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Hedgecourt Lake: SSSI Condition Summary

ECRC Research Report Number 188

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SSSI Condition Summary

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Cover photo: Hedgecourt Lake, June 2017

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1. Introduction

1.1. Background

Hedgecourt Lake is a shallow lake located in the upper reaches of the Eden Brook a tributary of the River Medway. The lake, which has a surface area of approximately 17 ha, is entirely artificial, created and altered over the centuries to provide a head of water for Hedgecourt Watermill which was located below the dam wall on Eden Brook. The age of the lake is uncertain, but there is evidence of a watermill in this area since 1562 (Felbridge & District History Group 2004), suggesting it to have been in existence for at least 500 years.

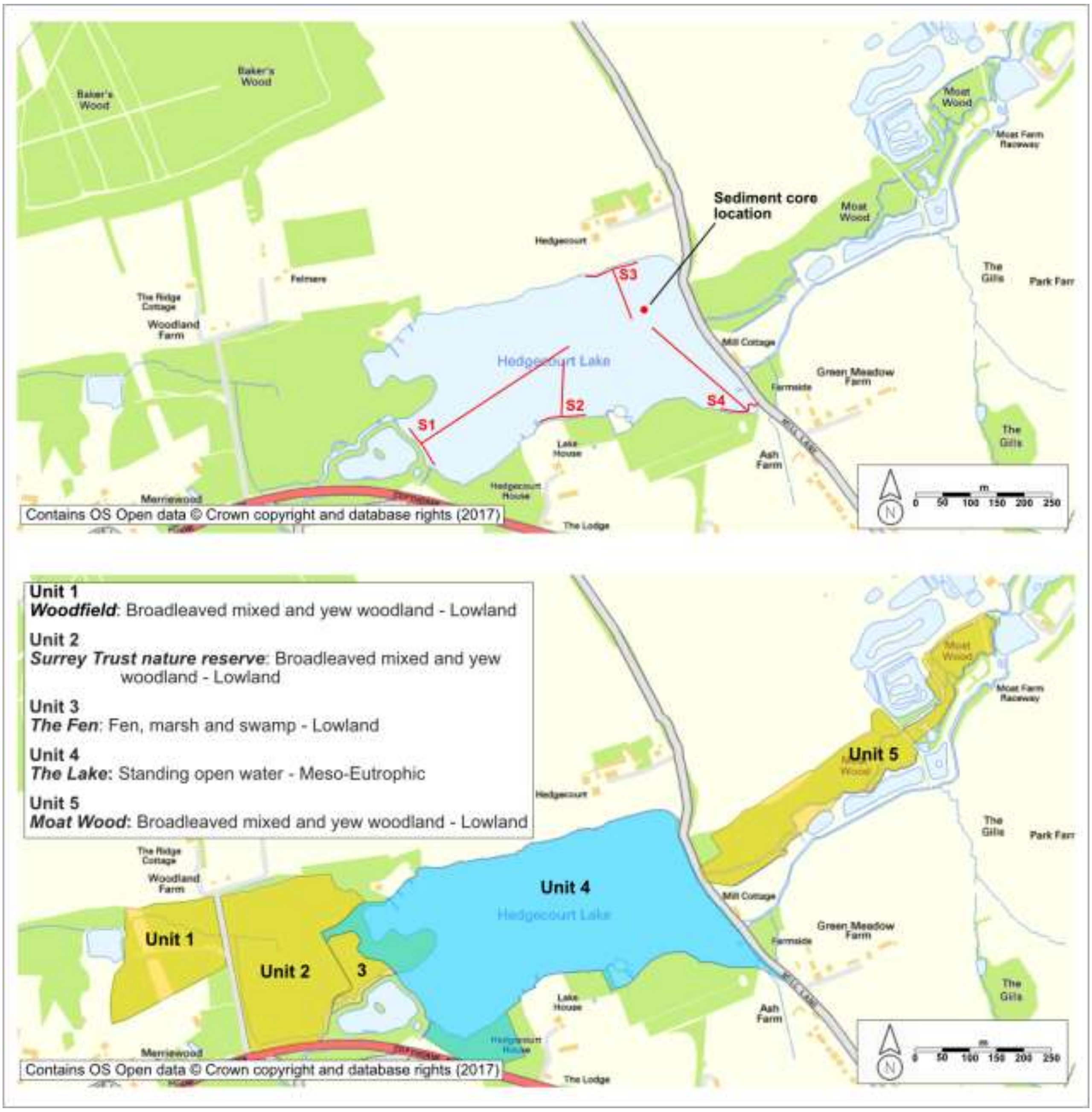


Figure 1 Hedgecourt Lake, showing the survey points (top) and SSSI units (bottom)

The lake forms part (Unit 4) of the Hedgecourt SSSI (Figure 1), first designated in 1975, and updated in 1986. The SSSI was primarily designated for its range of mixed wetland and woodland habitats which support a rich invertebrate community (including rare species), and a wide diversity of breeding birds associated with the margins of open water, scrub and woodland (NE 2017a). The Lake itself, although inherent within the mixed habitats of the SSSI, is not a primary designated feature; the vascular plant assemblage would not have met the minimum score to meet the relevant SSSI selection criteria at the time of SSSI designation.

Hedgecourt Lake is nonetheless significant for being the largest area of semi-natural open water in eastern Surrey and has in the past (pre-designation) supported a number of rare and notable plant species, including rare hybrid sedges, *Anagallis minima, Radiola linoides, Damasonium alisma, Potamogeton trichoides, Ranunculus arvensis, Elatine hexandra, Mentha pulegium, Littorella uniflora, Wahlenbergia hederacea, Apium inundatum, Myriophyllum spicatum, Baldellia ranunculoides, Hypericum elodes* and *Eleocharis acicularis* (Rich 1994). While it is unlikely these species exist within the current flora, the sites lacks recent surveys of the open water flora. The aim of this study is to fill this knowledge gap for the site by undertaking a Common Standard Monitoring survey (JNCC 2015) to assess the site condition with respect to the aquatic habitats.

1.2. Site description

Hedgecourt Lake (TQ355404) is a very shallow (average depth <1.0 m) lowland (66 m A.O.D.) lake covering an area of approximately 17 hectares. The lake itself was formed over 500 years ago by the damming of the Eden Brook. The current dam, at the eastern end of the lake, has a penstock and overflow weir via which the water level can be controlled. Crawley Mariners Yacht Club have an active sailing interest on the lake with their clubhouse, boat storage and slipways on the north-west shore. The responsibility for maintaining water levels is apparently under the control of the sailing club, who increase the level in summer and lower it slightly during the winter months (Madgwick 2017).

In addition to the sailing club, the lake is bordered by a number of residential properties on the south and north shore as well as the old mill buildings below the dam. Away from the residential properties, the lake shore primarily consists of *Phragmites* reedbed or *Salix*-dominated margins, grading into wet Alder (*Alnus*) and mixed broadleaf woodland.

Beyond the SSSI boundaries, the lake lies within a catchment of approximately 949 hectares, stretching out to the SW, SE and south of the lake (CEH 2017). The catchment is dominated by mixed woodland, but also comprises a significant area of urban and suburban land (parts of Crawley Down and East Grinstead and surrounding villages) as well as mixed agricultural land (Figure 2)

Other than sailing and general recreation, the lake is noted for its angling interest. East Grinstead Angling Society report the lake to have a mixed fishery including *"….good sized bream, roach, tench, pike perch and eels*." EGAS also note on their website that there has been a recent introduction of carp as a result of winter flooding further upstream (http://www.eastgrinsteadangling.co.uk/hedgecourt-lake.asp). The site is otherwise un-stocked.

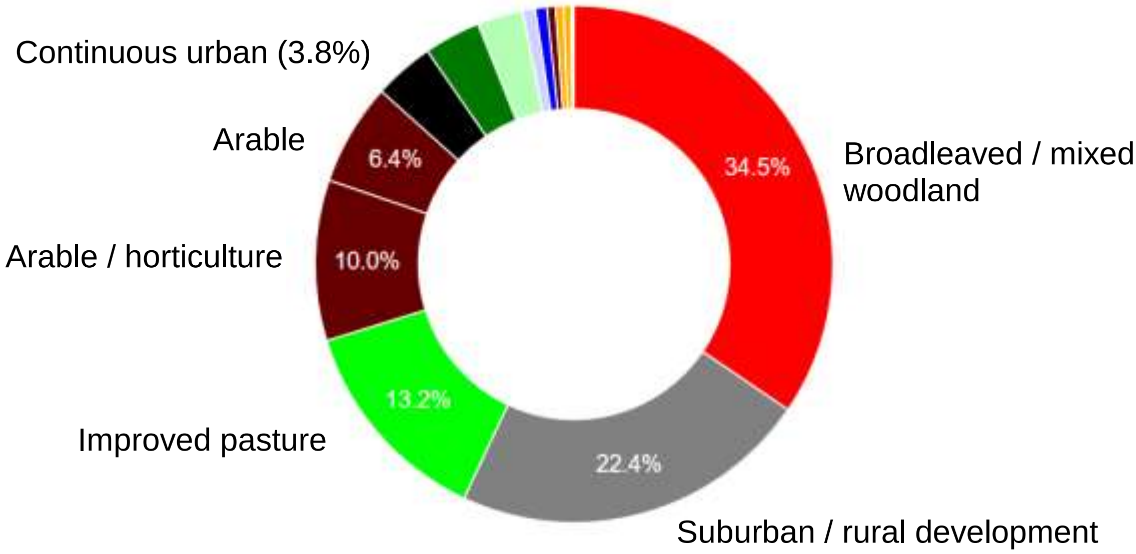


Figure 2 Land use data for the Hedgecourt Lake catchment (from CEH 2017)

1.3. Aims

The primary aim is to collect and analyse aquatic and wetland plant data from Hedgecourt Lake to determine the current status of the open water SSSI feature (Unit 4).

Secondary to the condition assessment, is the opportunity to collect a sediment core from the site. Lake sediments generally accrue over time and incorporate with them the micro and macro remains of the biota that lived within the lake (e.g. algae, plant remains, pollen, invertebrate remains, fish scales). By analysing the sediments, we are able to establish how the biota of a lake has changed through time and potentially, the main environmental drivers of change within a site. In terms of lake management, such data are invaluable for establishing site-specific restoration targets and providing real baseline data against which a site may be assessed in terms of its ecological status.

It is anticipated that the results will additional evidence for the SSSI Favourable Condition Tables and help to support the future management plans for Hedgecourt Lake.

2. Methods

2.1. Aquatic vegetation survey

Common Standards Monitoring (CSM) Methods

The full description of the survey methods used to collect macrophyte data are detailed in the Joint Nature Conservation Committee publication for the CSM guidance for lakes (see JNCC 2015). In brief, the plant survey consists of four components:

- a strandline survey of species uprooted and washed to the shore,
- a survey of the emergent and marginal species,
- a survey of the shallow littoral zone to approximately 80 cm depth,
- a boat survey encompassing species growing out into the open water

This method does not set out to survey the whole site, instead four discrete 100 m sections of shoreline are surveyed in detail, which in this case were chosen in 2006 (by ENSIS on behalf of NE), and the same points re-surveyed in 2017 for comparison.

The 100 m shore sections are located using GPS, backed up where appropriate by digital photographs to help relocate the start and end points. A total of up to 40 data points are collected from each section using either a Bathyscope (underwater viewer) or a double-headed rake to view and sample the aquatic vegetation.

Rather than setting out to find every species within the site, these methods were devised to provide quantitative species-abundance data that can be obtained in a pragmatic and repeatable manner. The technique optimises the chance of recording those species most typical of a lake site and detecting marked changes in their frequency. Although they do not aim to produce a complete species list for a lake, comparison with a more thorough mapping approach generally show that the transect method consistently detects more than 90% of the macrophyte species richness within a lake (e.g. Burgess *et al.* 2009). Additional efforts such as sampling strand line flora were made to record other species which did not occur in any of the survey sections. All field data were recorded onto standard forms printed onto waterproof paper and transferred onto a Microsoft Access database specifically designed to hold CSM records.

The specified survey methods use a point-abundance approach, with abundance recorded on a scale of 1-3. However, for the purposes of data analysis for condition assessment, the presence/absence data only are utilised (except in the case of emergent and marginal species). Plant data are therefore presented as frequency of occurrence rather than abundance, and it should be noted that this is frequency within the survey sections. The survey sections are assumed to be collectively representative of the site.

The survey was undertaken on 22nd June 2017 by Dr Ben Goldsmith and Stefania Goodrich (ENSIS / UCL) with Julie Huss (NE) in attendance. The site was accessed (with permission) from the Crawley Mariners Yacht Club on the NE shore and a small inflatable boat used to access the open water and survey sections.

In-situ macrophyte identifications were made by Ben Goldsmith (JNCC accredited) and Stefania Goodrich. Voucher specimens were collected for any taxonomically ambiguous species and identifications confirmed using microscopic examination back in the laboratory. Botanical nomenclature follows Stace (1997).

2.2. Sediment coring

While there was no funding to analyse a core, the collection of a sediment core was undertaken by ENSIS on the same day as the vegetation survey at no additional cost.

A sediment core of approximately 1 m in length and 8 cm in diameter, was taken from a location towards the north-eastern end of Hedgecourt Lake (TQ3575840462 – see Figure 1). The core was collected from 1.1 m water depth using a lightweight piston corer (Livingstone type – Livingstone 1955) operated from an inflatable boat. The total sediment depth at this point was not determined, but was in excess of the 1 m collected.

The rationale for coring toward the edge of the lake for macrofossil studies, as opposed to the centre, is based on our previous research that suggests the plant remains generally accumulate close to point of origin (Zhao et al. 2006). In most cases, this is towards the littoral zone, taking into consideration that the lake would also have been deeper in the past and less like to have high diversity at greater depths.

Directly after collection, the core was carefully extruded through the top of the tube and sliced into 1 cm subsamples. Samples were sealed in air-tight polythene bags and refrigerated. These sample have been archived in cold-storage at UCL (Dept. of Geography), and will be made available on request if further analysis is required.

3. Results and SSSI Condition Assessment

3.1. Aquatic macrophyte survey

The location of the survey transect are marked in red on Figure 1 (S1, S2, S3, S4) and the 10 figure grid references for start and end points in Table 1. A total of 18 aquatic plant species were recorded, which is high for lowland lake sites in southern England and results in a dynamic mosaic of submerged and floating leaved species within the open water.

Table 1 CSM survey point locations for Hedgecourt Lake

	Wader survey		Open water survey	
Section	**Start point**	**End point**	**Shore End**	**Outward End**
Section 1	TQ3535440256	TQ3540040165	TQ3537440229	TQ3561240399
Section 2	TQ3558540260	TQ3567440267	TQ3563140272	TQ3561940344
Section 3	TQ3565840528	TQ3576040546	TQ3571340492	TQ3573240449
Section 4	TQ3596440303	TQ3590840483	TQ3594940300	TQ3579340414

Table 2 CSM macrophyte data from Hedgecourt Lake 2006 & 2017

Submerged and floating vegetation	Common name	20/06/2006 % Frequency (n=96)*	22/06/2017 % Frequency (n=103)*
Callitriche sp.	Starwort	2.1	1.0
Ceratophyllum demersum	Rigid hornwort	4.2	5.8
Elodea nuttallii	Nuttall's waterweed	2.1	1.0
Lemna minor	Common duckweed	4.2	1.9
Lemna minuta	Least duckweed		+
Nitella sp.	Smooth stonewort		3.9
Nuphar lutea	Yellow water lily		+
Potamogeton crispus	Curled pondweed	8.3	7.8
Potamogeton natans	Common pondweed		1.0
Potamogeton obtusifolius	Blunt-leaved pondweed	9.4	6.8
Potamogeton pectinatus	Fennel pondweed	82.3	85.4
Potamogeton pusillus	Lesser pondweed	12.5	16.5
Zannichellia palustris	Horned pondweed	20.8	9.7

* Based on presence / absence data from all vegetated plots in the wader and boat surveys. A '+' denotes species recorded outside the survey sections. Species shaded in green are "characteristic" of natural eutrophic lakes. Non-native species are in pink.

A total of 13 aquatic plant species were recorded in 2017, which although more than in 2006 (9), the more common species appear to have remained very stable within the site

(Table 2). *Potamogeton pectinatus* was dominant, forming dense mats of vegetation throughout much of the site at depths of 50 – 90 cm, but tended to thin out towards the middle of the lake where the water depths are just slightly deeper (1.0 – 1.1 m). The assemblage is typical of hyper-eutrophic shallow lakes, with fine-leaved pondweeds, *Ceratophyllum demersum* and *Zannichellia palustris* making up the bulk of the species present. Of note was the presence of a *Nitella* species; usually an indicator of good water quality and rarely found where nitrate concentrations are high (Lambert & Davy 2011).

The extent to which the aquatic flora has changed since designation in 1975 is unclear. The lake was not included as a primary feature of the SSSI and the citation records only the follow information:

> "The aquatic flora has not been well-recorded in recent years but includes the naturalised pondweed *Elodea nuttallii*, broad-leaved pondweed *Potamogeton natans* and white water-lily *Nymphea alba*. The site was formerly important for other Potamogeton species including the rare hair-like pondweed *P. trichoides* which may still occur."

There is no mention of *P. pectinatus*, other pondweed species, *C. demersum* or *Z. palustris*, but it is assumed a thorough survey open water survey was not undertaken shining pondweed. Historical records listed in Rich (1994) do suggest the flora to have been of very significant interest in the 19th Century, and in addition to the species listed in the introduction above, there are also old herbarium records for *Potamogeton x angustifolius* (Collected by W. Beeby in 1883, Herbaria United 2017), a relatively rare hybrid of *P. lucens* and *P. gramineus* that is no longer found anywhere in the south of England (NBN Atlas 2017).

3.2. SSSI condition

Hedgecourt Lake is classified within the NE Favourable Condition Tables as being a "mesotrophic to eutrophic standing open water". Given is location within a lowland area with predominantly agricultural and urban catchment, the site is assessed here against eutrophic lake targets (as defined in JNCC 2015).

For a eutrophic open water feature for be considered as favourable condition, it should normally be expected to have at least six characteristic species (see JNCC 2015) present, and these should occur at more than 60% of the sample locations. At Hedgecourt Lake, of the 13 aquatic species recorded in 2017, only three are characteristic eutrophic species (*Callitriche* sp. *Potamogeton obtusifolius* and *P. crispus*) and these only occurred at 12% of the 103 survey points within the lake (see Table 2).

In terms of the water quality, favourable condition requires clear water with nutrient concentrations below the thresholds set for eutrophic lakes i.e. 50 µgl-1 for total phosphorus (TP as P), and 1.5 mgl-1 for total nitrogen (TN as N).

Based on Environment Agency (2017) water quality data, Hedgecourt Lake is currently eutrophic and has mean annual concentrations of total phosphorus (TP) well in excess of the expected values for natural waters (

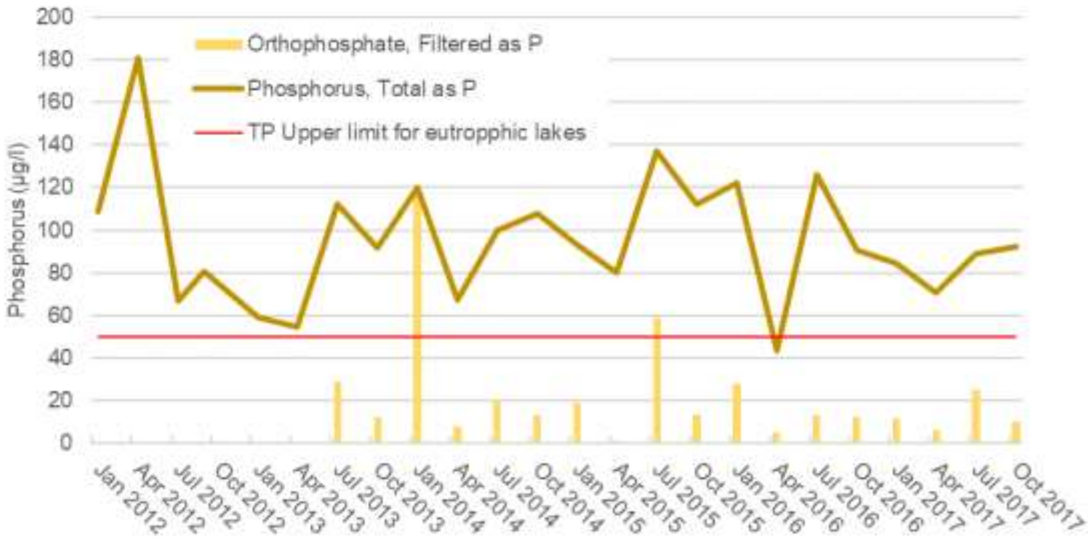
Table 3 and **Error! Reference source not found.**). Total nitrogen, is also relatively high, but rarely exceeds the CSM guidance limits of 12.5 mgl^{-1} (

Table 3 and Figure 3).

Table 3 Water quality from Hedgecourt Lake outflow (2012-2017 means based on quarterly sampling)

Section	2012	2013	2014	2015	2016	2017	5 yr Mean
Alkalinity	62.5	66.5	56	61.5	58.5	58	**60.5**
Chlorophyll a	28	20	39	26	23	31	**28**
Conductivity at 25 C	291	315	234	289	263	290	**280**
Total Nitrogen as N	1.07	1.65	1.21	1.30	1.53	0.98	**1.29**
Total Oxidised Nitrogen as N	0.45	0.92	0.42	0.40	0.66	0.17	**0.50**
Orthophosphate as P	-	20.6	40.0	23.1	14.6	13.2	**22.3**
Total Phosphorus as P	109.4	79.3	98.8	105.7	95.6	84.2	**95.5**

Source: Environment Agency 2017



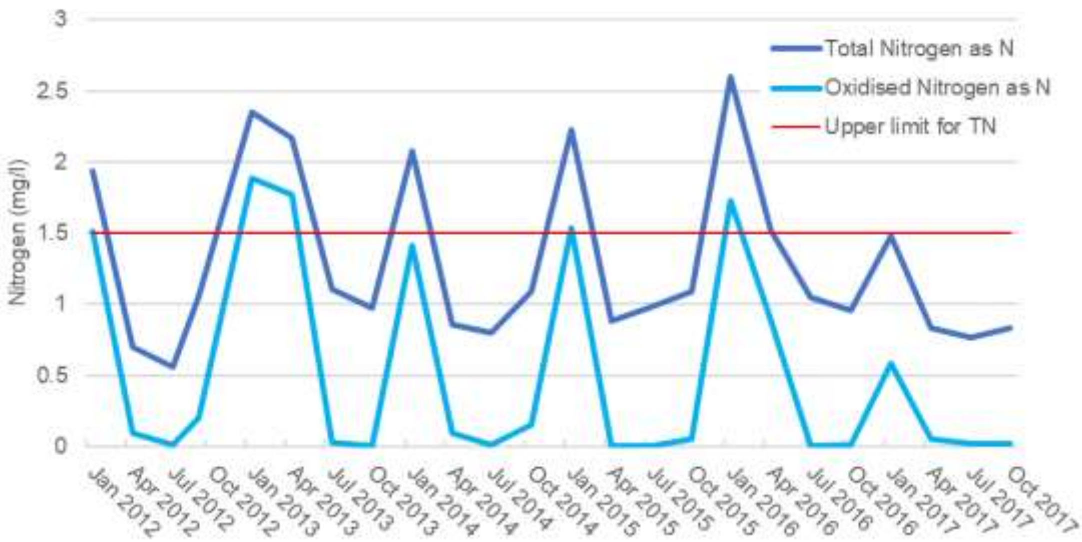


Figure 3 Phosphorus (top) and Nitrogen (bottom) concentrations recorded from the Hedgecourt Lake outflow 2013 – 2017

The following table (Table 4) summarises the main features used to assess condition as detailed in the Common Standards Monitoring guidance for freshwater lakes (JNCC 2015).

Table 4 Favourable condition assessment based on 2017 survey data and EA quarterly outflow chemistry (EA 2017).

Attribute	Target	Status	Comment
Extent	No loss of extent of standing water	✓	Some encroachment of reeds and *Salix* was noted, but there is no evidence to suggest this is causing accelerated loss of extent.
Macrophyte community composition	***Eutrophic target***: at least 6 characteristic species, including 1 broad-leaved *Potamogeton* spp.	**X**	Only 3 present including one broadleaved *Potamogeton spp. Callitriche* sp., *P. obtusifolius* & *P. crispus.*
	≥ 6/10 sample spots (boat & wader survey) have ≥ 1 characteristic species	**X**	Of the 103 survey points, only 12% had any characteristic species present
	No loss of characteristic species	**✓(?)**	No loss since 2006, but historic records suggest a more diverse and characteristic flora was present in the 19th C.
Negative indicator species	Non-native species absent or present at low frequency	**X?**	*Elodea nuttallii* present, but at low frequency. *L. minuta* present and newly recorded.
	Benthic and epiphytic filamentous algal cover <10% (i.e. non-*Chara*)	✓	No sample plots had significant growths of filamentous algae.
Macrophyte community structure	Characteristic vegetation zones should be present and no deterioration from baseline conditions.	**X**	Some good areas of hydrosere present along the west and SE shores. Characteristic species are uncommon within littoral and open water areas and the site is dominated by dense beds of *P. pectinatus* between 50-100 cm depth. The site is very shallow, with few plants in the centre of the lake where water depths are only 1-1.1 m. Little change since 2006 survey.
	Maximum depth distribution should be maintained	✓	Z_{max} (recorded) = 1.1 m, Z_s = 0.75 m. Z_{max} = 1.1 m
	At least the present structure should be maintained	**✓?**	There is no evidence of recent chance
Water quality	***Eutrophic target***: Stable nutrients levels: TP target / limit = 50 μgl^{-1}	**X**	TP = 95.5 μgl^{-1} (EA Jan 12 – Sept 16. Range 44 – 181 μgl^{-1})
	Stable pH values: pH ~ 7.0 – <9.0	**?**	No data
	Mean annual total nitrogen TN < 1.5 mgl^{-1}	✓	TN = 2.99 mgl^{-1} (EA Oct 15 – Sept 16. Range 1.84 – 3.98)
	Adequate dissolved O_2 for health of characteristic fauna (> 6 mgl^{-1})	**✓?**	Waters were well oxygenated at time of survey.

Attribute	Target	Status	Comment
	No excessive growth of cyanobacteria or green algae	X	Water clarity was poor due to both suspended solids and phytoplankton growth. Mean Chl a = = 28 $\mu g l^{-1}$ (EA Jan 12 – Sept 16. Range 5 – 92 $\mu g l^{-1}$). Site specific target required, but generally poor.
Hydrology	Natural hydrological regime	X?	Artificial water body subject to raising in summer and lowering in winter – this contrasts more natural regimes.
Lake substrate	Natural shoreline maintained	✓	Majority of shoreline comprises of emergent wetland and wet woodland.
	Natural and characteristic substrate maintained	?	No change since 2006. No evidence of major changes. Sediments are relatively organic, which is typical of eutrophic lakes.
Sediment load	Natural sediment load maintained	?	There was no evidence of any adverse sediment loading impacting the site, but requires additional information to assess.
Connectivity	Maintain good connectivity with ground and surface waters and marginal habitats	✓	Extensive wetlands above and below the lake with well establish hydrosere present.
Indicators of local distinctive-ness	Distinctive elements maintained	?	Not defined with respect to the open aquatic flora. Presence of *Nitella* sp. is of interest and warrants further investigation.

In summary, Hedgecourt lake is in unfavourable condition. Based on the CSM guidance (JNCC 2015), the lake fails to meet the eutrophic targets for:

- Aquatic macrophyte composition
- Aquatic macrophyte community structure
- Water quality
- Hydrological regime

The lake also has two non-native aquatic plant species present (*Elodea nuttallii* and *Lemna minuta*), which are currently at low frequency, but place the site at additional risk of deterioration if these populations increase. The lake is also bordered by residential properties to the north-east and south, with gardens fronting the lake shore. The presence of more invasive garden species such as bamboo and Rhododendron should be reviewed in context of the cultural and historical context of the gardens and where deemed necessary, controlled in conjunction with the property owners, to lessen the impact on the lake. The Bamboo in particular (north east shore) adds very heavy shade to the littoral habitat at the expense of native marginal flora.

Also pertinent to the non-native species category, although not surveyed here, is the anecdotal evidence of non-native carp within the site. Any opportunity to reduce the stock of carp should be taken.

4. Appraisal of the Evidence and Recommendations

4.1. Status of Hedgecourt Lake

Based on the current aquatic flora and water quality data, the condition of the standing water feature within Hedgecourt Lake SSSI is classifies as “unfavourable” for a eutrophic lake. Within the eutrophic lake classification, it would be expected that the un-impacted and favourable state would be manifested by clear-water conditions, with more characteristic eutrophic species and without the dominance of fine-leaved pondweeds such as *P. pectinatus.*

The evidence points towards the primary cause for the poor condition of Hedgecourt Lake is eutrophication, with high concentrations of phosphorus are consistently recorded within the site. Furthermore, the three most abundant species growing in the lake in 2017 and 2006 are *Potamogeton pectinatus, Potamogeton pusillus* and *Zannichellia palustris*, which are typical of hyper-eutrophic conditions.

Although dominated by fine-leaved pondweeds, Hedgecourt Lake nonetheless maintains a relatively diverse aquatic flora which has remained stable for over 10 years. This demonstrates the resilience of many aquatic plant species, that manage to hang on within a site despite conditions being unfavourable. It is also encouraging to note that although non-native species are present (*Elodea nuttallii* and *Lemna minuta*) they occur at low frequency in the site.

4.2. Eutrophication

Eutrophication is the primary driver of change and deterioration of freshwater habitats in lowland Britain (e.g. Moss 2010). Increased nutrients lead to increased algal abundance and reduced water clarity, which in turn impacts the composition and abundance of aquatic macrophytes. If algal dominance occurs, lakes can very quickly lose their plants and the knock-on effects of habitat loss and bacterial decay can have serious impacts on invertebrate and fish communities, which in turn impacts on birds and mammals. In very shallow lakes, such as Hedgecourt, the problem of water clarity can be further exacerbated by the re-suspension of fine sediments by wind stress and the disturbance by water birds.

Within Europe, there is an irrefutable evidence base to show that natural water quality is the most important requirement for a lake or pond to support a natural biological community (Hering *et al*. 2013).

Anthropogenic eutrophication is the main driver of ecological decline in lowland lakes in the UK (Moss 2010). The mechanisms by which eutrophication damages freshwater environments are well understood (see Box 1), and nutrient pollution has consequently been the focus of major legislative controls in the UK (e.g. Urban Wastewater Treatment Directive, Nitrates Directive and Water Framework Directive). These legislative controls are most easily implemented where pollution is acute and population size meets thresholds for positive actions (e.g. P stripping at STWs serving greater than 10000 people). Pollution from diffuse sources (e.g. agriculture) or from small domestic STWs comes under the jurisdiction of the WFD. Under the WFD, pollution pressures, including nutrients, which are causing freshwaters to fail targets for “good ecological status” require actions to be put in place to mitigate these pressures.

Eutrophication in Lakes **Box 1**

The term “eutrophication” is most simply defined as “*an increase in the concentration of inorganic plant nutrients, mainly phosphorus and nitrogen”.* This is a natural process in many lowland lakes, with the nutrient status of the water reflecting the geology, soils and vegetation of the catchment. Where anthropogenic inputs become more prevalent the natural balance is upset and the ecological status is often compromised.

Increased nutrients in lakes, promotes the growth of planktonic algae making the water turbid, which in turn can have significant impacts on the lake ecosystem by reducing the availability of light to aquatic plants and causing oxygen depletion and changes in pH. Increased algal turbidity can rapidly eliminate aquatic plants from a lake, and once lost, it is very unlikely they will re-establish where high nutrients prevail.

This process is complex however, and there are conditions where even under higher nutrients, clear water and plants can prevail. This so-called alternative stable state (May 1977) occurs where zooplankton occur in sufficient abundance to “graze” on the algae and keep the water clear. In turn, the zooplankton require the presence of aquatic plants to act as refugia from predation by fish. Where plants are lost, or where the balance in the fish community is disrupted, this state breaks down, and the switch to an algal dominated, turbid state is more likely. The risk of this switch occurring, increases as the nutrient status increases in the lake.

Resilience to the effects of eutrophication is increased where fish stocks are well balances and lack the benthic feeders such as Common carp and Bream, and where predatory fish such as Pike and large Perch exert a control on the numbers of zooplanktivorous fish. Conversely, once a lake becomes algal dominated and turbid, oxygen depletion occurs and results in bio-chemical processes that promote the release of nutrients from the sediments; thus exacerbating the problem further.

Where shallow lakes retain aquatic plants, even if only nutrient tolerant species such as those that dominate at Hedgecourt Lake, the most effective management is to reduce the anthropogenic inputs of nutrients and in so doing increase the resilience of the lake and prevent further degradation.

4.3. Siltation and water depth

In addition to eutrophication, there are also concerns about possible siltation and the lack of depth within Hedgecourt Lake. Ecologically, there is no reason why a lake of this depth cannot function normally; in fact, in eutrophic lakes where algal turbidity is often high, enough light can still reach the sediments and is therefore available to plants for photosynthesis. In deeper eutrophic lakes, the aphotic zone often becomes anoxic causing additional problems of nutrient release from the sediments and poor conditions for the lake biota. In turn, the plants help to buffer against the impacts of eutrophication by providing refugia to zooplankton, the primary grazers of phytoplankton (see Box 1). It was very noticeable during the survey work in June, that water clarity was higher within the dense beds of *P. pectinatus.* This is most likely due to the additional competition for light (between phytoplankton and higher plants), the impact of phytoplankton grazing within plant beds as well as a reduction in sediment re-suspension afforded by the plants.

Lake depth is doubtless the primary concern of the sailing club, but for the conservation status, it poses less of a problem. Currently, there is no immediate evidence of rapid infilling or encroachment in Hedgecourt lake (Madgewick 2017), and therefore no urgency to remove sediment or increase water depth. While water clarity remains poor (as a consequence of nutrient enrichment and high algal biomass), the macrophytes benefit from the site being shallow.

While siltation and water depth are not likely to be primary drivers of change in the site, the sediment may be acting as a source of nutrients within the site, particularly phosphorus. Phosphorus is bound within organic and inorganic particles that form the sediments, and where nutrient inputs are high, concentrations within the sediments can build up over time. Under certain conditions, particularly anoxia, this phosphorus can be released to the water column and thus the sediments act as a source of nutrients to the water. Where up-stream nutrient inputs are reduced, the sediments can become the primary source of nutrients in the lake, a problem that is exacerbated in sites like Hedgecourt Lakes that have relatively slow rates of throughput, and where water levels are held up artificially in summer, a time when P release and phytoplankton growth rates are highest. In this case, there may be grounds to manage internal P release by sediment removal, but only when external sources can be demonstrated to be low.

Given the nature of the catchment, which includes urban and rural run-off, it is likely that nutrient remain relatively high, and would require additional management before addressing internal nutrient release. A comprehensive nutrient budget of the catchment and lake is necessary to understand these problems in full and help to inform site management.

4.4. Catchment management

With nutrients identified as the key driver of deterioration within Hedgecourt Lake, it will be important to understand and control, where possible, nutrient inputs from the catchment.

Agricultural sources: Within the catchment, intensive agricultural land use is relatively low, with only c.16% of the land are under cultivation and 13% improved pasture, with approximately 35% wooded (CEH 2017). Despite the relatively low area of intensive agriculture, it is still likely to contribute to nutrients in the streams and ultimately into Hedgecourt Lake. Nutrient budgeting and full catchment assessment will help to identify any problem areas and, if necessary, facilitate mitigation through improved land management. Monitoring should include an array of sites which are monitored at a minimum of monthly intervals and during heavy rainfall events, when run-off is at its highest. This will establish is there any particular areas requiring additional management within the catchment.

The support of landowners and tenant farmers within the catchment, will therefore be vital to ensure nutrient (and sediment) loads are kept to a minimum. This is best achieved with the support and advice given through the Catchment Sensitive Farming scheme available through the joint provision of services from Natural England and Environment Agency (see NE 2017b).

Domestic sources: The majority of domestic sewage within the catchment is likely to be collected and treated via mains sewerage systems. It is beyond the scope of this report to identify if these fall within the Hedgecourt Lake catchment, but any sewage treatment works (STW) or smaller package plant discharges should be monitored and included within nutrient budgeting for the catchment. While these smaller (<10000 population equivalent) STWs are obliged to comply under their EA quality permits, the permits do not cover phosphorus concentrations, but focus on the levels of organic pollution, suspended solids and ammoniacal nitrogen, as well as microbiological quality. The additional management and control of nutrients from such discharges is largely unregulated, and therefore requires engagement with the water companies, or responsible operators, to encourage best practice where sensitive sites occur downstream of discharges.

In addition to mains STWs, there are a large number of rural dwellings within the catchment, many of which are unlikely to be serviced by mains sewerage and will have individual septic tanks in place. The impact of phosphorus from septic tanks can be significant where they are poorly maintained, or old (May *et al.* 2015), and we recommend that a full review of the location and function of all individually maintained septic tanks within the catchment is made.

Urban run-off: Urban and suburban areas account for approximately 25% of the Hedgecourt Lake catchment (CEH 2017), and therefore the quantity and quality of run-off may potentially be impacting the lake. Contamination of surface run-off with foul water due to poorly maintained drainage and domestic misconnections have the potential to impact on natural surface waters. The west side of East Crawley and Crawly Down are both within the surface water catchment, and their contribution to the quality of the Eden Brook headwaters and Hedgecourt Lake warrants monitoring to inform catchment and lake management.

Good quality of rivers is completely dependent on the supply of good quality water from the catchments. Good practice in river management, dictates that pollution, including nutrients, should be controlled from the headwaters in the first instance, and thus any nutrient control in the upper parts of the catchment will have positive impacts on Eden Brook, Hedgecourt Lake and ultimately on the wider Medway river basin downstream.

4.5. The 'Vision' for Hedgecourt Lake

This section is included to provide an indicative vision for Unit 4 of Hedgecourt SSSI. A full management plan should update this Vision to include and compliment the entire SSSI.

The objectives for 'Favourable Condition' in SSSIs (and SACs) are set out for each designated habitat type in a series of Common Standards (e.g. JNCC 2015 for lakes) agreed by the UK conservation agencies. The Common Standards provide biological and environmental targets that will support a characteristic biological community (rather than focus on any one species) for a natural habitat type. These are set out in the Favourable Condition Tables (e.g. NE 2014) which address the individual targets necessary to maintain the different habitat types within the SSSI unit.

Hedgecourt Lake fails to meet the targets set out for eutrophic lakes and therefore requires remedial action. To help deliver the improvements, a "Vision" for the site is required to provide the necessary goals to work towards. The Vision, presented here is based on the culmination of evidence collected from this study. A management plan will be required to ascertain and evidence the primary drivers of environmental change at the site and address these in order to ensure the Vision becomes a reality, returning Hedgecourt Lake to favourable condition.

The vision is focussed on both the open water and the array of marginal wetland habitats that surround much of the lake; a site of rich historical, cultural and environmental interest, and the largest area of semi-natural open water in eastern Surrey.

The Vision

The Vision is for a future in which the waters of Hedgecourt Lake remain clear and are dominated throughout the summer months by a diverse community of submerged aquatic plants, interspersed with white and yellow waterlilies. Broad-leaved pondweed and stoneworts will be important components of the aquatic flora, creating areas of dense weed growth right up to the water's surface. Around the lake, there will be areas of reed-bed grading gently into wet alder woodland and greater tussock sedge or species-rich fen. Water depth will, in the most part, exceed 1 m, reaching a maximum of 1.5 m in the middle of the pond. Within the shelter of the reeds, there will be shallower pools, providing good habitat for birds and fish fry. Non-native plant species will be absent, or remain at low abundance and no new introductions will occur.

The abundance of aquatic and wetland plants will play host to a diverse and important invertebrate community. Dragonflies and damselflies will be seen throughout the summer months: the many different species, including national rarities, being indicative of the good habitat and water quality within the pond. Molluscs will thrive at the site, both in the water, and within the wetlands. The quality and diversity of habitats will support a host of other invertebrate species, and thus the lake will be an important feeding ground for both birds and bats.

The fish population will consist of native species, such as pike, perch, eels, tench and rudd. Non-native fish species, such as common carp, will be absent and numbers of bottom-feeding species, such as bream, will be low, so as not to impact on the aquatic flora. The passage of eels to and from the lake will not be compromised by obstructions within the wider catchment.

The expanse of open water and marginal wetlands will attract a wide range of bird species, some, like the water rail, tufted duck, little grebe, great crested grebes, reed warblers and kingfishers will be resident breeders, while many other species of waterfowl will visit the lake during the winter.

Water quality will be very good. Concentrations of plant nutrients such as nitrogen and phosphorus will be low (TN < 1.5 mgl^{-1} & TP < 50 μgl^{-1}), both in the lake, and in the feeder streams. Agricultural management within the catchment will ensure that sediment loads and run-off are minimised and controls will be placed on domestic wastewater to ensure they do not pollute the pond. Water levels will be managed in such a way as to mimic natural lakes, with periods of lower water during summer and higher levels in winter.

Public access to Hedgecourt Lake will be sufficient to provide a vista of the natural and cultural heritage of the pond and its wetland habitats. The pond will be an area where people go to enjoy and learn about the natural environment and a place that promotes health and well-being through exercise and relaxation. The sailing club will continue to enjoy access to the open water and work in harmony with the site to compliment the amenity value with conservation. The provision of well managed public access and signage, will help to promote a wider understanding of the importance of freshwater habitats and thus safeguard this important SSSI feature, and other wetlands, into the future.

4.6. Recommendations

The control of nutrients within the catchment will be a key priority for the restoration and sustainability of Hedgecourt Lake. Future management and any restoration plans will require comprehensive evidence to identify the primary sources of nutrients within the catchment. Success of management is likely to be increased with the involvement of a wide stakeholder group to include: e.g. farm owners and tenants, local residents, South East Rivers Trust, Natural England, Surrey Wildlife Trust, Water companies and the Environment Agency, working towards a well-defined, common management objective.

In order to progress the lake towards favourable condition the following recommendations are made:

1. Undertake a full nutrient budget for the lake, inclusive of upstream catchment.
   - Ideally this will require a comprehensive catchment assessment and walkover to identify any potential sources of nutrients and silts to the surface waters (e.g. sewage treatment discharges, agricultural run-off, septic tanks, storm drains, road run-off, etc.). Following an initial assessment, monthly water quality monitoring (Table 5 fore recommended determinands) should be undertaken from the outflow and inflow of the lake as well as at strategic points within the catchment, to identify the primary sources of external loadings and to determine the contribution of internal nutrient cycling and release.
2. Restore a more natural hydrological regime.
   - Natural lake levels respond to rainfall and catchment processes, and therefore tend to be lower in the summer and higher in winter, with such natural fluctuations benefiting the marginal flora and fauna. This is contrary to the current management of water levels in Hedgecourt Lake, which are elevated in summer by raising the outflow weir, and lowered in winter. In additional to impacting on the littoral communities, this also prevents nutrients being flushed from the site when they are typically at their highest, and therefore facilitates internal nutrient cycling and sequestration, rather than the desired nutrient export. NE will need to work closely with key stake holders (primarily the sailing club) to achieve a positive outcome.
3. Define site-specific restoration targets.
   - Examining historical records (e.g. accounts of flora and fauna and archives samples) and the analysis of lake sediment records can provide additional evidence for lake restoration. Knowing how the biota of a lake has changed through time gives us a valuable insight into the expectations for conservation, and provides a baseline against which a site may be assessed in terms of its ecological status. The sediment core taken in June 2017 (Achived at UCL), is available to NE for further analysis and could be used to help set realistic and site-specific targets for restoration.
4. Sediment removal
   - Until such time that external nutrient sources can be demonstrated to be below recommended thresholds, there is little justification for silt removal as a means of controlling nutrients. The nutrient budget (point 1 above) will help to identify the relative contributions of internal and external nutrient sources and so determine the most effective means of control. In terms of the long-term management of the lake, it is inevitable that sediments will continue to accrue and thus the site will ultimately follow the natural path from open water habitat towards a wetland habitat. If this is to be prevented, some form of sediment removal will become necessary. As such it would be prudent to undertake an appraisal of the current sediment depth, quality and volume to enable the appropriate methods for de-silting to be most accurately assessed.

4.7. Policy drivers for lake restoration

In addition to the local concerned with regards to the condition of Hedgecourt Lake, there is a national framework in place to provide leverage and justification towards protected sites. Apposite to Hedgecourt SSSI there are three principal drivers for the protection and enhancement of freshwater habitats and species. These are highlighted within the Natural England Lakes Theme Plan (NE 2015) as follows:

Habitats and Bird Directives (EU Biodiversity 2020 Strategy). The Habitats Directive contains a wide range of obligations designed to protect a range of habitats, including a number of our rarest lake types and some wetland species. Similarly, the Wild Birds Directive provides protection to all naturally occurring bird species, and singles out the rarest, and regularly occurring migratory species, for additional protection. They allow for the establishment and protection of Natura 2000 sites.

Biodiversity 2020 (targets for SSSI and priority habitat condition). This is a national strategy for England's wildlife and ecosystem services. It sets out the Government's ambition to halt overall loss of England's biodiversity by 2020. Outcome 1A of the strategy states that, by 2020, better wildlife habitats will be established, with at least 50% of SSSIs in favourable condition, while maintaining at least 95% in favourable or recovering condition.

Water Framework Directive (WFD) Water dependent Natura 2000 sites are classed as 'Protected Areas' under WFD. Lakes greater than 5 ha are also classed as WFD 'water bodies' so are integrated into the WFD monitoring and reporting of 'Ecological Status'. This includes SSSI lakes notified for their aquatic interest, as well as SAC lakes. Although there are deadlines within the Directive to achieve 'Good Ecological Status' there is a recognition that given the timescales involved in lake habitat recovery, many lakes will require extensions. Where targets for WFD status and SSSI/SAC condition differ, then the most stringent shall apply.

Thus, there are a series of well-defined drivers which provide a framework for the future protection and restoration of Hedgecourt Lake. These drivers, in conjunction with evidence-based monitoring of the site, provide the over-arching legislative pathways through with the vision may be realised.

5. References

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6. Appendix I

6.1. Recommended monthly water quality

Table 5 Recommended water quality determinands for monthly monitoring

Determinand	Unit	MRV*	Notes
pH	pH	0.05	
Suspended solids	mg/l	3	
Alkalinity - Total	mg/l	5	
Conductivity @ 20C	µS/cm	10	
Orthophosphate	mg/l	0.001	Detection limit 3µg/l
Total Phosphorus (TP)	mg/l	0.003	Detection limit 3µg/l
Chlorophyll *a*	µg/l	0.5	Outflow only
Total Nitrogen (TN)	mg/l	0.05	
Total oxidised Nitrogen	mg/l	0.005	
Nitrite Nitrogen	mg/l	0.004	
Nitrate Nitrogen	mg/l	0.005	Derived from TON-NO_2^-

*Minimum recordable value

6.2. Aquatic / wetland macrophyte species list – Survey June 2017

Table 6 List of aquatic and wetland plants recording in the 2017 CSM survey

Aquatic plant species	
Callitriche sp.	*Potamogeton crispus*
Ceratophyllum demersum	*Potamogeton natans*
Elodea nuttallii	*Potamogeton obtusifolius*
Lemna minor	*Potamogeton pectinatus*
Lemna minuta	*Potamogeton pusillus*
Nitella sp.	*Zannichellia palustris*
Nuphar lutea	

Emergent and marginal wetland plant species	
Alisma plantago-aquatica	*Lycopus europaeus*
Alnus glutinosa	*Lysimachia vulgaris*
‘Bamboo’	*Mentha aquatica*
Carex paniculata	*Myosotis scorpioides*
Carex pendula	*Oenanthe crocata*
Carex remota	*Phragmites australis*
Carex vesicaria	*Rhododendron ponticum*
Cirsium palustre	*Salix sp.*
Equisetum fluviatile	*Scutellaria galericulata*
Filipendula ulmaria	*Solanum dulcamara*
Iris pseudacorus	*Sphagnum sp.*
Juncus effusus	*Typha latifolia*

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