered throughout the summer and flows increased considerably, at a time when they would usually be falling. The extent of recovery, and the contrast between winter and summer rainfall in 2012, were exceptional and have been reported thus far in bulletins by organisations including the Met Office and the Centre for Ecology and Hydrology, for example the December 2012 Hydrological Summary from CEH[1] reports that “the change in the groundwater situation in the last nine months, from a prevalence of exceptionally low levels in early spring to the current extremely high levels, has no modern parallel”. The same bulletin reports the total rainfall for southern England for 2012 to have been 999 mm, 902 mm of which fell from April-December. Figure 2.5 shows the delayed recovery of river flows in 2012 in the Hamble, Wallington, Ems and Lavant compared to the long-term average.

[1] http://www.ceh.ac.uk/data/nrfa/nhmp/hs/pdf/HS_201212.pdf

Figure 2.5 **Average monthly flow in relevant rivers, showing recovery in summer 2012**



3. River Hamble

3.1 Introduction

3.1.1 Catchment overview

The River Hamble is located on the east side of Southampton Water, immediately to the east of the Itchen catchment. The main course of the Hamble originates to the northeast of Bishops Waltham, where it is a small ephemeral channel that flows in to the northern of two ponds in the middle of Bishops Waltham. Abbey Pond north is the larger of the two but can dry out completely, while the smaller Abbey Pond south retains water all year and is used for angling. From the south pond, the Hamble flows in a general southwesterly direction to the tidal limit of the Hamble Estuary at Botley, over a total length of around 8 km. The Hamble has a number of tributaries, some of which flow directly to the upper estuary, but the main tributaries feeding in to the freshwater river are the Wintershill tributary (which joins the Hamble 1 km downstream of Bishops Waltham), the Moors Stream (another 1 km downstream) and the Horton Heath Stream (1.5 km upstream of the tidal limit at Botley, labelled Ford Lake on Ordnance Survey mapping). The latter two contribute a significant proportion of the total flow to the Hamble, as considered further in Section 3.2. The head of the Moors stream is from springs at The Moors SSSI on the southern edge of Bishops Waltham. These springs lie, similarly to the headwaters of the main Hamble and Wintershill tributary, at the southern edge of the Upper Chalk, where it falls beneath the Lambeth group and then Paleogene deposits. The rest of the river length then overlies the relatively impermeable Paleogene deposits.

Overall the land use in the catchment is mainly rural, but with the urban areas of Bishops Waltham in the upper catchment and Botley and Hedge End in the lower catchment. The main areas of modification to the natural channel are at Bishops Waltham (the ponds), and in the mid catchment around Durley Mill, where a system of former mill channels still exists.

The Hamble and its tributaries are separated in to a number of waterbodies in the Southeast RBMP (Environment Agency, 2009). All of the water bodies that are linked to the freshwater Hamble catchment are listed in Table 3.1, with the two that are the focus of this investigation in bold. The upper Hamble waterbodies do not include any biological elements in the classification, with the exception of the Moors Stream, where invertebrates are at High status. Failure to meet Good Ecological Status (GES) or Good Ecological Potential (GEP) in the catchment occurs as a result of phosphate and fish failures. The former of these is relevant to all waterbodies following the main Hamble channel. The fish failures are presumed to relate to Botley Mill, at the tidal limit, where a fish pass has now been installed.

Table 3.1 Waterbodies classified in the first RBMP (Environment Agency, 2009)

Reach	Waterbody ID	Overall status	Flow supporting condition	Reasons for failure*
Upper Hamble (Wintershill)	107042016280	Good	Band 2 failure	n/a
Upper Hamble	**107042016290**	Moderate Ecological Potential	Band 2 failure	Phosphate (P) and Mitigation Measures (fish access)
Upper Hamble	**107042016240**	Moderate	Band 1 failure	Phosphate (M)
Upper Hamble (Moors Stream)	107042016260	Good	Band 2 failure	n/a
Mid Hamble	107042016250	Moderate	Band 1 failure	Phosphate (P) (fish G, inverts H)
Lower Hamble	107042016580	Poor	Band 1 failure	Fish (P) (inverts G)
Horton Heath Stream	107042016570	Moderate Ecological Potential	Compliant	Fish (P) (inverts G)

* Where biological elements have been assessed and are not failing, they are included in brackets

3.1.2 Portsmouth Water abstractions

The main abstractions in the catchment are Portsmouth Water's sources (PWS) at Northbrook and Lower Upham. These comprise the vast majority of abstractions in the catchment, with the details provided in Table 3.2. The main discharge is Bishops Waltham sewage treatment works (STW) which is located midway between Northbrook PWS and Frogmill gauging station (see Figure 2.1).

Table 3.2 PWS abstractions in the Hamble catchment

Licence number	Name	Licensed quantity	Group licence	Recent actual abstraction
25.2/50	Northbrook	7487.262Ml/a, 28Ml/d	28Ml/d	15.03 Ml/d
25.2/50	Lower Upham	640Ml/a, 3.5Ml/d		0.39 Ml/d

Recent actual abstraction 2006-2010

3.2 Hydrological Assessment

A detailed hydrological assessment for the catchment is presented in Appendix A, which includes consideration of observed data and use of the EHCC groundwater model. A summary is provided here.

3.2.1 Observed hydrological regime

There is one permanent gauging station in the catchment, at Frogmill (NGR SU 523 149). This does not capture flows in the lower catchment or from the Horton Heath Stream. The mean flow recorded at Frogmill from the full period of record (1972-2012) is 0.47m^3/s, with a Q95 of 0.11m^3/s. The National River Flow Archive (NRFA) gives a Base Flow Index (BFI) of 0.66[2], indicating that the river is relatively baseflow dominated, but is also influenced by runoff. This is a reflection of the catchment geology, with Chalk springs in the headwaters providing baseflow, but overlying impermeable deposits in the lower catchment also increasing the amount of catchment runoff.

The gauging data from Frogmill is supplemented by spot flow surveys carried out by Hydro-Logic through the project, which has allowed the accretion through the catchment to be better understood.

The head of the Hamble comprises a short reach of channel to the north of Bishops Waltham, which then flows in to two ponds in Bishops Waltham (Abbey Pond North and Abbey Pond South). Abbey Pond North is often dry (it was not until late 2012 that the pond filled substantially), but the morphology of the basin suggests that this would not have been the case historically and that a larger pond would have existed naturally.

Below the Abbey Ponds, flow occurs in the river relatively consistently. Flow was recorded at site H4 (immediately upstream of the confluence with the Winterhill tributary) on every occasion throughout the period of monitoring, although it was as low as one litre per second in July and August 2011. There is considerable accretion from H4 downstream, with flow at H4 commonly being less than 5 per cent of the flow at Frogmill gauging station. The main source of accretion is the Moors Stream, which generally contributes 50 per cent or more of the flow at Frogmill.

3.2.2 Impact of historic, current and fully licensed abstraction regimes

The assessment in Appendix A shows that impacts from abstraction on flow occur as a result of groundwater-surface water interactions in the upper catchment. This includes the upper reaches of the River Hamble from just downstream of Bishops Waltham and above, as well as the upper-most headwaters of the Wintershill tributary and the Moors Stream. Further downstream the Chalk becomes confined, so there are no longer direct interactions with the river.

Under low flow conditions the impacts on groundwater-surface water interaction in the upper Hamble and tributaries are relatively small, because the abstractions are drawing primarily on storage, with limited interaction with the river (the exception to this is on the Moors Stream tributaries southeast of Northbrook PWS, where the springs in The Moors SSSI continue to flow at low flows). In contrast to the low flow periods, impacts of abstraction on the flow regime of the upper Hamble are more obvious under higher flows, where groundwater-surface water interaction and baseflow contribution to flows is higher.

The impacts of abstraction on low flows at key points through the catchment are summarised in Table 3.3. In the upper part of the catchment, where the river is naturally ephemeral or reaches very low flows, there is no potential for further reducing low flows compared to natural as a result of abstraction. In these upper parts of the catchment the following observations can be made:

Base Flow Index (BFI) varies between 0 (entirely runoff) and 1 (entirely baseflow)

- The outflow from waterbody GB 107042 016240 is located downstream of Bishops Waltham sewage treatment works (STW). Here, while flows are reduced compared to natural, they plateau at around 3.5Ml/d (in the historic, RA and FL scenarios), due to the influence of the discharge from the STW. Low flows from the upper river at these times are primarily contributed by STW discharge;

- Upstream of Bishops Waltham STW, where there is no artificial discharge to sustain a minimum flow, abstraction increases the length of time that the river would be effectively dry. As noted above, in the naturalised scenario the river is perennial as far as Bishops Waltham. However in this intervening reach between Bishops Waltham and the STW, abstraction causes flow to be reduced to zero for about 15 per cent of the time under the Fully Licensed scenario and for about 10 per cent of the time under Recent Actual.

- In this reach below Bishops Waltham (around the outflow from waterbody GB 107042 016240), there is a substantial reduction from natural during the times when there is flow[3]. The fully licensed scenario has a mean flow (Q30) of 2.3Ml/d, compared to the Naturalised mean flow of 16.2Ml/d;

- Upstream of the Bishops Waltham ponds, flow occurs only 74 per cent of the time in the naturalised scenario, reducing to just 33 per cent and 28 per cent of the time for the Recent Actual and Fully Licensed scenarios respectively.

Table 3.3 Modelled Q95 (Ml/d) at key locations in the Hamble catchment

Location	Naturalised	Recent Actual	Historic	Fully Licensed
Outflow from GB 107042 016290	3.5	0	0	0
Outflow from GB 107042 016240	3.8	3.2	3.2	3.2
Frogmill GS	18.6	10.2	8	5.3
Outflow from GB 107042 016580	19.5	11.1	9	6.5

The assessment shows that the river is naturally ephemeral upstream of Abbey Pond South. Compared to the naturalised scenario, abstraction at both Recent Actual and Fully Licensed rates has the potential to both extend the ephemeral reach further downstream, and to increase the length of time for which the river dries out (noting that the assessment using the groundwater model in fact has to assess the length of time that flows fall below a nominal threshold, rather than actually to zero).

Taking the dry summer of 2006 as an example, the groundwater model shows the onset of accretion being upstream of the Abbey Ponds for the naturalised scenario, but at the south pond for the Historic, Recent Actual and Fully Licensed Scenarios. In comparison, the onset of accretion in the wet spring of 2002 is noticeably different, with flow beginning to accrete around 2km upstream of Northbrook PWS for the Historic, Naturalised and Recent Actual Scenarios, reduced to approximately 1km upstream of Northbrook PWS for the Fully Licensed scenario. Thus the Fully Licensed abstraction has the potential to extend the upper ephemeral reaches of the River Hamble

[3] The observed data actually showed there to be flow at H4 throughout 2011 and early 2012, but the flow was so low that it may be treated as negligible/zero flow in the groundwater model

approximately 1km in the downstream direction compared to Naturalised. The presence of the ponds in Bishops Waltham, on the edge of the Chalk, helps to prevent the ephemeral reach from extending any further downstream.

Overall, it may be concluded that abstraction in the upper Hamble catchment has a significant effect on river flows that is manifested primarily as reduced rate of flow in the mid to lower catchment, and reduced duration of flow in the upper catchment. The impact on flows is proportionally greatest around the outflow of waterbody GB107042016290 (corresponding to monitoring point H4), and in a reach of around 1km in length upstream of the Abbey Ponds, where the duration of flow is significantly reduced as a result of abstraction.

3.3 Hydro-ecological Assessment

3.3.1 Assessment locations

Hydro-ecological assessment of the river has focussed on sites H4 (upstream of Brooklands Farm), H5 (Wintershill Tributary), H7 (Durley Mill) and H8 (Maddoxford Farm). Site H1 has not been included because it was dry for the vast majority of the study period, meaning that it is only feasible at that location to assess on a purely hydrological basis. Sites H2 and H3 are not included in the river assessments because they are in the ponds in Bishops Waltham: these have been assessed separately in Section 3.3.4. Although sites H6 and H9 are included in the overall catchment context, they are not included in detail in the impact analysis because they are located on tributaries.

3.3.2 Macroinvertebrate analysis

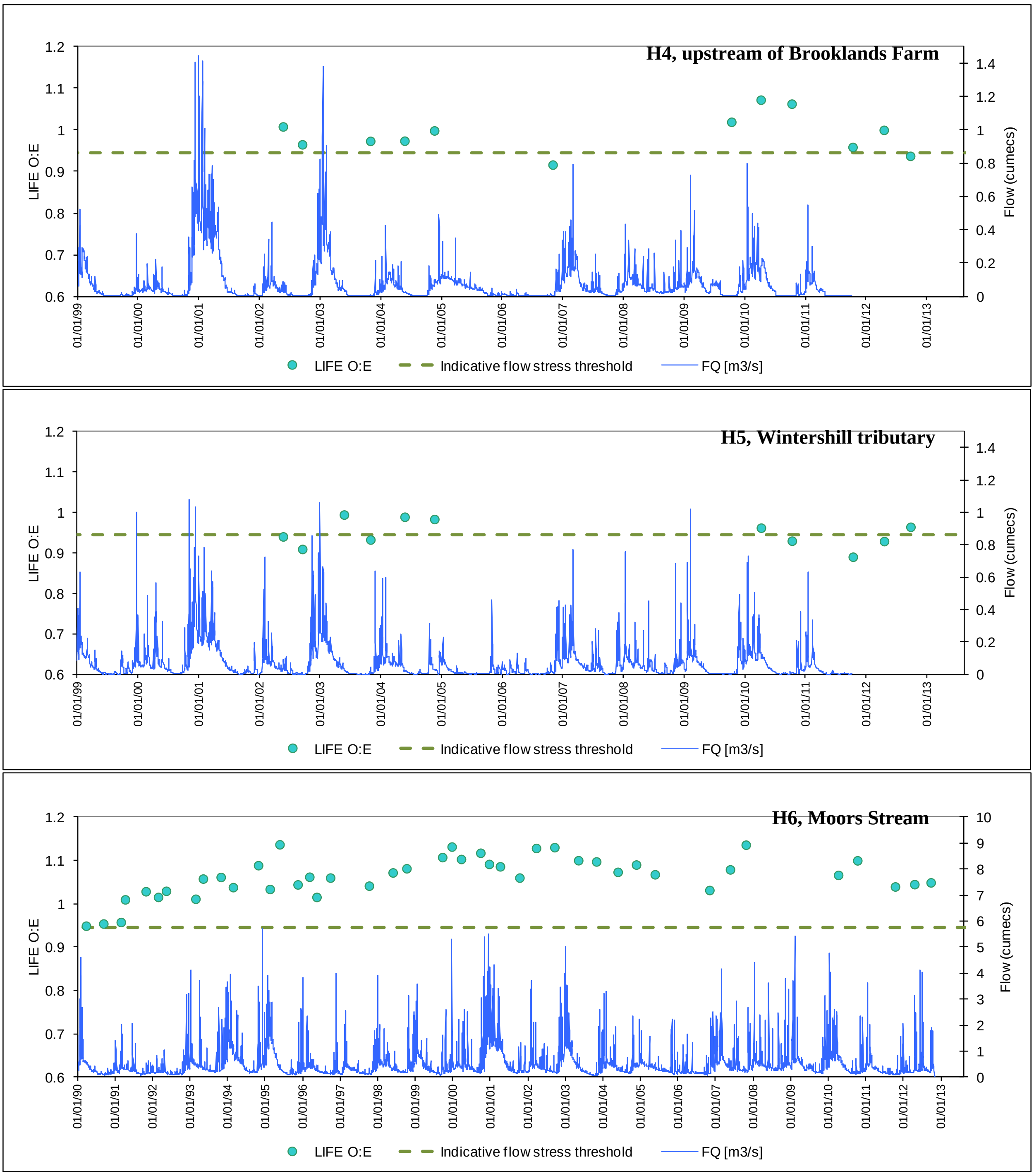
A detailed assessment of the invertebrate data (as assessed using the approach described in Section 2) is presented in Appendix F, with a summary here. Plots of observed LIFE scores over time are shown in Figure 3.1, and predicted LIFE scores under different abstraction scenarios, as modelled in DRIED-UP, are shown in Figure 3.2.

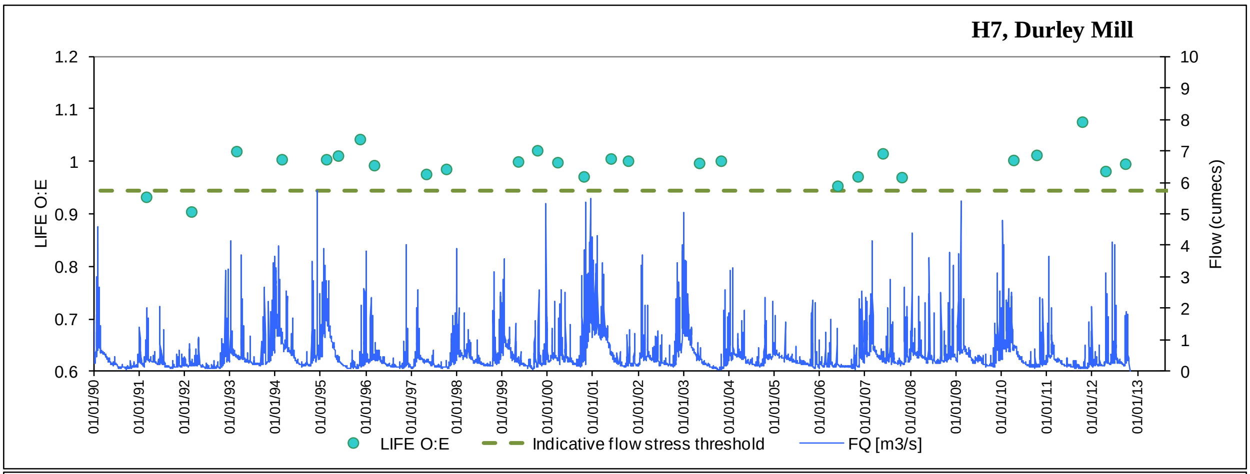
There is insufficient data at the furthest upstream site, H1, to compare with the other sites, although the single data point indicated Poor status for both LIFE and NTAXA. Given the very infrequent flow at this site, it would not be surprising if the macroinvertebrate communities are lacking in diversity and in species preferring high flows. The hydrological assessment here must dominate the conclusions for the site, in terms of the almost complete absence of flow at this site. As a result, H1 is not included in Table 3.4 below. The Abbey Ponds (sites H2 and H3) are considered separately below.

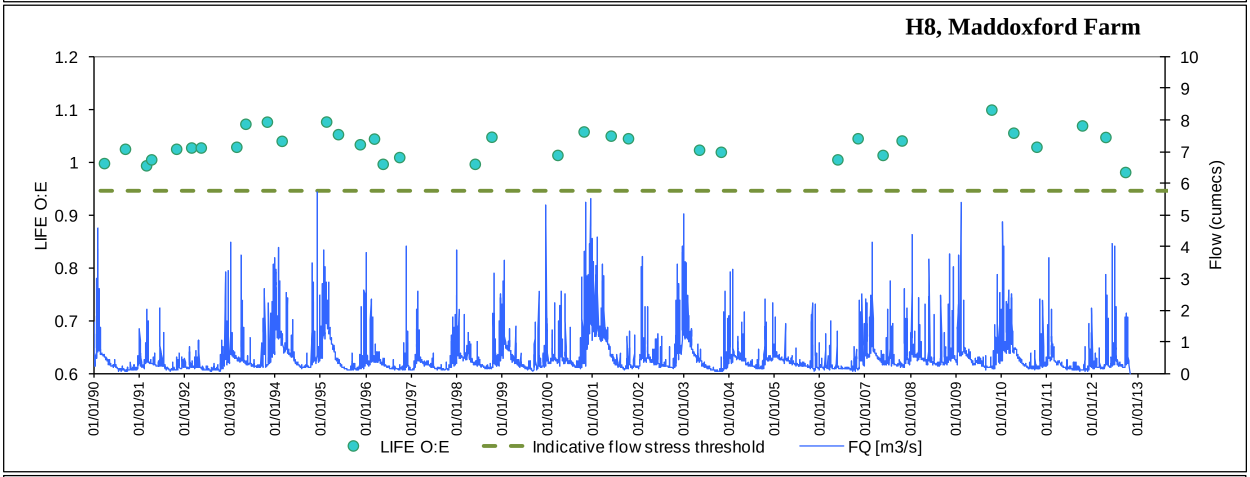
Table 3.4 Summary of hydro-ecological assessment using LIFE, for the River Hamble

Site	Assessment
H4	**Upstream of Brooklands Farm**. Invertebrate data are available from 2002 onwards, although not in every season/year. The observed data suggest good water quality, based on NTAXA and ASPT, which are almost always at Good or High. LIFE scores are generally found to be above the EQR threshold of 0.945, although have fallen below on two occasions. Regression relationships between LIFE and flow were tested. There were too few spring samples for the relationships to be significant. Autumn LIFE scores show little relationship to low flows, which is likely to be because summer low flows are normally very close to zero, and thus there may be little difference between years in the lowest flows. The regression relationships suggest that differences in mid to high flows between years may have more influence on LIFE scores, since relationships with high R^2 are for winter flows and for mid to high annual flows. The assessment using DRIED-UP indicates that differences in the flow regime as a result of abstraction are likely to have an influence on LIFE scores. The substantial difference in flows at this location between the historic and naturalised scenarios can be seen in the DRIED-UP results. When the model outputs are considered as EQRs, the results suggest that LIFE scores under the historic flow regime (and, for the most part, fully licensed) are sufficient to meet the 0.945 threshold. The naturalised scenario would allow an EQR of greater than 1 to be achieved almost all of the time.
H5	**Wintershill tributary**. Invertebrate data are available from 2002 onwards, although not in every season/year. The data suggest reasonable water quality, based on NTAXA and ASPT, with NTAXA commonly at High status and ASPT at Good. LIFE scores at this site have been inconsistent, varying quite widely above and below the 0.945 threshold. Regression relationships between LIFE and flow were tested but did not show any significant relationships. The assessment was hampered by the relatively small amount of observed data. Similar assessment using modelled data from DRIED-UP indicates the same: although flow does influence LIFE, there is not a direct linear relationship between the two for this site. DRIED-UP predicts that an altered flow regime (e.g. naturalised) would have an influence on LIFE scores. The modelling results suggest that with naturalised flows, LIFE scores would be more likely to achieve an EQR of greater than 0.945 for a greater proportion of the time.
H7	**Durley Mill.** Invertebrate data are available from 1991 onwards, with a few gaps. The data suggest good water quality, based on NTAXA and ASPT, with both commonly being a High status or the high end of Good. The exception to this is the last two years of NTAXA data, where scores have dropped sharply to Moderate. LIFE scores at this site have been consistently high since 1993, often being above 1 and always above 0.945. Observations of the time series data suggest there could be a tendency for scores to drop with flows, and this is reinforced with high R^2 in the regression assessment between LIFE and flow. Autumn flows show some relationship to higher flows, with some higher R^2 from mid flows upwards against annual and winter-only flows. When the same relationships are plotted using modelled LIFE scores from DRIED-UP, the results are similar, showing a more defined relationship to Q10 compared to Q95. The modelled and observed flows at this site show a similar range of LIFE scores, giving high confidence to the model results. The model results show, as the observed scores have done, that the historic regime allows LIFE EQRs above 0.945 threshold to be consistently achieved, and that there is relatively little variability between years compared to the upstream sites. The model results also indicate that this would still be the case under the fully licensed abstraction scenario, although there would be a small reduction at fully licensed compared to historic. The model results indicate that naturalised flows would have the potential to increase LIFE EQRs to consistently exceed a ratio of 1, and possibly to exhibit slightly less variability overall.
H8	**Maddoxford Farm**. Invertebrate data are available from 1989 onwards, with a few gaps. The data suggest good water quality, based on NTAXA and ASPT, with both commonly being at High status. The exception to this is the last two years of NTAXA data, where scores have dropped to Moderate- Good, similarly to H7. LIFE scores at this site have been consistently above 1 since the start of the record. Observations of the time series data suggest some tendency for LIFE to vary with flow. Regression relationships between LIFE and flow do not show this very strongly, but do show some moderately good R^2 values for autumn LIFE scores compared against annual low flows (particularly around Q90). When compared to the results from DRIED-UP, it suggests that the apparently limited relationship between LIFE and flow may result from contributing factors such as gaps in the observed data record and influences of other environmental variables besides flow, since the DRIED-UP model outputs show a reasonably clear relationship between LIFE and either Q95 or Q10. Comparison of model scenarios from DRIED-UP illustrates that naturalised flows would have the potential to allow increased LIFE scores. However this should b e considered in light of the already very high LIFE scores that are achieved at this site, with the model outputs based on the historic flows and also the fully licensed flows consistently having an EQR of greater than 1.

Figure 3.1 HEV plots (LIFE only) for the River Hamble (from upstream to downstream, and including tributaries)




H7, Durley Mill
LIFE O:E
Flow (cumecs)
LIFE O:E
Indicative flow stress threshold
FQ [m3/s]


H8, Maddoxford Farm
LIFE O:E
Flow (cumecs)
LIFE O:E
Indicative flow stress threshold
FQ [m3/s]

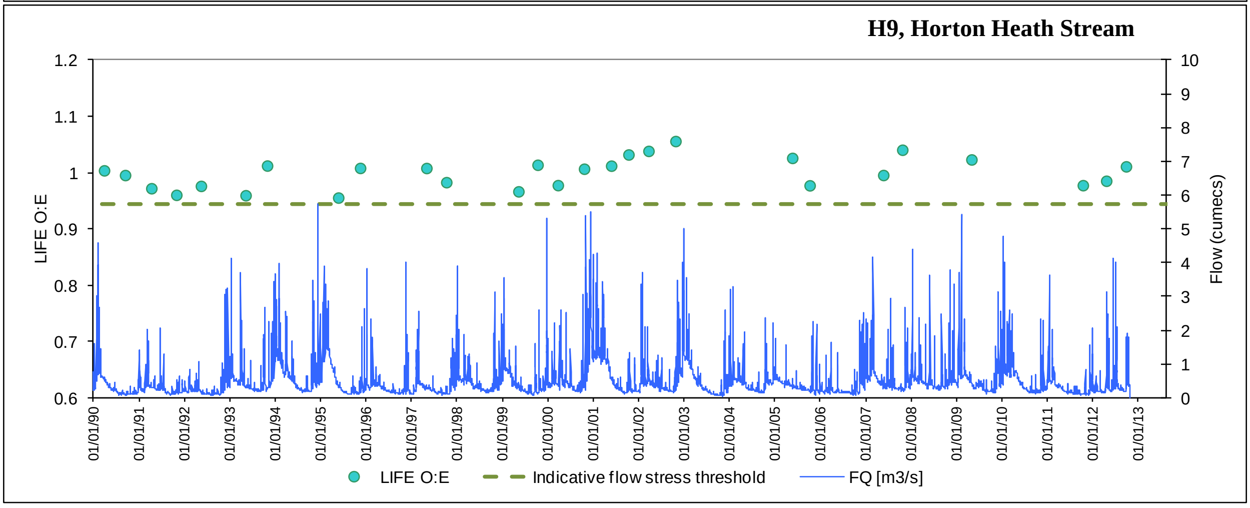
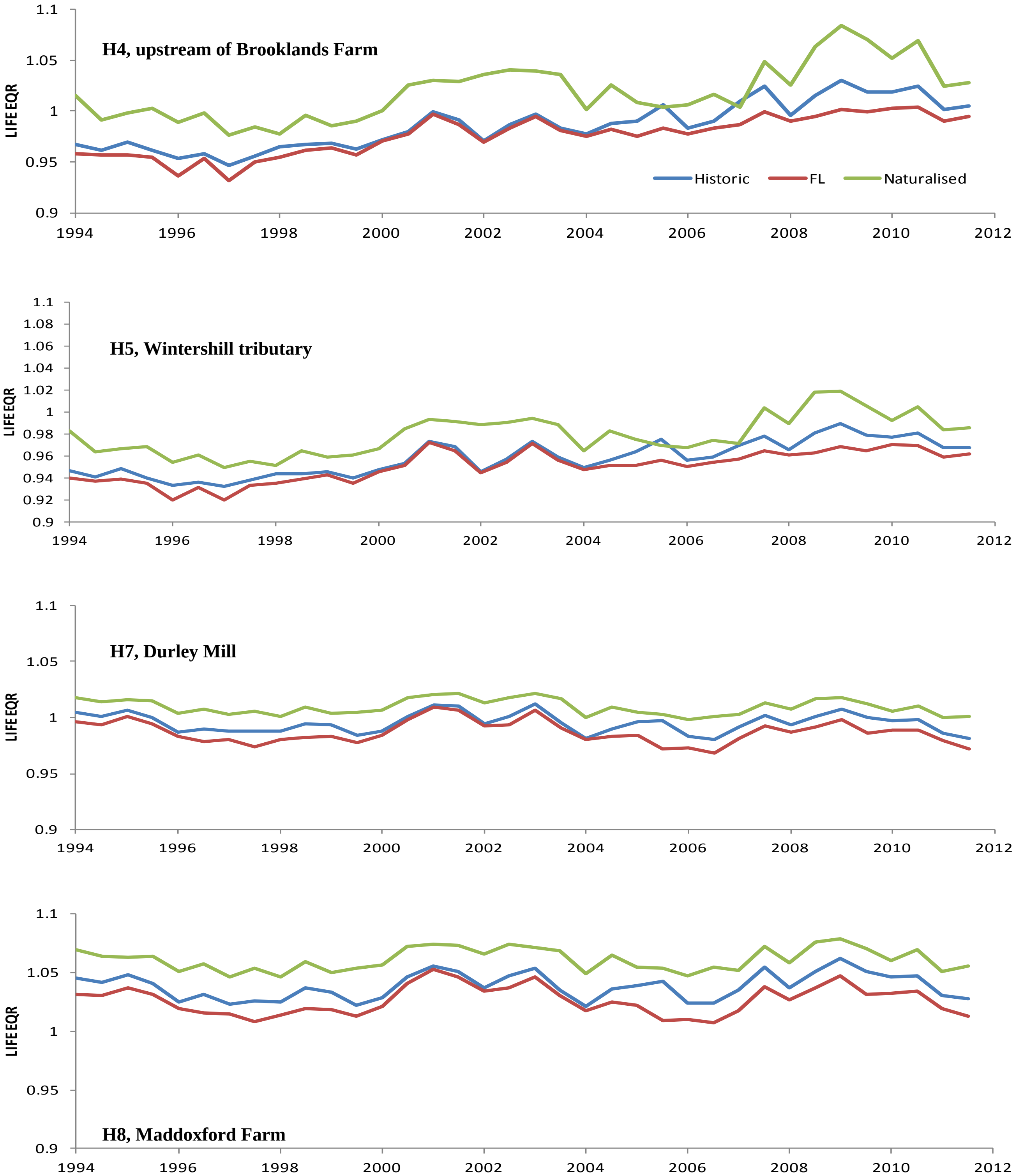

H9, Horton Heath Stream
LIFE O:E
Flow (cumecs)
LIFE O:E
Indicative flow stress threshold
FQ [m3/s]

Figure 3.2 Results of DRIED-UP modelling, showing predicted impacts of abstraction on LIFE scores



The assessments for the individual monitoring locations along the River Hamble have shown that, based on LIFE EQRs, the status of the river is improved in the downstream half of the river compared to the upper river (waterbodies GB107042016290 and GB107042016240). Sites H7 and H8, in the lower Hamble, consistently achieve a LIFE EQR of greater than one. In contrast, site H4 generally achieves or is close to the lower threshold of 0.945, whereas H5 (in waterbody GB107042016280) is more commonly slightly below 0.945.

The contrast between the upper and lower parts of the catchment is not surprising when the differing hydrological impacts are considered; with greater proportional impact in the upper catchment, which diminishes further downstream as a result of accretion. At H4 (in the upper catchment), the groundwater model predicts that abstraction significantly increases the length of time that flows are reduced to a nominal level in summer, and reduces mean flows to less than 20 per cent of the naturalised flow, yet the LIFE scores here are generally above the indicative threshold for significant flow stress of 0.945. This suggests that the river channel and the ecology in this reach have largely adapted to the long-term change in the flow regime that has occurred as a result of abstraction. It is possible that the expected LIFE scores may be under-estimated for this site in terms of what would occur naturally. It is therefore difficult to assess H4 with certainty in terms of what would be experienced at this site with a completely natural flow regime, but it can nevertheless be concluded that based on the current characteristics of the river and invertebrate community, the river is relatively resilient to abstraction and able to retain, for the most part, a reasonable quality of invertebrate community.

Given the conclusions above for site H4, the results for H5 are somewhat surprising. Although there is a hydrological impact from abstraction on this tributary, it is much less severe than on the main river, so it is unexpected that the LIFE EQRs here should be lower than at H4. The expected scores at H5 are slightly higher than H4, which may contribute, but in addition, the DRIED-UP modelling suggests that H4 has seen more of an upward trend in LIFE scores over the past 15 years compared to H5 (this type of trend is seen at many sites across the country (Dunbar *et al*, 2006), although the reasons for it are not known). It is possible that there could be some water quality pressures contributing to the lower scores on this tributary.

The assessment of different scenarios at each site suggests that naturalised flow would have the potential to increase LIFE EQRs by around 0.02. On this basis it might be considered that a naturalised flow regime might assist in pushing sites to reach Good status where they are currently close to it, such as at H5, but that the difference is smaller than the overall inter-annual variability. Overall, considering the extent of hydrological impact on the upper reaches of the main river, it is concluded that the invertebrate communities appear relatively resilient to hydrological impacts of abstraction.

Species of conservation interest

The following species of interest were recorded during the macroinvertebrate surveys carried out for this project:

- The riffle beetle *Riolus subviolaceus* was recorded in samples at H6 on the Moors Stream in October 2010 and April 2012. Until recently this species was given Nationally Scarce status, although has now been downgraded by Foster (2010). This riffle beetle is usually associated with unpolluted base-rich running water (Friday, 1988);

- The Nationally Scarce water beetle *Enicocerus exsculptus* was recorded at site H5 in April 2012. *Enicocerus exsculptus* is often found clinging to algal films developing on culverts, boulders and gravel in clean rivers and streams (Foster 2000);

- One Nationally Scarce alder-fly *Sialis nigripes* was recorded in October 2011, from the Moors Stream at Sample H6. This species is widespread nationally and has been recorded from watercourses to the northwest of Southampton according to the distribution map on the National Biodiversity Network (NBN) Gateway (http://nbn.org.uk). Little is known about the habitat requirements of this species but Irish records appear to be associated mainly with calcareous rivers, streams and lakes. This species is likely to be sensitive to pollution and most of the records are from clean, unpolluted rivers;

- A single horse-hair worm (*Nematomorpha*) was found at H8 on the Hamble in October 2011. Horse-hair worms are infrequently met within our surveyor's experience and are poorly known. The larvae are parasitic on terrestrial insects and the larvae cause their hosts to commit suicide by locating water and drowning so that the horse-hair worms can enter their adult aquatic stage;

- The trumpet ram's-horn *Menetus dilitatus* was recorded from South Abbey Pond (H3) in October 2010. This rarity has been recorded from a few canals and two Welsh lakes according to Kerney (1999). It is a North American species which was first recorded in Britain in 1869. Several occurrences are associated with warm-water discharges such as condensor water from steam engines in cotton mills but it is not restricted to such places and can survive freezing temperatures.

It will be noted that the majority of these were found at site H6, on the Moors Stream, from where the greatest proportion of baseflow in the river is derived. The species of interest were also found at other locations were less indicative of base-rich running water.

3.3.3 Velocity analysis

A detailed assessment of the in-river physical habitat availability through the catchment, as evidenced by the range of velocities, is included in Appendix L, with a summary here. The assessment covers sites H4, H5, H7 and H8.

Analysis based on the historic flow regime illustrates that velocities are very low or negligible in the upper catchment at H4 in summer, as would be expected. Moving downstream, there are clear increases in velocities, with associated improvements in habitat for *Ranunculus* and for macroinvertebrate species preferring higher velocities (those with higher LIFE scores), particularly at site H8.

The assessment of the impacts of abstraction on in-channel velocities shows that abstraction in the upper Hamble catchment does have an effect on the extent of physical habitat availability in the river for species preferring faster-flowing waters, which is most evident in the upper reaches of the main River Hamble at site H4 but is seen to a lesser extent in the downstream reaches as well. The magnitude of abstraction effects is by far the greatest at Site H4 of those assessed, before the confluence with the Wintershill Tributary, as a result of abstraction considerably increasing the length of time in summer for which negligible flows are experienced here. Further downstream, below the confluence with the Wintershill tributary and the Moors Stream, the proportional impact of abstraction is reduced. In general in the lower reaches, although in-stream velocities may be reduced by abstraction, the changes do not, for the most part, cause velocities to move outside the range of suitability for *Ranunculus* that they would sit in under a naturalised scenario.

3.3.4 Bishops Waltham Ponds

Annual macrophyte and two season (spring and autumn) aquatic invertebrate surveys of Abbey Pond North and Abbey Pond South in Bishops Waltham were carried out as part of this study.

Macrophytes

Abbey Pond North was dry at the times of both surveys and is reportedly dry in most years. In 2012, an area in the middle of the pond was 98 per cent bare, with many dead stems of *Persicaria maculosa* and many young seedlings. It appeared that this area had been flooded for part of the summer and then dried out again but most of the rest of the pond had probably been dry since the previous year. During the 2011 survey a local resident indicated that there was a proposal to dredge out an area in the southern part of the pond to create a more or less permanent pool to prevent fish being stranded. A small sump pond was noted in this area in the 2012 survey although it appeared to have been established for more than a year and could have been missed in the 2011 survey. When full the pond is probably around 1.5 metres deep. The pond did not fill until late 2012: it was observed full during a visit in February 2013, but had been full for some time prior to the visit.

The pond is fringed by willows, mainly *Salix fragilis* with some *Salix cinerea* and *Salix viminalis*. These form a more or less impenetrable tangle around the edge. This band is about 20 metres wide but in places it extends right into the middle of the pond. There has been some cutting back of willows in the southern part of the pond but these are re-growing quickly and are already up to four metres high. Further cutting had occurred between the 2011 and 2012 surveys, mostly trimming back re-growth.

Macrophyte samples for Abbey Pond North recorded predominantly terrestrial species although a few of the species are typically found in the margins of waterbodies. For example in 2011 the open middle of the pond had an almost complete cover of *Persicaria maculosa*, *Atriplex prostrata* and *Mentha aquatica* with locally abundant *Persicaria amphibia*, *Myosoton aquaticum* and *Myosotis scorpioides* and frequent scattered *Rumex hydrolapthum*. Swamp species are very restricted in the pond. There is a ten metre wide band of *Typha latifolia* and *Glyceria maxima* along the roadside at the south end which widens to 30 metres in the south-western corner. There are also some patches of *Carex riparia* at the north end. However, these species do not generally have a requirement for permanent water. A small sump pond was noticed in the 2012 survey about 30 metres north of the road at the south end. This was five metres in diameter and up to 10cm deep and contained an open swamp of *Typha latifolia* with abundant *Zannichellia palustris* beneath. Some *Lemna minor* and *Callitriche stagnalis* were also present. Overall however the flora of the pond was impoverished. No surveys were carried out after the pond re-filled, due to the late stage in the project.

The northern and western sides of Abbey Pond South have numerous fishing platforms built up using railway sleepers. Between these, the shores are mostly steep and protected by wooden piling or wicker fencing and often there are stones and boulder at the base of these. The east side was not accessible for survey due to private gardens. Willows overhang into the water over much of this shore, making it difficult to see the nature of the shore but it seems to be fairly steep and in some places there is stone facing or rubble along the shore. Two small areas on the western side have been fenced with netting, probably to allow wetland vegetation to develop, including *Iris pseudacorus*, *Carex riparia*, *Mentha aquatica*, *Myosotis scorpioides* etc. Otherwise wetland vegetation is very limited. The water in Abbey Pond South was very murky greenish-grey and the pond was devoid of any aquatic vegetation during both surveys. Some straw bales were present in the pond in 2011, presumably in an attempt to reduce the algal blooms but these were mainly used as roosts by the ducks. An additional problem for the vegetation is that the pond contains carp – a cluster of ten carp were seen in the north-western corner.

Invertebrates

There are invertebrate data for Abbey Pond North from three samples in total (including EA and this study), whilst there are data from six samples in total for Abbey Pond South (including EA and this study).

The first sample data available for Abbey Pond North dates from 2002 but there has often been insufficient water in the pond to enable survey. As a result of the long dry periods and hence poor quality aquatic habitat when water is present, the samples collected are species poor, when compared to the rest of the river (comprising on average 10-11 scoring taxa only), and generally comprise species typical of still or very sluggish water sites. Biotic indices calculated for the data are all suppressed compared to the river sites, although since the indices were not developed for still waters, little can be concluded from this.

Invertebrate samples taken from Abbey Pond South are also generally species poor containing a similar number of scoring taxa to the North pond. The reason for this however is probably different to Abbey Pond North. Abbey Pond South typically contains water, although the levels do vary, and the pond is used extensively for fishing. The water is believed to be turbid for the majority of the time, probably as a result of the presence of fish and possibly nutrients introduced by ducks and fish bait. When sampled for this study it had low DO levels, which is likely to be a result of a combination of fishing activity and low flow through.

Nature Conservation Status

The nature conservation status of ponds is typically assessed using the Predictive System for Multimetrics (PSYM). PSYM requires the completion of a proforma that is then analysed by Pond Conservation and the outcome is an assessment of whether a pond meets the criteria as a BAP Priority Pond or not. The assessment is based on an analysis of some environmental data, the invertebrate fauna and macrophyte flora of the pond. From a review of the invertebrate and macrophyte data it is considered very likely that neither pond would currently meet the criteria for Priority pond status.

3.3.5 Other pressures potentially affecting in-river ecology

The assessments above have indicated the extent to which abstraction influences flows in the River Hamble, and the subsequent effects that those flow reductions may have on in-river ecology. In addition to this, other potential pressures in the catchment should also be given some consideration.

Water quality pressures may be relevant in the catchment, particularly considering that the waterbodies of the main River Hamble were all classified as failing for Phosphorus standards in the 2009 RBMP. The biotic indices of NTAXA and ASPT do not show clear evidence of water quality impacts in the catchment, generally being consistently at Good or High, although the ASPT scores at site H5 on the Wintershill tributary are slightly lower.

Water quality pressures are certainly relevant at site H3, in the South Pond in Bishops Waltham, which is used for fishing and was very turbid with little vegetation growth at the time of the macrophyte surveys.

The uppermost waterbody of the Hamble (GB107042016290) is designated as Heavily Modified, for flood protection and urbanisation. The influence of these pressures can be clearly seen in Bishops Waltham, in the ponds and in the straightened, constrained nature of the reach of the Hamble immediately upstream of the ponds. Certainly in this part of the catchment, therefore, morphological pressures are a significant factor affecting the aquatic ecology, and the ponds serve to isolate the short reach of the Hamble upstream from the lower catchment.

Downstream of Bishops Waltham the river takes on a more natural character. Morphology and sediment-related pressures through the catchment have been considered by carrying out RHS and GeoRHS surveys. The results of the RHS assessment can be found in Appendix J, including a map showing the extent of habitat modification through the catchment. Overall the results of the RHS show a moderately to high level of modification, with all sites except one being in at least Habitat Modification Class 3 (where 1 is natural and 5 is the maximum, highly impacted). The break-down of sub-scores from the RHS shows that the modifications are contributed mostly by a combination of bed and bank re-sectioning, and presence of bridges. There are some specific reaches with more extensive modification, most notably where there are still the remnants of mill races at Durley Mill, where there are channels at different levels connected by weirs and sluices. Outside these reaches, in fact, the extent of re-sectioning is relatively low, based on the RHS results, when compared to many other Chalk streams. Overall it might be expected that the impact of habitat modification on in-river ecology will be relatively minor on a catchment-scale, but with some local influences.

The GeoRHS survey did not identify any significant geo-morphological impacts, with the reaches surveyed being stable and neither eroding or silting, and the river corridor being in good condition overall. There was some evidence of turbid runoff from adjacent farmland, with the survey having been undertaken during a wet period in late summer 2012. Turbidity in the river has not generally been noticed to be a concern during other site visits.

3.4 Conclusions

3.4.1 Catchment scale

The abstraction impacts on river flows in the Hamble catchment originate in the upper catchment, and are largely a result of Portsmouth Water's Northbrook abstraction. Abstraction alters the interactions between surface water and groundwater in the headwaters where the Chalk is unconfined, and the influence is then propagated downstream in the surface water course (with some influence being felt across the main tributaries including the Wintershill tributary, upper Hamble, and Moors Stream). The headwaters of the River Hamble are naturally ephemeral, but abstraction has the effect of increasing both the length of river and duration of time for which the river is dry. The spatial extent of this is limited quite effectively by the south pond in Bishops Waltham, which sits at the edge of the Chalk, although even below this abstraction has historically reduced flows down to the confluence with the Wintershill tributary to a negligible flow in low flow periods (with a much reduced flow at higher flows). Abstraction also results in the north pond in Bishops Waltham being dry for longer than would occur naturally. The effects of reduced flows as a result of abstraction can be seen throughout the length of the catchment, with the

Q95 at the tidal limit being only around half of the natural flow. There is relatively little difference between the historic and fully licensed impacts at low flows.

Considering the extent of hydrological impact in the catchment, and particularly in the upper reaches, the in-river biology is in much better condition than might be expected. Whilst the velocity regimes that result from reduced flows might be expected to be limiting in the upper reaches around H4 and H5, assessment has indicated that in the lower reaches a velocity regime suitable for *Ranunculus* growth and high LIFE scoring invertebrate species can be maintained under both the historic and fully licensed scenarios. Whilst this effect is seen in the LIFE scores, which are lower in the upper catchment, in fact when compared to Expected scores the results are fairly positive. Even at site H4, the LIFE EQR is generally able to achieve the value of 0.945, above which impacts on flow may be considered to be minor. At the downstream sites below the Moors Stream confluence (and on the Moors Stream itself), EQRs exceeding one occur regularly, indicating that the macroinvertebrate community is responding favourably to the flow conditions in the river.

Overall, therefore, the conclusions for the Hamble catchment are that while there is undeniably an extensive hydrological impact from abstraction in this catchment, the ecology of the river is relatively resilient to those impacts. The extent of ecology impact can be limited to the reach above Bishops Waltham STW, and even here is less extensive than might be expected given the extent of hydrological impact.

3.4.2 Waterbody scale

Conclusions relating to the waterbodies specifically identified for investigation are presented in Table 3.5.

Table 3.5 Summary of impacts at the waterbody (and sub-waterbody) scale for the upper Hamble

Waterbody	Hydrological impacts	Ecological impacts
GB107042016290 (Abbey Ponds North, and upstream)	Historic and fully licensed abstraction result in increased duration of drying of the north pond and the reach immediately upstream. Flow occurs for a minority of time upstream of the ponds, as a result of abstraction: naturally, the first 1km upstream might be expected to be nearly perennial.	Limited assessment has been undertaken, since the effect is dominated by the lack of flow in the short reach upstream of the ponds, and lack of water in the north pond.
GB10702016290 (Abbey Ponds south)	Flow is retained in this pond (e.g. throughout 2011-2012) but water levels are likely to be lower than natural, and outflow can be minimal	The vegetation in the south pond is limited, and invertebrate samples are species-poor. Although this may be partly contributed by lower water levels or less through-flow as a result of abstraction, the use of the pond for fishing is considered to have the predominant effect on the quality of the pond.
GB10702016290 (downstream of south pond)	Naturally this reach would be entirely perennial, with a flow of around 3.5Ml/d being sustained at the outflow at Q95, and 16Ml/d at Q30. Abstraction results in flow in this reach being reduced to a negligible amount for long periods, and significantly reduces the flow under higher flow conditions (reduction of Q30 to 2.3Ml/d at fully licensed).	Physical habitat is considerably constrained during low flow periods, with little or no flow occurring for significant periods of time. However the invertebrate communities show surprising resilience to this, with LIFE EQR of 0.945 or above being achieved in the majority of historic samples. Modelling using DRIED-UP suggests that this threshold should be mostly achieved under all abstraction scenarios

Table 3.5 (continued) Summary of impacts at the waterbody (and sub-waterbody) scale for the upper Hamble

Waterbody	Hydrological impacts	Ecological impacts
GB107042016240	Combined influence of Hamble and Winterhill tributary, although low flows from both are very low or negligible. Flow at the outflow from this waterbody is supported by a discharge from Bishops Waltham STW	No biological monitoring data were available from within this waterbody. The ecology can be expected to be similar to H4 and H5, given the limited summer flows.

4. Wallington Catchment

4.1 Introduction

4.1.1 Catchment characterisation

The River Wallington rises on the South Downs near the Forest of Bere, where small tributaries converge from Denmead (east), Hambledon (middle) and Hoe Gate (west). The tributaries from Denmead and Hambledon combine to form what is referred to in this assessment as the Worlds End tributary, while the tributary from Hoe Gate is known as the Newtown tributary. From the confluence of the Worlds End and Newtown tributaries, the Wallington takes an indirect course towards the coast, first flowing southward to Southwick, then turning to flow west, before turning back towards the south before Fareham, and ultimately discharging into Portsmouth Harbour through Fareham Creek. A major tributary flows from the east to join the Wallington at Southwick, which has a significant catchment area similar to that of the upper Wallington itself. Overall the Wallington catchment is mainly rural, although the headwaters of the Southwick tributary lie in Waterlooville, and the furthest downstream reaches flow through Fareham from the M27 to the tidal limit of Fareham Creek (a distance of around 1km).

The head of the Wallington tributaries sits on the southern edge of the Chalk, from which a relatively small amount of baseflow is received. For the majority of the river length, until past Boarhunt Mill, the river then flows across relatively impermeable Palaeogene deposits, before the Chalk is again exposed between Boarhunt Mill and the tidal limit of the River. As a result of the limited length of river flowing over the Chalk, the river is relatively flashy.

The Wallington is separated in to five waterbodies in the Southeast RBMP, as listed in Table 4.1. Those that are the focus of this investigation are in bold, although the Environment Agency has considered waterbody GB107042016360 in two separate reaches and it is only the downstream reach from North Fareham gauging station that is included in this investigation (in order to consider the localised influence of Maindell abstraction at the bottom of the catchment). Failure to meet GES in the Wallington catchment occurs as a result of phosphate failures (with invertebrates failing only in the Southwick tributary). The upper Wallington waterbodies do not include any biological elements in the classification, while biological data for the middle and lower Wallington both resulted in the invertebrate element being classified as High status.

Table 4.1 Waterbodies classified in the first RBMP (Environment Agency, 2009)

Reach	Waterbody ID	Overall status	Flow supporting condition	Reasons for failure*
Upper Wallington (above Worlds End)	GB107042016390	Moderate	Compliant	Phosphate (M)
Upper Wallington (below Worlds End, including Newtown trib)	GB107042016410	Moderate	Band 3	Phosphate (M)
Middle Wallington	GB107042016350	Good	Band 3	n/a (fish G, inverts H)
Southwick tributary	GB107042016400	Moderate Ecological Potential	Compliant	Inverts (M), Mitigation Measures (impoundment)
Lower Wallington	GB107042016360	Moderate	Band 3	Phosphate (M) (fish and inverts H)

* Where biological elements have been assessed and are not failing, they are included in brackets

4.1.2 Portsmouth Water abstractions

The main abstractions in the catchment are the Portsmouth Water groundwater abstractions at Newtown, Worlds End, Lovedean and Maindell. The details of these abstractions are presented in Table 4.2. Newtown and Worlds End are both located close to headwater tributaries, while Lovedean is located on the Chalk, further removed from the watercourses (Lovedean is not included in the scope of these investigations, having been shown to impact predominantly on the Havant and Bedhampton springs catchment (Entec, 2006)). Maindell is located close to the river in the lower catchment, where the Chalk is again exposed.

There is one sewage treatment works in the catchment, at Southwick, with a Dry Weather Flow (DWF) of 0.5Ml/d. There are also a small number of other private discharges to the middle and lower river, which as a result of the low baseflow in the river appear to become significant in sustaining flows at very low flows.

The locations of the main abstractions and discharges were shown in Figure 2.2.

Table 4.2 Public water supply abstractions in the Wallington catchment

Licence number	Name	Licensed quantity	Group licence	Recent actual abstraction
11/42/28.3/15	Newtown	3.9 Ml/d	Group licence with Soberton (Meon catchment) 9 Ml/d	232 Ml/a
11/42/33.6/10	World’s End	8296.45 Ml/yr, 25 Ml/d	-	3475 Ml/a
11/42/33.1/1	Lovedean	4148.23 Ml/yr, 13.6 Ml/d	-	1931 Ml/a
11/42/33.9/20	Maindell	2491.2 Ml/yr, 7.9 Ml/d	-	350 Ml/a

Recent actual abstraction 2006-2010

4.2 Hydrological Assessment

A detailed hydrological assessment for the catchment is presented in Appendix B, which includes consideration of observed data and use of the EHCC groundwater model. A summary is provided here.

4.2.1 Observed hydrological regime

There is one permanent gauging station in the catchment, at North Fareham (NGR SU 587 075). This measures flows from the majority of the catchment, although it will not fully capture influences from Maindell public water supply (PWS). The mean flow recorded at North Fareham from the full period of record (1976-2011) is $0.609m^3/s$, with a Q95 of $0.031m^3/s$. The National River Flow Archive (NRFA) gives a Baseflow Index (BFI) of 0.41, indicating that the river is relatively flashy, being influenced by surface runoff in addition to baseflow influences from the Chalk. This will be contributed from the relatively impermeable Palaeogene deposits in the upper and mid catchment (which extend from the headwaters as far as Boarhunt Mill).

The gauging data from North Fareham is supplemented by spot flow surveys carried out by Hydro-Logic during the project, which have provided a better understanding of the accretion profile through the catchment.

The upper Wallington waterbodies include GB107042016410 (which encompasses both the Newtown and Worlds End tributaries) and GB107042016350, which extends to just above the Southwick tributary. The spot flow survey programme showed these tributaries to be dry until around November-December 2011, after which only very low flows were experienced until April 2012. This indicates that during low flow conditions these tributaries contribute little if any flow to the lower river. The Southwick tributary (waterbody GB107042016400) which enters from the east has a considerable catchment area and adds a significant proportion of flow to the total found in the lower River Wallington. Spot flow surveys were not carried out on the tributary, but from the surveys at W3 and W4 it may be deduced that the Southwick tributary contributes generally around half to two-thirds of the flow in the lower river.

The reach between Southwick and North Fareham gauging station has been given relatively little consideration in this study, as a result of the inputs from the Southwick tributary (which is not significantly impacted by abstraction), and in addition the influence of artificial discharges and leakage. The groundwater model (as discussed further below) predicts that these artificial influences serve to maintain flows in the lower river during periods of very low flows. The very lowest reaches of the freshwater river, before it reaches tidal Fareham Creek, are of further interest as a result of the potential influence from Maindell abstraction. The spot flow surveys therefore included three locations in the lower catchment (W4, W5 and W6), as well as some further sites in the tidal reach which were predominantly of interest to the PIM investigation. An additional location was added in March 2012, to assess an apparent reduction in flow between W5 and W6 that had been recorded in a number of the spot flow surveys. Since there is only a relatively short distance between W5 and W6, a location downstream of W6 was selected (rather than between W5 and W6), to consider whether there could be some flow through the gravel bed at W6 that would mean the full flow was not captured by gauging at that location. Flows from site 6a indicated that there was not a loss of flow between sites W5 and W6a, although in fact from that time onwards, positive accretion was also seen to the original W6 site. This may have been due to higher flows through 2012.

Overall, the spot flow surveys suggest that accretion occurs through this reach when Maindell is not operating (see Table 4.3).

Table 4.3 Summary of accretion in the lower Wallington

Location	Range of flows recorded (m^3/s)	Average per cent of freshwater flow in river, compared to total at tidal limit*
W4 (Spurlings Farm)	0.04-1.37	75%
W5 (upstream M27)	0.04-1.43	79%
W6 (downstream M27)	0.02-1.74	97%
W6a (between W6 and W7)	0.13-1.95 (from March 2012 only)	105%
W7 (tidal limit)	0.05-1.96	100%

* Averages only consider data from March 2012 onwards, so that W6a can be included on a comparable basis

4.2.2 Impact of historic, current and fully licensed abstraction regimes

The upper and lower catchment can be considered separately, since the response is very different. This is because the upper catchment is partly ephemeral, with the main artificial influences being Worlds End and Newtown abstractions. In contrast, the lower catchment benefits at low flows from discharges and leakage, with only the furthest downstream reaches then experiencing the influence of Maindell abstraction.

Upper Wallington

The assessment in Appendix B shows that the most significant impacts on groundwater-to-surface-water flow occur under high flow conditions upstream of Worlds End PWS. Little or no effect is seen downstream of the Worlds End PWS, clearly indicating the change in geology: from this point until past Boarhunt Mill the river flows across relatively impermeable Palaeogene deposits, reducing groundwater-surface water interaction to a minimum.

The upper reaches of the Wallington are to all intents and purposes ephemeral, with the groundwater model predicting extensive periods of negligible flow under naturalised conditions for the summer months in the whole of waterbody GB107042016410, as well as in GB1070420350 during average or dry summers. The groundwater model predicts very little impact on the ephemeral nature of these upper reaches as a result of abstraction. The length of time that flows fall to negligible is increased very slightly through waterbody GB1070420350 (between W1 and W3), but abstraction does not significantly alter the total length of the ephemeral reaches compared to naturalised. The predicted impacts of abstraction on flow are presented in Table 4.4. Both flow statistics and time series data clearly show that impacts from abstraction in the upper catchment are almost entirely limited to high flow periods, when there is the greatest interaction between groundwater and surface water. At low flows there is no difference in flows in either the recent actual or fully licensed scenarios compared to naturalised.

Assessments of the impacts of the individual abstractions have also been carried out in Appendix B, which concludes that the majority of impact is attributed to Worlds End PWS, with the effect of Newtown abstraction alone being very minor.

Table 4.4 Flow statistics for standard scenarios in the River Wallington (Ml/d)

Flow Percentile	Naturalised	Recent Actual	Fully Licensed
Wallington at Tidal limit (outflow of waterbody GB107042016360)			
Q95	0.5	1.8	0.0
Q70	6.9	8.7	6.6
Q50	22.1	23.2	19.9
Q30	59.9	59.0	52.5
Wallington at site W6 (500m upstream of tidal limit)			
Q95	0	1.2	0.3
Q70	6.0	7.7	6.4
Q50	20.9	21.8	19.2
Q30	57.2	56.2	51.4
Wallington at outflow of waterbody GB107042016350			
Q95	0.3	0.3	0.3
Q70	2.0	1.8	1.8
Q50	6.4	5.1	4.9
Q30	17.8	14.8	13.5
Wallington at outflow of waterbody GB107042016410			
Q95	0.1	0.1	0.1
Q70	1.2	1.0	1.0
Q50	4.5	3.2	2.9
Q30	13.0	10.2	9.1

Lower Wallington

Downstream of the confluence with the Southwick tributary, the groundwater model predicts that impacted flows (i.e. the historic, recent actual or fully licensed scenarios) will be higher than naturalised at low flows. This effect occurs as a result of the influence of discharges (Southwick STW, and small discharges at Boarhunt and HMS Dryad), as well as leakage in the headwaters of the Southwick tributary at Waterlooville and the Wallington in Fareham, coupled with the lack of surface water-groundwater interaction in the upper catchment (as discussed above for the upper Wallington).

In the recent actual scenarios, the benefit of these artificial influences is seen all the way to the tidal limit, with flows remaining higher than natural. In contrast, abstraction from Maindell in the fully licensed scenario shortens the length of river where positive influence is seen, with negative effects on low flows downstream of Maindell in the fully licensed scenario compared to naturalised, recent actual or historic. This effect is not seen in the recent actual scenario since recent use of Maindell has been relatively low, and in the historic scenario impacts are only apparent in 2002-5.

However as shown in Table 4.3, the effect of Maindell abstraction on river flows is seen in very little of the freshwater waterbody even at fully licensed: at site W6, which is only around 500m upstream of the tidal limit, fully licensed flows are still higher than naturalised. It is only at the tidal limit that the potential impact of Maindell at fully licensed becomes evident. This suggests that the impact of abstraction on freshwater habitats of the River Wallington is negligible.

4.3 Hydro-ecological Assessment

4.3.1 Assessment locations

Hydro-ecological assessment of the river considers sites W1 to W6: i.e. all of the monitoring sites located in the freshwater River Wallington. W1 and W2 are located on the upper tributaries, with W3 being located just upstream of the major tributary of the Wallington that enters from the east at Southwick. Sites W4, W5 and W6 are located over a 2km stretch on the lower Wallington. The sites therefore cover the majority of the catchment of the main River Wallington.

4.3.2 Macroinvertebrate analysis

A detailed assessment of the invertebrate data (as assessed using the approach described in Section 2) is presented in Appendix F, with a summary here. Plots of observed LIFE scores over time are shown in Figure 4.1, and predicted LIFE scores under different abstraction scenarios, as modelling in DRIED-UP, are shown in Figure 4.2.

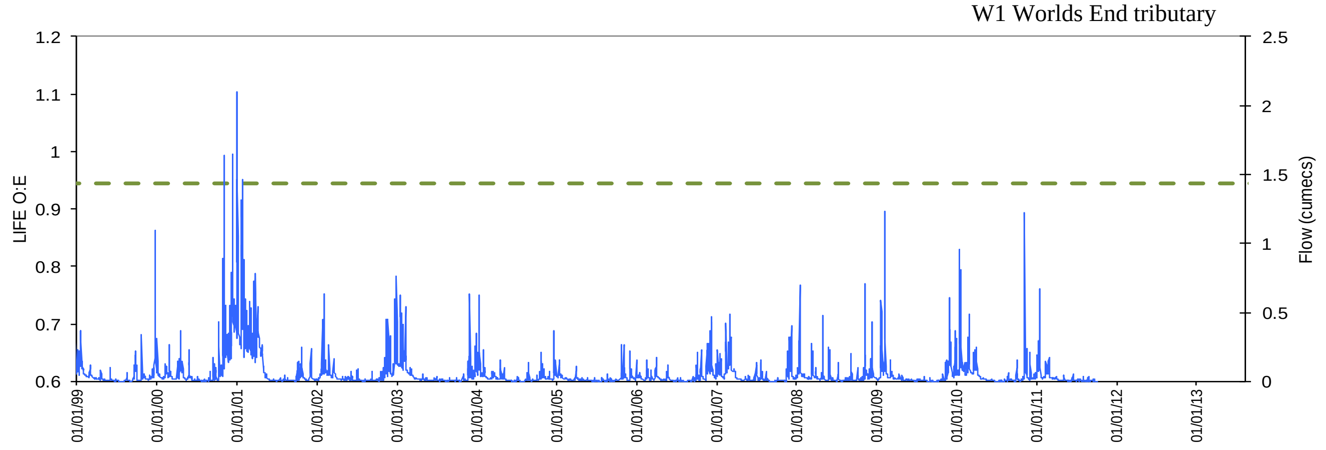
Table 4.5 Summary of hydro-ecological assessment (using LIFE) for the River Wallington

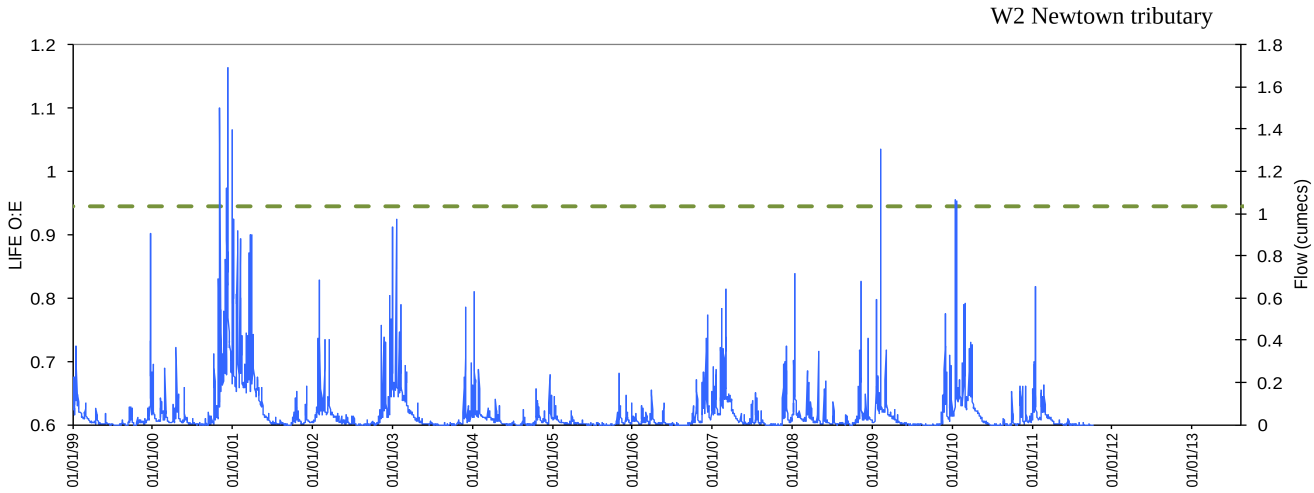
Site	Assessment
W1	**Worlds End Tributary**. All biotic indices (ASPT, NTAXA and LIFE) are variable at site W1. In the more recent monitoring from 2008 onwards, both ASPT and NTAXA have varied from High status to less than Good (NTAXA has fallen to Poor or Bad on two occasions). LIFE scores have varied similarly over time, varying above and below the 0.945 threshold. The assessment of regression relationships has been carried out using flows for W1 that have been calculated using a combination of gauged flows (from North Fareham) and outputs from the groundwater model. The results of the assessment suggest that there are good relationships between LIFE and flow particularly for autumn LIFE scores across a range of lows, but these results must be treated with care. Firstly, they include relatively few data points. Secondly, the low flow relationships, and even the mid-range flows in summer, are very low values since there is so little flow in the water course at this location at this time. A high R^2 is also achieved against the 2 years winter flow, when flows are higher, which may be more reliable although there is still considerable scatter about the trend line. Overall it might be concluded that flows do influence LIFE scores, and that this influence is likely to be largely linked to higher flows because there is very little water at this location at low flows, in any year. The DRIED-UP model results show a variability of LIFE with flow, with a particularly pronounced peak/plateau in LIFE scores under all scenarios from 2001-2003, following particularly high flows over the winter of 2000-2001. It is also in these years that the most difference is seen in modelled LIFE scores between the different abstraction scenarios. In most other years, in fact, there is very little difference in LIFE scores as a result of the different abstraction scenarios. From this it might be inferred that abstraction only significantly influences the ecology of the Wallington at this location during and following high flow years. The main effect is to suppress periods of higher LIFE score that result from higher flow years, reducing the variability and the long-term average LIFE score overall.
W2	**Newtown Tributary**. The results for W2 are very similar to W1. The HEV shows variability in ASPT and NTAXA scores between Moderate and High, with no clear trend over time. LIFE scores also are variable, above and below the 0.945 threshold. There is some similarity in the timings of the low scores between indices. Assessment of LIFE against flows shows better relationship with autumn LIFE scores compared to spring, as at W1. The apparent relationships at low flows relate to very low flows of 1 l/s or less, so it is difficult to interpret this in terms of a meaningful change to the regime of the watercourse at this location, due to the low flows naturally being so low. At higher flows there are some apparently good relationships, particularly when considering the winter flows over the previous two years. The modelled flows from DRIED-UP exhibit this apparent relationship further. The results are similar to W1, although at W2 the natural variation between years is slightly greater, being even more pronounced in 2001-3 following the high flows of 2000-2001. The results suggest that in most years abstraction would make relatively little difference to LIFE scores, with differences becoming most evident in higher flow years, potentially with the main influence being the high flows in winter rather than the naturally very low summer flows. While not causing LIFE scores to fall much lower than they would naturally, this has the effect of suppressing the potential for achieving the highest LIFE scores, in years following high winter flows. Whilst perhaps appearing to have the effect of making the macroinvertebrate community more stable, this removes natural variability that appears to be inherent in the system, associated with the relatively flashy nature of the catchment.
W3	**Newmans Bridge**. There is a long period of record at Newman's Bridge, extending back more than 20 years to 1990. Through the early part of this record, ASPT and NTAXA show an increase in scores, but from around 2000 onwards have fairly consistently recorded High status. LIFE scores show some evidence of a similar increase through the early 1990s, but since 2000 scores have fluctuated more than the other indicators. LIFE scores have not remained consistent, varying considerably about the 0.945 threshold over a five year period. The DRIED-UP modelling suggests that much of this variability is natural. The modelled scenarios predict that even under the naturalised flow scenario, LIFE EQR would have varied between 0.92 and 1.01. However within this it should be noted that this site also shows a significant increasing trend over time: the lower scores at the start of the model period are likely to be partly attributable to the upward trend and partly due to the low flows that around 1996-7, but it is possible that if similarly low flows occurred now the LIFE scores would not be as low. As at the upstream sites, the differences between scenarios are most evident in 2001-3, suggesting that abstraction has the greatest potential to impact in-river ecology at site W3 as a result of influences on high flows.

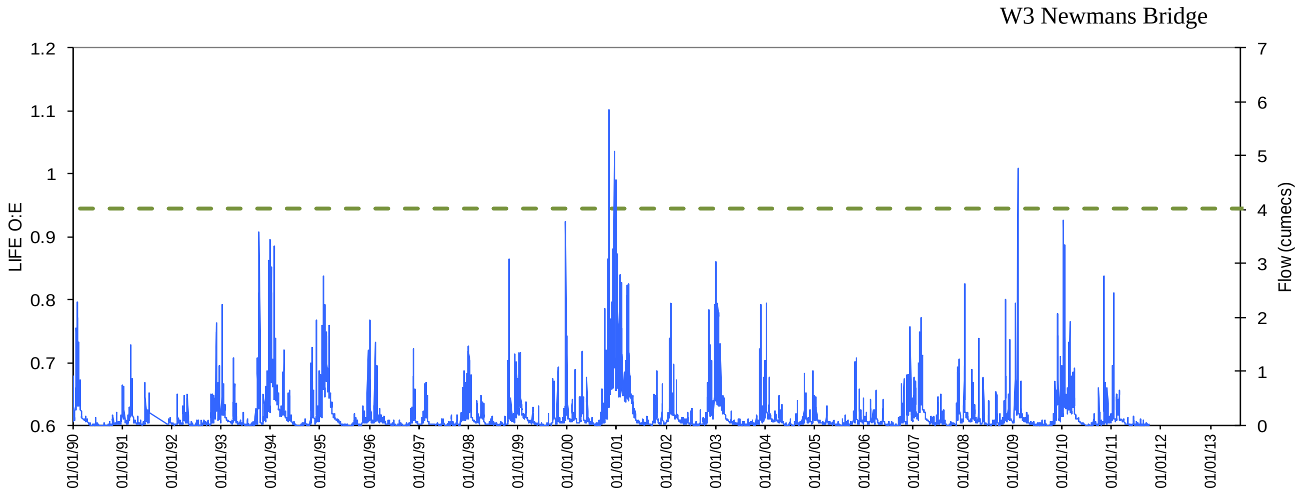
Table 4.5 (continued) Summary of hydro-ecological assessment (using LIFE) for the River Wallington

Site	Assessment
W4	**Spurlings Farm**. There is a clear increasing trend in ASPT at this site through the 1990s up until around 2003, after which point ASPT EQR has been consistently at High status. This trend is not seen in the NTAXA data, which has been predominantly at High status throughout the monitored period. In the LIFE scores, there is an increasing trend similar to that seen in the ASPT: in the 1990s, the LIFE EQR was commonly below the 0.945 threshold, but since 2000 has been consistently above it. There is a clear tendency at this site for LIFE scores to vary with flow, which is particularly evident on either side of the high flow years of 1993-5 and 2000-01. It is also clear in the assessment of regression relationships, which show good relationships to annual and summer-only flow statistics through much of the flow duration curve. The DRIED-UP model predictions replicate the observed increasing trend in LIFE scores through the 1990s, although much of this increase was a step change in 2001, after which LIFE EQRs have been retained at or above the threshold of 0.945 through the rest of the model period (as for the observed data). From this, it is difficult to assess whether a dry period such as those experienced in the 1990s would result in similarly poor LIFE scores being experienced again, or whether the baseline is now higher than previously. Whichever is the case, the conclusion that DRIED-UP is able to illustrate clearly is that abstraction is unlikely to result in any reduction in LIFE scores in the lower catchment around W4. As has been discussed more extensively in the hydrological assessment, this is because discharges and leakage that occur alongside abstraction in fact result in more water being returned to this reach of the river at low flows than is lost to abstraction. As a result, the naturalised flows are in fact lower than the historic flows, resulting in the predicted LIFE scores being lower for the naturalised than the historic flow scenario. The fully licensed scenario is predicted to result in LIFE scores that would be similar to the naturalised scenario.
W5	**Upstream of M27**. A very similar result is evident for W5 as for W4. Observed data are only available for the past two years, indicating that NTAXA and ASPT are both at Good, while LIFE EQRs sit just below the 0.945 threshold. In comparison to the observed data, DRIED-UP may be over-estimating LIFE scores, based on the limited data available. However as the model has performed well at sites with long-term records including W3 and W4, it is possible that it is providing a reasonable prediction for W5 overall but that there are some local factors further influencing the scores and causing larger fluctuations that are not captured in DRIED-UP.
W6	**Downstream of M27**. The observed and modelled data show a very similar result for W6 as at W4 and W5.

Figure 4.1 HEV plots (LIFE only) for the River Wallington (from upstream to downstream)




W2 Newtown tributary
LIFE O:E
Flow (cumecs)
1.2
1.1
1
0.9
0.8
0.7
0.6
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
01/01/99
01/01/00
01/01/01
01/01/02
01/01/03
01/01/04
01/01/05
01/01/06
01/01/07
01/01/08
01/01/09
01/01/10
01/01/11
01/01/12
01/01/13


W3 Newmans Bridge
LIFE O:E
Flow (cumecs)
1.2
1.1
1
0.9
0.8
0.7
0.6
7
6
5
4
3
2
1
0
01/01/90
01/01/91
01/01/92
01/01/93
01/01/94
01/01/95
01/01/96
01/01/97
01/01/98
01/01/99
01/01/00
01/01/01
01/01/02
01/01/03
01/01/04
01/01/05
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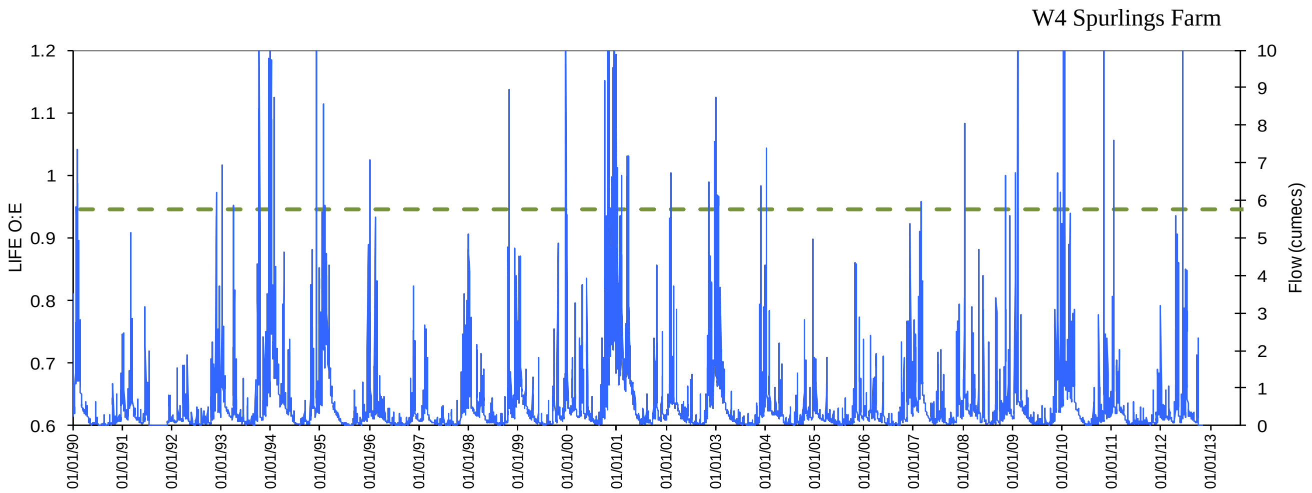
01/01/10
01/01/11
01/01/12
01/01/13


W4 Spurlings Farm
LIFE O:E
Flow (cumecs)
1.2
1.1
1
0.9
0.8
0.7
0.6
10
9
8
7
6
5
4
3
2
1
0
01/01/90
01/01/91
01/01/92
01/01/93
01/01/94
01/01/95
01/01/96
01/01/97
01/01/98
01/01/99
01/01/00
01/01/01
01/01/02
01/01/03
01/01/04
01/01/05
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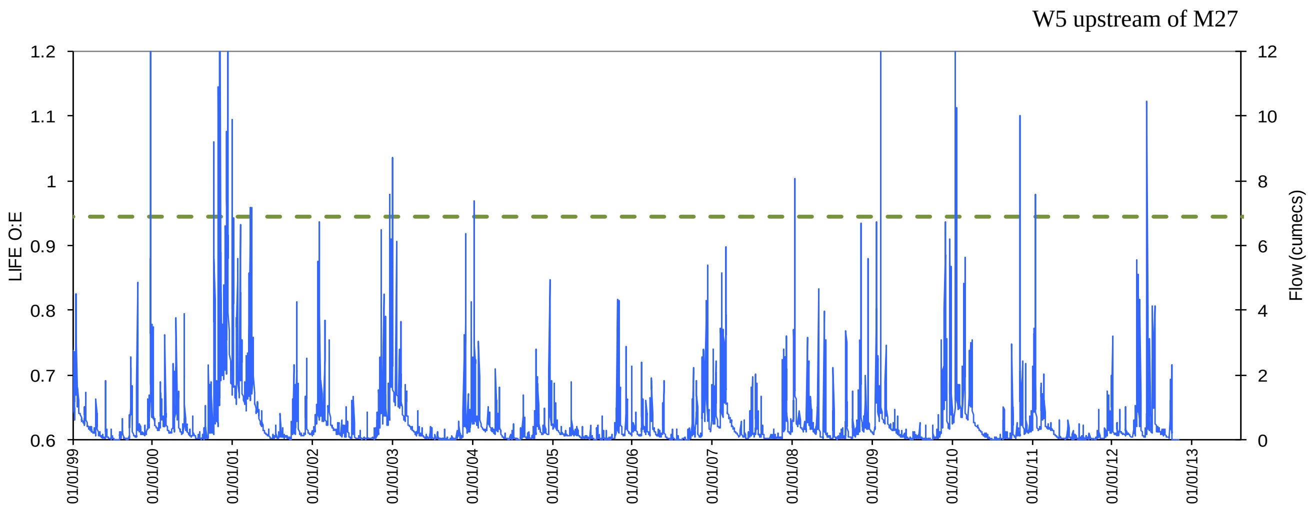
01/01/11
01/01/12
01/01/13



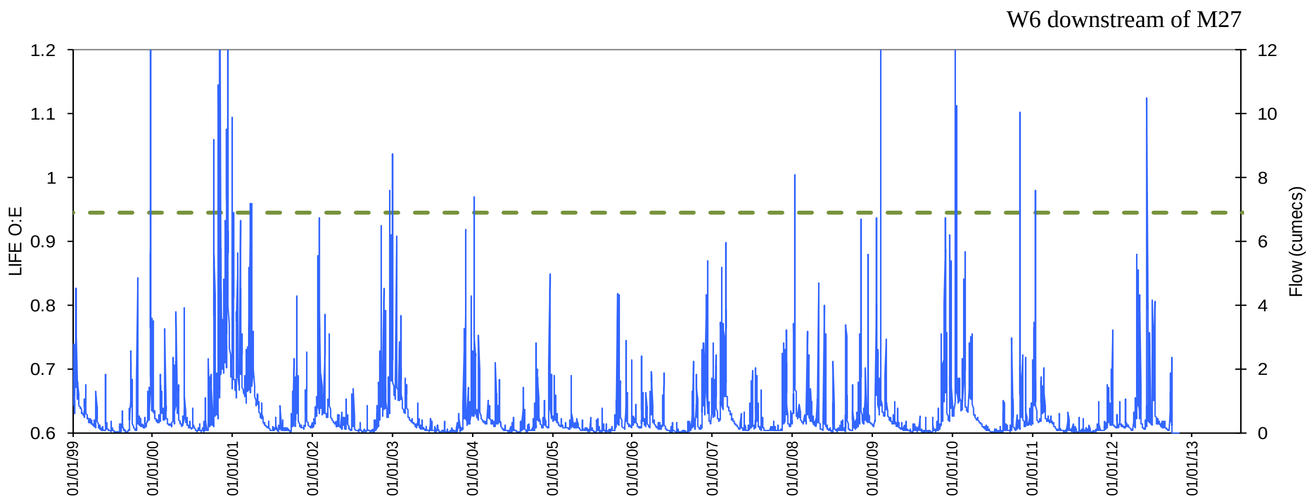
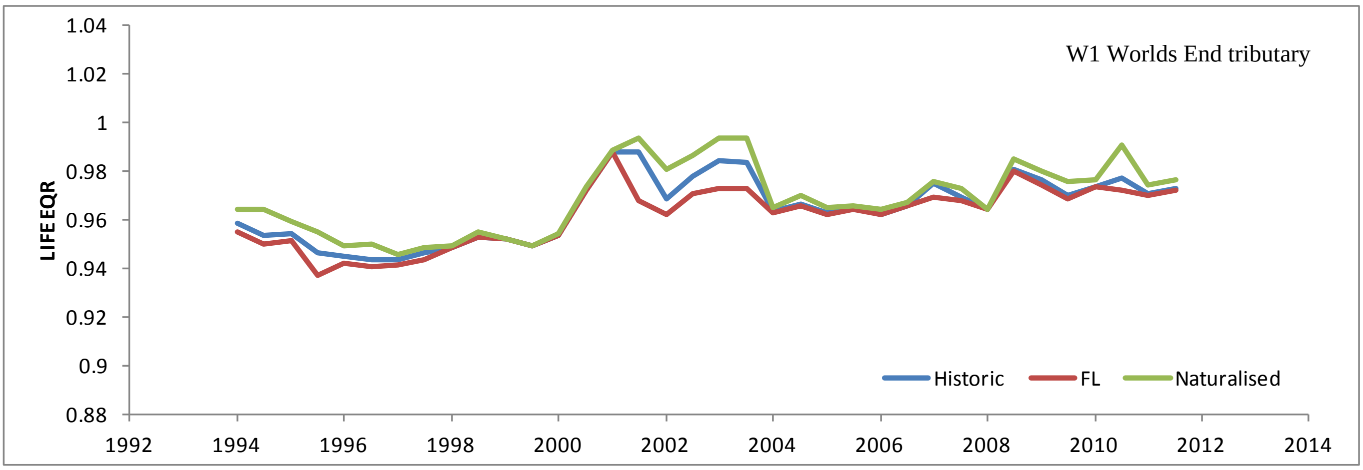
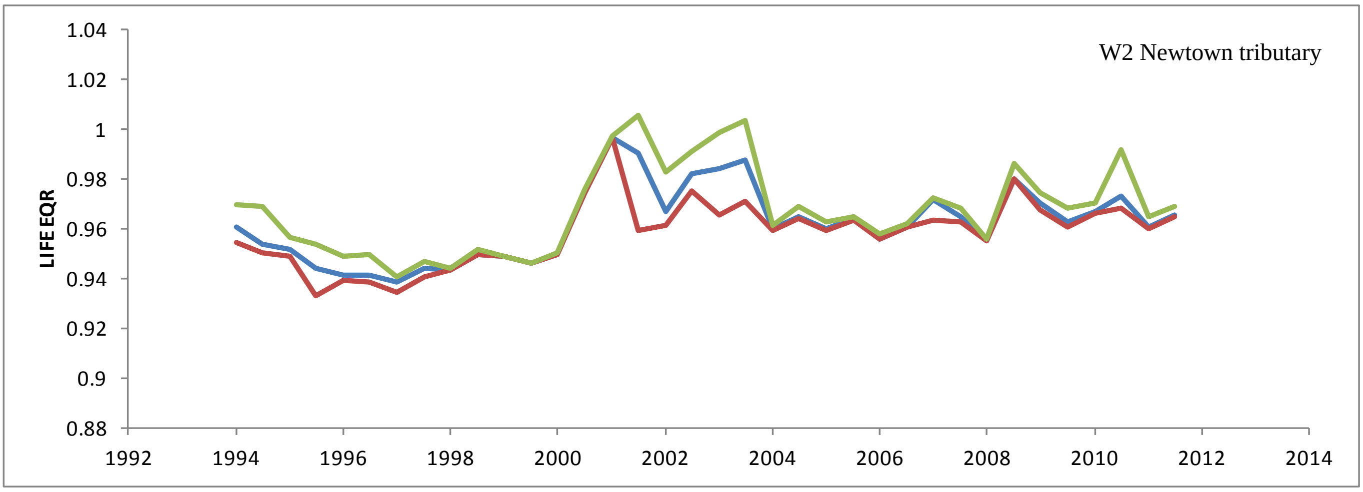
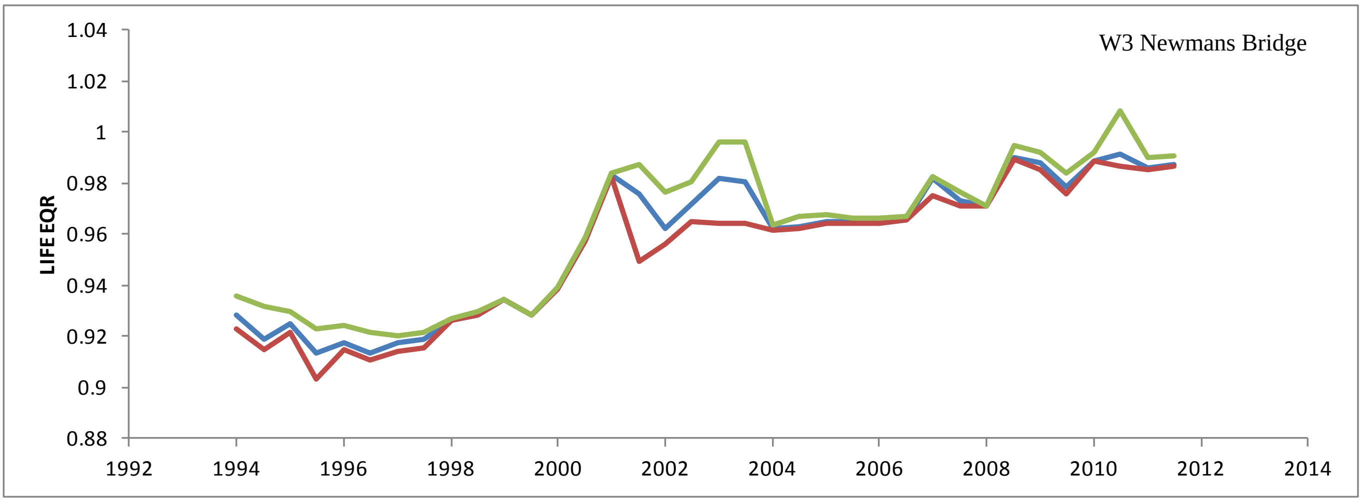
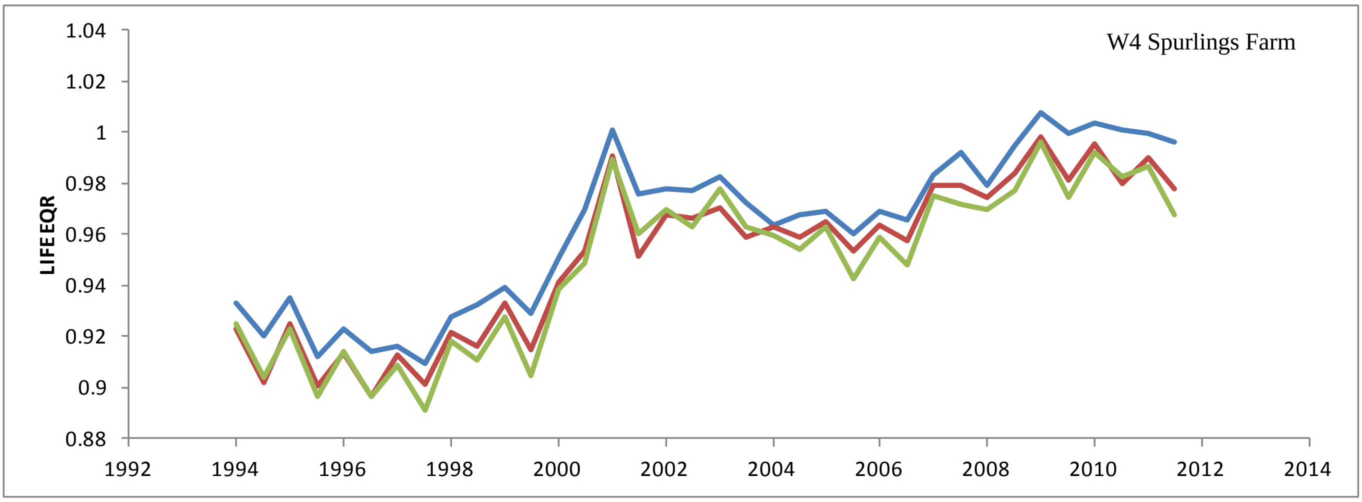


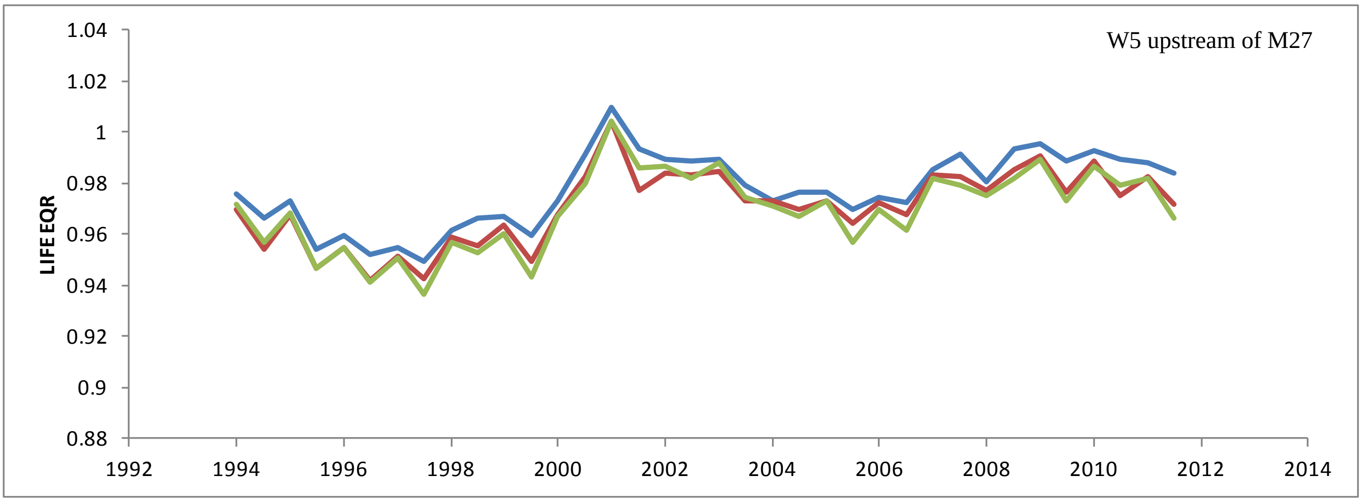
Figure 4.2 Results of DRIED-UP modelling, showing predicted impacts of abstraction on LIFE scores

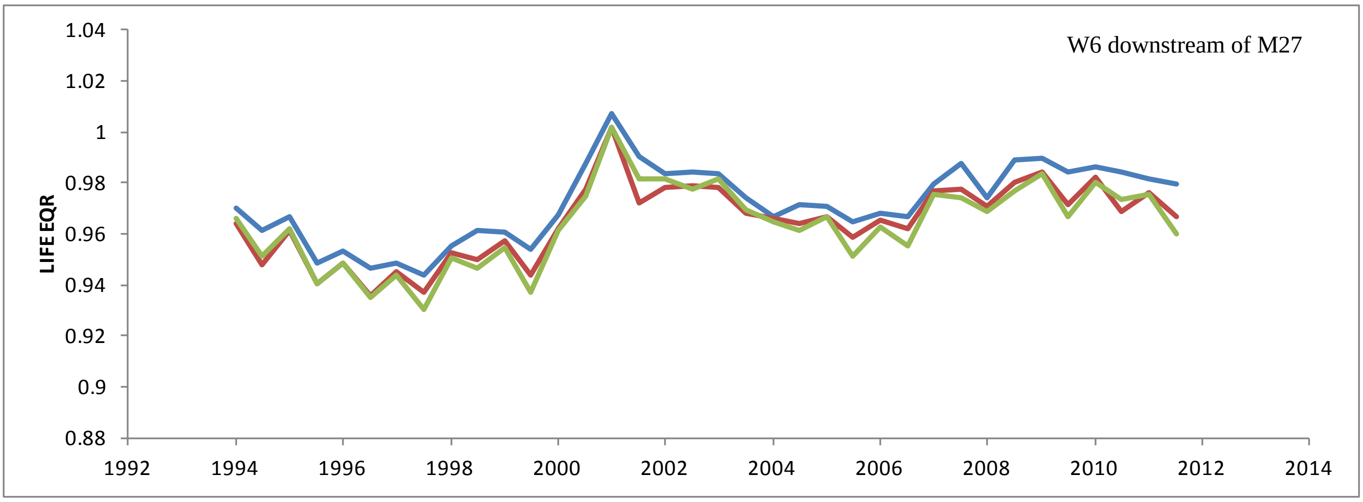



W2 Newtown tributary
LIFE EQR
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


W3 Newmans Bridge
LIFE EQR
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


W4 Spurlings Farm
LIFE EQR
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014





The situation differs clearly between the upper and lower catchments, which are considered separately below.

Upper catchment

In the upper catchment, the DRIED-UP modelling suggests that there is limited potential for impact in lower flow years. This is thought to be as a result of the flows naturally being very low at the upper sites in the summer, and the groundwater model not predicting any differences in low flows between abstraction scenarios. Whilst this result should be treated with a certain amount of caution as DRIED-UP is primarily based on perennial sites, and sites W1 and W2, which are essentially ephemeral, may respond differently, the results of the groundwater model do allow confidence in these conclusions. The groundwater model shows that abstraction does not significantly increase the length of time that zero or negligible flows occur in the upper reaches, increase the total ephemeral length, or have any effect on the quantity of low flows. Since there is no difference in the flow regimes of the low flow years between abstraction scenarios, the conclusion that abstraction does not directly impact upon the ecology of the upper river in low flow years seems reasonable. This is reinforced by the DRIED-UP model giving a reasonably good representation of the long observed record at site W3, suggesting that the model can appropriately represent these upper reaches of the river.

The DRIED-UP modelling suggests that LIFE scores may increase sharply in response to particularly high flow winters, and indeed this can be seen in the observed data for W3. The DRIED-UP modelling period extended from 1994-2011, and showed this type of response after high flows in the winter of 2000-1. The groundwater model outputs show those flows to have been the highest by a significant margin in the period 1965-2011, and the event and its impacts may therefore have been exceptional. It is likely that a large event such as this could have caused significant changes to channel morphology in the small headwater channels, and would have washed out sediment accumulations from the river bed. A change in the invertebrate communities over the next year or more might be expected as a result of the effects of washing out and changes to the physical habitat. It is in such high flow years that the impacts of abstraction may become most evident on river flows, because the vast majority of the abstraction impact is felt at high flows. The main effect of abstraction in the upper Wallington catchment, therefore, appears not to be reductions in LIFE scores overall or reductions in the driest years, but less of an increase in flow in wet years, which may result in less flushing of the system than would occur naturally. The result of this appears to be a reduction in inter-annual variability in the LIFE scores compared to the natural situation. While in some cases this might suggest a healthy, stable regime, the fact that the variability would occur to a greater extent in the naturalised scenario suggests that it is inherent in the character of this relatively flashy catchment. It is, however, noticeable from the DRIED-UP results that the effect of the 2000-1 event was not permanent, with the difference between abstraction scenarios diminishing and then disappearing entirely within three years. Overall therefore it might be concluded that abstraction has minimal impact on the invertebrate communities of the upper Wallington, with the possible exception of a relatively short term impact following extreme high flow events.

Lower catchment

In the lower catchment, the flow regime is still relatively flashy, and the influence of high flow years such as 2000-2001 is still seen but to a lesser extent. Both the observed data and the DRIED-UP assessment at W4 suggest that the invertebrate community in the lower catchment is influenced more by low flows than high flows, in contrast to the upper catchment. Since low flows downstream of Southwick are supported by discharges and leakage, there is no net impact on low flows in the majority of this reach due to abstraction, and as a result, little effect on LIFE scores.

As discussed above, at the very bottom of the catchment impacts on river flows from Maindell start to be felt at Fully Licensed, but this impact is not seen in the groundwater model at site W6, only becoming apparent at the tidal limit. Given the short distance between W6 and the tidal limit of approximately 500m, this suggests that any impacts on freshwater habitat from Maindell will be of negligible spatial extent, assuming that low flow support from upstream discharges continues. Whilst evidence of abstraction impact could in theory be looked for in the biological records, since the recent use of Maindell has been low, it is not possible to observe any effects since the biological record is very short in these furthest downstream reaches. DRIED-UP does not predict any impacts from abstraction at Maindell at any of the monitoring sites since there are no predicted reductions in low flows compared to naturalised. While DRIED-UP could perhaps be adjusted to take in to account the apparent flow deficit at the tidal limit itself, this is considered to be of little relevance since the ecology will there be affected by the tide with negligible influence on the freshwater habitat.

4.3.3 Species of conservation interest

Relatively few species of conservation interest were found during the 2011-12 invertebrate surveys of the River Wallington, with the exception of:

- In the autumn of 2010, one Nationally Scarce soldier-fly *Odontomyia tigrina* was recorded, at W1. *Odontomyia tigrina* is more associated with fens, ponds, canals and ditches both inland and in coastal areas (Stubbs and Falk 2001). As a result it was an unusual species to record in a river survey, but it was recorded in slack water in the World's End Tributary in 2010;

- In the same sample and at the same site, *Simulium angustipes* was recorded. This is normally associated with small seasonal streams, small permanent streams and occasionally larger streams and rivers in Great Britain. It might therefore be expected to turn up in winterbournes;

- The riffle beetle *Riolus subviolaceus* was recorded at W6 in spring 2012. The species is usually associated with base-rich running water (Friday 1988). The species was given Nationally Scarce status until recently but was downgraded by Foster (2010) because it is now considered too widespread to qualify for this status;

- *Enicocerus exsculptus* was found in sample W4 in spring 2012. The species is often found clinging to algal films developing on culverts, boulders and gravel in clean rivers and streams (Foster 2000).

The species found at W1 in particular highlight the ephemeral nature of the uppermost reaches of the River Wallington. The presence of these species illustrates that although the LIFE scores are relatively low, species of interest are found in the upper reaches of the river as a result of its ephemeral nature, which is not well reflected in biotic indices such as LIFE.

4.3.4 Velocity analysis

A detailed assessment of the in-river physical habitat availability through the catchment, as evidenced by the range of velocities, is included in Appendix L, with a summary here. The assessment has only covered sites W3, W5 and W6. Sites W1 and W2 were not included because they are often dry in the summer. W4 was not included because the spot flow surveys were carried out at a location (just upstream of the bridge at Spurlings Farm) that is not representative of the channel in that reach.

The upper reaches of the Wallington provide unsuitable habitat for species preferring fast-flowing water, which is largely a result of their naturally ephemeral nature and small size. Abstraction impacts are likely to only indirectly affect this, potentially by reducing higher flows and therefore not flushing the channel through to clear the bed quite as effectively as a natural flow regime might do.

In the middle to lower reaches of the Wallington, abstraction has limited opportunity to influence the habitat suitability during the summer, due to the limited interaction of the river with groundwater in the summer, coupled with the support from discharges and leakage in the lower catchment. However the assessment suggests that here also the habitat may naturally be relatively unsuited to species preferring fast-flowing environments, due to a combination of the natural flow regime coupled with a reduction in habitat variability within the channel due to physical modifications (this latter point may apply only to the very lowest reaches of the river, at and downstream of the M27).

4.3.5 Assessment of other pressures on in-river ecology

The assessments above have indicated the extent to which abstraction influences flows in the River Wallington, and the subsequent effects that those flow reductions may have on in-river ecology. In addition to this, other potential pressures in the catchment should be given some consideration.

Water quality pressures may be relevant, particularly considering that the waterbodies of the upper and lower Wallington were classified as failing against phosphorus standards in the 2009 RBMP. The biotic indices of NTAXA and ASPT do not show clear evidence of water quality impacts in recent years at most sites, with the exception of sites W1 and W2, where both NTAXA and ASPT scores have varied considerably over time and have been relatively low for the last few years. The RHS (as discussed further below) found evidence of poaching, particularly at sites W1 and W2, which could also be an indication of a source of nutrients to the system.

Morphology and sediment-related pressures through the catchment have been considered by carrying out RHS and GeoRHS surveys. The results of the RHS assessment can be found in Appendix J, including a map showing the extent of habitat modification through the catchment. The RHS indicated a relatively high level of channel modification (class 4 or 5) at all of the reaches surveyed, although the majority of this was due to the presence of bridges. Overall the river is relatively natural in character along much of its length, with the most significant modifications occurring in the furthest downstream reaches at W5 and W6, where the re-sectioning scores are higher where the river has been straightened at and downstream of the M27 crossing. Early DRIED-UP runs considered the potential influence of habitat modification on the ecology of the River Wallington, as shown in Appendix G, and found that re-sectioning in the furthest downstream reaches of the Wallington (at sites W5 and W6) could be influencing the macroinvertebrate community and reducing LIFE scores. This could go some way to explaining the variable and sometimes relatively low LIFE scores at these sites and, certainly in recent years, is likely to have had more influence on the ecology of this reach than abstraction, given the low level of use of Maindell.

4.4 Conclusions

4.4.1 Catchment scale

The River Wallington has a naturally flashy catchment, with Chalk exposed only in the very headwaters, and much of the river then being underlain by impermeable deposits. In summer, interactions between surface water and groundwater are very limited, with the river being naturally ephemeral. The impact of abstraction in these upper reaches is a reduction in moderate to high flows, but abstraction does not significantly alter the total length of the ephemeral reaches compared to naturalised, and results in only a minimal difference in the length of time that ephemeral reaches remain dry.

The nature of the natural flow regime and hydrological impacts feeds through to the ecological assessment. In the naturally ephemeral reaches of the headwaters, LIFE scores and EQRs are low at sites W1 and W2, with EQRs being variable and sometimes being below 0.945, which might be expected to indicate flow stress. However modelling of these reaches in DRIED-UP does not show a significant effect on LIFE scores from abstraction in most years, and considering the lack of influence of abstraction on the flow regime at low and even moderate flows, this is considered to be a reasonable conclusion. The results of the modelling suggest that impacts of abstraction on macroinvertebrate communities will be felt most strongly after winters with very high flow. Changes to the invertebrate community are likely to occur as a result of the high flows flushing out the headwaters, clearing fine sediments and perhaps naturally altering the channel morphology. Naturally, the invertebrate communities may respond sharply to such events, resulting in a significant increase in LIFE scores for one or more years afterwards. The main effect of abstraction seems to be to reduce these spikes and therefore, it must be assumed, reduce the natural variability inherent in the system. However the effect of such events is reduced within one or two years, after which there is no lasting difference compared to the naturalised situation.

The RHS survey found evidence of poaching in these upper tributaries, which can also have an effect on invertebrate communities that would be evidenced in LIFE scores, and is likely to introduce nutrients to the river. The latter is particularly of relevance since the upstream Wallington waterbodies fail for phosphorus in the 2009 Southeast RBMP. It is likely, therefore, that a combination of pressures including morphological alterations and nutrient inputs all contribute towards lower scores of biotic indices in these headwater reaches of the river. Given the naturally ephemeral nature of these reaches, the impacts of abstraction may not be the primary factor, with only the temporary effect of high flow events reduced as a result of abstraction.

In the lower catchment, the Wallington receives significant inflow from the Southwick tributary to the east. In addition to this, there are a number of small discharges to the river, as well as contributions to low flows in the river from leakage in urban areas. The effect of these positive artificial influences is to increase low flows above the natural flow in the lower catchment, and this benefit is sustained through a considerable portion of the flow duration curve (up to around Q50). Only in the very bottom reaches of the River Wallington might this effect be overturned, by abstraction at Fully Licensed rates from Maindell. However the groundwater model outputs show that the effect of Maindell is not enough to reduce fully licensed flows below naturalised until the tidal limit is reached. In the recent actual scenario, flows do not reduce below naturalised even at very low flow percentiles at the tidal limit. It is therefore possible to conclude, based on the results of the hydrological modelling, that the recent abstraction regime at Maindell does not result in a reduction in low flows compared to naturalised over any significant length of the freshwater waterbody, and therefore might not be expected to have a noticeable effect on the ecology of this stretch. While it is recognised that the limited period of invertebrate data available at W5 and W6 shows fairly poor LIFE scores, assessments of the physical habitat and the velocity regime at W6 suggest that the habitat in this reach may be relatively unsuited to invertebrate or macrophyte species preferring fast-flowing environments, and that physical modifications to the channel have reduced the heterogeneity of the habitat. The DRIED-UP modelling has indicated that habitat modification may be causing a reduction in LIFE scores in this downstream reach, and alternative factors besides abstraction therefore seem likely to be responsible for suppressed LIFE scores.

4.4.2 Waterbody scale

Conclusions relating to the waterbodies specifically identified for investigation are presented in Table 4.6.

Table 4.6 Summary of impacts at the waterbody scale for relevant reaches of the River Wallington

Waterbody	Hydrological impacts	Ecological impacts
GB107042016410 (upper Wallington) and GB107042016350 (upper mid Wallington)	Worlds End and Newtown tributaries are naturally ephemeral. Abstraction has very little effect on the ephemeral extent, either spatially or temporally. Abstraction impacts are seen only at high flows.	Modelling using DRIED-UP predicts that impacts from abstraction would only be evident in high flow years, where abstraction appears to reduce the potential for the river to respond to its natural flashiness (for example, reduced flushing of sediments), reducing some of the natural variability in invertebrate communities. However this effect is associated only with very occasional events (e.g. once in the last 20 years) and has only a temporary effect of 1-2 years following.
GB107042016360 (lower Wallington)	Impacts from recent actual abstraction are masked for the full length of this waterbody by discharges and leakage, which support low flows. If abstraction at Maindell was to be increased to fully licensed, this could result in the very lowest reaches of the river drying out at Q95 and below, but this would only be apparent at the tidal limit.	Impacts on ecology in the lower Wallington are not expected under the current abstraction regime from Maindell, because recent levels of abstraction have been low. The implications of the hydrological assessment are that even at fully licensed levels of abstraction, effects would not be seen within the freshwater waterbody to any significant extent. Therefore it might be concluded that impacts on the freshwater ecology are negligible.

5. Ems Catchment

5.1 Introduction

5.1.1 Catchment characterisation

The River Ems lies to the north of Chichester Harbour, flowing (at its greatest extent) from Stoughton in the north, southwest through Westbourne to Emsworth in the south, where it enters the Emsworth Channel of Chichester Harbour. The river is ephemeral over much of its course, down to around 0.5km upstream of Westbourne, from which point on the river can be supported at low flows by an augmentation scheme and can be considered to be perennial.

The upper reaches of the River Ems flow directly over the Chalk, except between Woodmancote and the A27 crossing, where the Reading Beds overlie the Chalk. Superficial deposits are sparse or absent in the upper reaches of the catchment, with Alluvium and Head deposits mostly restricted to the main river course and tributary valleys. Superficial Alluvium and Head deposits are more widespread in the lower reaches of the catchment and raised marine sands and gravels dominate the surface geology south of Emsworth.

The catchment is predominantly rural and contains significant woodland until Westbourne and Emsworth are reached. The Ems waterbody is classified as heavily modified in the 2009 RBMP for flood defence: although the whole river is included in the same waterbody ID, the flood defence modifications apply mainly to the lower river in the urbanised areas. However the upper reaches of the Ems have also experienced significant modification in some parts. For example, around Lordington Manor the channel is raised above the bottom of the valley, and in at least two locations the channel is widened or passes through ponds which were previously watercress beds.

Table 5.1 Waterbodies classified in the first RBMP (Environment Agency, 2009)

Reach	Waterbody ID	Overall status	Flow supporting condition	Reasons for failure*
River Ems	GB107041012370	Poor Ecological Potential	Band 3	Fish (P), Inverts (M)

* Where biological elements have been assessed and are not failing, they are included in brackets

5.1.2 Portsmouth Water abstractions

The main abstractions in the catchment are Walderton PWS close to the source of the Ems, and Woodmancote PWS, which is upstream of Westbourne. These abstractions are summarised in Table 5.2. These comprise the vast majority of abstractions in the catchment. There are no sewage treatment works discharging to the Ems. The main discharge is the Ems compensation scheme, which operates during periods of low flow, introducing flow to the

Ems upstream of Westbourne: this is discussed further in the following section. The locations of the abstractions and discharges are shown in Figure 2.3.

Table 5.2 PWS Abstractions in the River Ems catchment

Licence number	Name	Licensed quantity	Group licence	Recent actual abstraction*
10/41/511007	Walderton PWS	9955.74Ml/yr, 27.28Ml/d	23740.5 Ml/d with Funtington, Fishbourne, Lavant & Brickkiln	4472 Ml/yr, 12.25 Ml/d
10/41/520101	Woodmancote PWS	1363.80Ml/yr, 3.74Ml/d		237 Ml/yr, 0.65 Ml/d

Recent actual abstraction 2006-2010

5.2 Hydrological Assessment

A detailed hydrological assessment for the catchment is presented in Appendix C, which includes consideration of observed data and use of the EHCC groundwater model. A summary is provided here.

5.2.1 Observed hydrology

There is one permanent gauging station in the catchment, at Westbourne (NGR SU 755 074), which captures flows from the upper catchment. The mean flow recorded from the full period of record (1967-2012) is 0.467m^3/s, with a Q95 of 0.015m^3/s. The National River Flow Archive (NRFA) gives a Base Flow Index of 0.92, indicating a very high proportional contribution from baseflow, which is to be expected since the river flows entirely over the Chalk until shortly before the gauging station.

Perennial flow in the river extends to upstream of Westbourne, above which the river is ephemeral. However the perennial nature of the lower river is partly artificially maintained, because during particularly dry conditions, flow is supported by a compensation release upstream of Westbourne at NGR SU 763 078 (using water abstracted at Walderton, within the normal licensed abstraction regime (Entec, 2007)). Switching on the compensation scheme is triggered by flows at Westbourne gauging station falling below 2.25Ml/d (0.026m^3/s).

As a result of the low flows that developed through the summer of 2011, the compensation scheme was switched on in early September 2011, and spot flow surveys indicated that the majority of the compensation flow was reaching Westbourne gauging stations. Switching off the scheme is triggered by a prolonged period of flow above 2.75Ml/d (0.032m^3/s) (as such, the scheme was switched off in December 2011 and remains off at the time of writing this report).

The monthly spot flow gauging programme as part of this project has monitored flows at six locations on the River Ems. The data from these surveys shows that the upper reaches of the river, above the Westbourne augmentation, were dry from prior to the project start in July 2011, up until June 2012. Anecdotal evidence reported by Holmes (2007) suggests that the river is naturally ephemeral as far as Broadwash Bridge (Site E3), but that the ephemeral extent may have been extended further downstream as a result of abstraction (this is assessed in Section 5.2.2). At E4 and E6 there was always some flow during the 2011-13 monitoring period, as a result of the augmentation scheme. At E5, which is on the tributary heading north from Westbourne, flow was at or close to zero (1l/s or less) until January 2012, showing significant increases in flow only from May 2012 onwards.

5.2.2 Impact of historic, current and fully licensed abstraction regimes

The impacts on the upper ephemeral reaches and the lower perennial reaches may be considered fairly separately. In the former, it is the impact of abstraction on the duration of flow that is of the most interest, while in the latter it is the impact on the amount of flow that is likely to be of more importance.

Ephemeral Ems

The assessment in Appendix C shows that under natural conditions the River Ems downstream of Woodmancote nearly always has flow, whereas upstream of this location the Ems can be described as ephemeral. The extent of drying is intensified between the months of June and November where the flows to zero or a negligible rate as far downstream as Broadwash Bridge (monitoring site E3).

When compared to Naturalised, the duration of drying in the ephemeral reaches is often more than 10 per cent greater under both the Recent Actual and Fully Licensed scenarios, with drying starting earlier in the year than it would do naturally. The fully licensed scenario shows that generally flows are below the lower threshold for a greater percentage of time in comparison to Recent Actual.

As an example, Appendix C considers accretion in the dry summer of 2006. In that year, the onset of accretion occurs approximately 250 m upstream of monitoring site E3 for the naturalised scenario. This shifts to 250 m downstream of E3 for the Historic and Recent Actual scenarios, and around 850 m downstream of E3 for the Fully Licensed scenario. This is a total difference of 1.1km between the onset of flows between the Naturalised and Fully Licensed scenarios, and takes the perennial head closer to E4 than E3.

In comparison, during wet periods such as the spring of 2002, flow commenced in the river 850m north of monitoring site E1 for the Historic, Recent Actual and Fully Licensed scenarios, and approximately 1.6km upstream of E1 for the Naturalised scenario. The difference between the onset of accretion for the Naturalised and Fully Licensed scenario is approximately 750m: i.e. under both low and high flows, abstraction shifts the location and extent of the ephemeral Ems. A comparison of the selected spring versus summer accretion onset gives an indication that the ephemeral reach of the upper River Ems is typically around 5km in length.

Perennial Ems

Table 5.3 illustrates that there is a clear reduction in flow in the Ems catchment between the naturalised scenario and all the groundwater abstraction scenarios. However it is notable that the predicted fully licensed impact is no greater than the historic impact, at Q95.

The first two locations in the table are downstream of the augmentation scheme, which means that the River Ems should not run dry at either of these locations due to support received from the scheme. The bottom row of the table clearly shows how much more impact is seen at low flows without the augmentation. Upstream of the Walderton-Ems augmentation scheme, the Q95 flow is 4Ml/d under Naturalised scenario, but zero under all groundwater abstraction scenarios. The reduction in flow as a result of abstraction is clear and under the Fully Licensed scenario the model results show that the River Ems is dry at this location for approximately 17 per cent of the time. It is clear that river support is necessary in order to maintain flow in the River Ems downstream of this location at times of low flow (at that support would not be necessary to the same extent in the absence of abstraction).

Table 5.3 Impacts of abstraction on Q95 in the Ems catchment (Ml/d)

Location	Naturalised	Recent Actual	Historic	Fully Licensed
Outflow of waterbody GB107041012370	5.2	1.6	1.2	1.4
Westbourne GS	4.9	1.5	1.1	1.3
Upstream of augmentation scheme	4	0	0	0

5.3 Hydro-ecological Assessment

The ecohydrology of the mid and upper Ems has been assessed using available hydrological data with aquatic macroinvertebrate monitoring and river habitat survey (RHS) data. A summary of the analysis is presented here whilst the full report, prepared by the Centre for Ecology and Hydrology (CEH), is presented in Appendix H. The analysis builds on earlier studies, e.g. Holmes (2007), using more up to date macroinvertebrate monitoring data and RHS data, and using a wider range of metrics and indices.

Data Available

The analysis uses invertebrate data collected by the Environment Agency as well as through this study. Sites E1-E6 (as per Table 2.2) are the main sites used in the assessment as they, in general, have the most data and are the sites sampled during this study, but information has been used from some of the other EA sites when appropriate and useful.

For each site biomonitoring scores were provided for invertebrates (BMWP, Ntaxa, ASPT, LIFE(F), LIFE(S)) as well as predicted RIvPACS scores. Diversity scores (Simpsons and Shannon diversity indices, Margalef richness, Berger-Parker dominance, total sample richness, total sample abundance[4]) have been calculated from the data supplied.

[4] Simpson's index is a diversity index. Shannon index is also a diversity index but downweighs rare species. Margalef richness standardises the number of species by the total number of individuals to adjust for passive increases in diversity expected with bigger samples. Berger-Parker is a species dominance index i.e. an inverse of diversity indices

Hydrological data are available for Westbourne Gauging Station and from anecdotal observations reported in Holmes, 2007, as well as from spot flow surveys during this project. RHS data were collected for sites E1-E6 through this study.

5.3.1 Analyses Undertaken

An initial examination of all the available data was undertaken comprising:

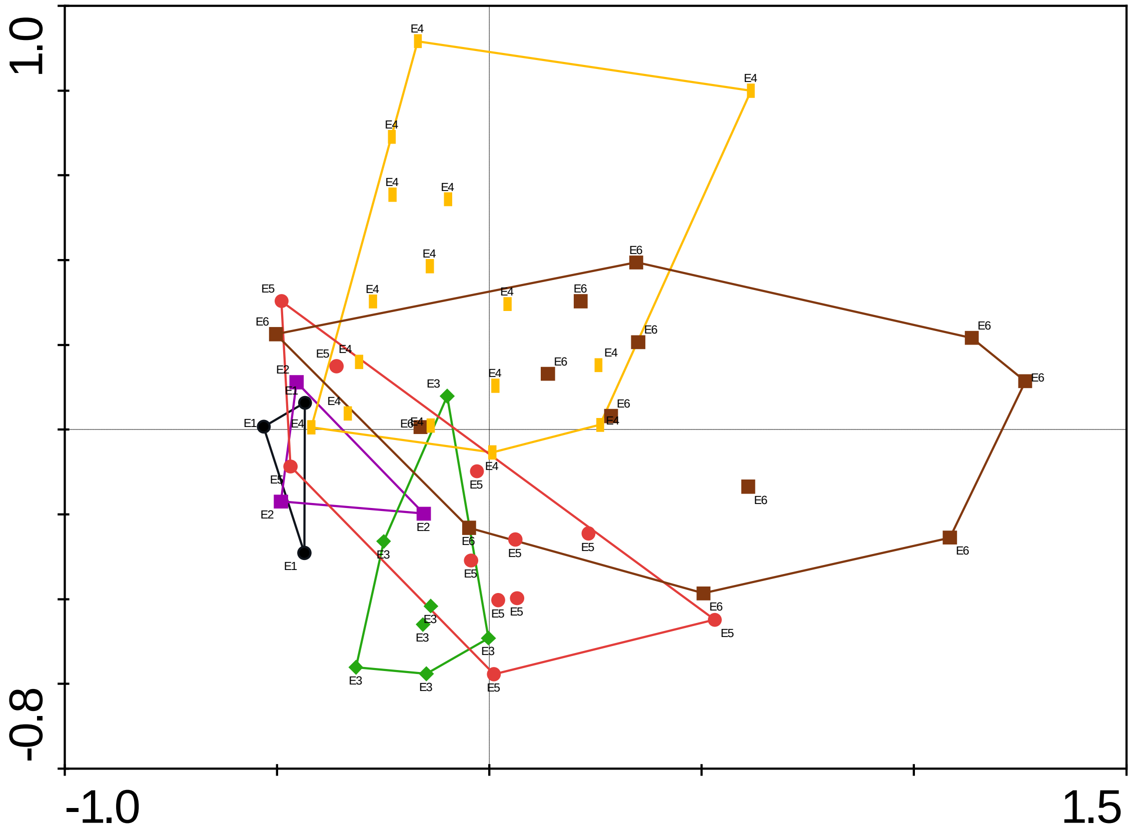
- Principal component analysis (PCA) of the invertebrate data to determine how similar the data from the different sites were (see Figure 5.1). This identified that sites E1 and E2, which are both ephemeral in nature, are similar. In contrast E3, which is also ephemeral, was more similar to site E5, which dries out only infrequently during periods of drought (it was dry in autumn 2011 meaning it could not be sampled for this study at that time). Sites E5 and E6 are quite similar to one another and E4 is different from all the sites;

- Analysis of the RHS data was undertaken to determine how modified the channel of the Ems is compared to sites on similar rivers, indicating that the sections were generally towards the modified end of the spectrum. Site E3 was the exception to this, being by far the least modified of the sites surveyed; and

- Analysis of Westbourne GS data concluded that the observed flow data were most representative of site E6 (located just upstream), but were unrepresentative of sites E1-E3. The data could only be related to the flows at E4 and E5 if the augmentation discharge data and discharge data for either the New Street tributary or the Ems upstream of the augmentation is known or by use of the groundwater model. Nonetheless an attempt was made to correlate mean monthly flows for a range of antecedent flows periods with the sample biomonitoring scores and diversity indices at each site. No significant correlations were detected.

Further detailed analysis was then undertaken for the ephemeral Ems (sites E1-E3), the perennial Ems (sites E4-E6), the effects of the Westbourne augmentation, and comparing the data from the ephemeral compared to the perennial reaches (see Appendix H).

Figure 5.1 **Ordination plot of a PCA for macroinvertebrate community data in the Ems**



Samples from each site are contained in a different coloured envelope. Black, E1; Purple, E2; Green, E3; Yellow, E4; Red, E5; brown, E6

Conclusions of the Hydro-ecological Analyses

Sites E1 and E2 are naturally ephemeral sites, though Holmes (2007) relates longer historical periods of wetness (as also shown by the groundwater model in Section 5.2). Although these sites tend to fall below the expected biomonitoring values, they do have conservation value with often unusual species (species that do not necessarily contribute to the biomonitoring scores). Observed information on past flow regimes in these reaches of the Ems is known only from anecdotal information, and current information is limited to the groundwater model, so it is hard to surmise with certainty what a change (increase) in flow would achieve ecologically. It is clear however that these reaches are heavily modified and in some places still display historical in-stream structures associated with more prolonged periods of flow, which are not suitable for what is now an acutely ephemeral stream. When these sites are in flow, the morphological degradation limits any positive effect of flow on the communities.

Site E3 is of particular interest because it is deemed to have been the true historical fully perennial head as recently as the 1960s, though the site is now observed to dry regularly, making it ephemeral in nature (as discussed by Holmes, 2007, and illustrated by the groundwater model findings in Section 5.2 and Appendix C). Nonetheless, biomonitoring scores, the groundwater model, ordination of the species data and invertebrate community structure (as well as the plant communities described by Holmes 2007) indicate that flow is likely to be more regular at this site than at E1 and E2, making it more similar to the downstream perennial sites than the more ephemeral sites upstream. As the communities of plants and animals retain some characteristics of the historical perennial communities, this may be the reach where changes (increases) in duration of flow would have the most beneficial effect. Though the site already often meets the expected biomonitoring thresholds, it has the potential to achieve these more regularly. This site and surrounding area provides the most natural habitat in the catchment, so managing flow would be more effective in this reach than habitat management.

Site E4 is of interest because it lies downstream of the augmentation, thus making the site perennial. The site however falls consistently below expected biomonitoring thresholds, while displaying a good level of biodiversity. This site is a particularly good example of how morphological characteristics limit the benefits of the augmented flow. The site is straightened and widened, with very low velocities, an accumulation of silt and excessive macrophyte growth. This shapes a diverse community, which is not reflected in the BMWP and LIFE scores (both of which are generally low) because the taxa are more typical of standing waters, yet the site is treated as a river site. Here only extensive morphological restoration has the potential of raising the ecological status (in terms of expected Chalk river habitat), as extra flow would make little difference. On the other hand, the site provides a pleasant area for the local human community and provides habitat for a range of plant and animal species that may not otherwise occur. Hence, a management decision is needed as to whether the river at this site should be restored, or should be treated as a standing waterbody and conserved as such.

Site E5 is more variable in its ecological status than the other Ems sites as it can vary between falling below, meeting or exceeding expected biomonitoring thresholds from year to year. Holmes (2007) describes the reaches just upstream of this site as historically perennial, but then drying regularly for short periods of time from the 1960s onwards, and the groundwater model indicates similar (Appendix C). Although the HMS score is high, the habitat (HQA) is of good quality. Holmes (2007) collected accounts from local residents that state that this tributary was known for sea trout runs, which also stopped in the 1960s. It is difficult to separate the effects of flow duration and habitat modification at this site without further hydrological data; however it has good fish habitat potential and thus would benefit from a fully perennial flow regime (currently it appears to dry during periods of drought, as indicated by it being dry in autumn 2011).

E6, despite being in a more urbanised area, has a relatively low HMS and high HQA indicating good habitat quality (although the reach immediately downstream is more modified than E6 itself). E6 also has a good ecological status with the highest scores and metrics of all the Ems monitoring sites, and good biodiversity (though no particularly rare or unusual taxa). Furthermore E6 usually meets or exceeds the expected values of the biomonitoring scores and indices. This site is also mentioned by Holmes (2007) as having very high trout abundance historically, with the river described as ‘black with trout’ by a local resident. EA fish monitoring data reported by Holmes (2007) indicate a small fish community in this section of the river comprising trout, bullhead and eels.

Increased flows *per se* may not provide significant improvements to the ecology at E6, however the essentially perennial-adapted communities would be particularly sensitive to drying episodes in drier years and increased low flows may help avoid these. Perennial flow at E6 is achieved by the augmentation on the Ems just upstream of E4, but may still mean that flows are sustained for a longer duration at a lower flow than would naturally occur.

For all sites the ecological metrics were not correlated to antecedent flow conditions, but there was a clear ecological distinction between perennial and ephemeral sites in community data and monitoring metrics. It is generally accepted that in these types of intermittent streams, presence/absence of flow has a greater influence on the ecology than the volume of the flow when it occurs. Nonetheless it is clear that hydromorphological degradation is an important driver in this catchment and could limit the benefits of additional flow at most of the sample sites, as seems to be the case at E4. The ephemeral nature of the most upstream sites (E1-E3) contributes to biodiversity at the catchment scale; however there is scope to improve the habitat to better exploit wetted periods. For example, remnants of historical impoundments could be removed (e.g. around Lordington Manor) and the channel morphology could be improved in areas where the channel has been flattened or turned into a ditch (e.g. between E1 and E2). The lower sites E3 to E6 are better adapted to a perennial flow regime. Although sites E4-E6 are already perennial or near-perennial, E3 is not but it is suggested that this site E3 could benefit from such a change. It should be noted that E4 has become more of a flow-through pond than a river and a decision is needed as to how it should be managed. Maintaining perennial flow is essential at E6 to maintain the current good ecological status and support the fish community, and a fully perennial flow regime would be desirable at E5 as it provides good habitat for invertebrates and fish.

5.4 Conclusions

There is only one waterbody covering the full Ems catchment (GB107041012370), and hence these conclusions apply both at the catchment-scale and waterbody-scale.

The River Ems is naturally ephemeral in its upper reaches until just upstream of Broadwash Bridge (monitoring site E3). Abstraction in the catchment increases the extent of the ephemeral reach, by about 500m downstream with recent actual levels of abstraction, and 1km downstream under a fully-licensed abstraction scenario. This moves the perennial head of the river under fully licensed conditions closer to monitoring site E4, around the location of the discharge from the augmentation scheme. The shift from naturally perennial to artificially ephemeral at E3 is evident from the ecological analysis. The macroinvertebrate data show this site to be more similar to the downstream perennial sites than the upstream ephemeral ones, and the macrophytes retain some characteristics of a perennial community. Restoring more frequent and higher flows to this location would be expected to be effective in recovering those characteristics fully.

From E4 downstream, the river flows constantly, but this is partly due to the use of the augmentation scheme, which supports flows during dry periods (noting that use of the augmentation depends on accurate gaugings at Westbourne GS to trigger use of the scheme. If low flows at the gauging station are over-estimated, this may result in flows dropping very low in the river through Westbourne before use of the augmentation scheme is requested by the Environment Agency, as appears to have been the case in 2011). Maintenance of a small flow at E4 allows an interesting although unnatural ecology to be sustained, since this reach upstream of Westbourne is widened and deepened (having previously been a watercress bed). There is a high diversity of invertebrates at this site, with some species of conservation interest being observed. This high diversity is not reflected in the biotic indices since the site is not representative of flowing waters. Increasing LIFE scores at this site would require restoration of the channel to a more natural form, but given the habitat and diversity currently provided, even if not representative of a Chalk stream, this may not be a desirable change to make.

Through Westbourne, flows are reduced significantly by abstraction. Although a minimum flow is sustained as a result of the augmentation (which spot flow surveys in 2011 suggest has a high effectiveness in reaching the lower catchment), the abstracted scenarios have a Q95 of only around 25 per cent of natural, with all abstracted scenarios showing a similar result. Although much of the habitat through Westbourne is limited as a result of modification (with the channel being straightened with artificial vertical banks), the monitoring site in Westbourne at E6 is in a more natural reach and generally achieves good LIFE EQRs. However the observed data do suggest that this site will be susceptible to sustained periods of low flows (such as in 2005) and this is likely to be exacerbated by abstraction.

6. Lavant Catchment

6.1 Introduction

6.1.1 Catchment characterisation

The River Lavant at its maximum extent flows from near Charlton on the South Downs, westwards to West Dean, then south to Chichester, discharging into Chichester Harbour near Fishbourne. The river flows across the Chalk from its ephemeral source to the northern edge of Chichester. Through Chichester, the Chalk is overlain by the Reading beds, Paleogene deposits and alluvial deposits. Downstream of Chichester, as the river discharges to the Fishbourne Channel of Chichester Harbour, it flows back on to the Chalk.

The vast majority of the Lavant is ephemeral, including the entire reach upstream of Chichester that has been the subject of this investigation. Despite the river being naturally dry during times of low groundwater flow, it can also respond rapidly when groundwater levels are high, and significant flooding has occurred in the past (both from the river and groundwater). This led to the construction of the Chichester flood alleviation scheme, by which flood flows are diverted from the Lavant upstream of Chichester, to eventually discharge to Pagham Harbour.

The upper half of the catchment is rural, with small settlements at Charlton, Singleton, West Dean and Mid Lavant. Below this, the river flows in to Chichester, where for much of its course it is culverted. In the upper part of the catchment also there are modifications to the channel, notably around West Dean Gardens, and the river channel is in some reaches left unfenced, allowing cattle and horses to enter.

The Lavant catchment is separated in to four waterbodies in the 2009 South East RBMP, as shown in Table 6.1. The upper and lower of these were classified as being at Good Ecological Status. The middle reach was mis-classified as being in the Pagham Harbour harbour catchment (perhaps as a result of connectivity via the flood alleviation channel), which means that there is no classification for the mid Lavant in the RBMP.

Table 6.1 Waterbodies classified in the first RBMP (Environment Agency, 2009)

Reach	Waterbody ID	Overall status	Flow supporting condition	Reasons for failure
Upper Lavant	GB107041012360	Good	Band 3	n/a
Lavant (Brickkiln dry valley)	GB107041013100	n/a	n/a	n/a
Middle Lavant	Not included	Not included	Not included	n/a
Lower Lavant	GB107041006520	Good	Band 3	n/a

6.1.2 Portsmouth Water abstractions

The main abstractions in the catchment are Portsmouth Water's public water supplies (PWS) at Lavant and Brickkiln. The details of these abstractions are summarised in Table 6.2. There are also a number of smaller groundwater abstractions in the catchment, and in addition the gravel workings to the southeast of Chichester affect the groundwater regime.

There are two sewage treatment works in the catchment: Lavant STW in the ephemeral reach (the discharge from which is sometimes the only flow in the channel), and Chichester STW, which is located close to the harbour.

Table 6.2 PWS Abstractions in the Lavant catchment

Licence number	Name	Licensed quantity	Group licence	Recent actual abstraction*
10/41/522002	Lavant PWS	9950 Ml/a combined	23740 Ml/a with Walderton, Woodmancote, Funtington and Fishbourne	4701 Ml/yr
10/41/522002	Brickkiln PWS			1377 Ml/yr

Recent actual abstraction 2006-2010

6.2 Hydrological Assessment

A detailed hydrological assessment for the catchment is presented in Appendix D, which includes consideration of observed data and use of the EHCC groundwater model. A summary is provided here.

6.2.1 Observed hydrology

The River Lavant is almost entirely naturally ephemeral. Holmes (2007) classified reaches of the Lavant by the permanence of their flow, and classified only the lowest 2km from Chichester to the Harbour as being truly perennial.

The only permanent gauging station in the catchment is located at Graylingwell (SU 871 064) which captures flows from the upper catchment. Flows measured at Graylingwell will include impact from the two public water supply abstractions and the discharge at Lavant STW. Flows at Graylingwell gauging station are zero for about 50 per cent percent of the time (1967-2012), and the mean recorded flow is $0.36 m^3/s$.

Flow in the catchment commonly commences around West Dean and Singleton, with the river bed then drying out again below West Dean. The dates of flow commencing at Singleton (from Holmes, 2007) has been compared to the onset of flows at Graylingwell gauge. From the few years of data available, there does not seem to be a clear relationship between the two. There are a few years where there is a delay of around three weeks from flow commencing at Singleton to flow commencing at Graylingwell, although in other years there has apparently been a delay of months. However it is apparent from the data that flow often occurs at Singleton when Graylingwell gauge is still dry.

The onset of flow throughout the catchment was monitored throughout the winter period of 2011-12 by undertaking monthly spot flow visits, supplemented by weekly visits since January 2012. In 2012, there was a lengthy delay between flow at Singleton and at Graylingwell. Flow at West Dean and Singleton commenced in January 2012 and continued throughout the year, but until April 2012 the flow continued through only a short reach, including sites H3 and H4 but drying out again around Preston Farm, before H5. The heavy rainfall from April 2012 onwards resulted in un-seasonal rises in groundwater levels, with the result that flow finally extended down the catchment over a period of two weeks or so, with flow commencing at Graylingwell on the 12th May 2012.

6.2.2 Impact of historic, current and fully licensed abstraction regimes

The impact of abstraction on the River Lavant is illustrated most clearly by Figure 6 of Appendix D, showing the proportion of time at which flow is expected to occur along the length of the river, and the difference resulting from Recent Actual and Fully Licensed abstraction scenarios.

Under natural conditions, the groundwater model predicts significant flows (> 1 Ml/d) to occur only downstream of site L1 (although flow surveys during this project have shown that some flow does occur at this location, and for a short distance upstream, at some times). This upper extent of flow accretion does not vary significantly between abstraction scenarios, with flows occurring for about 25 per cent of the time in all scenarios.

Although the river naturally dries out in summer, the assessment in Appendix D shows that, when compared to naturalised, the duration of drying in the middle reaches of the Lavant is often up to 15 per cent (recent actual) or 25 per cent (fully licensed) longer in the ephemeral reaches under the modelled standard scenarios, with the river drying out earlier in the year than it would do naturally. At the outflow of waterbody GB107041012360 (upper Lavant, at the confluence with the dry valley from Brickkiln, and just upstream of Lavant abstraction) this equates to flow being zero for about 50 per cent of the time under the fully licensed scenario and for about 40 per cent under the naturalised scenario. In contrast at Graylingwell, there is relatively little difference between the abstraction scenarios in the length of time that the river is dry for. The overall nature of the ephemeral characteristics, including the greater duration of flow around West Dean, which can then dry out again downstream, is clearly a natural phenomenon caused by a change in the underlying geology, and not a result of abstraction.

When there is flow in the river, the rate of accretion is reduced as a result of abstraction. Predicted flows under the fully licensed scenario exceed 15Ml/d only for 30 per cent of the time (Q30). The Q30 flow for the naturalised scenario is 22.2Ml/d.

6.3 Hydro-ecological analysis

The ecohydrology of the upper River Lavant has been assessed using available hydrological data with aquatic macroinvertebrate monitoring and river habitat survey (RHS) data. A summary of the analysis is presented here whilst the full report, prepared by the Centre for Ecology and Hydrology (CEH), is presented in Appendix I. The analysis undertaken for this report builds on earlier studies, e.g. Holmes (2007), using more up to date macroinvertebrate monitoring data and RHS data, and using a wider range of metrics & indices.

Data Available

The analysis used invertebrate data collected by the Environment Agency as well as data collected through this study. Sites L1 and L3-7 are the main sites used in this report as they, in general, have the most data, but information has been used from some of the other sites when appropriate and useful. Note that the site 'D/S Lavant STW' was named L8 for the purposes of this hydro-ecological analysis, as it is a particularly important site at the catchment scale (reportedly the only perennial site) and has a good data time series, and has been added to the other sites. The hydro-ecological analysis presented considers sites from the upper Lavant only, i.e. L8 and upstream, not the downstream Lavant at Chichester.

For each site, biomonitoring scores were provided for invertebrates (BMWP, Ntaxa, ASPT, LIFE(F), LIFE(S)) as well as predicted RIvPACS scores. Diversity scores (Simpsons and Shannon diversity indices, Margalef richness, Berger-Parker dominance, total sample richness, total sample abundance) have been calculated from the data supplied.

Hydrological data are available for Graylingwell Gauging Station and from anecdotal observations of when the river starts and stops flowing at Singleton. RHS data were collected for sites L1-L7 through this study.

Analyses Undertaken

An initial examination of all the available data was undertaken comprising:

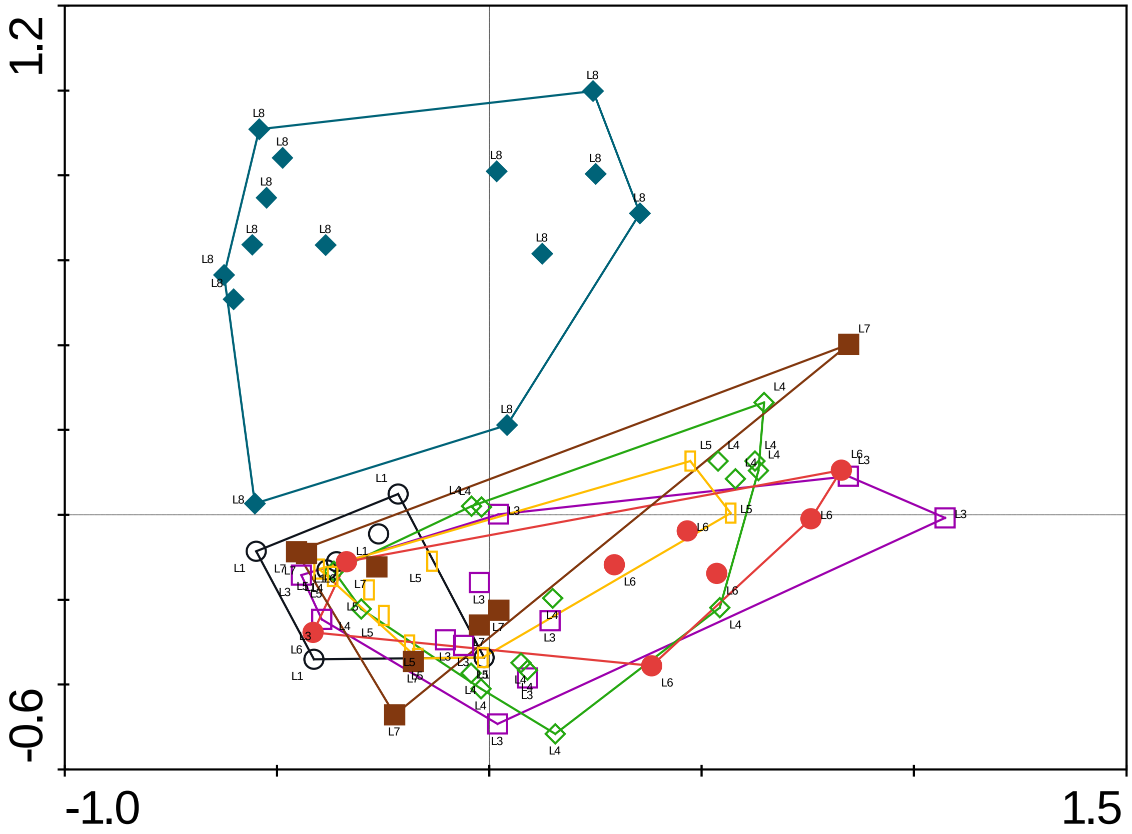
- Principal component analysis (PCA) of the invertebrate data to determine how similar the data from the different sites were (see Figure 6.1). This identified that site L1 and site L8 were different from each other and from all the other 'L' sites (with all others being relatively similar);

- Analysis of the RHS data was undertaken to determine how modified the channel of the Lavant is compared to sites on similar rivers, indicating that the sections were generally towards the modified end of the spectrum; and

- Analysis of Greylingwell GS data against anecdotal observations of flow from Singleton to determine how comparable they were in terms of when the river flows and when not and also the number of wetted days prior to invertebrate samples being taken. In general there was poor agreement apart from in 2004.

Further detailed analysis was then undertaken for the Lavant upstream of Singleton, Lavant from Singleton to Lavant STW and Lavant immediately downstream of the STW. Analyses comprised consideration of the biotic indices, and statistical tests of diversity (see Appendix I).

Figure 6.1 Ordination plot of a PCA for macroinvertebrate community data on the River Lavant



Samples from each site are contained in a different coloured envelope. Black L1, purple L3, green L4, yellow L5, red L6, brown L7, blue L8

Conclusions of the Hydro-ecological Analyses

The hydrological data available from Graylingwell GS and from the Singleton observations reported by Holmes (2007) do not show strong relationships with the ecological data of the River Lavant. These two sources of information correlated poorly with one another and are poor descriptors of flow conditions at all of the sample sites (this was clear from the hydrological assessment in Section 6.2, in which the groundwater model has been used to develop a more comprehensive assessment of historic hydrology as well as potential impacts of abstraction).

RHS data describe poor habitat potential and high levels of modification through much of the catchment. The bed has been levelled in many places leaving the channel open to livestock. In other places the river is channelled. Hydromorphological degradation appears to be a strong pressure at the catchment scale.

The upper Lavant reaches upstream of Singleton are characterised by the incidence of groundwater and hyporheic fauna in the surface water, and thus provide unique biodiversity at the catchment scale.

There is a trend for higher diversity and species richness among sites in an upstream direction (L3/L4 vs L5/L6/L7), which was also observed by Holmes (2007). This was partly driven by better habitat conditions (RHS) at L3.

The macroinvertebrate communities show a high degree of adaptation to flow intermittence and in most cases all sites recovered between approximately six to eight weeks after the return of flow. There was no evidence that more prolonged flows would raise biomonitoring scores or increase species diversity, except perhaps at site L4. Data collected for this project in 2012 are in line with other years, despite the 2011/2012 drought. It is generally accepted that in these types of intermittent streams, presence/absence of flow has a greater influence on the ecology than the volume of the flow when it occurs (e.g. Smith *et al.* 2003, Wood et al 2005 and Stubbington *et al.* 2011), and the hydrological assessment in Section 6.2 has shown that this is affected only to a minor extent by abstraction, with no fundamental changes to the regime.

The findings of the assessment regarding influences of flow are consistent with biodiversity being limited by factors other than flow, specifically hydromorphological degradation throughout the catchment, and water quality downstream of the STW. Any benefit of flow increases would be limited in such degraded sites, as indicated by the absence of an increase in scores when there are several hundred days of flows before sampling compared to much shorter periods. Morphological degradation of channel and banks reduces the quantity and diversity of wetted habitat, reduces the amount of refugia from extreme flow events for the biota, reduces the resistance and resilience of plant and animal communities to change, and increases the impact of point (e.g. low water quality of STW effluent) and diffuse (e.g. fine sediments in field run off) pollution events. The ecological benefits of channel restoration would raise the ecological potential of the sites when they are in flow.

The reach downstream of the STW is reported to flow perennially. It provides unique biodiversity at the catchment scale, however is of a lower ecological status, because it lacks the taxa adapted to intermittent flow which generally have high biomonitoring values. It also shows signs of organic pollution, further constraining the community.

6.4 Conclusions

The Lavant catchment is naturally ephemeral through almost its entire length (excepting the 1-2km at the bottom of the catchment, which is beyond the extent of this investigation). The whole river upstream of Chichester naturally dries out in the summer and autumn, wetting up again over most winters. The reach around Singleton and West Dean flows for the greatest proportion of the time, normally wetting up before flow occurs at Graylingwell gauging station. In some years, where only a moderate recovery of groundwater levels occurs, this intermediate reach may continue to flow in the absence of flow at Graylingwell for a period of months, as was the case in early 2012.

Results from the EHCC groundwater model indicate that the main impact of abstraction on the river is to reduce the length of time that flow occurs for in the upper-mid catchment. At the outflow of waterbody GB10704102360 (upstream of Lavant abstraction), fully licensed abstraction increases the length of time over the whole model period for which there is no flow from 40 per cent (naturalised) to 50 per cent (fully licensed). When flow does occur in the river, the rate of flow is somewhat reduced by abstraction, with a reduction of around one third at Q30.

The ecological assessment, however, has found that the ecological data do not correspond clearly to the duration of flow. The macroinvertebrate communities throughout the catchment show a high degree of adaptation to flow intermittence, and tend to recover between six to eight weeks after the return of flows. There is little evidence that the kind of hydrological changes that would be effected by reducing abstraction in this catchment would raise biotic indices (e.g. LIFE) or increase species diversity. In this catchment it is considered that any improvements to the biodiversity of the river would be more effectively achieved by channel restoration, to reduce the extent of morphological degradation that is evident at a number of sites.

7. Conclusions and Recommendations

7.1 Conclusions

This assessment has considered the impacts of Portsmouth Water's abstractions on four catchments in Hampshire and West Sussex (the Hamble, Wallington, Ems and Lavant). The assessments have taken in to account the historic/existing abstraction regime in each catchment, which has until now been the focus of WFD assessments (i.e. evidence of existing impact). However the assessment has also considered the potential impacts to each river of abstraction occurring at the maximum licensed quantity, i.e. the potential for future changes to abstraction, within the existing licences, which is of increasing concern to the Environment Agency for ensuring 'no deterioration' of status in future.

Hydrological, physical habitat and ecological data have been collected for every catchment in 2011-12 as part of this study, and the results have been used along with other available historic data to carry out both hydrological and ecological impact assessments. In order to distinguish the impacts of abstraction from the natural hydrological regime, and to predict the effects of 'fully licensed' abstraction, tools including the East Hants and Chichester Chalk (EHCC) groundwater model, and the DRIED-UP model of LIFE score predictions have been used. The assessments have focussed at the catchment scale, but conclusions have also been drawn at the waterbody scale where necessary.

The conclusions relating to each catchment have been provided at the end of the relevant catchment chapters. They are summarised again in Table .7.1, which also includes recommendations for further work and addressing remaining uncertainties. Further work is recommended in relation to the Hamble and Ems catchments.

Table 7.1 Summary conclusions and recommendations from the WFD assessments

Catchment/ waterbodies	Abstractions	Conclusions of impact assessment	Recommendations
Hamble	Northbrook, Lower Upham	The River Hamble experiences considerable hydrological impact as a result of abstraction in its upper reaches. This is relevant to both the historic and fully licensed abstraction regime. Given the extent of hydrological impact, the ecology is in relatively good condition and appears relatively resilient to abstraction impacts. However the hydrological impact on the Abbey Pond North and the river reaches upstream and downstream is difficult to ignore. Morphological alterations at the ponds and upstream clearly also alter the ecology from its natural state, and water quality may have a minor influence.	Consideration needs to be given to the realistic extent of improvement that might be expected, with preference given to providing greater support to the Hamble and Wintershill tributaries downstream of Bishops Waltham. Options should be considered for increasing flow in the river downstream of Bishops Waltham.
Upper Wallington	Worlds End, Newtown	The upper Wallington has little or no connectivity to groundwater at times of low flow, and this limits the potential for abstraction to influence the hydrological regime of the river to periods of high flow. The main influence of flow on ecology in the upper catchment seems to be flushing through of the system during high flow events, and the effectiveness of this may be reduced by abstraction, but the effect is only temporary. Overall therefore the impact of abstraction on the ecology of the upper reaches of the river is considered to be minor. Morphological alterations and nutrient enrichment as a result of poaching may have some influence on parts of the upper river.	No further work required.
Lower Wallington	Maindell	The groundwater model outputs predict that any impact from Maindell would only be apparent at fully licensed quantities, and even then would have little effect in the freshwater waterbody, having a clear effect only at the tidal limit (extending less than 500m upstream). Impacts are also ameliorated by support to low flows from discharges and leakage. Morphological alterations (channel straightening) in Fareham may have some influence on the ecology of the lower river.	No further work required.

Table 7.1 (continued) Summary conclusions and recommendations from the WFD assessments

Catchment/ waterbodies	Abstractions	Conclusions of impact assessment	Recommendations
Ems	Walderton, Woodmancote	Abstraction increases the ephemeral length of the river by around 1km: the reach that would be naturally perennial still retains some perennial characteristics and would be improved by more flow. In the perennial reach, low flows are sustained by augmentation. The resilience of the reach may be improved by increased low flows. Morphological alterations are significant in this catchment, including straightening, raising channel above valley bottom, and widening/ deepening for watercress beds.	Options should be considered for restoring the natural perennial extent of the river, and increasing low flows in Westbourne. Options may include moving the augmentation scheme further upstream, but the effectiveness of this requires consideration, since moving it further up in to the ephemeral reach may result in greater losses. However the value of benefits that would be achieved by increased flows needs further consideration.
Lavant	Lavant, Brickkiln	The river is naturally ephemeral. The overall ephemeral nature and extent is not affected by abstraction (either at historic or fully licensed rates), although it does have some effect on the length of time that the river remains dry for. The ecological data show relatively little sensitivity to the duration of wetting and drying, recovering quickly once flow commences. There is little indication that reducing abstraction would have a significant effect on the ecology.	No further work required.

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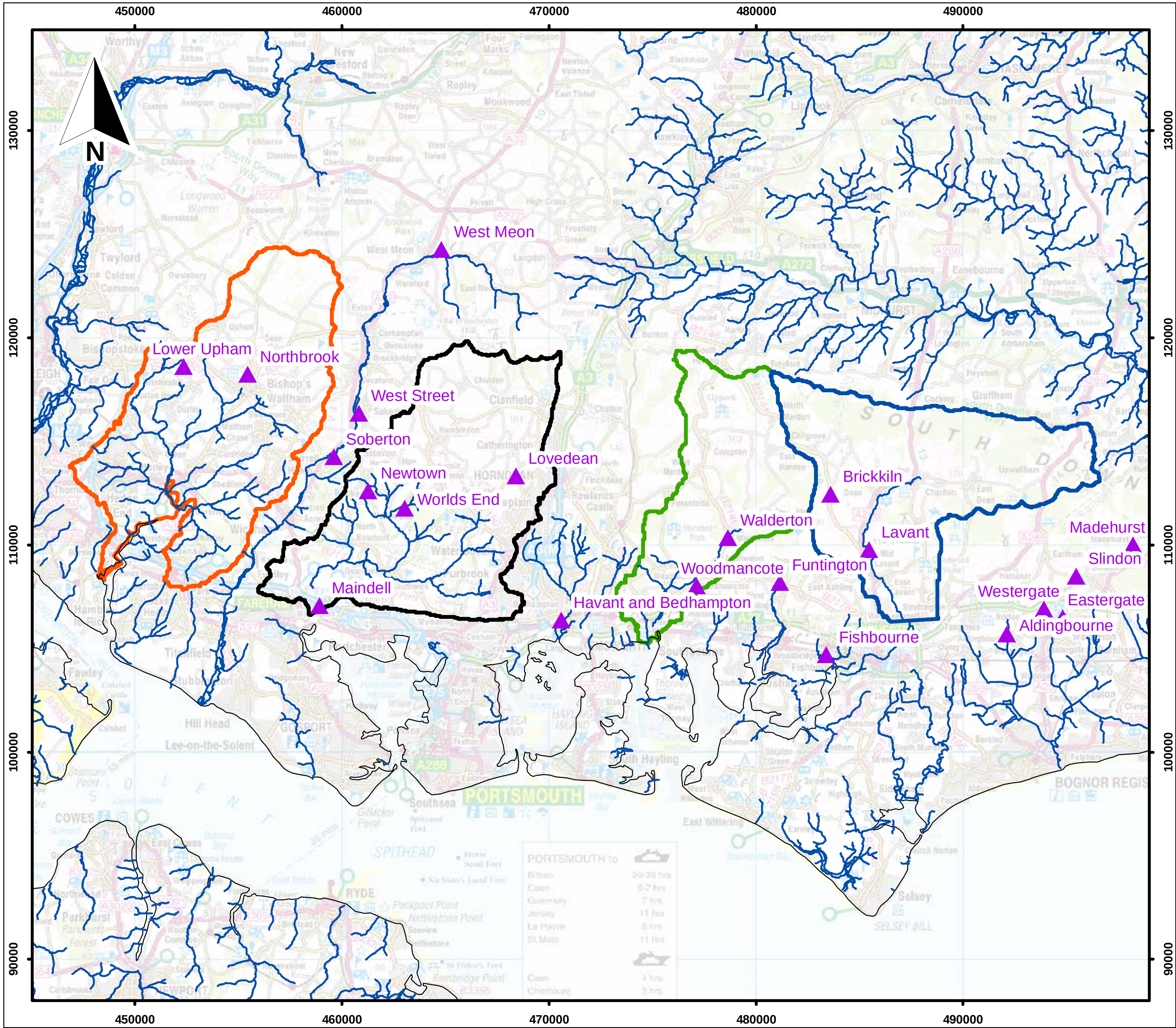
Figures



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Portsmouth Water PIM and WFD Investigations: WFD final report

Figure 1.1
Overview of Study Area

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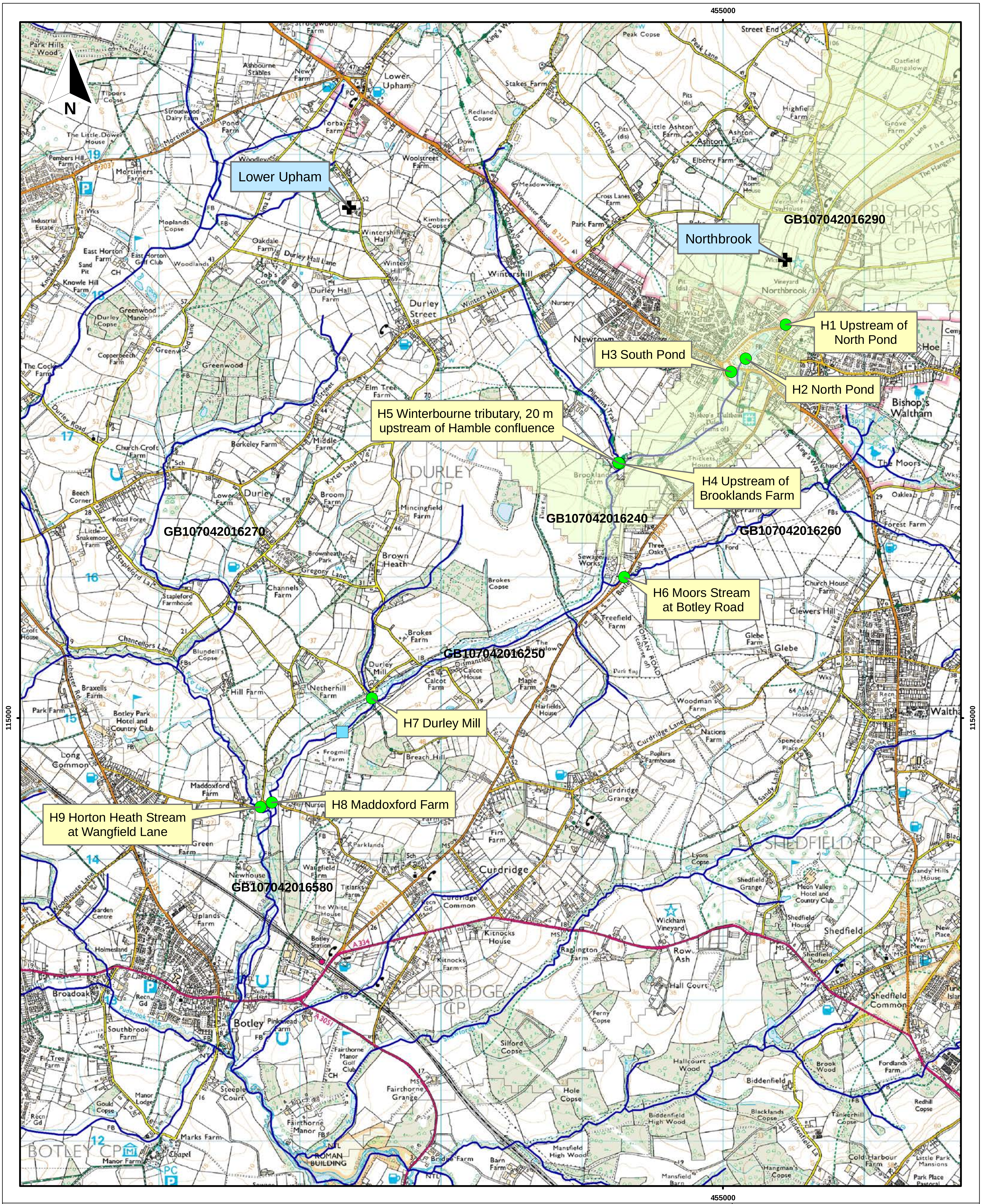

Key:

- Water body boundary
- Portsmouth Water source
- Flow, water quality and biology monitoring
- Gauging station

Portsmouth Water PIM/WFD Investigations: WFD final report

Figure 2.1
Monitoring in the Hamble catchment

0 500 1,000 Metres
Scale: 1:25,000 @ A3

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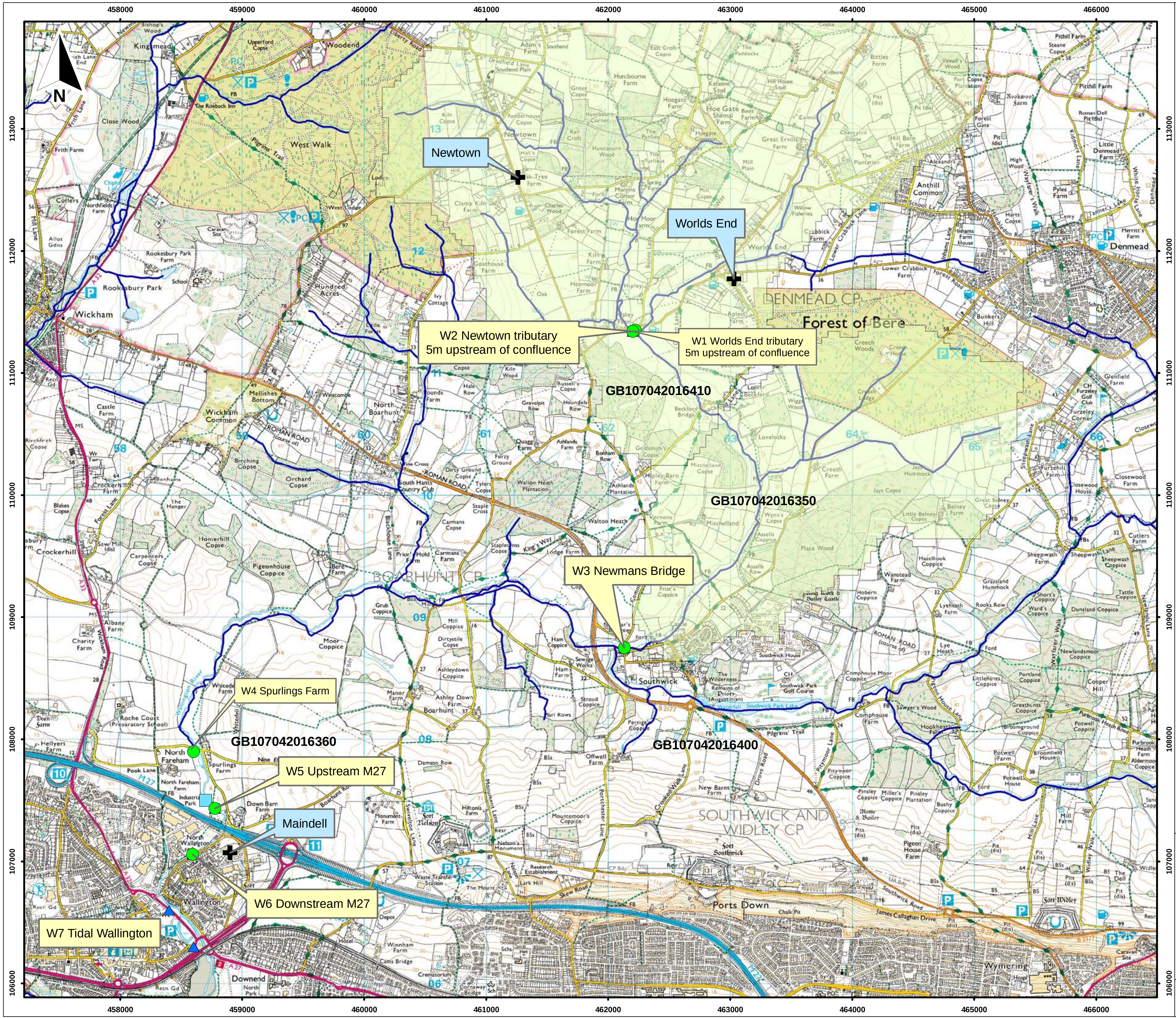

Key:

- Water body boundary
- Portsmouth Water source
- Flow, water quality and biology monitoring
- Flow and water quality monitoring
- Gauging stations

0 500 1,000 Metres

Scale: 1:30,000 @ A3

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Portsmouth Water PIM/WFD Investigations: WFD Final Report

Figure 2.2
Monitoring locations in the Wallington catchment

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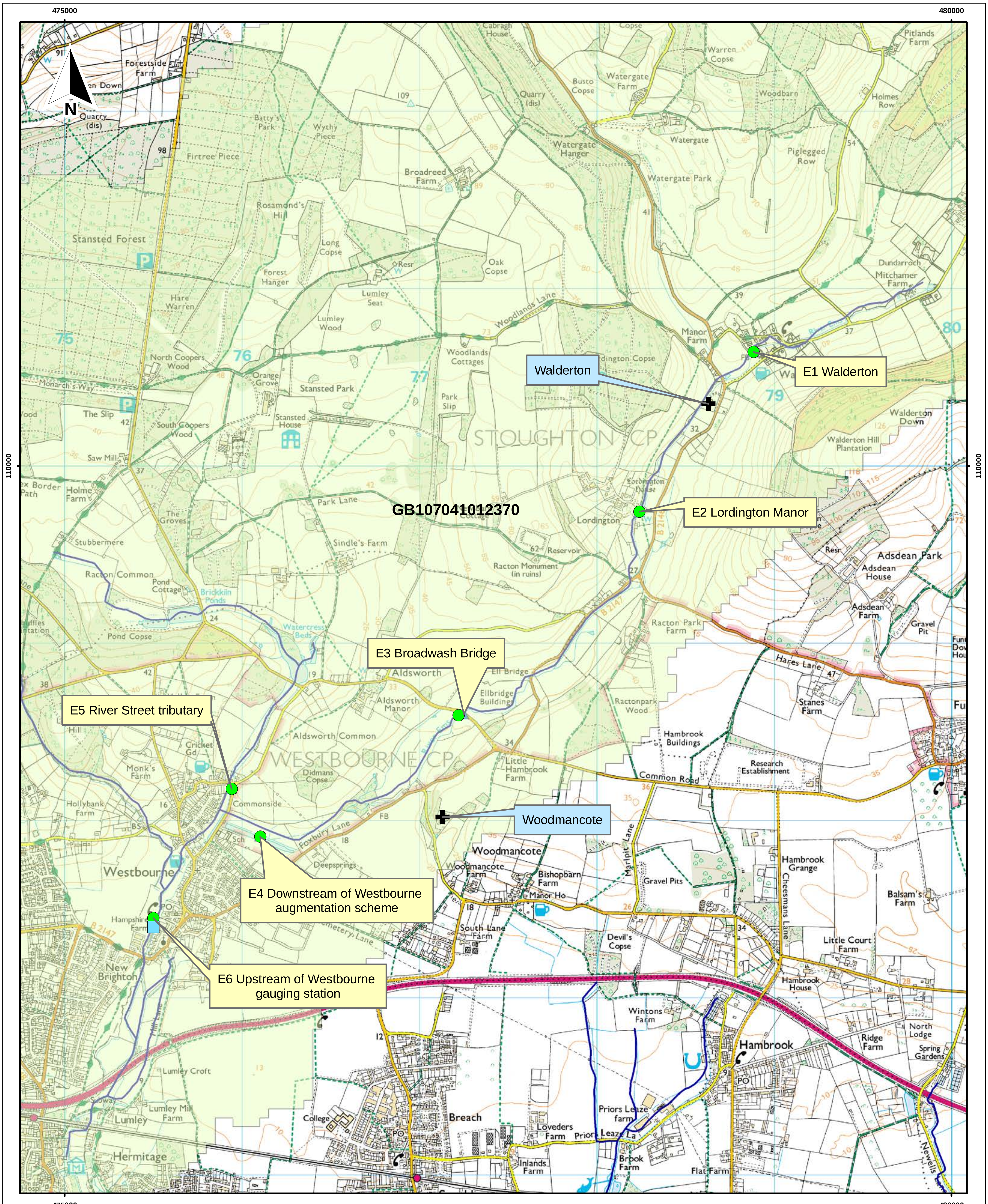

Key:

- Water body boundary
- Portsmouth Water source
- Flow, water quality and biology monitoring
- Gauging station

Portsmouth Water PIM/WFD Investigations: WFD Final Report

Figure 2.3
Monitoring in the Ems catchment

0 500 1,000 Metres

Scale: 1:20,000 @ A3

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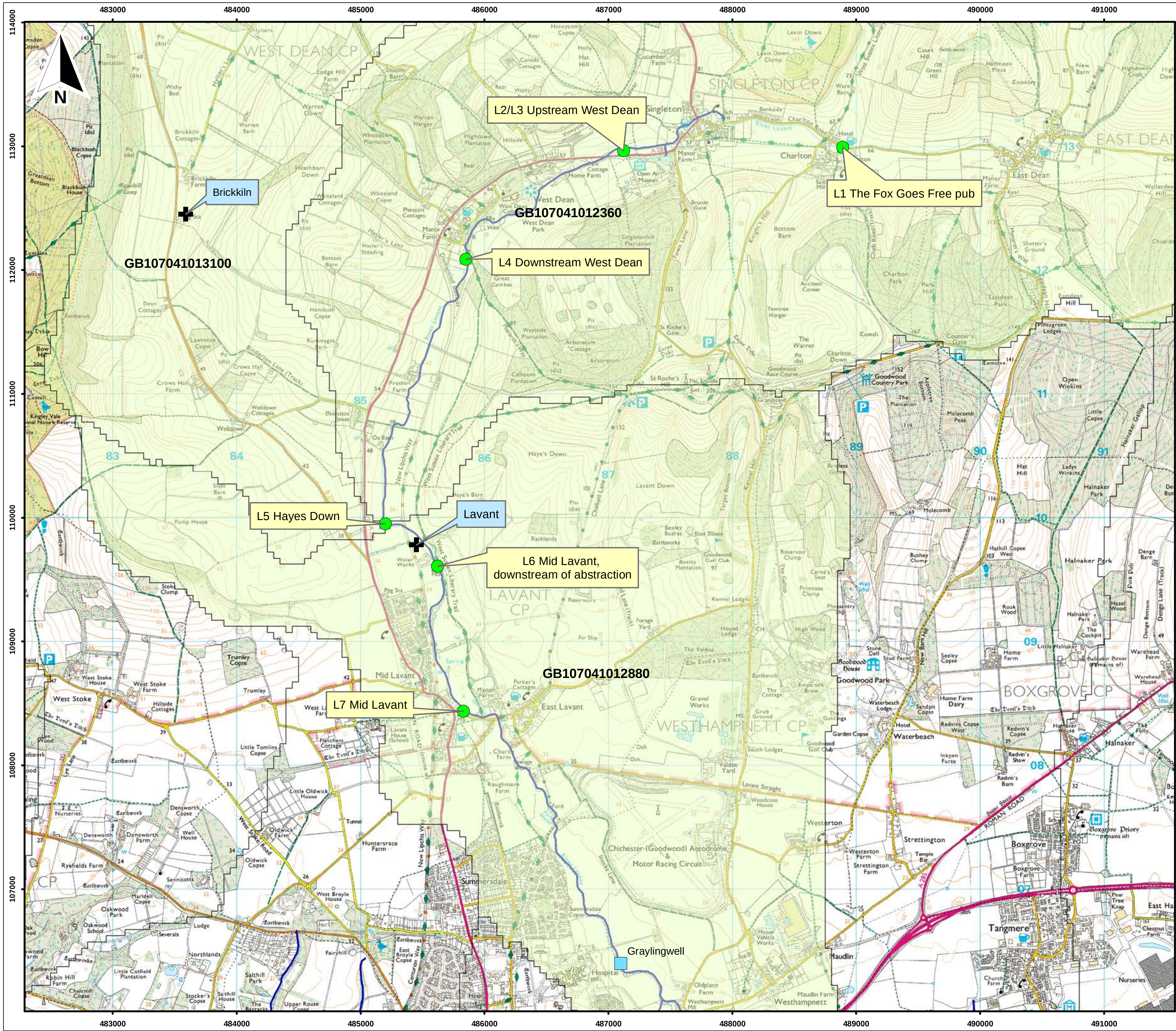

Key:

- Portsmouth Water source
- Flow, water quality and biology monitoring
- Gauging stations
- Water body boundary

0 500 1,000 Metres

Scale: 1:30,000 @ A3

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Portsmouth Water PIM/WFD Investigations: WFD Final Report

Figure 2.4
Monitoring locations in the Lavant catchment

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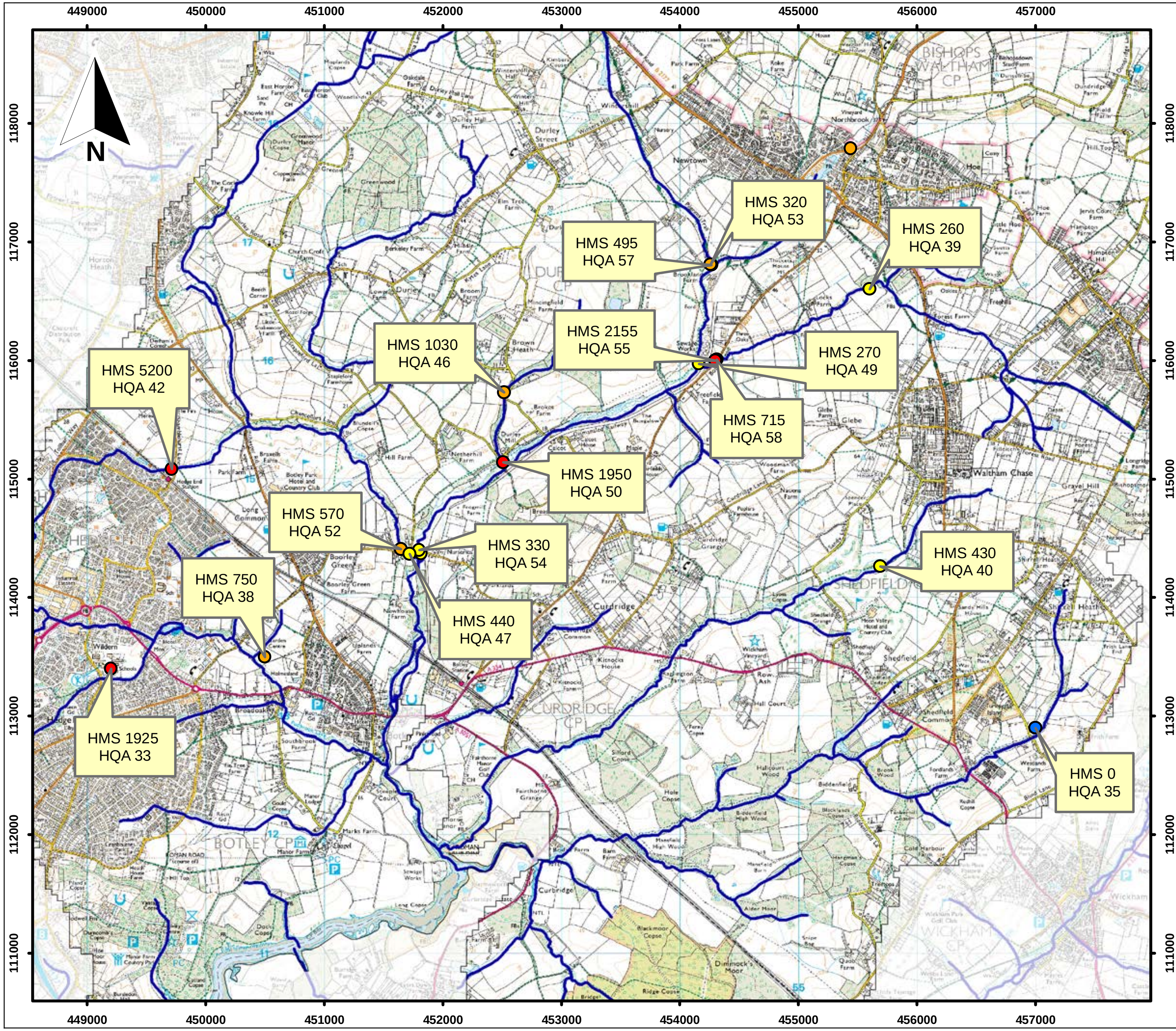

Key:

Catchment boundary

River Habitat Survey locations

- HMS class 1
- HMS class 2
- HMS class 3
- HMS class 4
- HMS class 5

1 0.5 0 1 Kilometers

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Portsmouth Water WFD/PIM Investigations: Final Report

Figure 3.3
River Hamble River Habitat Survey Summary

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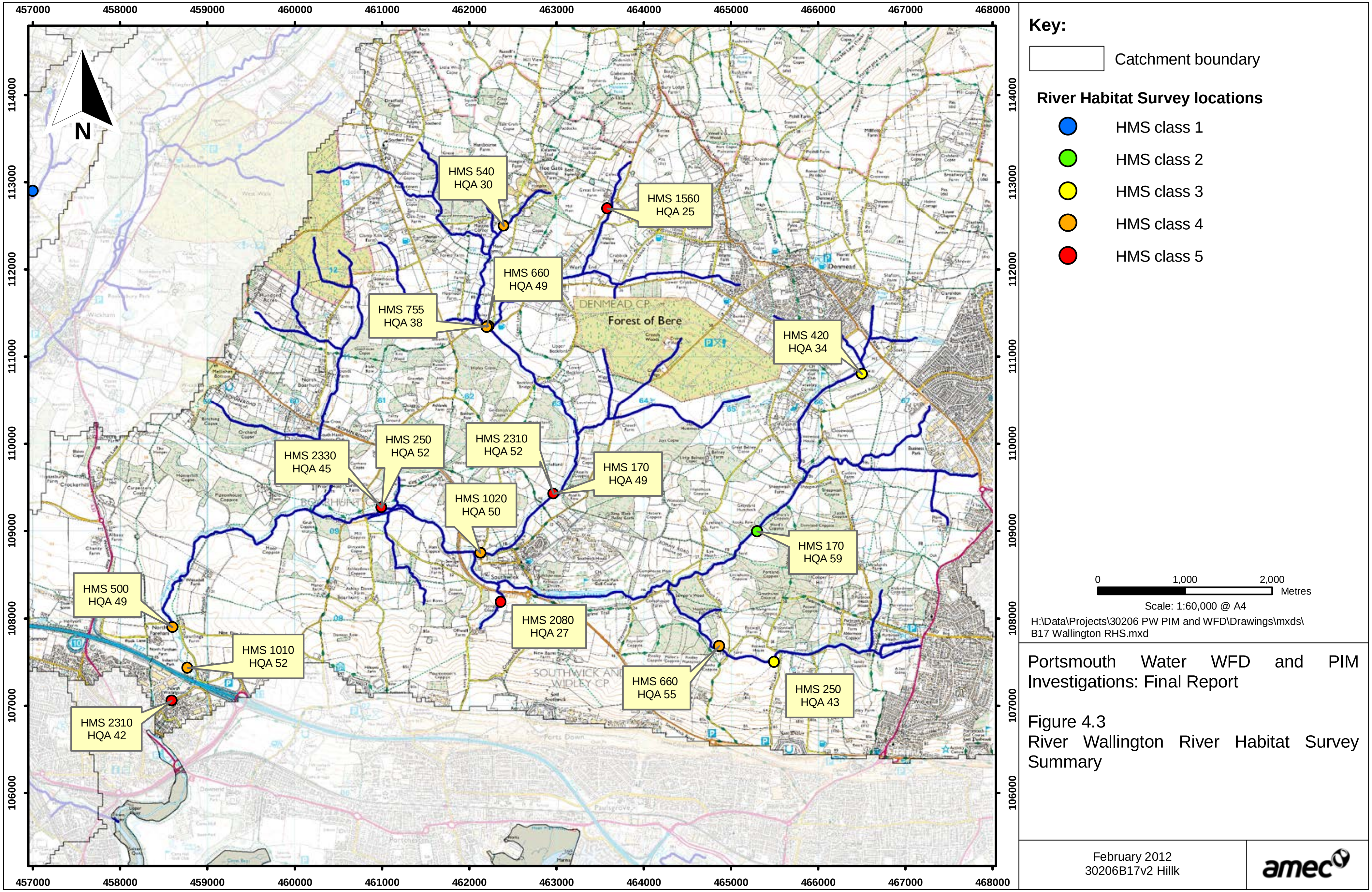

Portsmouth Water WFD and PIM Investigations: Final Report

Figure 4.3
River Wallington River Habitat Survey Summary

February 2012
30206B17v2 Hillk

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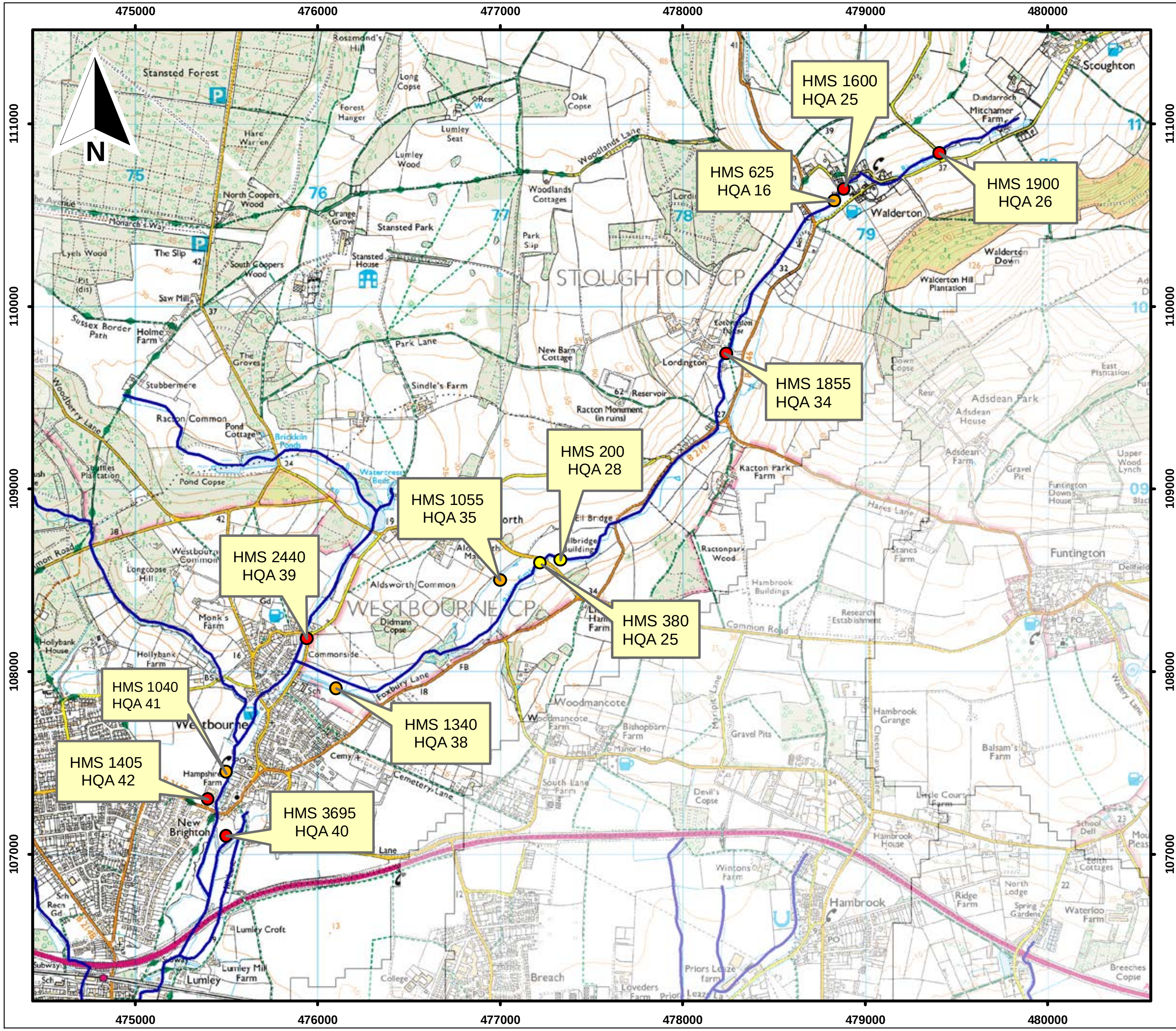

Key:

Catchment boundary

River Habitat Survey locations

- HMS class 1
- HMS class 2
- HMS class 3
- HMS class 4
- HMS class 5

0 1,000 Metres

Scale: 1:60,000 @ A4

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Portsmouth Water WFD and PIM Investigations: Final Report

Figure 5.2
River Ems River Habitat Survey Summary

February 2013
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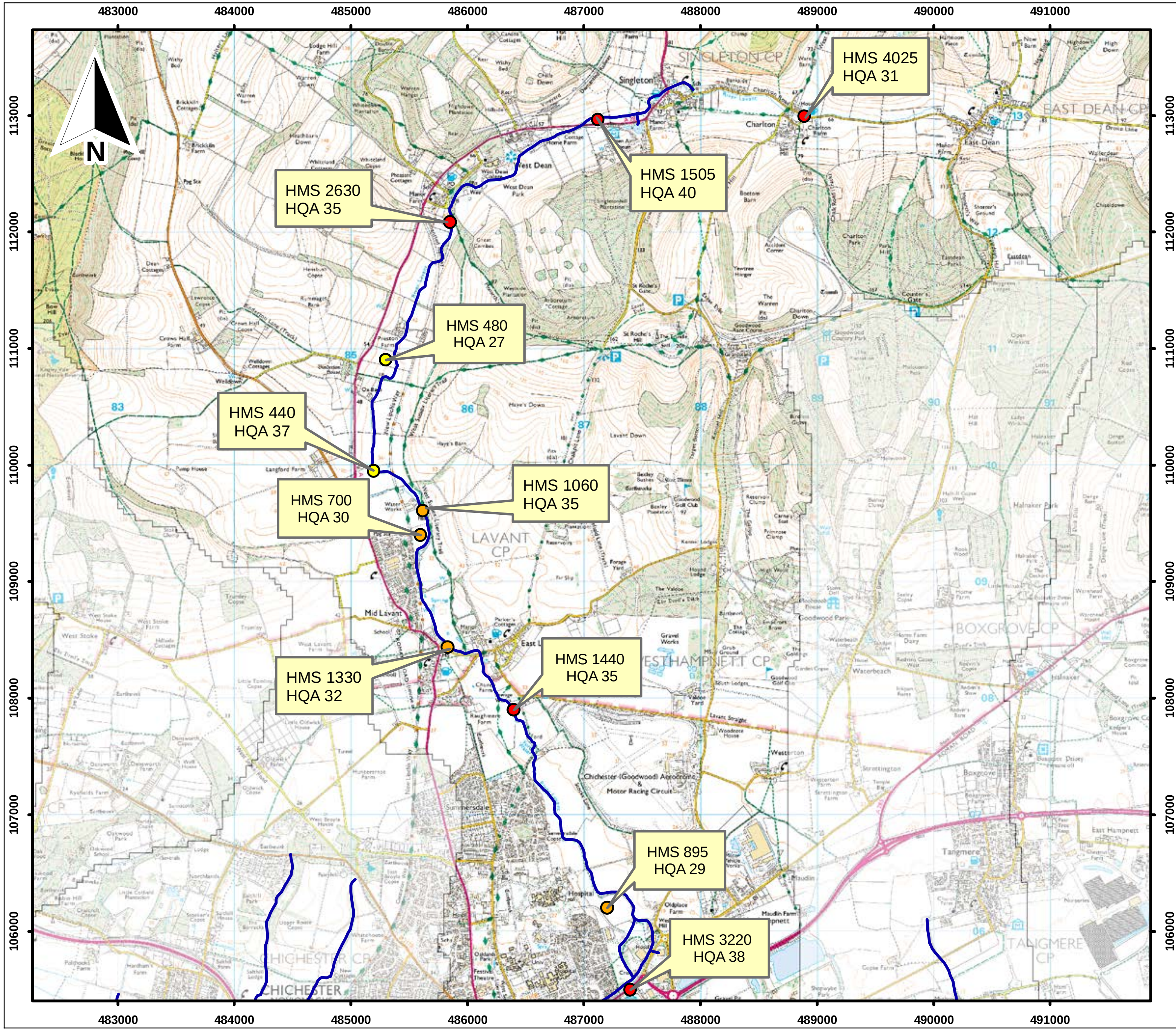

Key:

Catchment boundary

River Habitat Survey locations

- HMS class 1
- HMS class 2
- HMS class 3
- HMS class 4
- HMS class 5

1 0.5 0 1 Kilometers

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Protsmouth Water WFD/PIM Investigations: Final Report

Figure 6.2
River Lavant River Habitat Survey Summary

February 2013
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Appendix A
Hydrological impact assessment: River Hamble

Appendix B
Hydrological impact assessment: River Wallington

Appendix C
Hydrological impact assessment: River Ems

Appendix D
Hydrological impact assessment: River Lavant

Appendix E
Summary of historic invertebrate data

Appendix F
Hydro-ecological impact assessment of the River Hamble and River Wallington

Appendix G
DRIED-UP report (River Hamble and River Wallington)

Appendix H
Hydro-ecological assessment of the River Ems

Appendix I
Hydro-ecological assessment of the River Lavant

Appendix J
River Habitat Survey scores

Appendix K
Summary of GeoRHS surveys

Appendix L
Velocity analyses: River Hamble and River Wallington

Appendix M
Results of macrophyte surveys

Appendix N
Hydrological impacts of individual abstractions

Appendix O
Monitoring database

Appendix P
Illustrations showing 2011-12 ephemeral extent