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Burton Mill Pond
Vision and Work Programme

ECRC Research Report Number 184

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Burton Mill Pond Vision and Work Programme

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Cover photo: Burton Mill Pond, June 2016 (B. Goldsmith)

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Executive Summary

This Report, commissioned by West Sussex County Council, provides environmental and ecological evidence to determine the current conservation value and status of Burton Mill Pond (BMP), and builds the evidence into a vision for the site. Site management is discussed within the context of achieving this vision, and a work programme presented, from which WSCC can develop and detailed management schedule.

Burton Mill Pond is a shallow lake in West Sussex situated within the South Downs National Park. The pond and surrounding woodlands, heath and fen are designated as a Site of Special Scientific Interest (Burton Park SSSI) and the pond is a component of the larger Burton Mill and Chingford Ponds Local Nature Reserve (LNR). The Pond is owned by West Sussex County Council and is currently managed in accordance with the approved Burton and Chingford Ponds LNR Management Plan 2015 – 2025.

The rich array of wetland and aquatic flora and fauna supported by the site is of regional and national importance, and the pond is one of very few lowland lakes in the south of England that remains plant-dominated and clear throughout the year. The open water is dominated by Shining Pondweed and water lilies, but supports upwards of 18 aquatic plant species, and is surrounded by an extensive mosaic of wetlands, forming excellent habitat for many aquatic organisms, including zooplankton, invertebrates and fish, which in turn support wetland birds, by providing important areas for breeding and feeding. In particular, the site is important for the extant population of the Desmoulin's whorl snail (*Vertigo moulinsiana*), an Annex IIa EU Habitats Directive species, and for the large population of the marginal wetland plant Cowbane (*Cicuta virosa*), which is rare in southern England. Other records include two nationally rare species of Craneflies, the Mud snail *Omphiscola glabra* and among the 15 species of dragonfly and damselfly observed, the Variable damselfly and Hairy dragonfly are of national importance. The site is important for birds, inclusive of Bittern and Osprey, both of which are regularly sighted during annual migration.

This report brings together a comprehensive range of evidence to determine the current conservation status of the site as well as identifying the primary stressors and threats to enable informed management. New data have been collected to assess the current status of the aquatic and wetland flora, and to ascertain how the flora has changed over time by examining sub-fossil records from the lake sediments. New data were collected to establish the extent and distribution of Desmoulin's whorl snails within the site. Water quality and land-use data were collected from around the BMP catchment to identify the main inputs of nutrients and sediments that could be targeted for reduction. Historic maps and aerial photographs were used within geographic information systems (GIS) to accurately determine the extent of habitat change for open water, wetland and wet woodland. Radiometric sediment dating was used to calculate the rates of siltation within the open water.

The evidence presented in this report shows the aquatic flora and fauna to be in good condition for a high-alkalinity, lowland lake. The aquatic flora has remained relatively stable over the past 15 years, but differs from the historic flora recorded in the sediments records pertaining to the 19th Century. It seems likely that an historic increase in nitrate concentrations in the ground-waters that feed the lake, were responsible for a decline in stoneworts, and subsequent increase in a more typical, and currently very good, eutrophic flora.

Environment Agency water quality data, show the phosphorus concentrations in BMP to have almost doubled since monitoring began in 2003, placing the site at significant risk of losing its diverse aquatic habitat and species therein. This is a key area of concern. Nitrates concentrations within the chalk aquifers that feed the lake are also high, but this is a more widespread problem, well-beyond the control of the surface water catchment of BMP.

A high percentage of the catchment land management is under low input, agricultural production and forestry. The primary sources of phosphorus were identified as coming from domestic sources at Duncton sewage treatment works and Burton House package treatment plant. Both discharges comply with their required public health and gross pollution standards, but are not required to control phosphorus release, and typically discharge effluent with concentrations of total P of approximately 1000 μgl^{-1}. Eutrophication due to the release of phosphorus into surface waters is the single largest treat to biodiversity in the UK lakes, and at BMP, poses a significant threat to the quality and conservation status of the site. Recommendations are made to monitor water quality and to engage with stakeholders to manage and reduce inputs to the lake.

We could find no evidence for accelerated in-filling by siltation of the lake. The restoration of the Chingford pond dam (completed in 2016) and de-silting of Trout Pond (above Chingford Pond), means the majority of catchment derived silts will not reach BMP. Radiometric dates were obtained from a sediment core taken in BMP which suggest sediment accumulation rates to be in the region of 0.77 cm per year. With the majority of open water being between 1 – 2 m in depth, evidence suggests that Burton Mill Pond has many years to go before losing its open water to externally derived silts. Best practice in lake management stresses the need to address external problems, particularly nutrients, before resorting to major within-lake restoration measure such as sediment removal. Current evidence points to external nutrient inputs from domestic sewage treatment works as the major threat to ecological function.

The development and encroachment of the marginal wetlands was evidenced using aerial photography. Based on comparisons of 1956 and 2013 data, there has been a 16% loss of extent of open water area to reed encroachment (5.23 ha in 1956 to 4.37 ha in 2013). This figure is significantly lower than previous estimates. Total reed cover has also decreased over the same period (by 35%), as tree and scrub cover has expanded towards the lake edge. Increased productivity within the lake and shading towards the landward side of the reedbeds are suggested as the primary factors driving the encroachment on open water. Recommendations are made for the management of trees and scrub around the lake on a rotational basis, and periodic reed cutting to reduce encroachment of reed into open water. Management intervention needs to be conducted within a framework that recognises the value of both existing and developing marginal habitats (e.g. willow scrub, alder carr with *Carex paniculata* understory).

A vision is presented for Burton Mill Pond which promotes the potential value of the site as an excellent conservation resource and recognises its importance within the historical and cultural landscape of West Sussex. For such a vision to be achieved and remain sustainable for the long-term, management needs to be evidence led and supported by regular species and environmental monitoring. Implementation of the management recommendations will facilitate the vision and help to preserve this important site into the future.

1. Introduction

1.1. Background

Burton Mill Pond is a shallow, plant-dominated lake which currently supports a species rich mosaic of aquatic plants and is surrounded by extensive areas of wetland. Previous surveys undertaken by ENSIS ltd. (Author data) reveal that Shining Pondweed has been abundant in the open water, alongside Yellow Water-lily (*Nuphar lutea*) since before 2003. Such high plant cover forms an excellent habitat for many aquatic organisms, including zooplankton, invertebrates and fish, which in turn support wetland birds, by providing areas for breeding and feeding.

In addition, the site is of regional importance for the extant population of the Desmoulin's whorl snail (*Vertigo moulinsiana*), an Annex IIa EU Habitats Directive species, and for the large population of the marginal wetland plant Cowbane (*Cicuta virosa*), which is rare in southern England.

Given the conservation interest, Burton Mill Pond is accordingly afforded protection within Burton Park Site of Special Scientific Interest (SSSI) and lies within the South Downs National Park. In addition, the pond is a component of the larger Burton Mill and Chingford Ponds Local Nature Reserve (LNR). The site is managed in accordance with the Burton and Chingford Ponds LNR Management Plan 2015 – 2025.

However, despite its protected status, Burton Mill Pond is thought to be moving away from its designated status as a high quality shallow lake due to the detrimental influx of nutrients from the catchment (eutrophication). Monitoring data provided by the Environment Agency demonstrate the mean annual total nitrogen (TN) between 2003 and 2016 to be 3.3 mgl^{-1}, which is more than twice the maximum value of 1.5 mgl^{-1}, for a lake to be classified as being in favourable condition (JNCC, 2015). Similarly, annual mean Total Phosphorus (TP) was also slightly high, averaging 84 μgl^{-1}. The recommended maximum level for a high alkalinity, very shallow lake (maximum depth less than 3 m) is 50 μgl^{-1} (JNCC, 2015). If assessing Burton Mill Pond as mesotrophic (moderate alkalinity), then the maximum acceptable level decreases to 20 μgl^{-1}.

In addition to elevated levels of nutrients in the site, there is some concern about the loss of open water. Whilst there is a clear need to preserve the open water near to its original state at the point of designation in 1954, it should also be emphasized that the wetland habitats form a vital and valuable part of the SSSI and the structure and extent should also be maintained. The encroachment of reeds is not a recent phenomenon at Burton Mill Pond with anecdotal evidence and documented records of regular reed cutting having been an active part of the site management after the SSSI designation and this, along with water lily clearance, continued with volunteer groups until the early 1980's (Ann Griffiths – unpublished records). What differs with the more recent concerns however, is that as well as encroachment being a potential problem, increased siltation has also been identified as possible problem. It was deemed appropriate to remove silt from Burton Mill Pond, and this was done in 1985, using a suction pump to remove water and silt to settling ponds on the adjacent farmland. Since then, it is thought likely that additional siltation may have occurred during a period of management work at Chingford Pond which lies immediately above BMP. Chingford Pond was first lowered by 1.5 m in the mid 1980's following concerns about the safety of the dam structure. The dam was then breached again in 1991 and the water level in Chingford Pond dropped further still to 2.2 m below historic datum. The exposure of sandy deposits from the breaching at Chingford Pond dam are thought to have resulted in the in-wash of sand directly to the western arm of Burton Mill Pond and so exacerbating siltation and the reed encroachment.

Following the full restoration of the Chingford Pond (completed in 2016) and de-silting of Trout Pond (above Chingford Pond), there now exists two ponds above BMP through which the bulk of inflow must pass and hence these will act to reduce siltation to BMP. While undoubtedly the breach of the Chingford Pond dam caused increased sedimentation in Burton Mill Pond when it happened, the inputs of silt are likely to have been reduced significantly after these events and further still since the dam was reinstalled at Chingford Pond.

The encroachment and periodic clearance of marginal reed bed appears to be a necessary and well-established management task at BMP. The extent to which the natural reed edge has migrated into the lake during the last 60 years has caused concern. The rough figure 34% loss of open water, calculated by comparing recent aerial photography to the extent of different habitats with sketch maps produced in 1982. The amount of fen vegetation remains the same during this period, and it is the encroachment of alder carr that has increased around the site that accounts for this apparent loss of open water. It should however be noted that these figures are deduced from the digitisation of sketch maps, rather than actual measurements and are thus subject to unquantifiable error. It is also clear from historic maps that some areas of the lake, and particularly the south-western arm, have long been dominated by wetland vegetation, with no open water at all detailed past the island on the 1912 OS County Series 1:2500 map.

The extent to which infilling and encroachment are internal or external processes is also unclear. Current estimates for the infilling (loss of depth) in Burton Mill Pond range from the extreme scenario of approximately 12 cm per year (Atkins 2012), to a more sedate 0.5 cm per year based on radiometric dating of sediment cores from the site (ENSIS data). The build-up of organic material derived from within the site and in-wash of material from the wider catchment are both natural processes, but both can be exacerbated and accelerated by catchment processes (e.g. eutrophication and poor land management). Future management of Burton Mill Pond therefore requires a full understanding of catchment management and processes to ensure the value of the SSSI is maintained.

Recent biological data suggest the site to be of high value as a wetland and aquatic habitat. Although the open water is relatively shallow (80 - 180 cm), it supports extensive beds of aquatic plants that dominate the site. One species, Shining pondweed *Potamogeton lucens*, has dominated the site since at least 2003 (Author data), is now rare in shallow lakes in the UK and although not an original component of the SSSI citation, nonetheless classifies BMP as one of the best quality shallow lowland lakes in the country, yet this type of feature would have been common-place in the past (pre-1940s), especially in the Norfolk and Suffolk Broads (Sayer, 2016, pers. comm.).

Similarly, the emergent vegetation, grading from reed bed (Common reed and Reed mace), to wet woodland and alder carr, inclusive of extensive areas of Greater tussock sedge is of considerable importance. As well as providing excellent habitat for a wide range of common invertebrates, birds and mammals, this habitat also harbours several notable rarities, including one of the only known populations of Desmoulin's whorl *Vertigo moulinsina* in West Sussex, a rare species that has declined in parts of southern England (e.g. Willing 2011a) and a large population of Cowbane *Cicuta virosa,* a rare wetland plant in England. Other records include nationally rare species of Craneflies *Erioptera meijerei* and *Tipula marginata,* Mud snail *Omphiscola glabra* and among the 15 species of dragonfly and damselfly observed, two are of national importance: the Variable damselfly *Coenagrion pulchellum* and the Hairy dragonfly *Brachytron practense* (NE 2014). The site is important for birds, inclusive of Bittern *Botaurus stellaris* and Osprey *Pandion haliaetus,* both of which are regularly sighted (SxBRC, 2016).

While concerns have been raised about potential threats to the site, the current data indicate that the pond has not yet undergone the major ecological changes seen in the majority of lowland lakes in the UK and therefore has excellent potential for successful restoration and management. The direction and implementation of future management requires a thorough understanding of the past and present ecological functioning of the site as well as knowledge of the pressures and stressors that influence it. Instrumental in the future management will be the creation of a vision for the site, underpinned by rigorous ecological understanding and monitoring to inform best practice.

Highlights

- High conservation status – high biodiversity, inclusive of nationally rare species from different biological groups;
- Excellent aquatic habitat – clear-water, plant-dominated lakes are rare in lowland England;
- Extensive wetland habitat – a good range of wetland habitats grading into wet woodland;
- Cultural importance – important local history and focal point within the landscape;
- Active local stakeholder group – important to ensure effective management.

2. Evidence

2.1. Catchment Walkover

Aims and Methods

A walkover of the Burton Mill Pond (BMP) catchment was undertaken on 21st April 2016. The aim of the assessment was to identify any potential sources of nutrients and sediment in-wash which may impact upon Burton Mill Pond. In addition to a visual assessment at each site, water samples were collected from a number of streams and standing waters around the catchment in order to assess water quality, including phosphorus, (Soluble reactive P (SRP) and total P (TP)), nitrogen (Nitrate (NO_3^--N) and total nitrogen TN)), suspended solids, chlorophyll *a*, and pH. Total phosphorus, total nitrogen and chlorophyll *a* measurements are more relevant to standing waters and were only analysed for samples from BMP, Chingford Pond and the outlet from the trout fishery (where there are a number of small ponds). All water samples were couriered directly to the UKAS accredited National Laboratory Services (EA) for analysis.

Catchment Characteristics

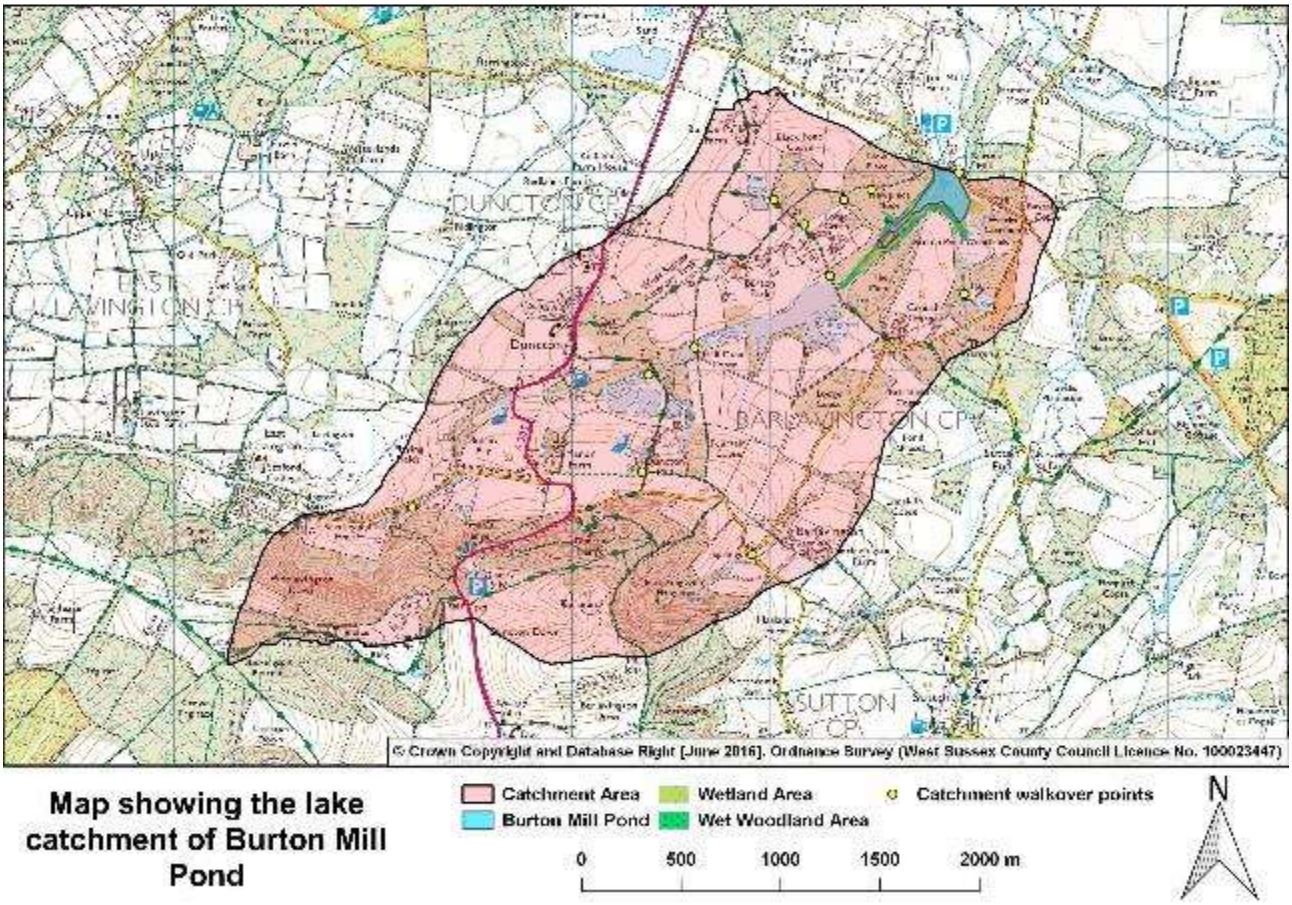

Figure 1 Map of Burton Mill Pond

Burton Mill Pond has a catchment area of approximately 507 ha (Environment Agency, 2016) draining an area mainly to the southwest of the site (Figure 1). The lake itself is underlain by a layer of bedrock which is part of the Folkestone formation, comprising sandstone with other superficial deposits creating an alluvium layer of clay, silt, sand and gravel (Onshore GeoIndex, BGS 2016). Although the lake lies on this slightly acid geology, much of the water supply comes from the upper reaches of the catchment which are on the alkaline chalk geology of the South Downs and hence the ponds are of relatively high alkalinity.

The main surface inflow, rises from a spring in the chalk aquifer just below Beechwood House (near site 12). The stream takes a north-easterly course through several small impoundments to Trout Pond, and from there it flows directly into Chingford and on to Burton Mill Pond. There is a subsidiary stream rising from two (or more) springs south of Duncton Mill. This stream is also impounded (the original mill pond) and feeds a series of small ponds (part of Dunton Mill Fishery), before joining the main stream just below Dye House Lane. A second artificial channel also runs directly to Trout Pond. The Duncton Mill Fishery has a series of ponds, which outflow to a point just above Dye House Lane, as well as (it is assumed) to the subsidiary stream from Duncton Mill. The OS Mastermap layers show a number of small surface drains and springs contributing to the main stream.

There are two sub-catchments feeding directly into BMP which from visual assessment, contribute significant surface water inputs to the lake. To the south of the catchment, there is a spring-fed stream arising at Barlavington Hanger, which is then channelled along the lane running north-east from Barlavington to Crouch Farm. Below Crouch Farm, the stream flows into the wet woodland where it meets other minor tributaries from the Warren and forms an extensively braided woodland stream before flowing into the southern arm of the BMP wetland.

To the northwest of BMP there is a small stream that joints the lake just north of the island near the old boat house. Several small surface tributaries join this stream, with observed flow coming from Black Pond Copse, Black pond and from the stream originating at Burton Park House. The latter stream also receives treated effluent directly from the Burton Park sewage treatment works (see below).

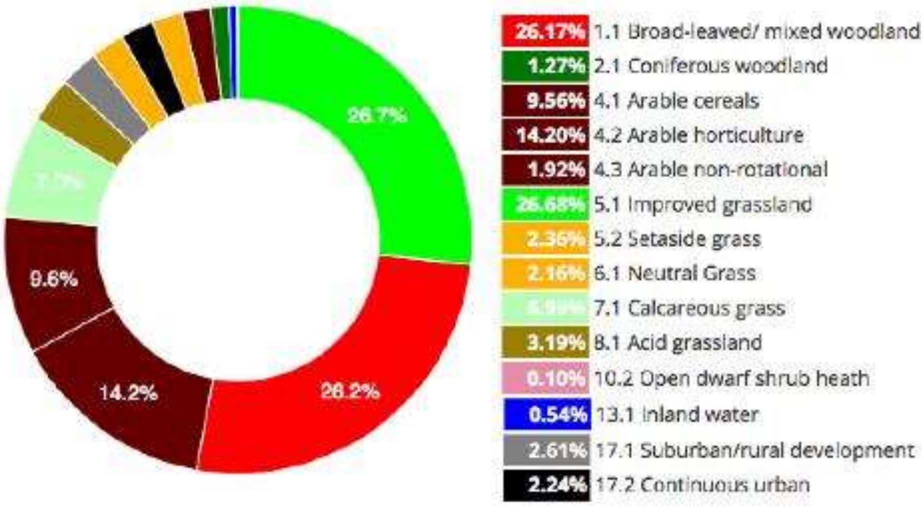

Figure 2 Land use data for the Burton Mill Pond catchment (from CEH 2016)

Land use within the catchment is mixed and, in part, governed by the varied terrain and complex geology. The upper slopes extend on to the South Downs and are dominated by mixed woodland, some of which is managed for timber production, but the majority of the woodland is permanent. Lower down in the catchment, there is a mix of good quality semi-improved grassland and a range of arable usage as well as residential developments.

covers the lower part of the catchment (Figure 2 and Figure 3). It is interesting to note that a significant proportion of the more intensively farmed areas of the catchment are being managed within Environmental stewardship schemes, including both Entry Level plus Higher Level Stewardship and Organic Entry Level plus Higher Level Stewardship, both of which should help to reduce nutrient inputs to the freshwaters.

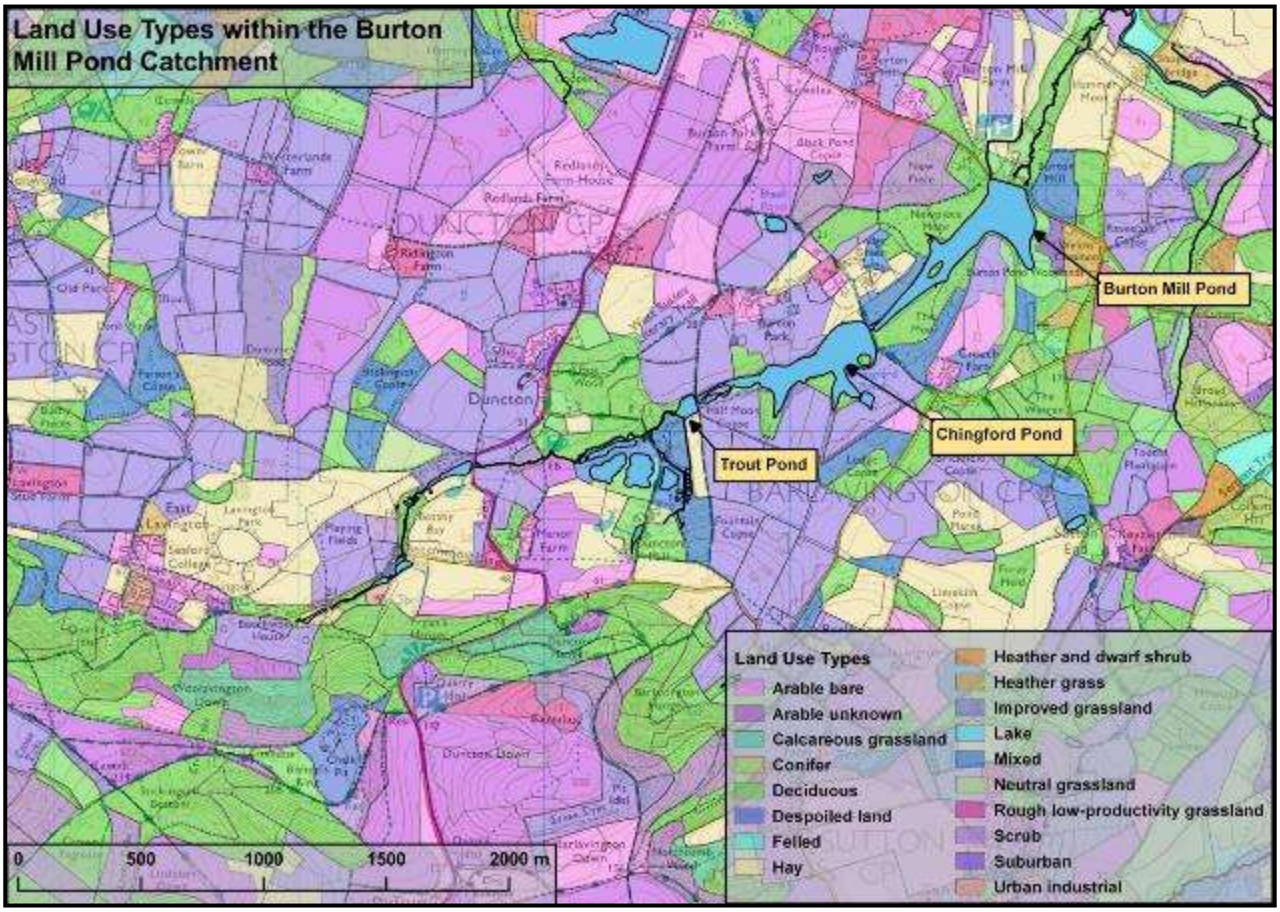

Figure 3 Land Cover Map of Burton Mill Pond Catchment (© Crown Copyright and Database Right [2007]. Ordnance Survey, Scale 1:2500 (WSCC Licence 100023447))

There are a number of rural dwellings within the catchment including the village of Duncton (population c.345 in 2011 census), Duncton Junior School (68 pupils 2014/15), the apartments within Burton House and grounds (over 25 apartments and "mews" houses) and Lodge Green within the Burton Park (12 houses). The majority of these houses are understood to be on serviced or mains sewerage, with Duncton sewage treatment works (STW) located at SU9611817271 (operated by Southern Water) and Burton Park serviced by a private STW (package plant installed in 1996) within the Burton Park Estate (operated by Petworth Management Company).

Findings

During the course of the visit, the catchment (with the exception of the wooded areas in the upper catchment) was accessed on foot via public (and permissive) footpaths and driven. Additional permission was granted to access areas of the Barlavington Estate land. No samples were taken from the fishery ponds, but the outlet was sampled where it meets the main stream (Site 9). The sits visited are shown in Figure 4 and the results from the water chemistry analysis in Table 1.

The weather conditions on the day of the catchment walkover were clear, fair and dry and followed a period of dry weather. The streams were all at low to moderate flow following a period of relatively dry weather. The table below details the water chemistry data obtained from the water samples collected at all 12 sites within Burton Mill Pond catchment. It should be noted that to achieve the highest ecological quality for a shallow mesotrophic lake, phosphorus concentrations should ideally be below 20 μgl^{-1} (JNCC 2015). Ground-water nitrogen is high in this region, making the stringent 1.5 mgl^{-1} limit set for standing waters unlikely to be met.

Results are also presented in Table 1 for the effluent discharges at the Duncton village and Burton Park STWs. These samples were collected and analysed independently of this project by Southern Water (31 May 2016) and Petworth Management Company (18 October 2016).

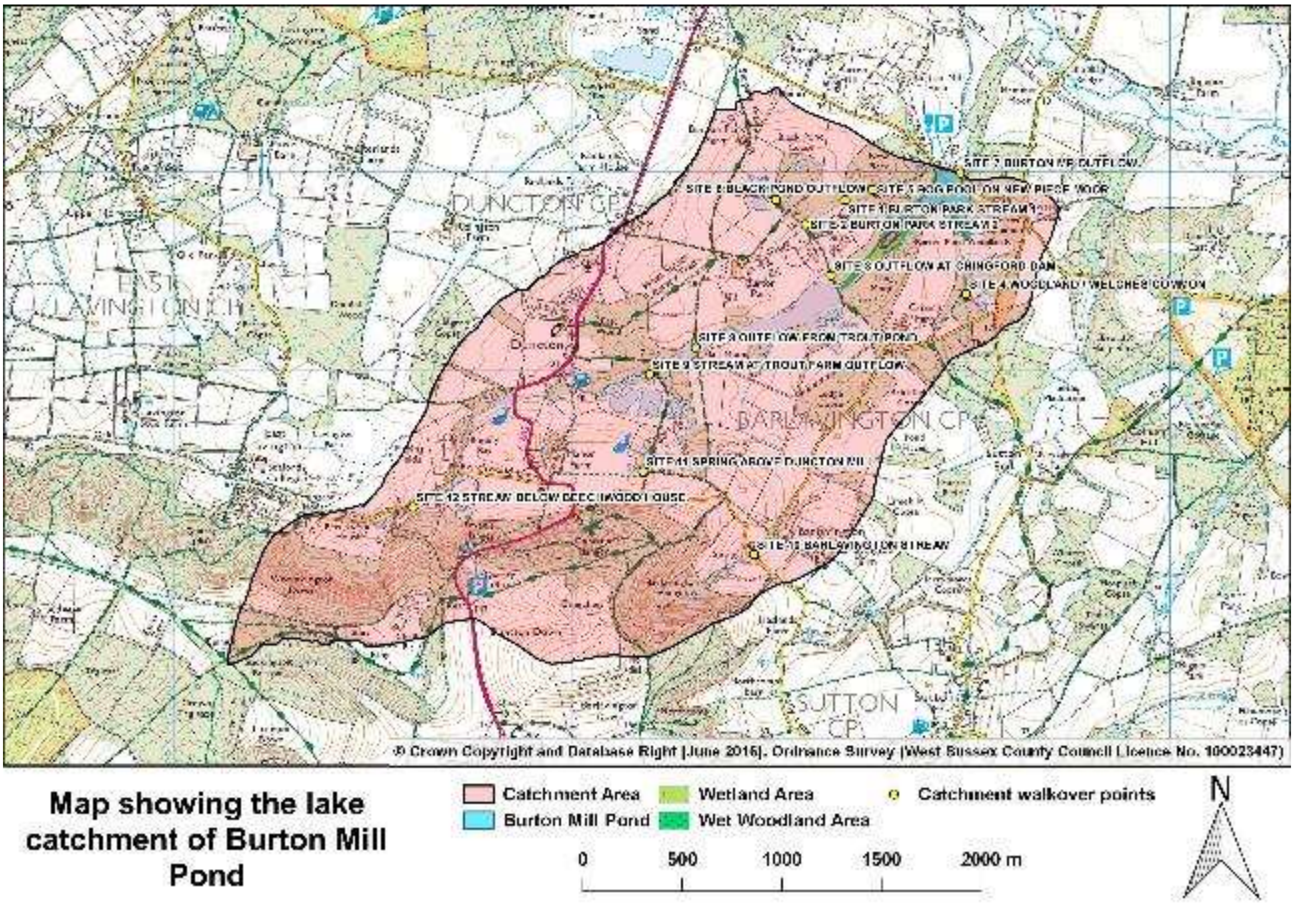

Figure 4 Site locations where water samples were taken.

The sites are discussed below, relative to their location and water quality. There were no concerns raised about significant sediment inputs other than at sites 2 (see below). At site 4, the slight increase in suspended solids was noted at time of sampling as disturbance during the collection of sample from very shallow water rather than any sediment load within the stream.

Table 1 Water chemistry data for Burton Mill Pond catchment (21 April 2016)

Sample site	Location	Total Phosphorus (TP) µgl^{-1}	Soluble reactive P (SRP) µgl^{-1}	Total Nitrogen (TN) mgl^{-1}	Nitrate Nitrogen NO_3-N)	pH	Conductivity µScm^{-1}	Suspended Solids mgl^{-1}	Chlorophyll a (Chl a) µgl^{-1}
Site 1	SU9737117858		68		4.57	7.38	287	3.93	
Site 2	SU9717217734		731		2.85	7.12	352	46	
Site 3	SU9730017477	26	1.4	2.99	2.70	8.22	418	3.48	14.8
Site 4	SU9797917385		24		6.79	8.36	436	33.8	
Site 5	SU9750917910		33		0	4.15	108	<3	
Site 6	SU9702217860		41		2.34	7.55	241	<3	
Site 7	SU9795017994	39	1.4	2.88	2.38	8.42	399	7.43	22.8
Site 8	SU9662017116		14		3.75	8.30	456	5.23	
Site 9	SU9641316986	34	18	4.36	4.20	8.29	446	13.8	2.5
Site 10	SU9691316074		2.5		7.98	8.19	415	7.3	
Site 11	SU9635116491		9.1		4.04	7.53	524	<3	
Site 12	SU9519916312		11		4.39	7.96	381	<3	
Duncton STW	Treated effluent: 31 May 2016	9760	4970						
Burton Park STW	Treated effluent: 18 Oct 2016	8700	9700	>23.8		7.6		14	

Site 1 Burton Park Stream SU9737117858

A wooded stream, located downstream of Burton House (Figure 5, photos A and B). A water sample was obtained at the culvert, which at the time of the walkover was in poor condition. The stream was heavily silted and within the woodland, provides good habitat where natural obstructions such as fallen trees and foliage cause the channel to split and in places flood the woodland. A large fish (species unknown) was observed in the pool below the culvert. Immediately downstream of Site 1 was an area of wet alder and sycamore habitat, with an understory of *Carex paniculata* and *Oenanthe crocata (*Figure 5, photo C). Analysis of the water samples taken from the stream indicated that nitrate (TON) levels were slightly elevated, at 4.59 mgl^{-1}, and soluble reactive phosphorus (SRP) levels were high, measuring 67.6 µgl^{-1}. The SRP level exceeds the phosphorus limits set for shallow mesotrophic lakes (20 µgl^{-1}) in the UK (JNCC 2015). The pH of the samples was neutral (7.38).

Figure 5 Photos A, B and C, Burton Park Stream (downstream)

Site 2 Burton Park Stream SU9717217734

Site 2 is located upstream from Site 1, situated directly below a road and the houses at Lodge Green (

Figure 6, photo D). The channel drains the area directly around Burton Park House and is approximately 200 m downstream of the Burton Park STW outfall on the barder of the SSSI. It is a slow flowing stream, with slightly turbid water. The local vicinity is unshaded and the stream had dense growths of an aquatic grass (*Catabrosa aquatica*) growing in the channel (

Figure 6, photos E and F). Other aquatic species observed include a starwort (*Callitriche* sp.), common willowherb (*Epilobium hirsutum*), branched bur-reed (*Sparganium erectum*) and water horsetail (*Equisetum fluviatile*).

The water quality is notably poor at this site, with exceptionally high phosphorus levels measured at 731 μgl^{-1}, which can almost certainly be attributed to the Burton Park STW. At the time of sampling, the area immediately downstream of the sampling point had dense cover of emergent wetland vegetation (mainly dense *Catabrosa aquatica*). At this time of year, the submerged and marginal plants have a strong uptake of nutrients which, in combination with the dilution effects from the Black Pond stream, would explains why nutrient levels are lower further downstream. Any uptake of nutrients by the wetland is positive in the short term, but over the year, many of the nutrients will be returned to the water as the vegetation dies back in autumn and winter, and therefore the nutrients will ultimately reach BMP.

The small water body in Black Pond Copse (not Black Pond) has a low level of surface flow towards Burton Park Stream. Some evidence was observed of soil and hardcore dumping at the top of the copse (not analysed), but with no obvious problems for water quality. Pasture above the copse at Burton Park Farm was at the time being grazed only by horses, with at least 14 noted. There is a stock yard and stabling at Burton Park Farm, along with an artificial riding track which circumnavigated the pasture to the edge of the woodland. No evidence of detrimental run-off was observed during the survey, but future monitoring should include a full assessment of this area.

Figure 6 Photos D, E and F, Burton Park Stream (upstream)

Site 3 Chingford Pond Outflow SU9730017477

Chingford Pond was observed to have clear water and a good level of water flow out via the piped outlet. At the time of sampling the water level in Chingford Pond was in the process of being raised from an intermediate level of 16.8 m (OD), to the full level required to overtop the historic cascade (18.4 m OD).

As a result of the restoration works, the outflow is heavily engineered (Figure 7, photo G) but naturalised below the track, with good clean gravel beds present as the water flows back towards the cascade. The outflow stream continues through a pleasant area of wet woodland and *Carex* fen, towards Burton Mill Pond (Figure 7, photo H). Green filamentous algae (*Vaucheria* sp.) was present at the outflow. Total phosphorus was measured at a moderate 25.7 μgl^{-1} (where 20 μgl^{-1} is the recommended maximum level for a very shallow mesotrophic lake, JNCC 2015 CSM guidelines), while nitrate was 2.72 mgl^{-1}.

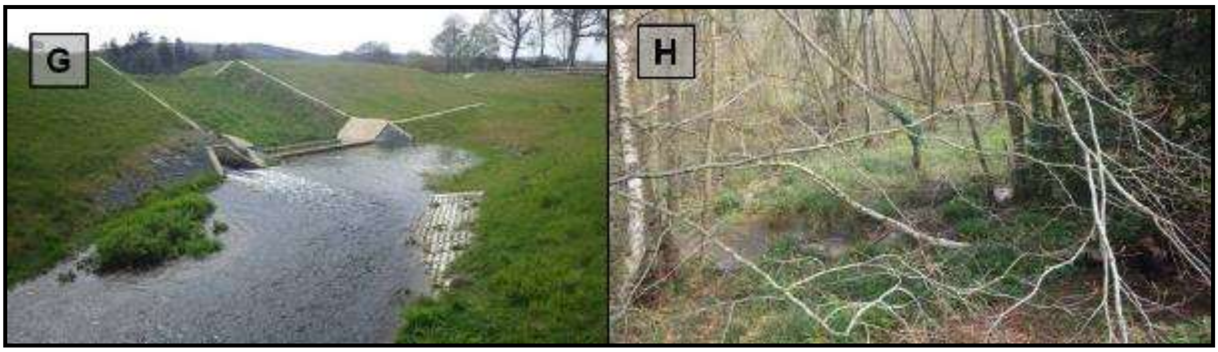

Figure 7 Photos G and H, Chingford Pond Outflow

Historic water chemistry taken by the EA just below the Chingford outflow, suggest the TP concentrations may normally be higher than measured in April 2016. The EA data are poorly spaced for most years making average data unreliable.

The woodland to the east of BMP consists of mixed coniferous and birch trees on higher ground, which then merges into wet alder woodland and carr habitat towards the lake, with an extensive *Carex* understory.

Site 4 Welches Common Stream/ Woodland SU9797917385

An excellent example of a woodland stream with very clear water and a good rate of flow over a sandy bed (Figure 8, photos I and J). Approximately one metre wide at the sample point, but heavily braided and meandering through areas of wet woodland slightly further downstream (Figure 8, photo K). This is a good example of wet woodland habitat that supports a healthy population of freshwater shrimps (*Gammerus* sp.) within the stream, which is typical in areas of abundant leaf litter. Levels of soluble orthophosphate (SRP) were moderate (24.4 μgl^{-1}), while nitrate was rather high, at 6.8 mgl^{-1}. The high nitrate is most likely the consequence of the high groundwater concentrations (see site 10), but the stream also flows adjacent to arable land and improved grassland, which, despite being within low input agriculture, will still contribute nutrients to surface waters, albeit less than from conventional systems.

Figure 8 Photos I, J and K, Welches Common Stream/ Woodland

Site 5 Black Hole Bog SU9750917910

Black Hole Bog is a recently cleared bog pool, created by Sussex Wildlife Trust as part of a habitat improvement project within the Burton and Chingford Ponds Local Nature Reserve (funded by Veolia Environment Trust as part of the Landfill Communities Fund). (Figure 9, photo M). The water was noted to be very brown (Figure 9, Photo N), and water chemistry analysis reveals it to also be very acidic, with a pH of 4.15, a natural process on base poor geology where bogs develop. In addition, SRP levels were moderate, measuring to be 32.9 μgl^{-1}, while nitrate was virtually absent (<0.005 mgl^{-1}). Nitrogen limitation is typical of this type of acid, brown-water pool. The slopes above the pool have been cleared of birch and bracken as part of the management within the reserve (Figure 9, photo O). Overall, the area appears to be of excellent habitat creation.

Figure 9 Photos M and N, Black Hole Bog and O, recent management works

Site 6 Black Pond Outflow Stream SU9702217860

Black Pond appears to be an artificial impoundment lying between the Park Grounds and Burton Park Farm (Figure 10, photo P). The pond is fringed with Alder and has a small copse to the west, but is otherwise surrounded by improved pasture. There is a small stock shed and hay storage, which are to the east of the pond (Figure 10, photo Q). The outflow extends to the northeast from Black Pond, where a water sample was taken at a small bridge 25 m away from the main water body (Figure 11, photos R and S). No obvious problems were observed, although SRP and nitrate levels are above the desired levels (41.3 μgl^{-1} and 2.38 mgl^{-1} respectively) suggesting some enrichment from the nearby pasture is likely. This should be explored with further monitoring.

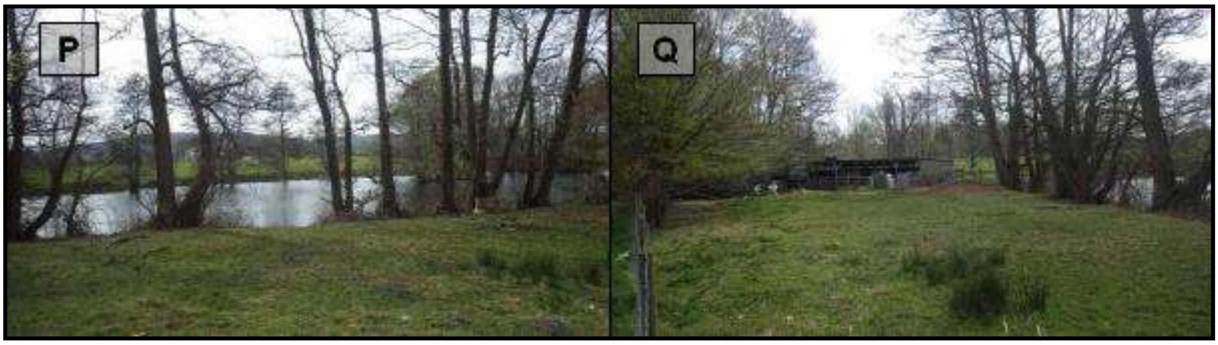

Figure 10 Photos P and Q, Black Pond and stock/hay storage

Figure 11 Photos R and S, Black Pond Outflow Stream

Site 7 Burton Mill Pond Outflow SU9795017994

At the time of survey, the Burton Mill Pond was moderately turbid due to a spring phytoplankton bloom (

Figure 12, photo T). Floating scum/ FLAB (Floating Algal Biomass) was also observed, which is mainly phytobenthos (algal biofilm) that lifts from the lake bed due to the rapid rate of photosynthesis during the springtime when there is an increase in light and temperature. This is a natural process, but is exacerbated by nutrient enrichment, which poses a greater risk of the site remaining turbid for longer, to the detriment of the aquatic habitat and quality.

Water chemistry analysis indicates nutrient enrichment, with total phosphorus of 38.8 μgl^{-1} and total nitrogen concentrations of 2.88 mgl^{-1} (where maxima of 20 μgl^{-1} for TP and 1.5 mgl^{-1} are recommended for mesotrophic waters (JNCC, 2015)).

There are also historical records for water chemistry at Burton Mill Pond collected and analysed by the Environment Agency for the purpose of Water Framework Directive monitoring and assessment. Sampled at the outflow in 2003/4 and 2008/9, the annual mean TP was 43 μgl^{-1} and 59 μgl^{-1} respectively (from Burgess & Goldsmith 2012) and the annual mean based on EA monitoring in 2015/16 was 84 μgl^{-1} and TN of 3.0 mgl^{-1} (EA 2016[1]). These data suggest there is a trend towards increased TP within BMP and show it to be well in excess of the 20 μgl^{-1} maximum expected for shallow mesotrophic lakes in favourable condition (JNCC 2015). It should be noted that the collection of water quality data by EA has been sporadic, with many years with partial of no data collected.

[1] Uses Environment Agency water quality data from the Water Quality Archive (Beta) available at: http://environment.data.gov.uk/water-quality/ .

Figure 12 Photo T, Burton Mill Pond Outflow

Site 8 Trout Pond Outflow SU9662017116

Following the restoration and sediment removal at Trout pond, the site had only recently refilled and had very clear, turquoise-blue water. The water level had reached its maximum and there was a good flow into Chingford Pond (Figure 13, photos U, V, W). An artificial bank is located about 5 m away from the pond on the north side, formed during sediment removal work (Figure 13 photo X). Trout Pond is surrounded by birch carr woodland to the west and alder woodland to the east. Pasture is located on the north shore, beyond the artificial bank. Nitrate levels were high (3.76 mgl^{-1}) and SRP concentrations moderate (13.5 μgl^{-1}).

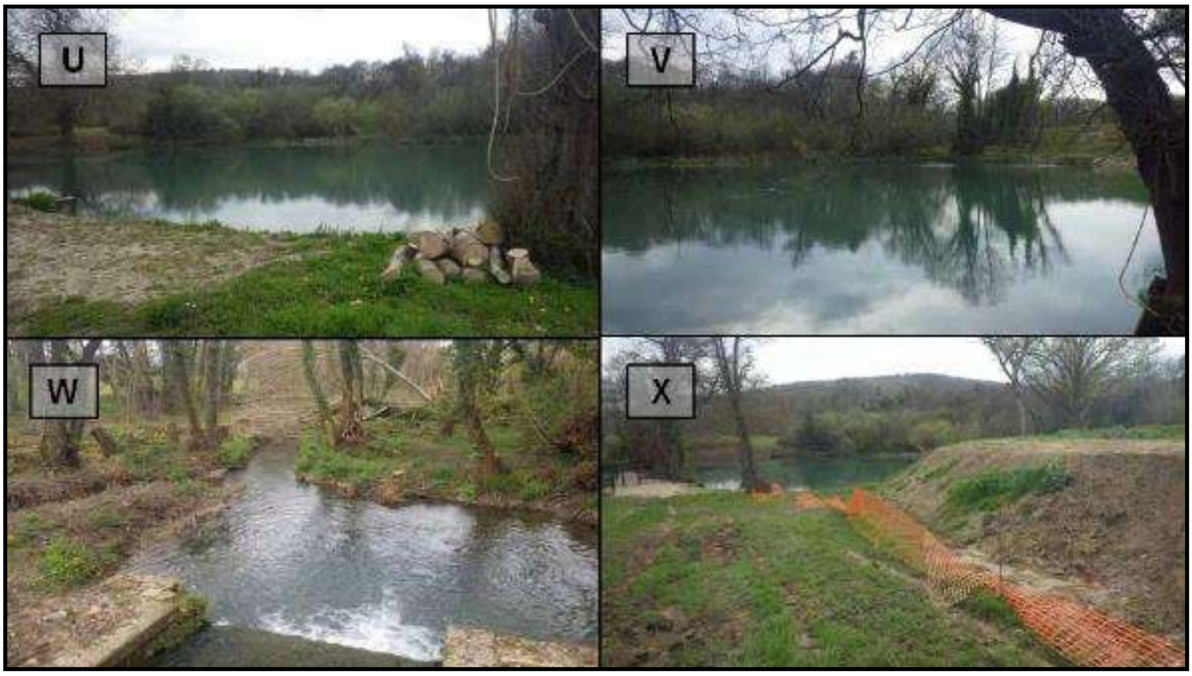

Figure 13 Photo U, V, W, X, Trout Pond Outflow

Site 9 (Stream at Duncton Mill Fishery Outflow SU9641316986

The stream had a good flow rate (Figure 14, photo Y). Water from the Duncton Mill Fishery Ponds flows into the stream via a pipe. It is unknown whether this is the only overflow from the trout farm or if there are further outflows to this stream or to the Duncton Mill Stream to the east. The water in the stream and outlet had a slightly milky appearance (Figure 14, photo Z). Total phosphorus concentrations were moderate (34.3 μgl^{-1}), while total nitrogen levels were high, at 4.36 mgl^{-1}, which is in line with the ground water supply.

As a commercial fishery, the inflow and outfall of the Duncton Mill ponds are subject to regular monitoring by the Environment Agency to ensure compliance for a range of water quality parameters. As part of this, nitrate, ammonia and SRP are monitored regularly (often monthly, but sometimes weekly) and the data available via the EA Open Government Licence[2]. These data show slight increases in the concentrations of SRP at the outfall, but mostly the difference is below detection limits. Total oxidised nitrogen is high in the system due to high ground water concentrations. Ammoniacal nitrogen increases in the ponds (to be expected from fish ponds), but concentrations are relatively low and diluted further on exit. Furthermore, oxidised nitrogen is overall lower on exit from the fishery.

The fishery appears to be managed at relatively low intensity and there is no evidence that is adds significantly to the phosphorus concentration within the catchment.

Figure 14 Photos Y and Z, Stream at Trout Farm outflow

Site 10 Barlavington Stream SU9691316074

This is a small, clear stream towards the top of the sub-catchment (Figure 15, photos AA, AB). It originates from a spring at Barlavington Hanger (SU9657915885), flows under the road and follows the lane towards Crouch Farm. Water chemistry analysis indicates very low SRP levels (2.5 μgl^{-1}), but very high nitrate concentrations (7.98 mgl^{-1}) from the background levels in the groundwater.

[2] Uses Environment Agency water quality data from the Water Quality Archive (Beta) available at: http://environment.data.gov.uk/water-quality/ .

Figure 15 Photos AA and AB, Barlavington Stream

Site 11 Duncton Mill Spring SU9635116491

This is a spring, originating from directly beneath a high bank (approximately 20 m) into the valley and pond above the Mill (Figure 16, photos AC and AD). The water was crystal clear, with low SRP levels (9.1 μgl^{-1}) and high nitrate concentration (4.04 mgl^{-1}). Interestingly, conductivity was measured to be the highest at this spring out of all the sites analysed in the catchment, measuring 524 μScm^{-1}, most likely as a result of localised weathering of the calcareous bedrock.

Figure 16 Photos AC and AD, Duncton Mill Spring

Site 12 Stream below Beechwood House SU9519916312

This is a wide stream (7 m) which is shallow and heavily shaded at the sample site (Figure 17, photos AE and AF) and has a number of small in-stream impoundments along its course. A gravel bed is present, with a good rate of flow and very clear water. The exact origin of the stream is unclear as the spring is not marked on OS maps and was on private land without access. SRP was low, but nitrate levels from the groundwater high, with measurements of 11.4 $\mu g l^{-1}$ and 4.39 $mg l^{-1}$ respectively.

Figure 17 Photos AE and AF, Stream below Beechwood House

Overview

Overall results from the walkover show the majority of the catchment to be well managed and we were unable to identify immediate threats to the freshwater environment from the agricultural land. The majority of the farm land within the catchment is within either Organic Entry Level plus Higher Level Stewardship (Crouch Farm) or Entry Level plus Higher Level Stewardship (Burton Park), and therefore best practice in terms of fertilizer and manure application should be observed. Furthermore, the extensive woodland and fen that occurs around most of the Burton Mill Pond shore provides good buffering from indirect agricultural inputs and will help to stabilize soils and prevent erosion and sediments entering the site.

Due to the rather unique location of BMP, lying as it does on acid sandstone geology, but with a mainly alkaline catchment, there is a wide range of natural variation in water quality. This is most marked by the difference seen between Black Hole Bog (Site 5), which had naturally acidic, brown water, compared to the crystal clear, alkaline waters of the upper catchment (e.g. site 11) (see Figure 18). The chemistry of BMP along with the observed drainage pattern within the catchment, is indicative of the lake receiving the majority of its water from the main inflow draining the South Downs chalk.

Figure 18 Water samples from four sites. From left: Burton Pond Outflow (7); Duncton Mill Spring (11); Burton Park Spring (1) and Black Hole Bog (5).

The total nitrogen concentrations in BMP are high and this is almost certainly as a result of the high concentrations of nitrate within the groundwater of the South Downs. To some extent elevated groundwater nitrate is natural, but the general pattern seen in nitrate levels is that they increase during the winter as the aquifers re-charge, suggesting that anthropogenic inputs (mainly from diffuse agricultural sources) remain a problem that reaches far beyond the BMP catchment. Although high background nitrogen levels are therefore beyond control at a catchment level, management of any additional nitrogen inputs within the catchment is therefore important; something that is addressed in part by agricultural stewardship schemes.

Groundwater phosphorus on the other hand is very low (see sites 10, 11 & 12 in Table 1) and therefore elevated concentrations of P within the lake and streams is catchment derived. Given that much of the catchment comprises of arable and improved grassland, moderate levels of diffuse phosphorous pollution may be expected. Again, the management of land with agricultural stewardship will help to limit inputs.

There is some evidence to suggest diffuse pollution is reaching the Black Pond sub-catchment to the north of Burton Park House. This warrants future monitoring of the higher reaches of this sub-catchment to determine if there are any land management or stock-yard issues that may result in higher nutrients in this area.

Elevated levels of phosphorus are more typically derived from domestic sources however, with wastewater being the primary source. In rural catchments, this can come from poorly managed or out-dated cesspits, or where any misconnections[3] occur. Throughout most of the catchment, phosphorus concentrations reflect typical lowland concentrations and, with the exception of the Burton Park stream and BMP, there was no immediate evidence of any point source inputs.

The chemistry of the ponds is of additional interest. The total P concentration in BMP was higher than that of Chingford Pond (38.8 μgl^{-1} and 25.7 μgl^{-1} respectively) and is above the limit for high quality mesotrophic lakes. Given that the majority of the water from BMP is coming from Chingford Pond there must also be additional sources of P entering the waters of the lower pond. Although it is possible that some phosphorous is released from the sediments in Burton Mill Pond, which would partially explain the increase, the addition of P from Burton Park Stream will also contribute. If this has occurred over many years, it is likely to have contributed to sediment P as well as being directly cycled through the lake. Hence, while it is unlikely that this alone has initiated the process of eutrophication at Burton Mill Pond there is a strong possibility it has contributed and the cause should therefore be investigated as a priority.

Sewage Treatment Works

Duncton STWs discharges treated liquid effluent within the catchment of BMP. Southern Water is obliged to ensure that the effluent meets the required standards for public health as well as suspended solids, ammonia and biochemical oxygen demand (BOD), but there is no requirement for removal of phosphorus from the system. SW provided phosphorus data from the treated effluent for 31st May 2016 showing TP at 9.76 mg/l and orthophosphate at 4.97 mg/l. SSSI standards require natural mesotrophic waters such as BMP to be below 0.02 mg/l and therefore the volume and quality of treated effluent is highly relevant to the site condition if these nutrients are reaching the pond. Where effluent is soaking into the ground, P often becomes chemically bound to soil particles and therefore does not directly impact surface waters in the short term. The extent to which soil has a capacity to permanently bind P is however limited and although the process is poorly understood, it is recognised that over time, P saturated soils can become a source of P instead of a sink (May *et al.* 2015).

The exact fate of the Duncton STW effluent could not be traced via surface flow, and the majority is thought likely therefore to enter the groundwater. There is evidence of surface water flow below the STW, approximately 200 m to the south, with a small drain / ditch running east, then southeast alongside Dye House Lane to the main catchment stream at SU9641516987 above Trout Pond. At time of sampling, this drain was wet, but not visibly flowing. Further investigation is required to establish the exact course and quality of the discharge (See final recommendations).

The Burton Park sewage treatment plant was installed in 1997 as part of the development of the main house for residential apartments. The plant operates with twin two-stage primary settlement tanks which gravity feed to a submerged aerated filter. Aeration is facilitated with compressed air over an inert media to ensure optimal treatment. Following aeration, the liquid components gravity feed into a final settlement tank and disperses into the outfall via the weir trough. The final settlement tank also incorporates a pumped sludge return system to periodically recycle accumulated sludge back into the primary settlement tanks. The sewage treatment plant is currently operating and performing within its consented volume and standards with data provided in October 2016 showing it to be well with the limits imposed for BOD and suspended solids. Similar to Duncton STW, the effluent discharged from Burton Park has phosphorus concentrations in the region of 10

[3] Misconnections refer to wastewater from e.g. washing machines, dishwashers, sinks, baths etc. that incorrectly drain into streams and rivers instead of the sewerage system.

mg/l[4] (as P). Discharged effluent outflows to the small surface ditch / drain at SU9702217603 which runs 190 m northeast to the boundary of the SSSI (unit 6 Snipe Bog) and onwards to Burton Mill Pond were it outflows at SU9756017696, just northeast of the old boathouse.

Data provided by Southern Water, Petworth Management Company and EA[5] show these STWs to be functioning as designed and that the release of effluent falls well within the legal compliance of their discharge licence for suspended solids and BOD and certainly in the case of Burton Park, volume of release.

The control of phosphorus from the STWs is more complex. Large STWs, serving populations over 10000 people (termed population equivalents) are required by law to remove P from effluent where it is released into sensitive environments where is may cause damage (eutrophication). Thus, most large STW's now undertake costly tertiary treatments to strip nutrients from the effluent prior to release. Smaller treatment plants fall outside this legal framework and are therefore governed mainly with the Water Resources Act (1991), from which the EA issue consents under Section 88.

In the case of the Burton Park STW, consent was granted as part of the planning process to discharge up to 45 m^3 of effluent daily, providing BOD is below 40 mgl^{-1} and suspended solids less than 60 mgl^{-1} (EA Consent No. P.66340L, 1996). In this respect the effluent is in full compliance. The consent also details the following:

As far as is reasonably practical the works shall be operated so as to prevent:

- *(a) any matter being present in the discharge, other than that matter specifically covered by numerical conditions in [the] consent, to such an extent as to cause the receiving waters, or any waters of which the receiving waters are a tributary, to be poisonous or injurious to fish in those waters, or as to the spawning grounds, spawn or food of fish in those waters, or otherwise cause damage to the ecology of those waters, and*
- *(b) the treated effluent from having any other adverse environmental impact.*

The fact that the Burton Park STW discharges high levels of phosphorus to a tributary of a SSSI that shows evidence of eutrophication (see below) gives rise to concern. The discharge is approximately 200 m from the SSSI boundary where SRP was 731 μgl^{-1}, and approximately 700 m (via ditch / stream) to Burton Mill Pond itself. The volume of effluent is not measured, but total water usage at Burton Park complex is in the region of 7000-7500 m^3 per year (Pers. comm., PMC) inclusive of water used within the gardens, for livestock and for irrigation (and therefore not processed by the STW). Based on a conservative estimate of 5000 m^3 per year of effluent, the Burton Park STW is discharging approximately 50 kg of phosphorous to the SSSI per year. Similarly, nitrogen, recorded only as ammoniacal N in the discharge data, is very high and given that this is only one fraction of the total nitrogen within the effluent (which is not measured here), it may be estimated well in excess of 200 kg of N per year comes from the STW.

While the STWs are demonstrated to be major sources of nutrients within the BMP catchment, additional monitoring is required to examine the full extent of the impact of both Duncton and Burton Park STWs on the nutrient loading to BMP. Comprehensive nutrient monitoring is recommended within the future Work Program (below).

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[4] The laboratory report requires further interpretation. It shows total P as 8.7 mg/l and orthophosphate as 9.7 mg/l. The latter is a fraction of TP and should therefore be a lower figure.

[5] Uses Environment Agency water quality data from the Water Quality Archive (Beta) available at: http://environment.data.gov.uk/water-quality/

2.2. Wetland Succession and Sediment Loadings

Aims and Methods

The extent of open water and associated wetland habitats (reed swamp and wet woodland) is best analysed using geographical information systems (GIS) to determine these changes from historic aerial photography. Previous analysis of historic maps (Atkins 2012) and sketch maps (NE 2014) were insufficient to provide the necessary detail to determine the extent of habitat change in the site. Although analysing new aerial data was outside of the original scope of this study, it became clear during the project, that more accurate information was required to inform the vision and future management. Aerial photography was acquired from 1956 (taken by RAF, 2 years after original SSSI designation) and compared using GIS to 2015 aerial images available online (Google Maps 2017).

The impact of sediment loadings was based initially on the catchment walkover observations and measurements of sediment loads. This is purely a snap-shot of time however, and one would expect the main external loadings to occur during the winter when vegetation cover is at its lowest and the ground more likely to be saturated. Other estimates of sediment accumulation were estimated from a 1 m long sediment core taken from BMP in 2013 which was subject to radiometric dating. This method used a detector to count the radioactive activity within different levels of the sediment core. These can be determined against known markers such as the peak of nuclear weapons testing (1963), the Chernobyl accident (1986), and natural rates of radioactive for naturally occurring isotopes of lead (^{210}Pb).

Wetland Encroachment

It is noted that within the 13.14 hectares of SSSI Unit 001 “Standing Open Water & Canals” also include that there are other wetland habitats that are themselves notifiable, which although present at the time of designation (1954, updated in 1986), were recorded simply within the open water feature (NE 2014).

In an effort to quantify the loss of extent from true open water to encroaching fen and alder carr, Natural England digitised the sketched habitat maps from 1982 and compared them to aerial photographs taken in 2012, at first this suggested the open water to have reduced from 6.46 ha (with 2.55 hectares of marginal vegetation, and 4.13 hectares of alder carr/woodland within unit 1) to 4.15 ha (with 2.53 ha marginal vegetation, and 6.46 hectares alder carr/wood). The apparent loss of extent of open water inevitably caused concern. The 1982 sketch map on which they are based and without the geo-referenced data associated with it provides considerable margin of error so figures are not accurate.

Looking to maps to assess change is also inconclusive. Ordnance Survey Maps from 1910’s show very similar areas of wetland to present day, roughly equating to 5.4 ha of open water compared to 2013 aerial photography which shows the extent of open water as approximately 4.37 ha. Given that the site has been subject to periodic, and at times quite extensive, reed cutting as well as silt removal in 1986 (Griffiths 2012), it is fair to concluded that the actual location of the reed-front is likely to have varied since the site was first designated as a SSSI in 1954. Similarly, anecdotal evidence, mapping and aerial photography show the extent of the wet woodland (mainly alder carr, a SSSI feature) to be extending towards the lake.

It is also clear from field observations that there has been some encroachment of the reed beds and alder carr at Burton Mill Pond over many decades. The conservation value of some of the resulting habitats are intrinsic to the site (see below) and as such require management and protection in their own right, as well as the need to maintain the extent of open water.

While there is no doubt that encroachment has occurred at BMP since designation, there has been considerable conjecture as to the rate and extent to which this has occurred. In the 2012 report compiled by Atkins (Atkins 2012), efforts were made to use historic OS maps and 2007 aerial photography to calculate the area of wetland expansion (1947 aerial photographs were accessed, but not used). Table 2-9 and the map on page 59 presented in the report, suggests there to have been 12.18 ha of open water in 1912 (we calculate 5.4 ha), and as much as 9.2 ha of open water in 1979. It appears that these figures have been calculated using the Ordnance Survey lake outlines, and ignores the wetland infill which is clearly marked on these maps. The apparent rapid decrease in open water between 1979 to 2007 is therefore calculated incorrectly. To then use these figures to extrapolate: a) the loss of catchment material to the ponds and b) the loss of all open water in Burton Mill Pond by 2026, was a fundamentally flawed methodology.

Encroachment is a natural part of succession in most wetland habitats. Within managed wetlands, such as Burton Mill Pond, there is a logic in determining a threshold level at which succession becomes detrimental to the site as a whole and thus management is required to either maintain an equilibrium, or, with robust evidence, even reset the natural process to a historic point in order to allow natural encroachment to start again without losing open water habitat. Determining where this threshold is, and when, and in what form management should take place, requires the application of sound ecological knowledge. Furthermore, in terms of management best practice, it is crucial to tackle external problems (particularly sediment load and nutrient pollution), before attempting large-scale works within the lake to address the problems, otherwise restoration will not be sustainable (Mainstone *et al.* 2016).

To this end, we were given permission to access hard copies of RAF aerial photography taken in 1956; two years after the SSSI designation of Burton Park (With kind permission of School of Global Studies, University of Sussex). The 1956 aerial image was scanned and geo-referenced using fixed markers (houses, the dam, roads), and the areas of open water, emergent vegetation and woodland digitised using GIS. These were then compared to the latest available (2013) aerial image from Getmapping PLC (see Figure 19).

Figure 20 below, shows the latest available (2013) aerial image, with an overlay of the areas that were open water in 1956, but are now wetland, and also the areas that were wetland in 1956, that are now occupied by wet woodland. The total area of open water in 1956 was 5.23 ha (±0.1 ha), compared to 4.37 ha (±0.1 ha) derived from 2013 aerial photography; a loss of 0.86 ha (approximately 16%).

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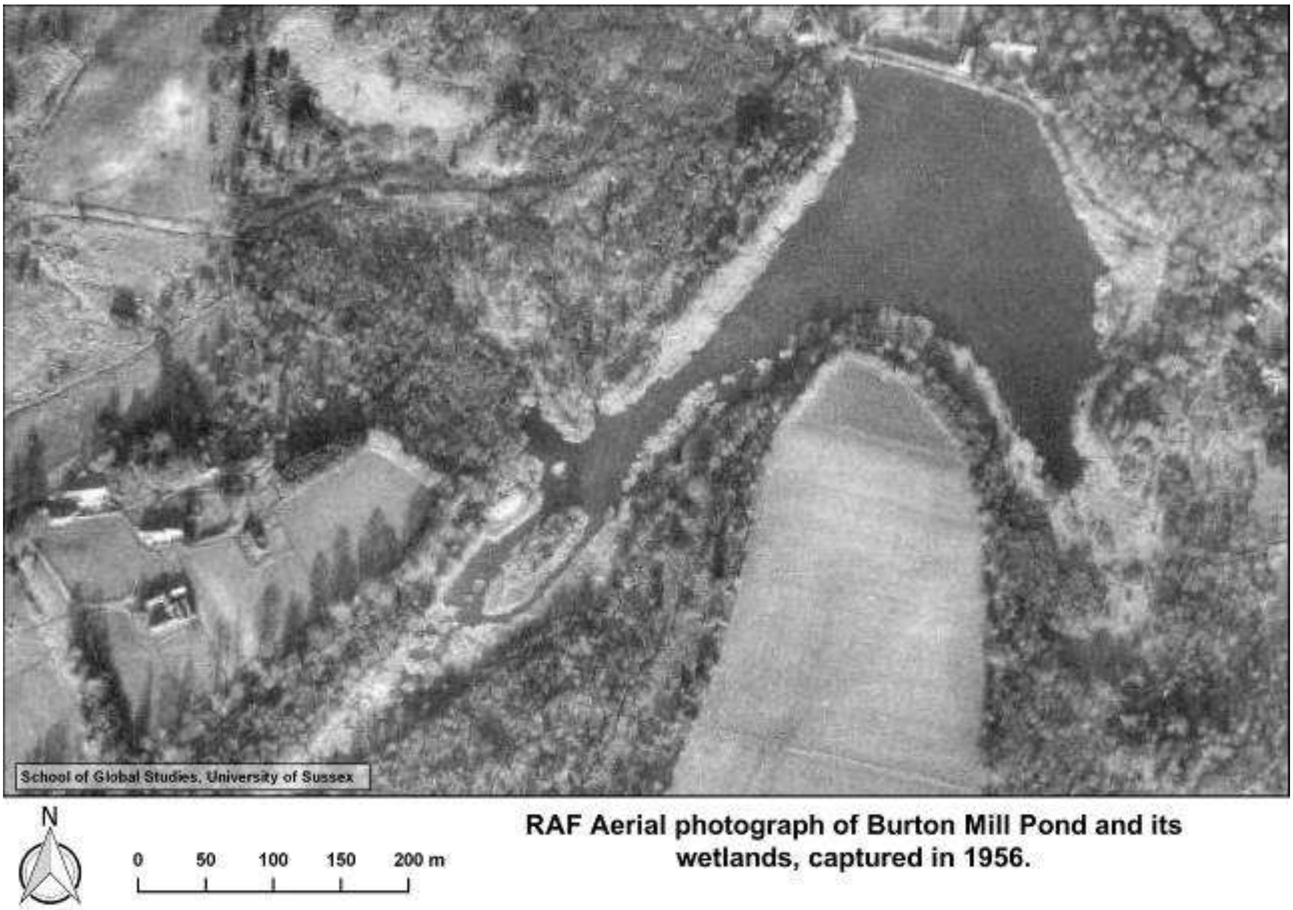

RAF Aerial photograph of Burton Mill Pond and its wetlands, captured in 1956.

Aerial photograph of Burton Mill Pond and its wetlands, captured in 2013.

Figure 19 Aerial photographs of Burton Mill Pond from 1956 (top) and 2013 (bottom).

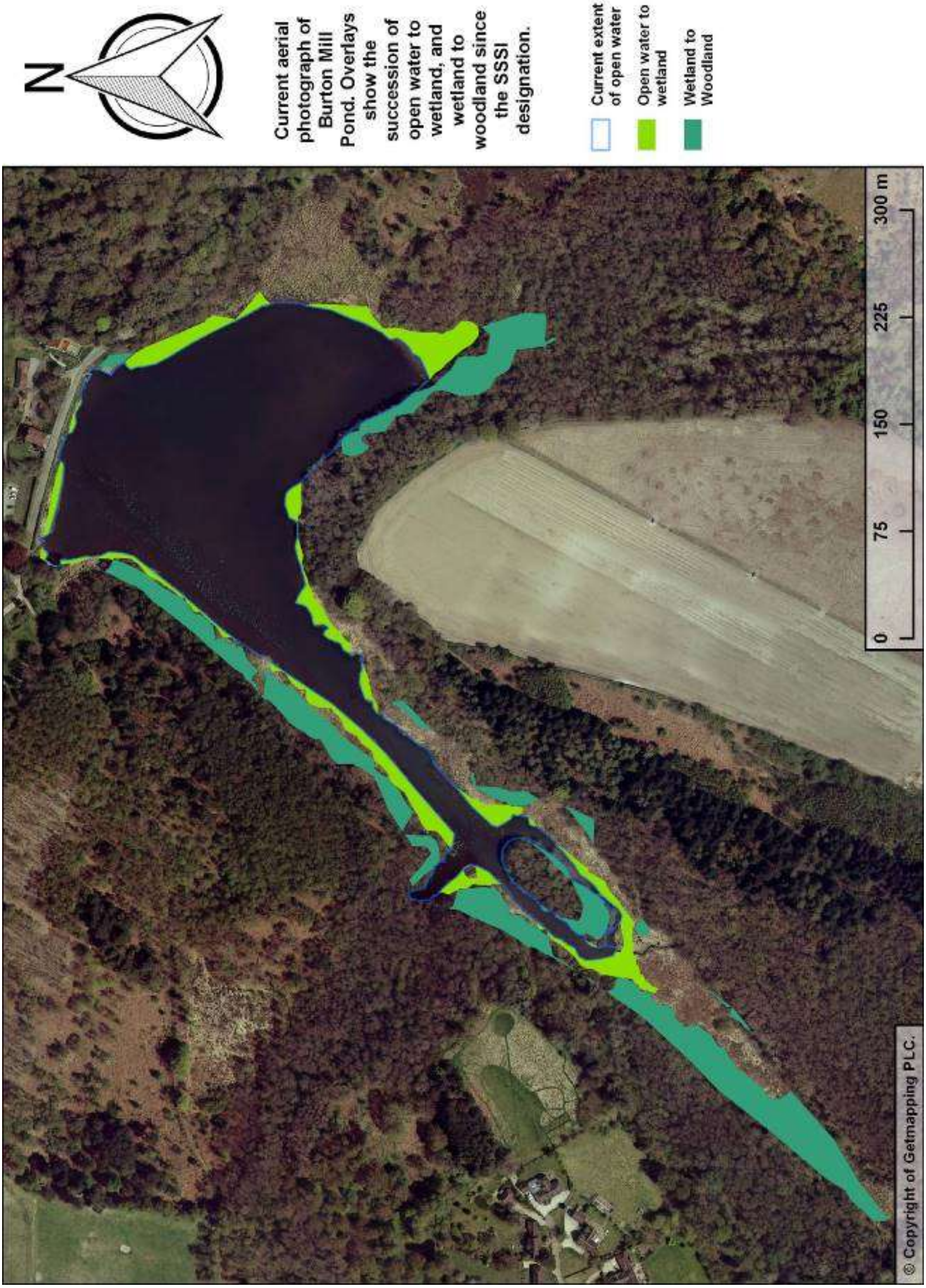

Figure 20 Aerial photograph taken in 2013, showing the extent of habitat change since 1956.

Table 2 Extent of habitat change at Burton Mill Pond: 1956 to 2013

Habitat	1956	2013	Area change	% change
Open water	5.23 ha	4.37 ha	- 0.86 ha	- 16.42
Reed-bed	3.53 ha	2.26 ha	- 1.27 ha	- 35.81
Wet woodland / scrub*			+ 1.40 ha	

* The total area of wet woodland is not calculated, only the change.

We can therefore conclude, that although BMP has lost some of its open water to the encroachment of reed-bed and wet woodland, the actual extent of loss is far lower than previous calculations suggest. What is clear from our data however, is that while the loss of open water has not been as dramatic as previously thought, the encroachment of the wet woodland and resultant loss of reed-bed habitat and open wetland habitat has been significant, with a 35% loss of wetlands and 1.4 ha increase in woodland and wet scrub (primarily willow, alder and birch) since 1956.

The encroaching woodland has two main impacts on the site.

1. It shades the landward edge of the common reed *Phragmites australis* and reedmace *Typha* spp. community causing it to be replaced by lower growing and more shade tolerant communities e.g. *Carex acutiformis* fen.
2. The shade causes the reeds to grow towards the light and hence conditions for reed growth are best at the water's edge, and so they are more likely to encroach on open water.

The rate at which the woodland has encroached on the site appears to be greater than the rate at which reeds are growing out into the open water. This is probably due to a combination of active reed management and a slower rate of growth at the open water face of the reeds. Future management will inevitably require reed cutting to continue (see below), but in order to prevent further loss of wetland, there will need to be a active management of the wet woodland and encroaching scrub around the site. Some of this management is ongoing, but as part of the management plan we recommend additional areas of cutting to ensure the integrity and overall area of reed-bed and open wetland habitat is maintained closer to the extent at designation. Furthermore, the impact of shading over reed-beds, has been demonstrated to adversely impact the survival Desmoulin's whorl snail *Vertigo moulinsiana* (see Section 2.5 below).

These data provide clear evidence that will be used to inform the location and extent of management required at the site to maintain it relative to its SSSI designation and historic baselines.

Sediment load

Sediment loads measured within the inflow streams were generally low. There was some turbidity in the Burton Park Stream (Site 2), but the stream was clear after passing through the wetland below this point.

Agricultural land, particularly arable fields, has the potential to produce elevated sediment loads after cultivation and during wet weather. Within the BMP catchment, the majority of run-off will be focussed towards the main inflow which runs first into Trout Pond and then Chingford Pond, before reaching BMP. This stream is well buffered from agricultural land by woodland throughout most of its course and although there are points where heavy run-off can access the stream (e.g. at the bridge at Dye House Lane), generally the risk of high sediment loads reaching the stream is considered to be low. Furthermore, any silt laden waters flowing towards BMP from the main stream, are likely to lose the majority of their sediment load in Trout and Chingford Ponds before the water passes on to BMP, further lowering the risk of high sediment loadings from this part of the catchment.

Where livestock poaching was observed, it was relatively minor, or managed by restricting the passage of cows to paths with electric fencing.

The smaller catchment, flowing directly to the south-eastern arm of BMP has the potential to carry sediments directly to the lake during high flow. This will be alleviated somewhat by the passage of the stream through the woodland and reed-beds, but has the potential to carry significant sediment loads into the lake at periods of very high flow. The fields north-east of Crouch Farm slope directly towards the lake, and although currently laid to grass, have in the past been cultivated, increasing their potential as a source of silt to the lake.

It is recommended that sediment loads are monitored during a high flow event to ascertain the potential impact of external sediment loading to the site and to identify if there are any high-risk areas where better management may be implemented to reduce the impact.

Siltation

The extent to which siltation has impacted the site is complicated by the history of the Chingford Dam and subsequent lake management. It is thought likely that there were significant deposits of sediments during the breaching of the Chingford Pond dam in 1983, with the observation of subsequent erosion of sandy deposits from the dam being washed into BMP (Griffiths 2012). Concerns about this siltation led to the dredging and marginal vegetation clearance of BMP. Details of the exact location of the dredging are not available, but Griffiths (2012) certainly details work being undertaken along the western arm and around the island where the majority of courser material from Chingford dam was deposited.

To what extent the overall sediment distribution and depth changed as a result of Chingford dam removal and subsequent dredging, is poorly documented. Certainly the concerns were not only about the mineral sediments, but also the build-up of organic material, assumed to be derived mainly from within the lake and its surrounding wetlands and woodland. It is thought likely therefore that mud pumping would have been conducted within the main basin as well as the western arm, limited primarily by the volume of mud that could be contained in the disposal areas on the farmland to the south of the site.

As a result of the dredging, evidence from the sediment core is somewhat compromised. In undisturbed lake sediments, it is normally possible to obtain a chronology based on the natural radioactive decay of the lead isotope ^{210}Pb. Where the upper sediments have been disturbed or removed, this signal is absent or confused and, as in the case of the core taken in 2013, cannot be used to age a sediment core. In addition to ^{210}Pb however, there are other markers that can be quantified and used to date specific parts of a sediment core.

The onset of nuclear weapons testing in the 1950's, mainly in the Pacific region, resulted in a rapid increase in the radio-active isotope of caesium ^{137}Cs within the upper atmosphere. Testing reached a peak in 1963, shortly before being internationally banned by the Non-Proliferation Treaty in 1968. Thus, atmospheric concentrations and deposition of ^{137}Cs also peaked in 1963, and this signal is often well preserved within lake sediments and can be measured. The activity of ^{137}Cs within the BMP core (BURTb 2013) are shown in Figure 21 and suggest that in this core the deposits from 23.5 cm below the sediment surface date back to 1963. Thus, 23.5 cm of sediments have been laid down in 50 years which under natural conditions would imply a sedimentation rate of approximately 0.5 cm per year.

What we do not know however, is how much sediment was removed from the coring location during the dredging work in 1985. The ^{137}Cs curve in Figure 21 is very similar to the natural signal from other lakes until the upper 15 cm, after which it becomes variable, where normally it would continue to fall. This is indicative of sediment mixing and consistent with the knowledge that the site was dredged and hence highly disturbed in the upper sediments. Despite having a dated point within the core, we cannot derive an accurate sedimentation rate. It is however possible to offer a range of accumulation rates based on the limited evidence we do have.

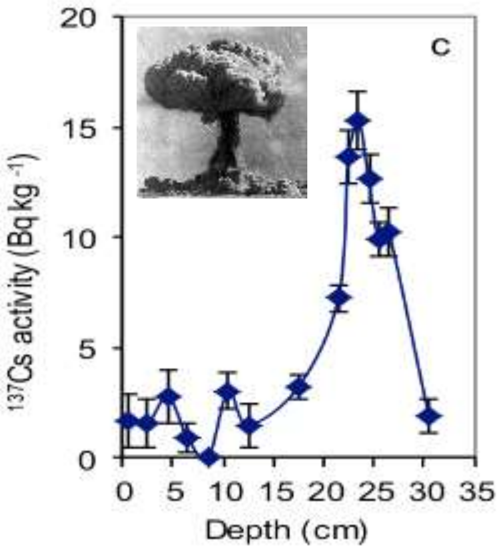

Figure 21 Rate of decay of ^{137}Cs in the BURTb sediment core taken in 2013

Given that the ^{137}Cs peak appears to be intact, it is reasonable to suggest that the maximum accumulation rate is 23 cm since 1985, a rate of 0.77 cm per year (equating to 0.132 g cm^{-2} yr^{-1}). Estimates based on the shape of the ^{137}Cs curve being undisturbed below approximately 15 cm would place the accumulation rate in the region of 0.5 cm per year. Accumulation rates in the region 0.5 – 1.0 cm per year are consistent with shallow, productive lowland lakes in the UK (Rose *et al.* 2011).

Conservative estimates of 0.77 cm of sediment accumulation per year, suggest that Burton Mill Pond has many years to go before losing its open water altogether. This is not to ignore the fact that as sites become shallower and the wetlands encroach, the rate at which they infill increases, from both siltation and succession. Nonetheless, if management focuses on limiting the encroachment of the reeds, there is no evidence to suggest the site is at any risk of losing open water to sediment accumulation within the next 50 years.

Again, we stress here the need to address external problems, particularly nutrients, before resorting to major within-lake restoration measure such as sediment removal. External nutrient inputs drive the productivity of the lake and pose a major threat to ecological function. Current water depths within the open water are mostly between 1.0 -2.0 m and provide adequate depth for aquatic plants to grow throughout the main basin. Figure 22 shows the measured water depths taken in June 2016.

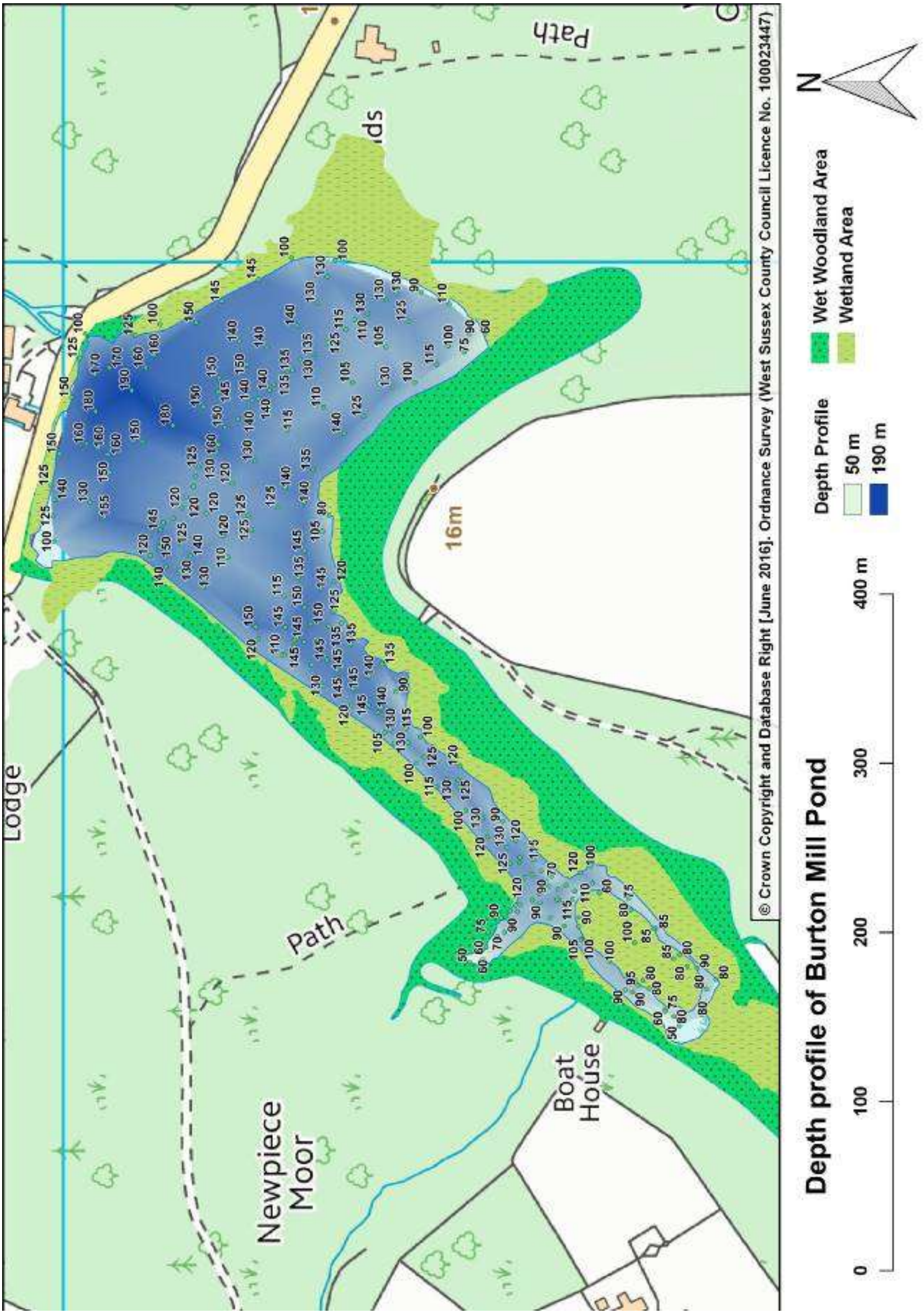

Figure 22 Map of Burton Mill Pond showing water depths as measured in June 2016

2.3. Aquatic vegetation survey

Aims

In order to determine the current status of the SSSI feature it is necessary to collect structured and repeatable data of the aquatic plant community. Additionally, the collection of good baseline data of the aquatic species and habitats, is essential for informing future management and assessments of the site. The methods used to achieve this are two-fold: SSSI monitoring in undertaken using the UK standard methods and protocols for standing water SAC and SSSI sites (JNCC 2015), whereas baseline data collection requires a more comprehensive survey of the site involving multiple point surveys at geo-referenced locations.

Common Standards Monitoring 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 surveys consisted 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 1.0 m and a boat survey encompassing species in open water and extending to the point of maximum colonisation. 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 2003, and resurveyed in 2007, 2010, 2013 (by ENSIS on behalf of EA). The 100 m 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 drift 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.

Vegetation Mapping Methods

In addition to using Common Standard Monitoring methods, whole site data were also collected for aquatic macrophytes. Data were collected using similar survey techniques (double-headed rake and bathyscope) as described above, but sample locations were chosen to ensure representative data were collected from the entire site. In Burton Mill Pond, where vegetation grows throughout the site, this involved multiple transects to gain maximum coverage the lake. A total of 218 points were sampled (Figure 23).

All sample points were recorded using hand-held GPS and macrophyte plant species recorded onto a geo-reference, gridded lake outline. Species abundance was recorded on a 1-5 scale where: 1 = <2.5% cover (or one or two small individual), 2 = 2.5-10% cover (a few isolated individuals or small patch), 3 = 10-25% cover (several larger individuals, or a few patches), 4 = 25-50% cover (very obvious with many small individuals or substantial larger plans, but not dominant) and 5 = >50% cover (dominant). The scores were in most parts decided by a combination of visual assessment (bathyscope) and rake sampling.

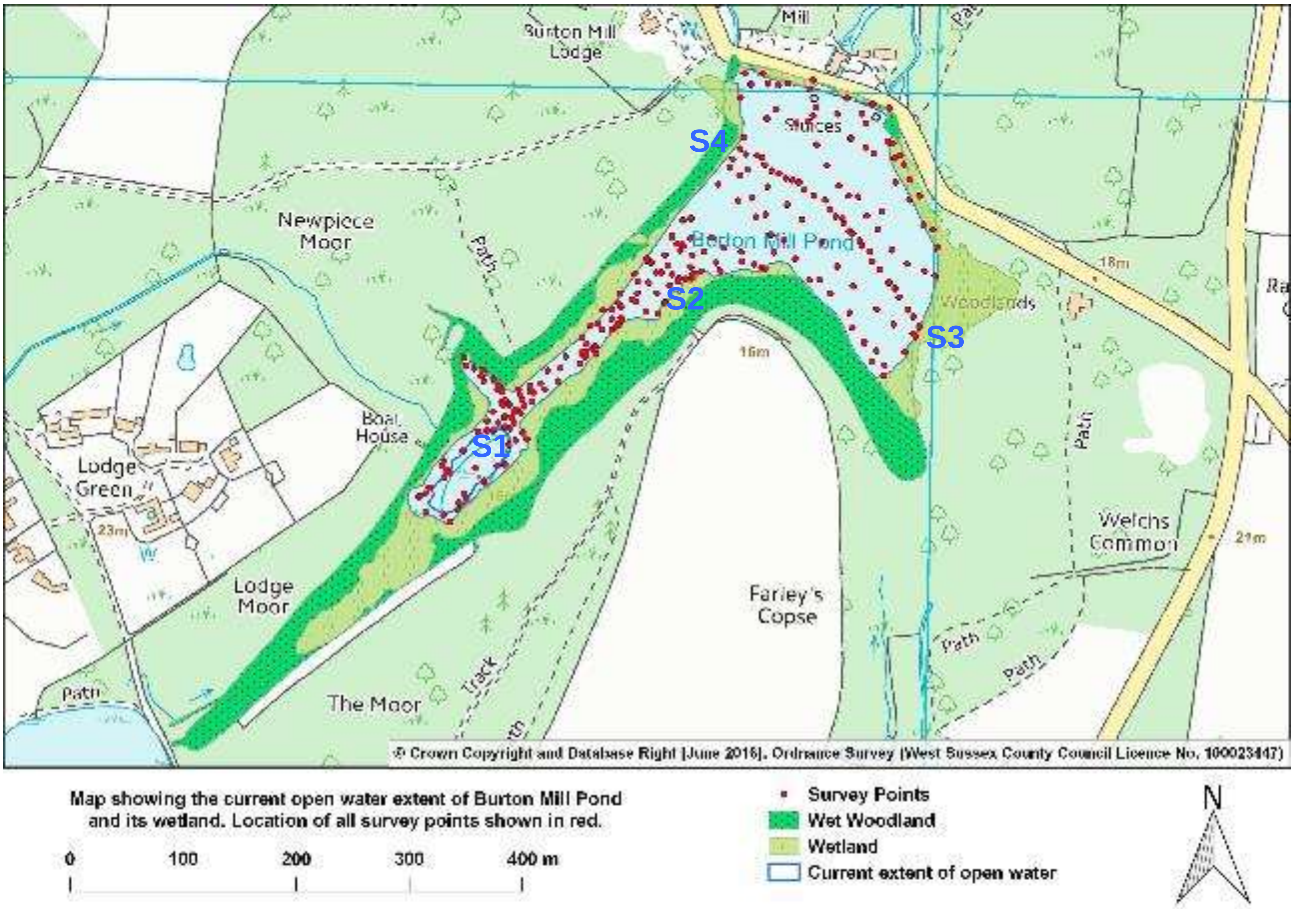

Figure 23 Map of Burton Mill Pond showing macrophyte survey points

The patchy nature of aquatic plant distributions within the site, means that no assumption should be made that any one species is growing between two or more points where it is recorded. The use of modelled species layers is not therefore appropriate and data are instead presented as geo-referenced abundance points within the lake outline map.

Species identifications were made on site, where possible, by Ben Goldsmith and Stefania Goodrich. One species of stonewort was found and the species identification confirmed by Nick Stewart (BSBI Charophyte Referee and expert on aquatic botany). Botanical nomenclature follows Stace (1997) for higher plants and Moore (1986) for Stoneworts (updated by N. Stewart, pers. comm.).

Results - Common Standards Monitoring and SSSI Condition

The location of the survey transect locations are marked in blue on Figure 23 (S1, S2, S3, S4) and the 10 figure grid references for start and end points in Table 3. 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 3 CSM survey point locations

	Wader survey		Open water survey	
Section	**Start point**	**End point**	**Shore End**	**Outward End**
Section 1	SU9761717668	SU9758817678	SU9762017707	SU9771417806
Section 2	SU9775217805	SU9781417848	SU9777217840	SU9777517868
Section 3	SU9794617765	SU9800317854	SU9799317808	SU9793417848
Section 4	SU9781117930	SU9783518000	SU9783217962	SU9785917967

Table 4 CSM macrophyte data from Burton Mill Pond 2003 - 2016

Submerged and floating vegetation	15/09/2003 % Frequency (n=110)*	10/08/2005 % Frequency (n=110)*	19/08/2010 % Frequency (n=113)*	13/07/2013 % Frequency (n=102)*	30/06/2016 % Frequency (n=127)*
Ceratophyllum demersum	1	-	5	-	2
Callitriche cf. platycarpa	**11**	**7**	**-**	**-**	**-**
Chara globularis	**1**	**1**	**-**	**-**	**1**
Chara vulgaris	**1**	**-**	**1**	**-**	**-**
Elodea canadensis	23	8	19	6	7
Hydrocharis morsus-ranae	**+**	**3**	**5**	**2**	**5**
Lemna minor	43	47	42	10	35
Lemna minuta	-	-	-	-	17
Myriophyllum spicatum	4	-	-	-	-
Nuphar lutea	34	39	47	47	37
Nymphaea alba	2	1	3	2	5
Potamogeton berchtoldii	-	9	4	7	7
Potamogeton crispus	**1**	**2**	**5**	**-**	**2**
Potamogeton lucens	**57**	**53**	**65**	**45**	**54**
Potamogeton pectinatus	9	29	19	19	25
Potamogeton perfoliatus	**2**	**1**	**4**	**3**	**1**
Potamogeton trichoides	16	11	4	5	4
Ranunculus aquatilis agg.	-	-	-	-	2
Ranunculus circinatus	**16**	**8**	**4**	**11**	**9**
Sagittaria sagittifolia	1	3	11	7	10
Zannichellia palustris	-	-	2	-	1

* 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, and in blue, of mesotrophic lakes. Non-native species are in pink.

Ensis has conducted five surveys at BMP since 2003, all using the same sample transects, thus allowing comparisons to be made over the past 13 years. In terms of overall frequency, the site appears to have remained relatively stable (Figure 24). Shining pondweed *Potamogeton lucens* and Yellow water lily *Nuphar lutea* have remained surprisingly stable, and a high cover of lily leaves results in good habitat from Common duckweed *Lemna minor*[6]. Fennel-leaved pondweed *Potamogeton pectinatus* has increased since 2003, but remained relatively stable since 2005. Some of the less frequent species have not been recorded in all survey years (e.g. *Ceratophyllum demersum, Myriophyllum spicatum, Chara* spp., *Callitriche* sp.), but overall the site shows remarkably little variation over the past thirteen years.

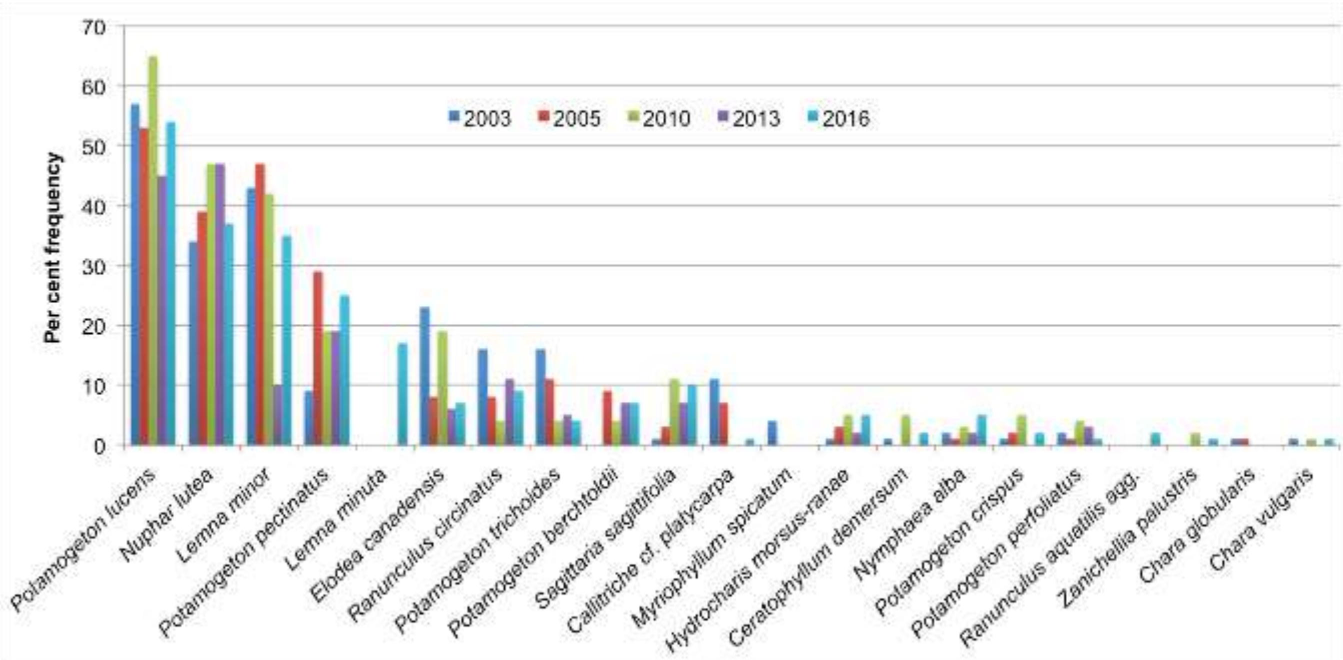

Figure 24 Comparative macrophyte frequency in Burton Mill Pond 2003 - 2016

SSSI condition

Of the 18 aquatic species recorded in 2016, only one (*Potamogeton perfoliatus*) is considered to be characteristic of mesotrophic lakes and this was only recorded at one location in the CSM survey. A total of six characteristic eutrophic species were recorded (see Table 4) and at least one of these was present in 65% of the 127 survey points.

Within the Burton Park SSSI, Burton Mill Pond needs to consider the local geography and site history, which has a bearing on the site character, and in the case of artificial water-bodies like BMP falls outside of the typical structural expectations of a mesotrophic lake as defined by Mainstone *et al.* (2016). The extensive wetland margins for example, are a key attribute within the SSSI, are more typical of natural eutrophic lakes than mesotrophic sites, and these habitats are long established in the site.

While there is a lack of any reliable baseline data for aquatic macrophytes in BMP, palaeoecological data from this study (Section 2.4), show the lake to have once (>100 years ago) supported significant populations of the more typically mesotrophic *Nitella* spp.,

[6] It is worth noting that these data are based on presence / absence only, and do not capture abundance; thus the similar frequency of *L. minor* to the other common species greatly over-estimates its actual biomass in the site.

but this was alongside rigid hornwort *Ceratophyllum demersum,* a species most common in eutrophic waters. The artificial construction and somewhat unusual geology of the catchment (which crosses both alkaline chalk and acid sandstones) makes the site rather unique and difficult to categorise in terms of its expected vegetation assemblage under un-impacted conditions.

The extent to which the flora has changed since designation in 1954 (revised in 1986 (NE 1986)) is also unclear. The SSSI reads as follows

> "*The open water of Mill Pond is dominated by yellow water-lily Nuphar lutea with abundant spiked water milfoil Myriophyllum spicatum and some uncommon species of pondweed including fennel pondweed Potamogeton pectinatus, perfoliate pondweed P. perfoliatus and hair-like pondweed P. trichoides.*"

There is no mention of rigid hornwort *C. demersum* or shining pondweed *P. lucens,* yet we know both species to have been present in the site in the past and the latter to have dominated the open water since before 2003 (author surveys). Exactly when *P. lucens* colonised the site is unknown; there are records of it growing in BMP as early 1907 (Arnold 1907) and it is clearly visible in pictures of the site taken in 1982 (Griffiths 2012). The absence of these two very easily identifiable and visible species in the SSSI citation (NE 1986) suggests they must have been rare or absent from the site at time of designation.

The following table (Table 5) summarises the main features used to assess condition as detailed in the Common Standards Monitoring guidance for freshwater lakes (JNCC 2015). Where the assessment uses different targets for mesotrophic and eutrophic condition targets, these are shaded blue and green respectively.

Table 5 Favourable condition assessment based on 2016 survey data and EA monthly outflow chemistry (EA 2017).

Attribute	Target	Status	Comment
Extent	No loss of extent of standing water	X	Some encroachment of reeds and Alder carr is on-going and requires control. Approximately 16% of open water has been lost since 1956.
Macrophyte community composition	***Mesotrophic target***: at least 8 characteristic species present.	X	1 present: *P. perfoliatus*
	≥ 6/10 sample spots (boat & wader survey) have ≥ 1 characteristic species	X	< 1 %
	No loss of characteristic species	X	Historical loss of significant *Nitella* sp. population – evidenced from macrofossil records
Macrophyte community composition	***Eutrophic target***: at least 6 characteristic species, including 1 broad-leaved *Potamogeton* spp.	✓	6 present including two broadleaved *Potamogeton spp.: Chara globularis, Hydrocharis morsus-ranae, P. crispus, P. lucens, P. perfoliatus & Ranunculus circinatus.*
	≥ 6/10 sample spots (boat & wader survey) have ≥ 1 characteristic species	✓	65%
	No loss of characteristic species	✓	*Callitriche* not recoded, but present within the inflow streams

Attribute	Target	Status	Comment
Negative indicator species	Non-native species absent or present at low frequency	**X?**	*Elodea canadensis* 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.	✓	Extensive, species-rich reed bed and emergent vegetation surrounds much of the lake (including *C. virosa*). The lake had clear water and high aquatic plant biomass throughout to 1.7m, dominated by *P. lucens* and *N. lutea* interspersed with a species-rich mosaic of submerged and floating-leaved species. Remains similar since 2003
	Maximum depth distribution should be maintained	✓	Z_{max} (recorded) = 1.9 m, Z_s > 1.9 m. Plants growing to Z_{max}
	At least the present structure should be maintained	**✓?**	Hydrosere present with evidence of encroachment. Careful management of this marginal feature required.
Water quality	***Mesotrophic target***: Stable nutrient levels: TP target / limit = 20 µgl^{-1}	**X**	TP = 84 µgl^{-1} (EA Oct 15 – Sept 16. Range 25 – 246 µgl^{-1})
	Stable pH values: pH ~ 6.5 – 8.0	✓	pH = 7.96 (EA Oct 15 – Sept 16. Range 7.65 – 8.26)
Water quality	***Eutrophic target***: Stable nutrients levels: TP target / limit = 50 µgl^{-1}	**X**	TP = 84 µgl^{-1} (EA Oct 15 – Sept 16. Range 25 – 246 µgl^{-1})
	Stable pH values: pH ~ 7.0 – <9.0	✓	pH = 7.96 (EA Oct 15 – Sept 16. Range 7.65 – 8.26)
	Mean annual total nitrogen TN < 1.5 mgl^{-1}	**X**	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 throughout the water column. DO = 11.24 mgl^{-1} at 1.5 m
	No excessive growth of cyanobacteria or green algae	✓	No excessive algal growth reported.
Hydrology	Natural hydrological regime	**X?**	Artificial water body subject to up-stream changes to Chingford Pond. Hydrology is well managed, but not natural.
Lake substrate	Natural shoreline maintained	✓	Majority of shoreline comprises of emergent wetland and wet woodland.
	Natural and characteristic substrate maintained	**?**	Sediments are relatively organic, which although typical, there is evidence to suggest organic matter has increased over time – indicative of eutrophication.

Attribute	Target	Status	Comment
Sediment load	Natural sediment load maintained	**?**	Breach of the Chingford dam (1983) caused a reported increase in sediment load. Site partially dredged 1985. There is no evidence of any adverse sediment loading impacting the site today.
Connectivity	Maintain good connectivity with ground and surface waters and marginal habitats	✓	Extensive wetlands with well establish hydrosere present. Provision for up & down-stream eel passage is adequate
Indicators of local distinctive-ness	Distinctive elements maintained	✓	A number of rare species occur in the site. 2016 surveys show the Cowbane *Cicuta virosa* population is stable. Populations of Desmoulin's whorl snail *Vertigo moulinsiana* are also good. This is an important site for both species. The plant dominated, clear water is excellent habitat for invertebrates, including dragonfly and damselfly species and beetles. Additional survey recommended to assess.

The previous condition assessments undertaken by NE, placed the site in unfavourable condition due primarily to the perceived loss of open water (extent). While encroachment of the wetlands is undoubtedly an on-going issue that requires management, the estimated loss of extent is not as high as originally estimated from the SSSI sketch maps (see NE 2014). The wetland habitats therefore require sensitive management to ensure the balance of designated and valued habitats is maintained throughout the SSSI and LNR. This requires addressing via an informed and structured programme of management work (See Work Programme). Similarly, there is no evidence to support the claims that siltation will result in the complete loss of open water by 2026 (Atkins 2012). Catchment management should nonetheless continue to exercise good practice to minimise erosion and sediment loads to surface waters, and this will be further helped to the south of the site by the deepening of Trout Pond and raising of the water level in Chingford Pond, both of which will act as silt traps and reduce inputs to BMP.

Based on the available evidence, the primary concern at BMP is eutrophication. High concentrations of total nitrogen (TN) and an increase in mean annual total phosphorus have been recorded in the site. Environment Agency data show the 2003-4 and 2008-9 mean values for TP as 43 and 59 μgl^{-1} respectively (Burgess & Goldsmith 2012), with the most recent data for 2015-16 giving a mean annual TP of 84 μgl^{-1} (EA 2017). 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. High nutrients are also likely to be fuelling the growth of the marginal wetlands and therefore exacerbating the problem of encroachment at the site.

To conclude, by using the Common Standards Monitoring for eutrophic open waters for Burton Mill Pond the macrophyte assemblage feature is considered in favourable condition but is in unfavourable condition due to poor water quality i.e. excessive TP and TN. This should not however detract from what is currently an excellent aquatic plant community. Current mean annual concentrations of TN are double the recommend upper limit for freshwater lakes and TP has doubled in the site since 2004. This trend is of extreme concern and its reversal should be key to any future management plan.

Vegetation Mapping

In addition to the CSM survey, the full extent of the aquatic macrophyte flora is presented below. The data provide an important baseline from which any future assessment and management work can take guidance. The maps presented below are for all aquatic species encountered in the site, with the final map showing the location and abundance of Cowbane *Cicuta virosa*.

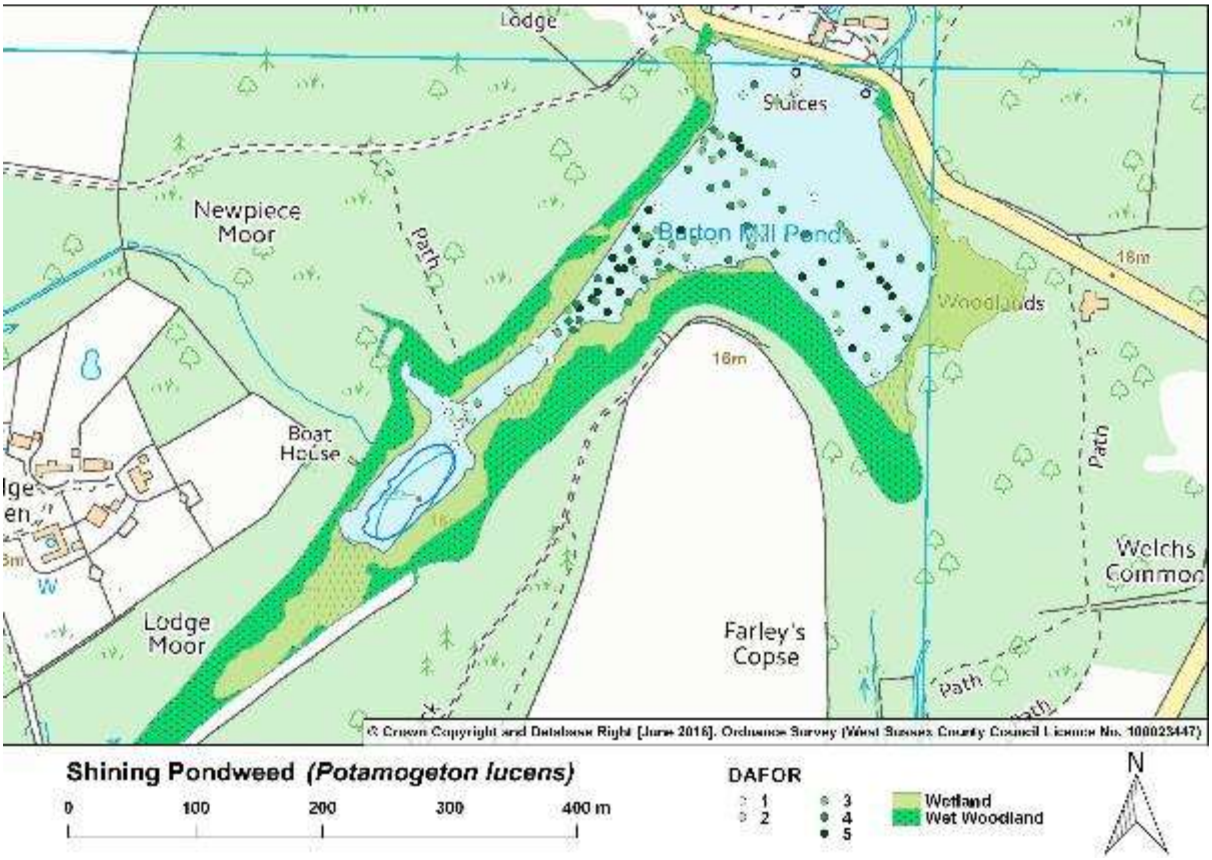

Figure 25 The extent and abundance of *Potamogeton lucens* in BMP (June 2016)

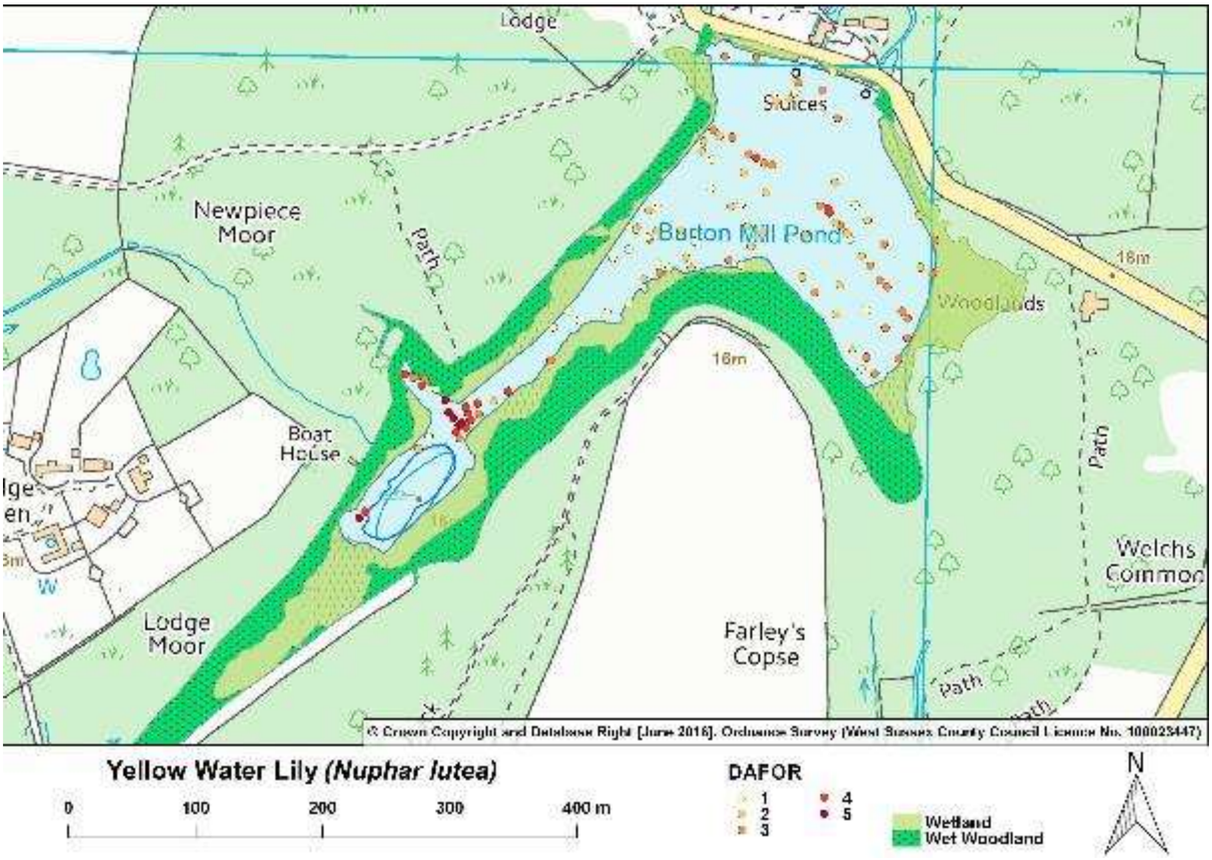

Figure 26 The extent and abundance of *Nuphar lutea* in BMP (June 2016)

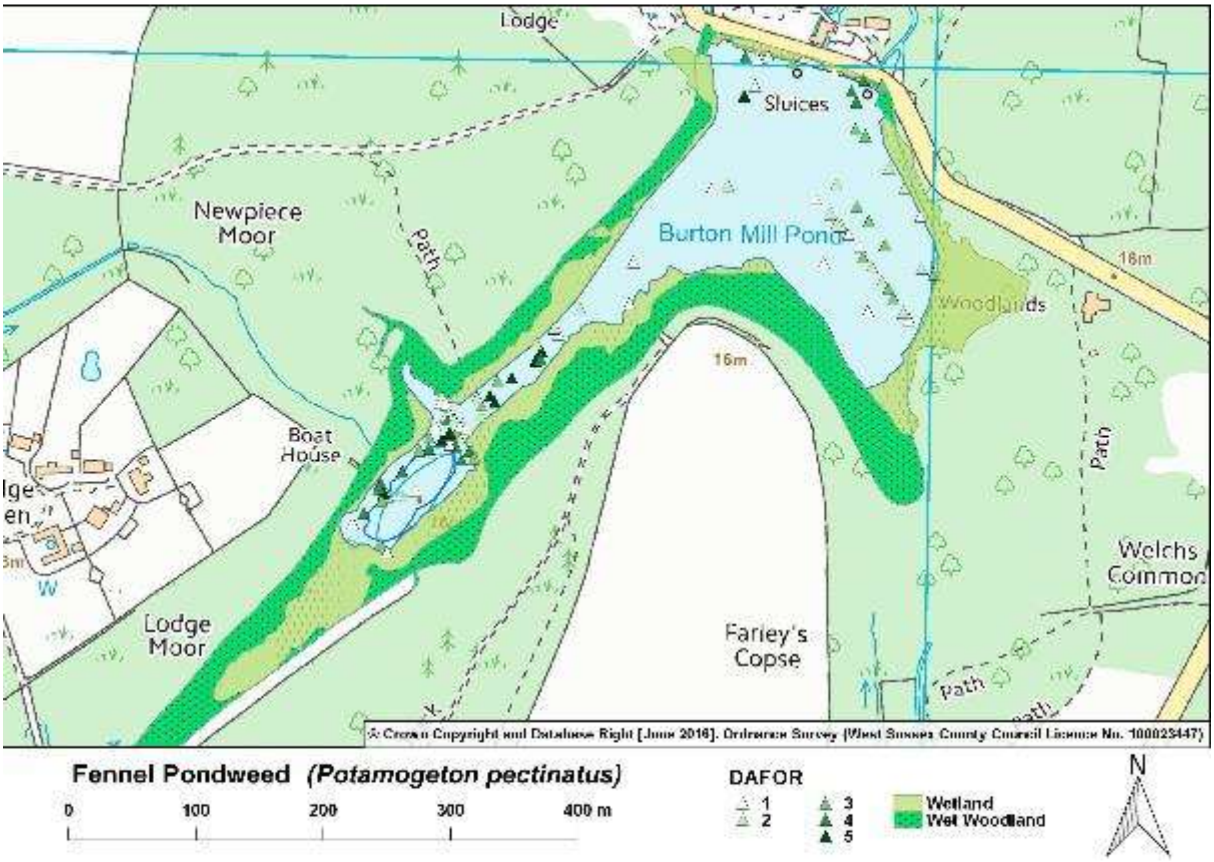

Figure 27 The extent and abundance of *Potamogeton pectinatus* in BMP (June 2016)

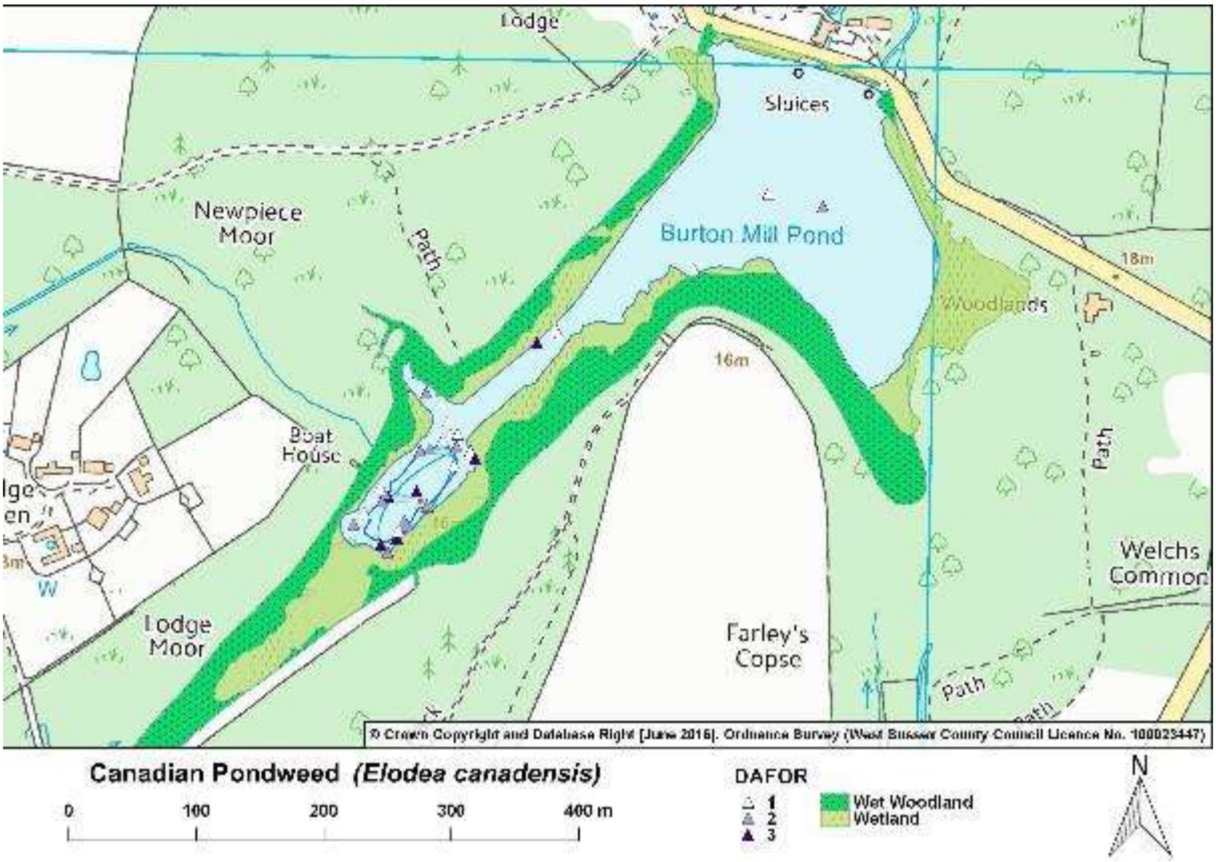

Figure 28 The extent and abundance of *Elodea canadensis* in BMP (June 2016)

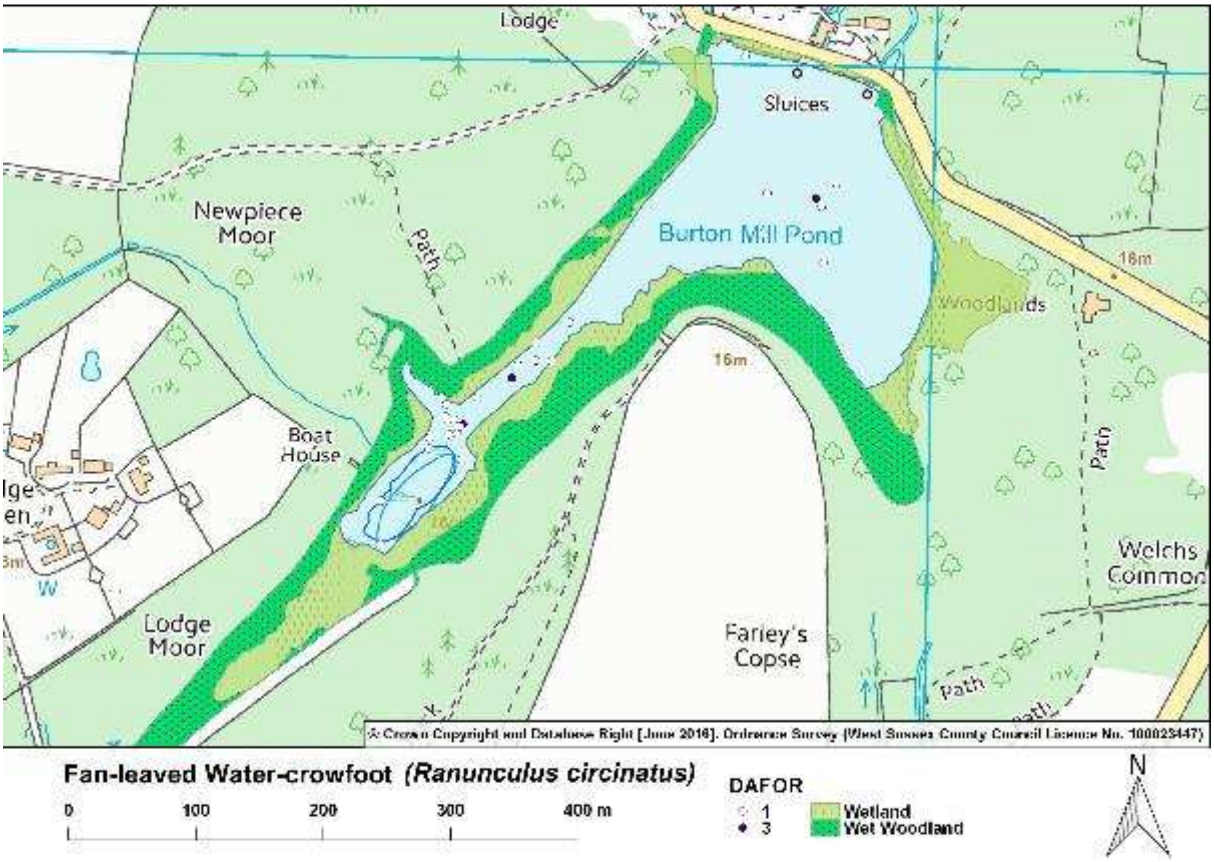

Figure 29 The extent and abundance of *Ranunculus circinatus* in BMP (June 2016)

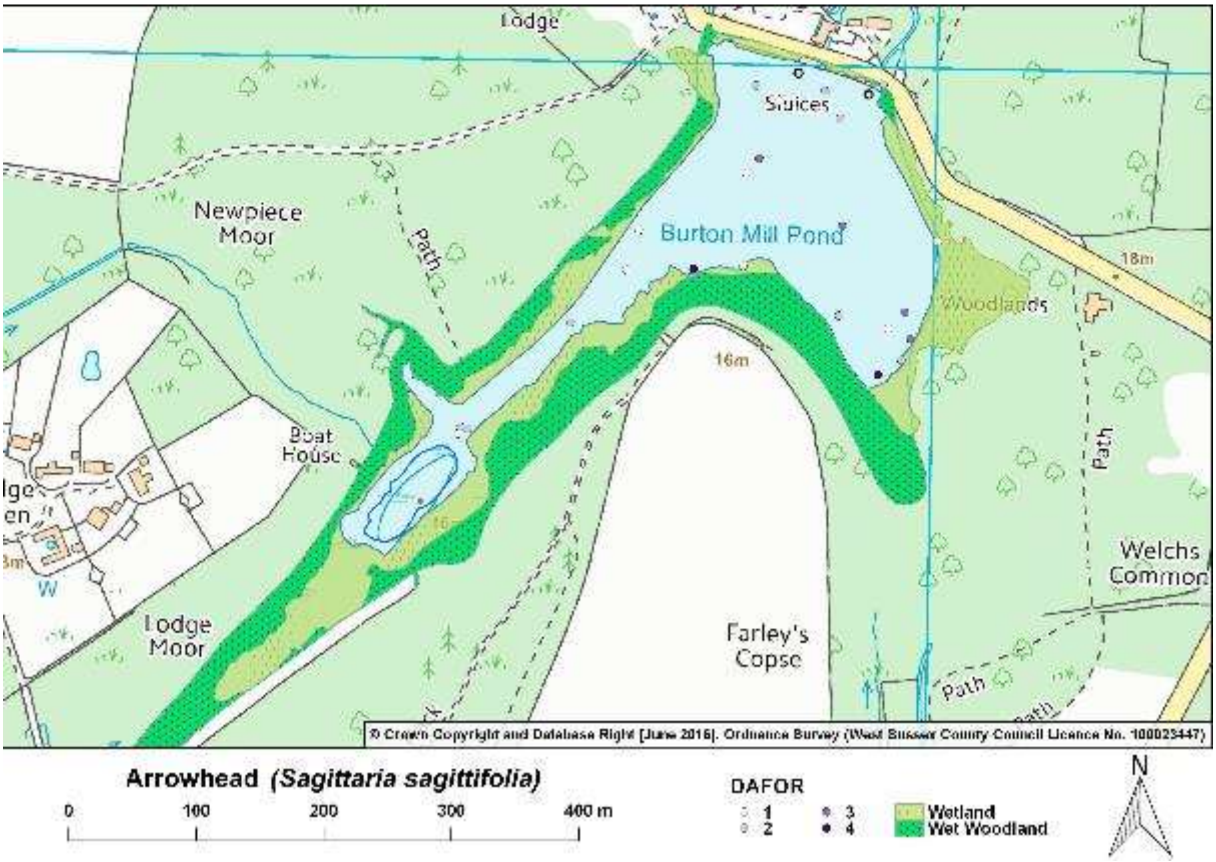

Figure 30 The extent and abundance of *Sagittaria sagittifolia* in BMP (June 2016)

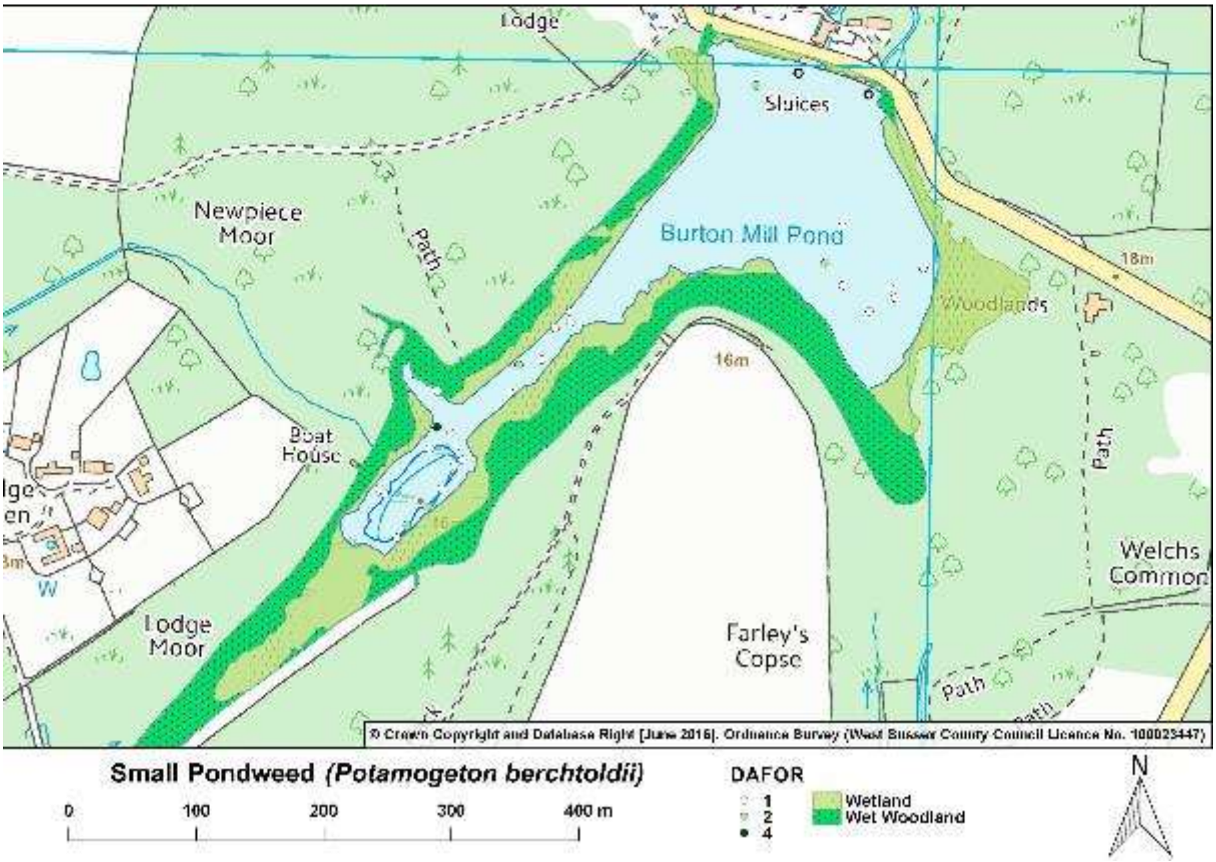

Figure 31 The extent and abundance of *Potamogeton berchtoldii* in BMP (June 2016)

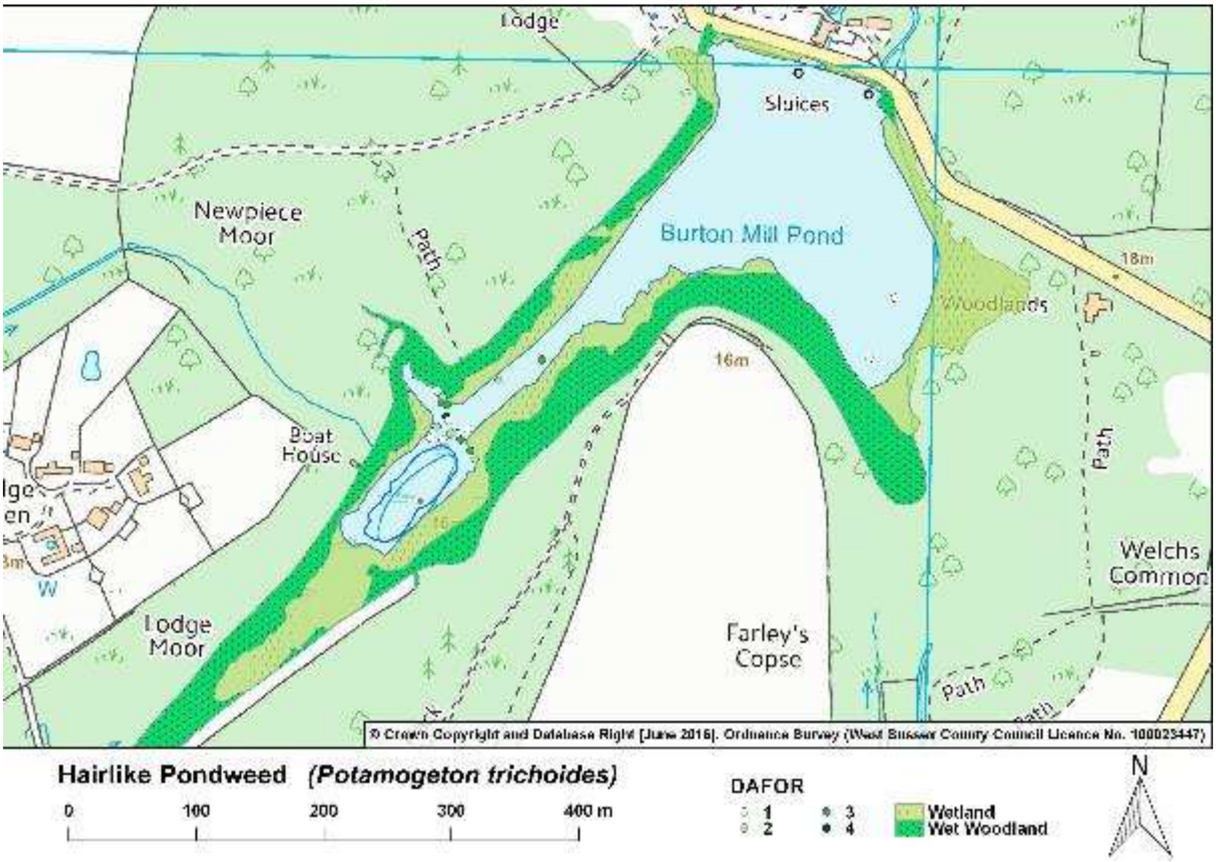

Figure 32 The extent and abundance of *Potamogeton trichoides* in BMP (June 2016)

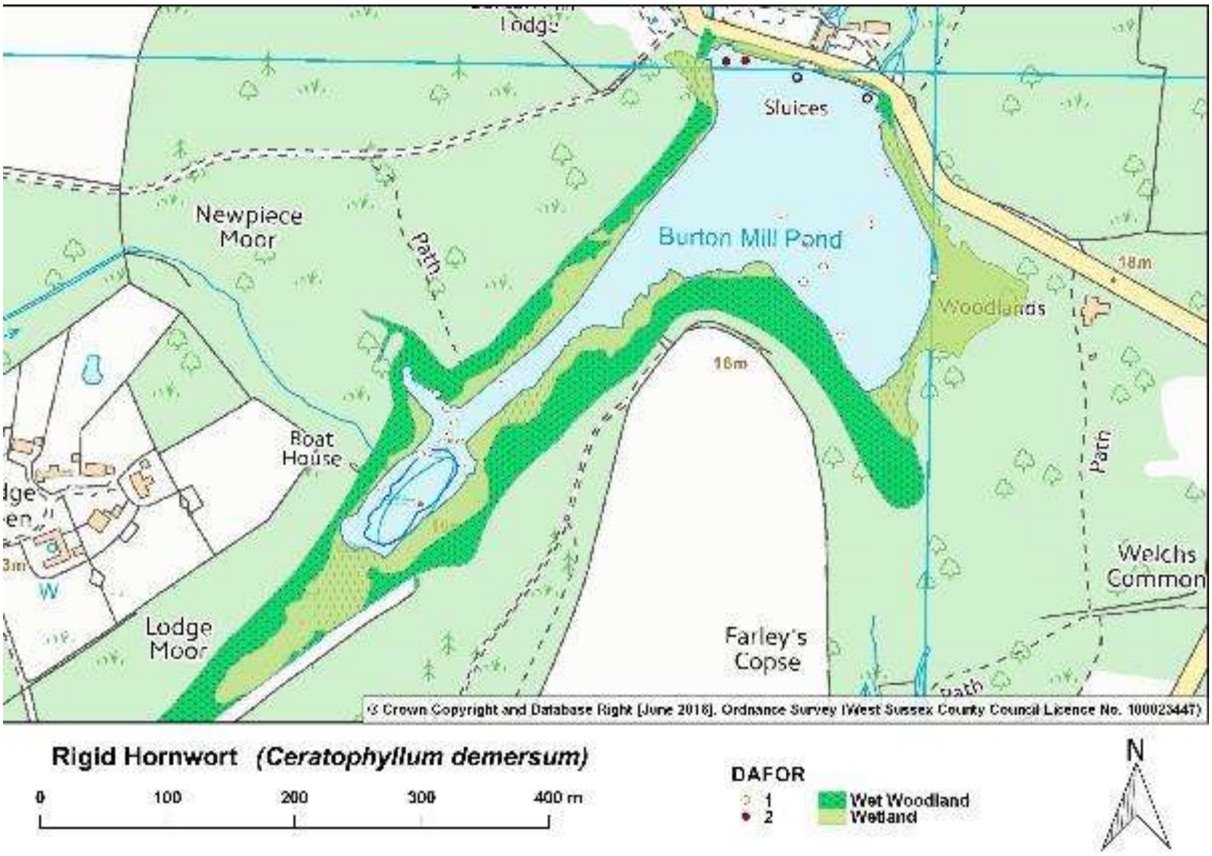

Figure 33 The extent and abundance of *Ceratophyllum demersum* in BMP (June 2016)

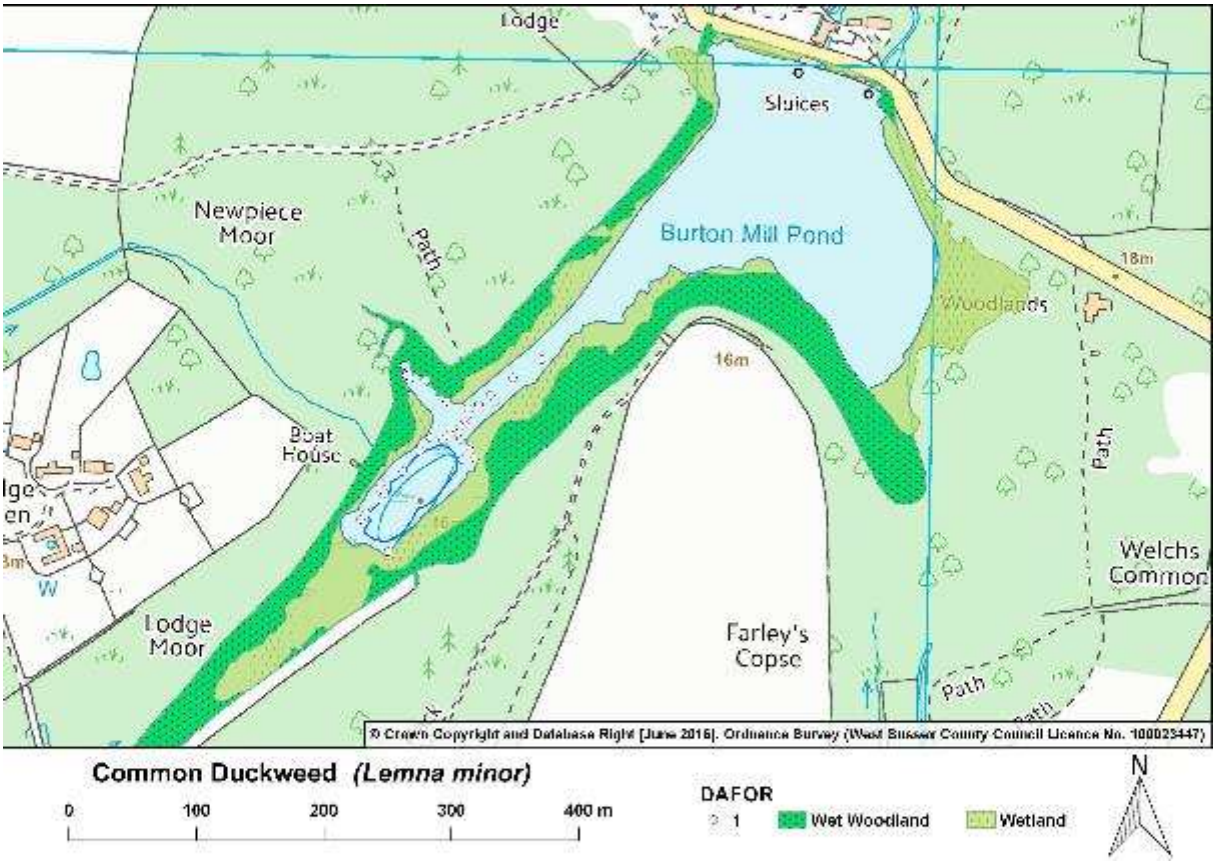

Figure 34 The extent and abundance of *Lemna minor* in BMP (June 2016)

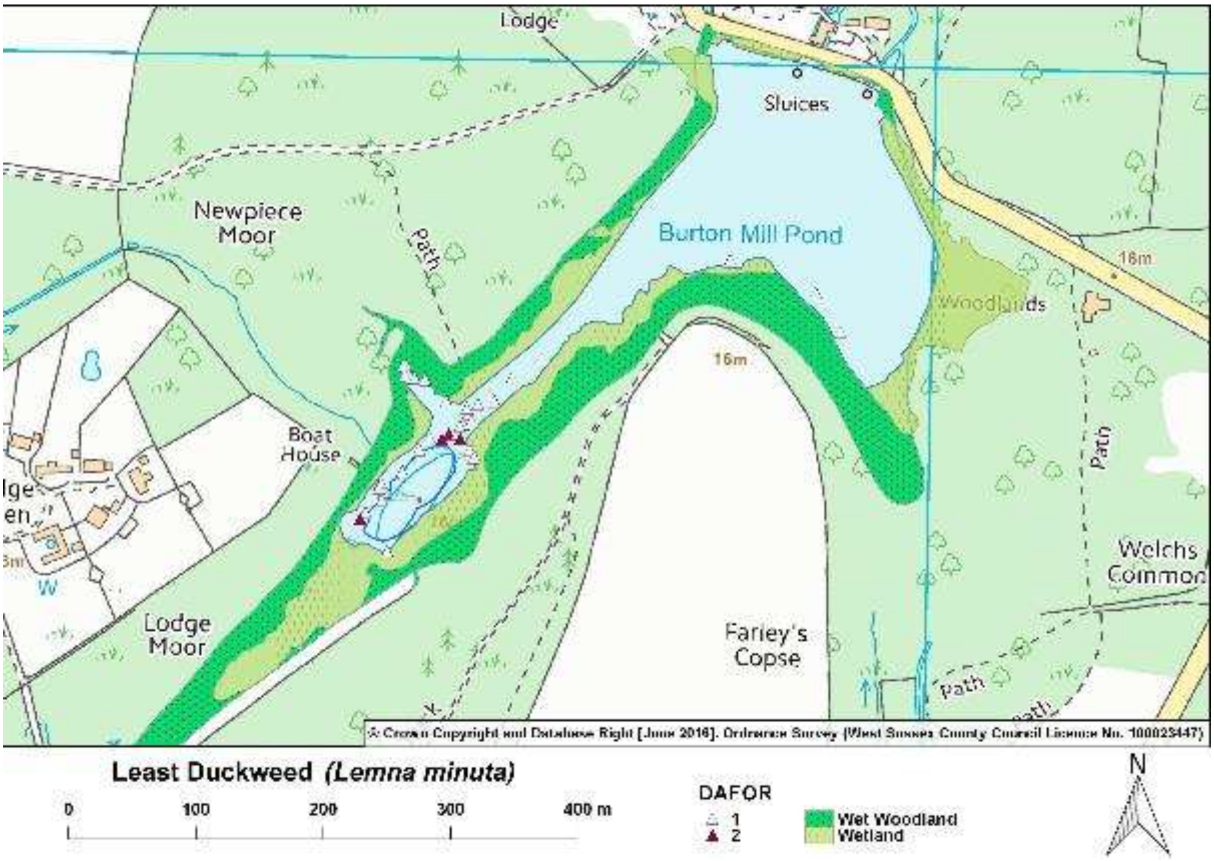

Figure 35 The extent and abundance of *Lemna minuta* (non-native) in BMP (June 2016)

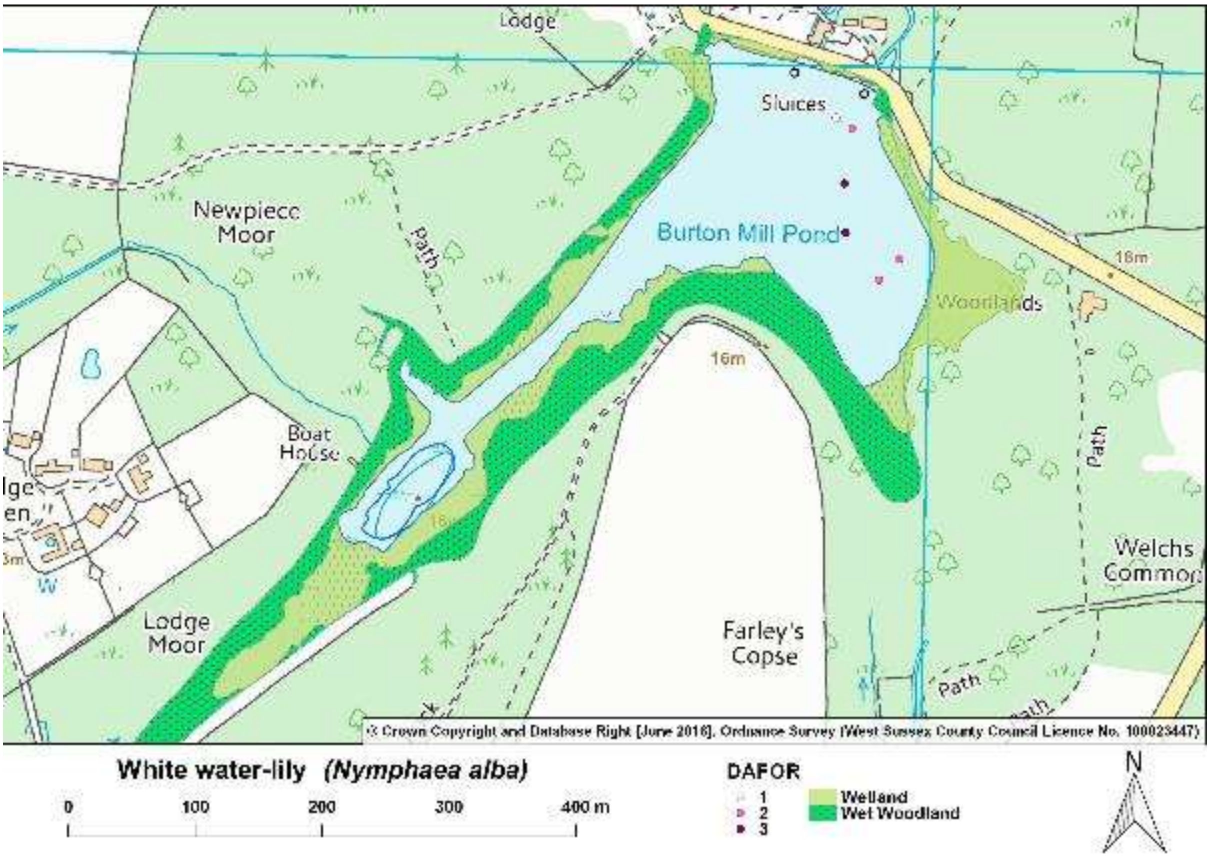

Figure 36 The extent and abundance of *Nymphaea alba* in BMP (June 2016)

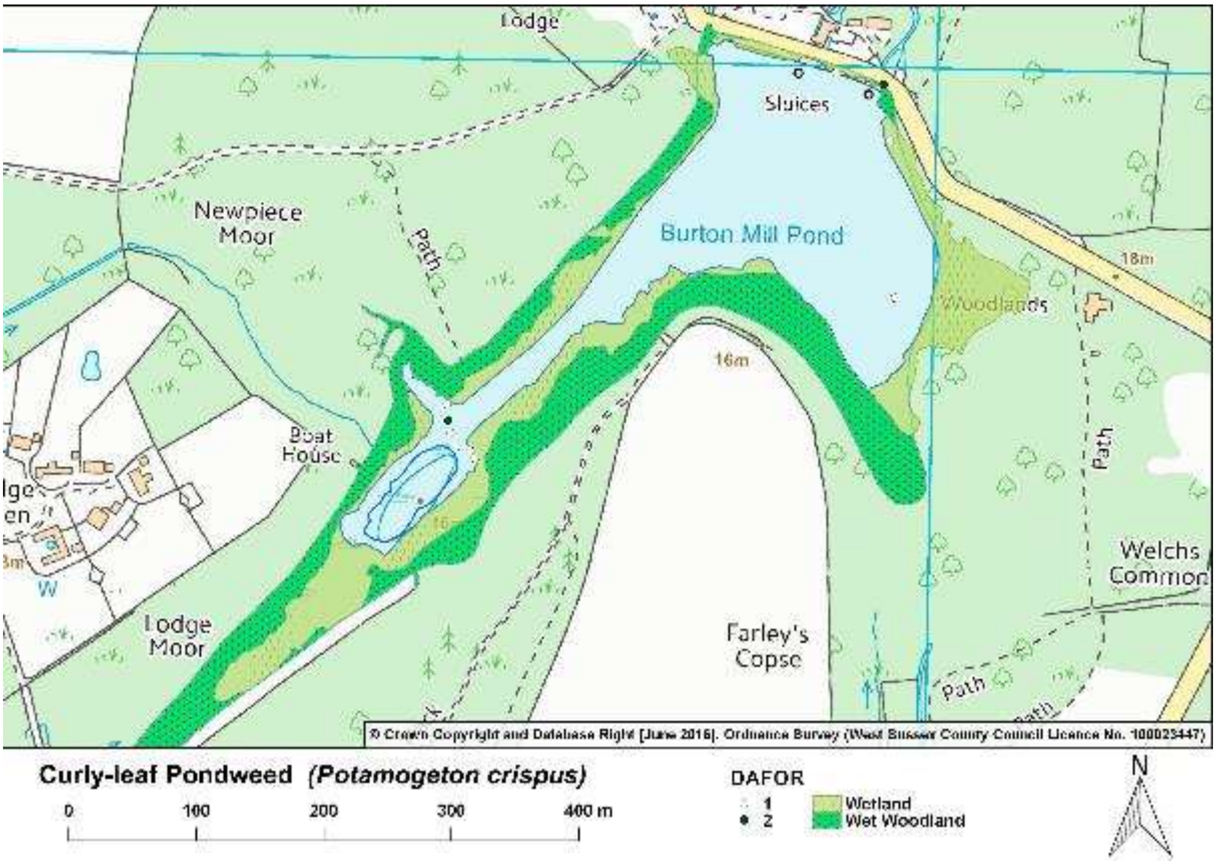

Figure 37 The extent and abundance of *Potamogeton crispus* in BMP (June 2016)

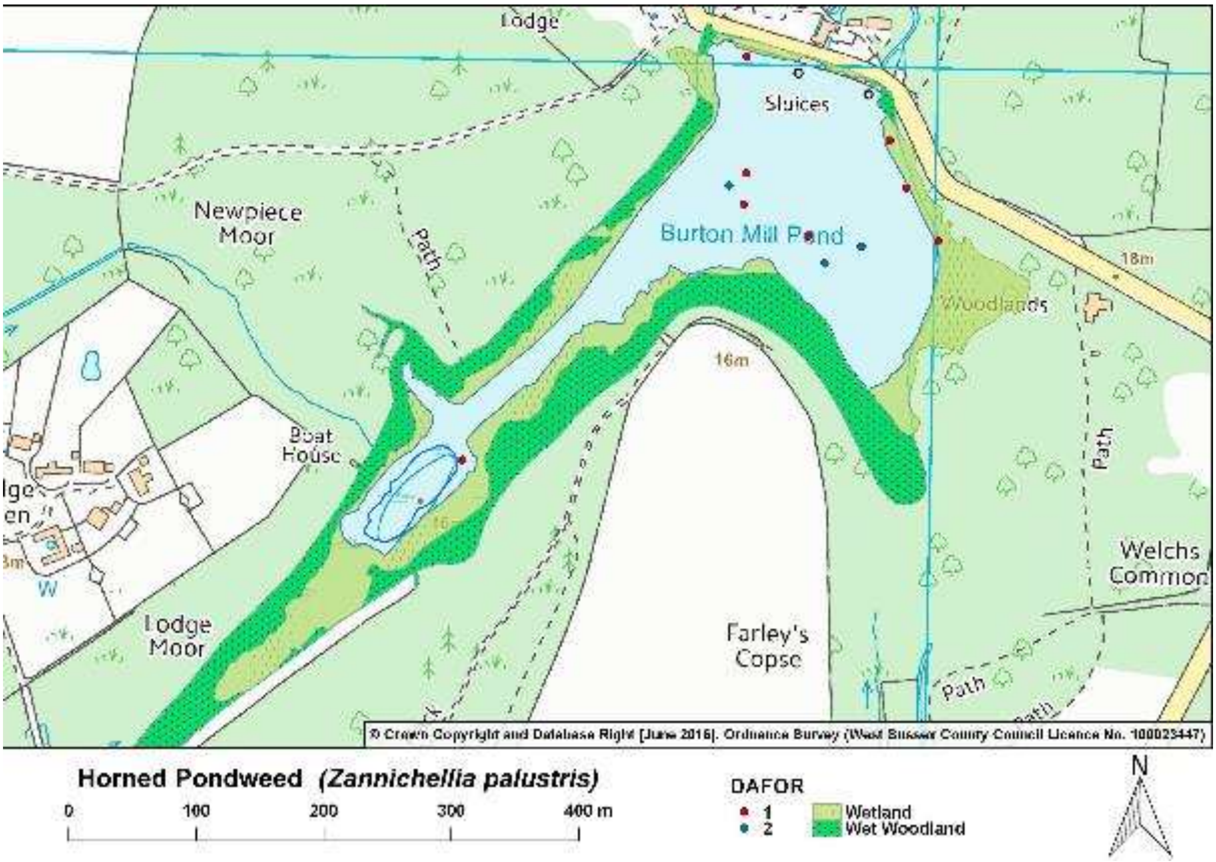

Figure 38 The extent and abundance of *Zannichellia palustris* in BMP (June 2016)

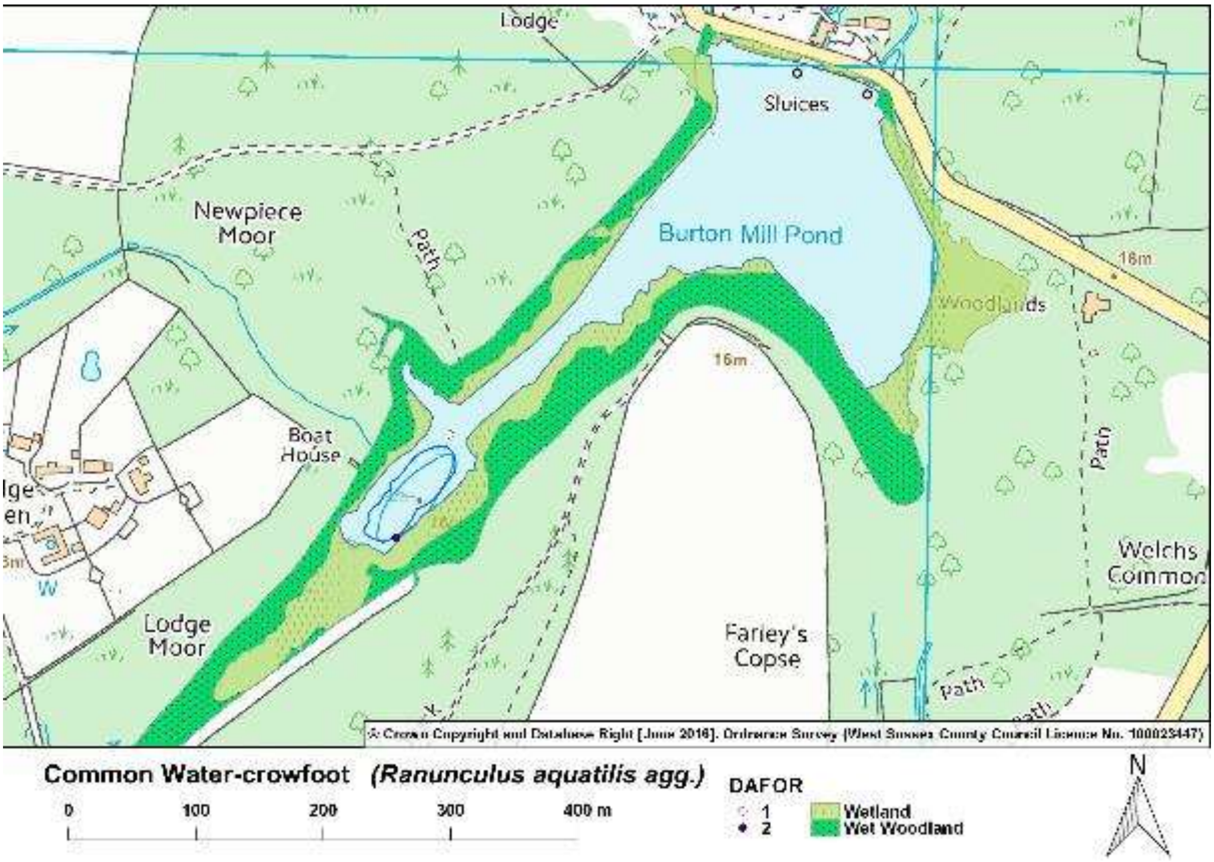

Figure 39 The extent and abundance of *Ranunculus aquatilis* agg. in BMP (June 2016)

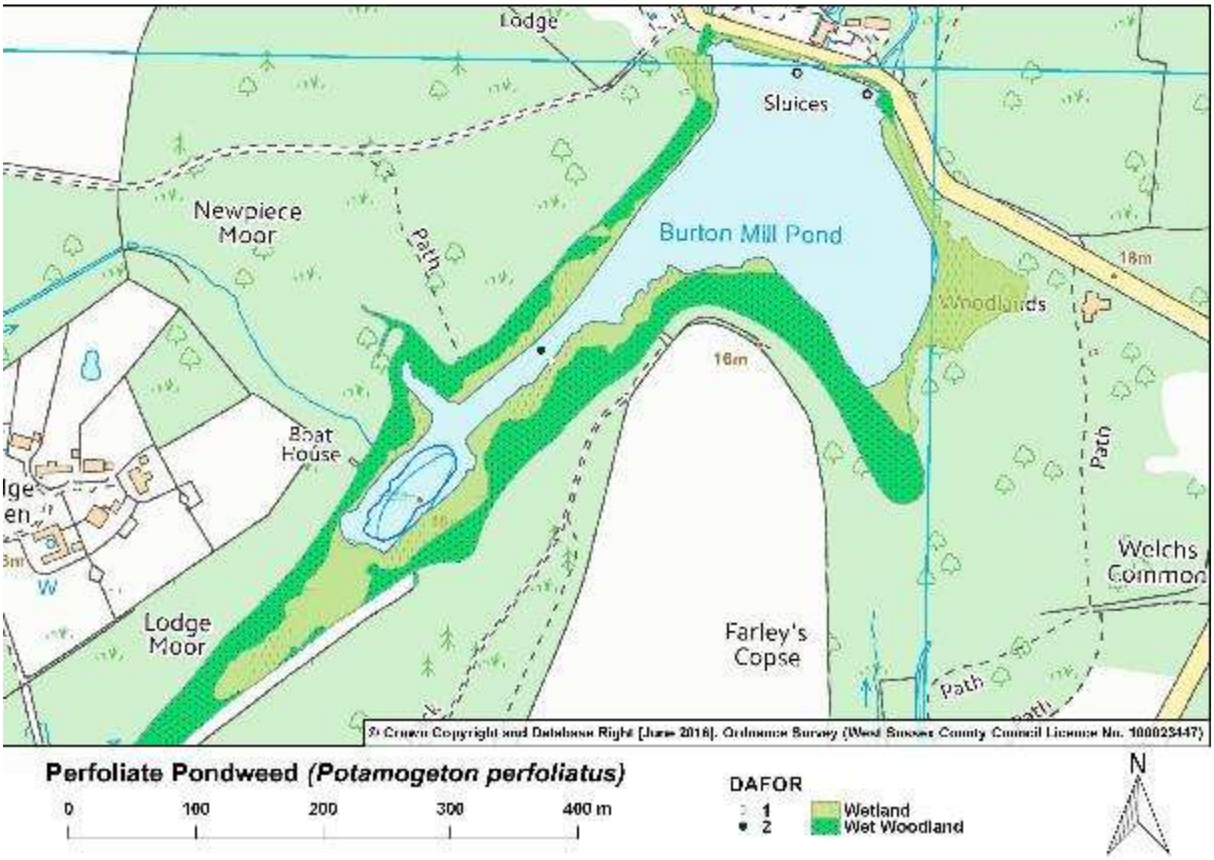

Figure 40 The extent and abundance of *Potamogeton perfoliatus* in BMP (June 2016)

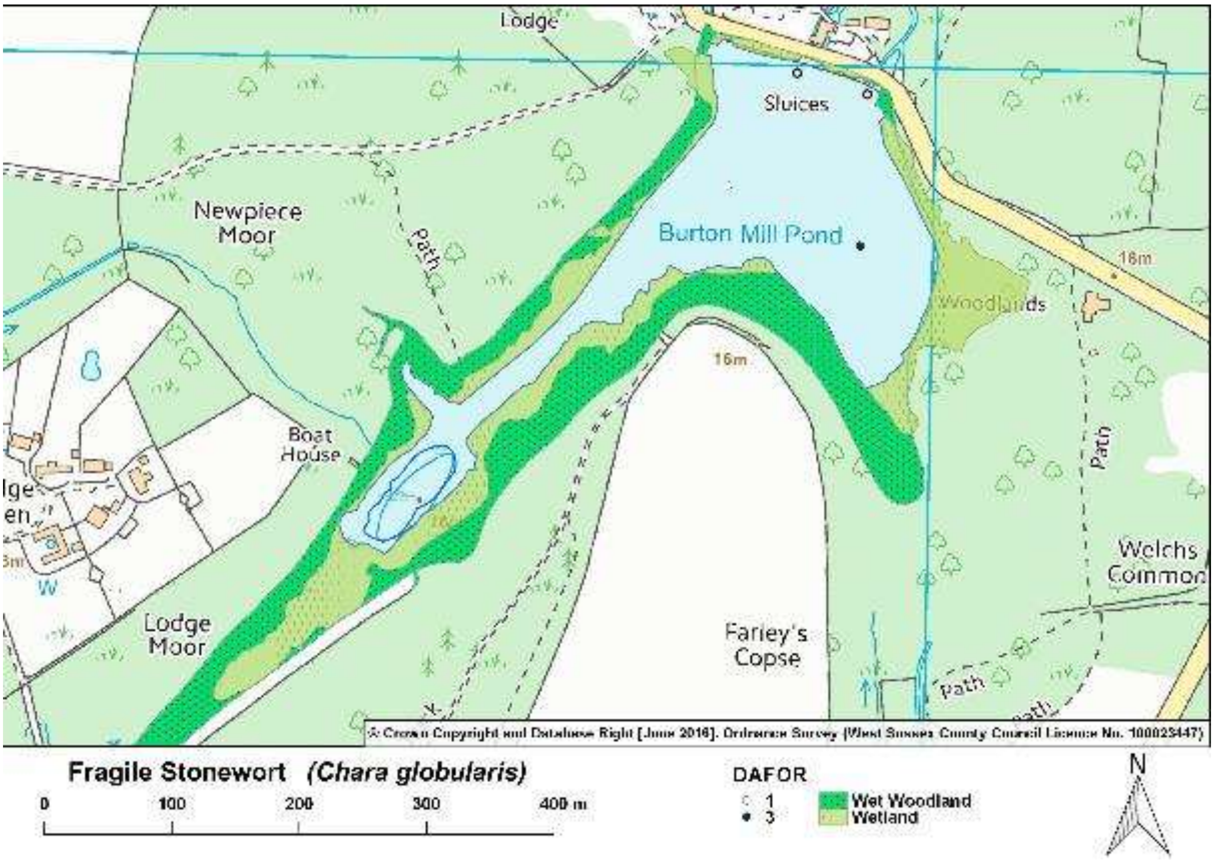

Figure 41 The extent and abundance of *Chara globularis* in BMP (June 2016)

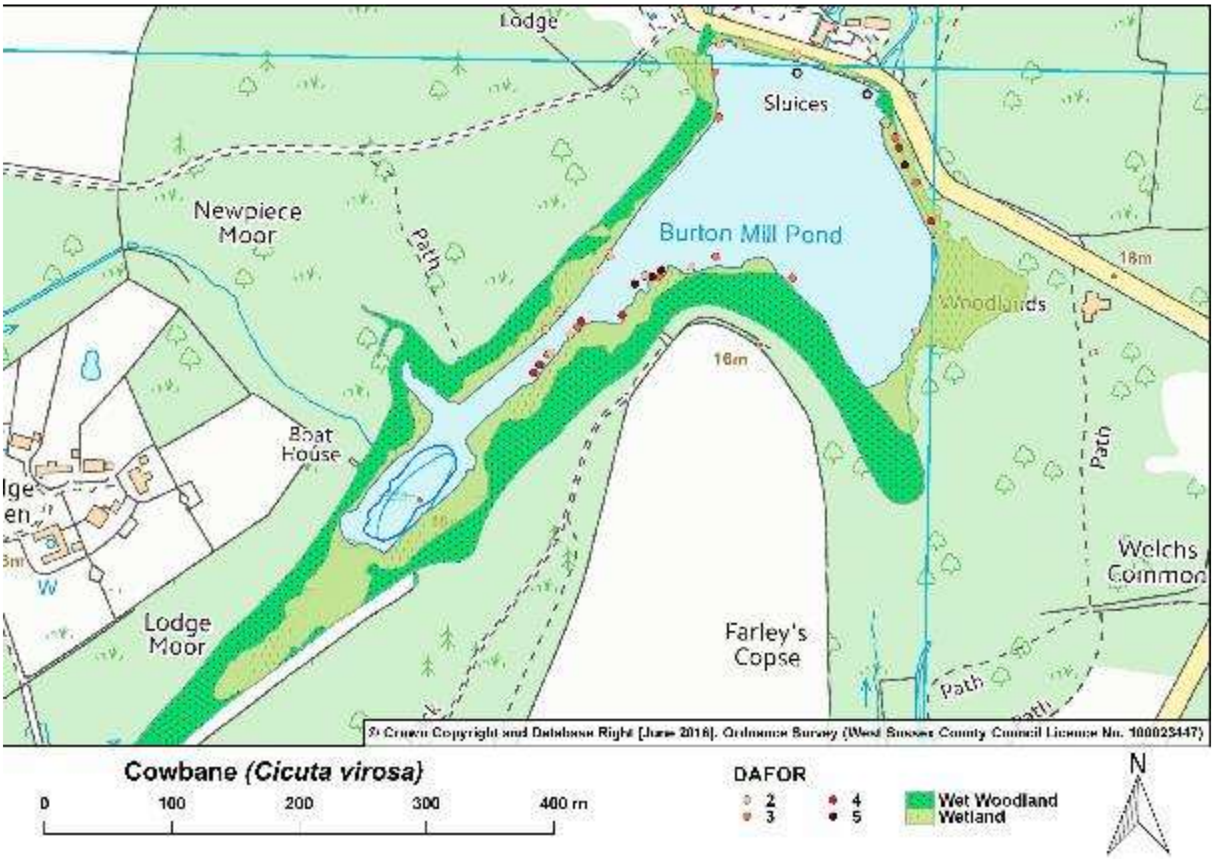

Figure 42 The extent and abundance of *Cicuta virosa* in BMP (June 2016)

Burton Mill Pond is one of only a few sites in the south of England to have Cowbane *Cicuta virosa* present. This species is a wetland plant categorised as 'Nationally Rare' (Lockton, 2016) and BMP is thought to be the only site where it occurs in West Sussex. A survey undertaken by the West Sussex County Council in July 2015 recorded 50 individual populations of Cowbane, totalling an area of 75 m^2 (Hogan and Ratsey, 2015), and this survey (2016) recorded a similar distribution, and over 100 individual plants noted. The preference of this plant for areas of outer reed edge, often on floating root mats, shows the reed front to be important habitat which requires careful management if reed cutting is to be used at the site. The current population at the site is considered to be stable.

2.4. Palaeoecological evidence

Before examining the current flora and fauna upon which the conservation status of the lake is based and assessed, it is of considerable value to assess the past communities. 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.

Aims and Methods

The aim is to examine the lake sediment remains to establish the extent to which the aquatic plant communities have changed through time at Burton Mill Pond.

In order to do this, we use palaeoecological techniques, an area of research that utilises the preserved remains of plants (and invertebrates) from the lake sediments to give us a window into the past environments. Very much in the same way as archaeologists can sift down through the layers of soil to look at human history, we look down through the layers of lake sediments to examine the lake history. In addition to the biological remains, we can also examine the physical and chemical properties of the sediments to shed light on shifts in catchment inputs, including pollutants, such as heavy metals, and the sequestration of phosphorus.

There are a wide range of plant and animal remains that are preserved in sediments. The extent to which some preserve is dependent on environmental conditions, but generally research focuses on biological groups such as diatoms, zooplankton, molluscs, invertebrates, pollen and various aquatic and wetland plant remains. With the interest at BMP being mainly on habitat change, the focus for this study is on the aquatic plants. These tell us a great deal about both the ecology of the site and also the habitats, and have been used to excellent effect in other UK studies to assess community level changes in Lakes (e.g. Davidson et al. 2005, Sayer *et al.* 2006, Ayres *et al.* 2008, Bennion *et al.* in press).

When looking at plants, the types of remains (termed “macrofossils”) varies widely and are dependant not only on the conditions under which the sediments are laid down (which can influence preservation), but also on the plant types present. After careful sieving of the sediments, microscopic examination (at between 10 – 400 x magnification) of the remains reveals for example, seeds, fragments of leaf, algal oospores (stoneworts), leaf spines, turions (vegetative propagules), leaf cells (sclereids) and stem fragments, most of which can be identified with reference to extant material in our reference library, or from taxonomic texts. It should be stressed, that while this method gives us a good insight into the history of plants within a lake, the data are rarely quantitative, and some species leave no visible remains and are thus not represented.

Field methods

A sediment core of approximately 1 m in length and 8 cm in diameter, was taken from Burton Mill Pond in May 2016. The location of the core was towards the north-eastern end of the lake (SU9795217903 – see Figure 43) in an area close to beds of yellow water lily *Nuphar lutea* and fennel pondweed *Potamogeton pectinatus*. The core was collected from 1.4 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 well 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.

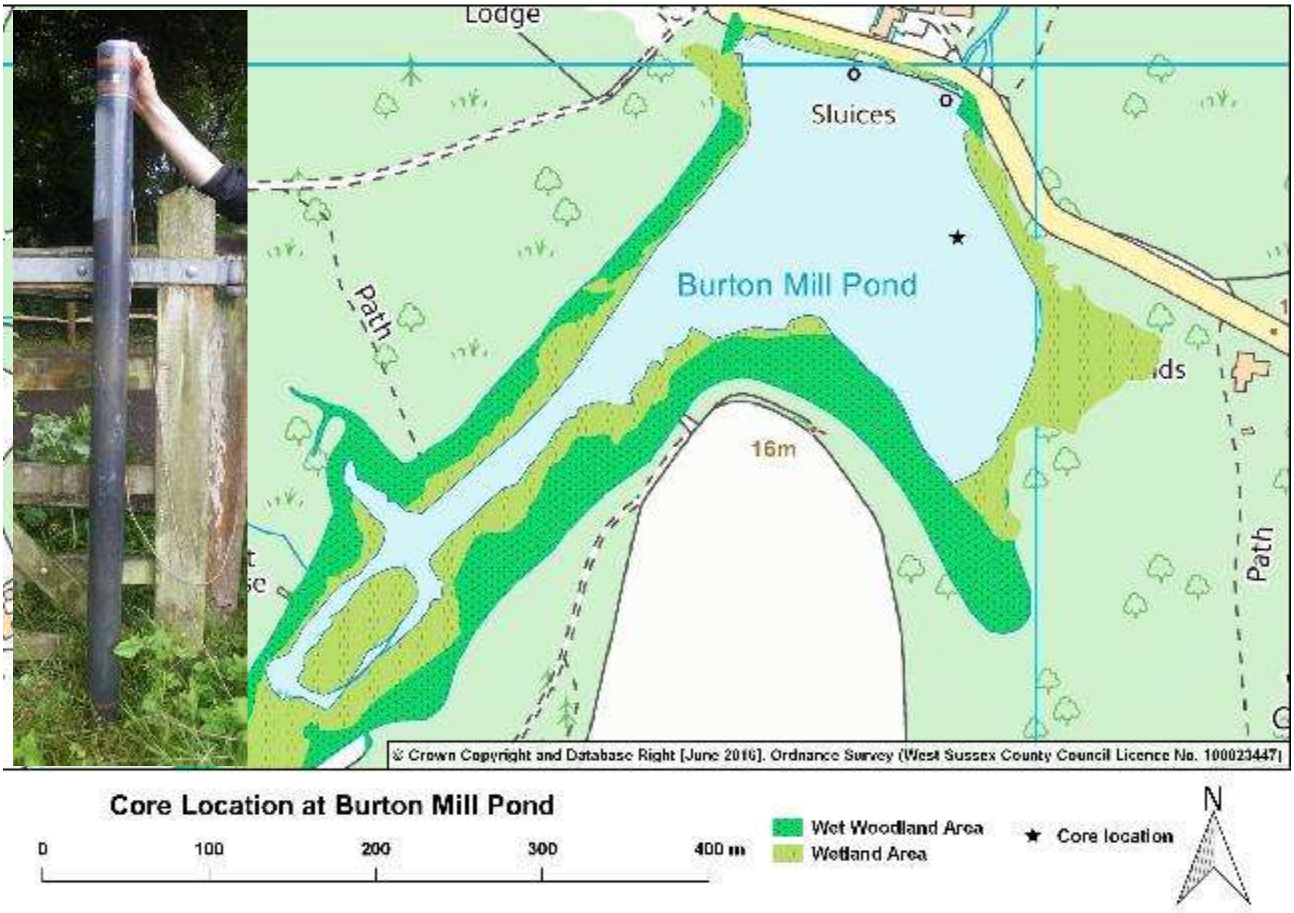

Figure 43 Core location with picture of core, inset.

Directly after collection, the core was carefully extruded through the top of the tube and sliced into 2 cm subsamples ready for analysis. Samples were sealed in air-tight polythene bags and refrigerated.

Laboratory methods

For the macrofossil analysis, ten levels were examined from the core. Although ten samples provide a relatively low analytical resolution, it is considered sufficient to characterise the major changes over the time scale represented by the core; estimated to be 100 to 200 years.

A known volume (~30 cm^3) of wet sediment was measured by displacement and the samples individually sieved at 350 and 125 µm and residues from each were transferred using distilled water to plastic vials for storage. The entire residue from the 350 micron sieve was examined under a stereomicroscope at magnifications of x10-40 and macrofossils were picked, identified and enumerated. Where identification was uncertain, reference was made to herbarium material held at the Environmental Change Research Centre, University College London and via photograph exchange within the UCL macrofossil expert group.

Although the focus of the analysis was on plant remains, animal macrofossils were also identified, including: zooplankton ephippia (egg cases), molluscs and mollusc larvae (glochidia), bryozoans (simple colonial filter feeders), oribatid mites and fish scales. Zooplankton remains can be used to infer changes in fish population density and shifts in habitat structure (Davidson et al. 2007) as well as changes in macrophyte density with nutrient-enrichment (e.g. Davidson et al. 2010). Given their intermediate and important position in the food-web zooplankton data complement the plant macrofossil records and hence are reported briefly here.

A measured sub-sample of the 125 micron sieve sample was analysed for smaller remain types (using up to 400 x magnification) such as leaf spines and fragments. These fragments are less easily identified to species level, and thus in some cases an aggregate group of species corresponding to the highest possible taxonomic resolution was used. In the graph below a category of *Potamogeton/ Zannichellia* leaf tips has been used. This refers to remains of very fine, very pointy leaf tips which are so small they are hard to separate. Likewise, the category of *Potamogeton berchtoldii / pusillus* agg leaf fragments groups both species as these can be hard to determine definitively to species level with just the leaf remains present.

All macrofossil data are presented as numbers of remains per 100 cm^3 of wet sediment.

Results of the palaeoecological analysis

The results from of the plant macrofossil analysis are summarised in Figure 44. There are a number of key features within these results that require comment, but in order to fully understand the results it should be noted that the total numbers of remains do not necessarily relate to the abundance of these species within the lake. The leaf cells (astrosclereids) from water lilies for example, are tiny, and produced in huge numbers, so while it is safe to assume that shifts in their numbers represent changes in relative abundance within the site, we cannot assume water lilies dominated the site in the same way as they dominate the remains within the core. Similarly, charophyte oospores (*Nitella* and *Chara*) are produced in very high numbers, and preserve very well in sediments, and numbers should therefore be considered relative, rather than assuming they dominated the lake.

Conversely, we do not see remains of shining pondweed *Potamogeton lucens* in the core top, despite if dominating the aquatic flora of the site. This species does fruit quite readily, but we rarely ever find its seeds within the sediments and the leaves do not appear to preserve. Similarly, the non-native species Canadian waterweed *Elodea canadensis* does not leave sub-fossil remains in the sediments, and although present in BMP, we cannot determine when it arrived at the site and if it has ever been abundant. Thus the picture we generate from the sediment record needs careful interpretation and is based primarily on positive results, but with the knowledge that other species may also have been present.

Based on a core taken from the same location, we know the upper 25 cm of sediment represents approximately the past 50 years. Within this timescale, we also have records based on actual survey data, albeit unclear if the species list in the SSSI citation was generated in 1954, or during revision in 1980s. The SSSI citation (NE 1986) detailed a very different submerged aquatic flora to that seen today, and this is apparent in the macrofossil results. The macrofossil diagram (Figure 44) is divided into three zones based on the major changes seen.

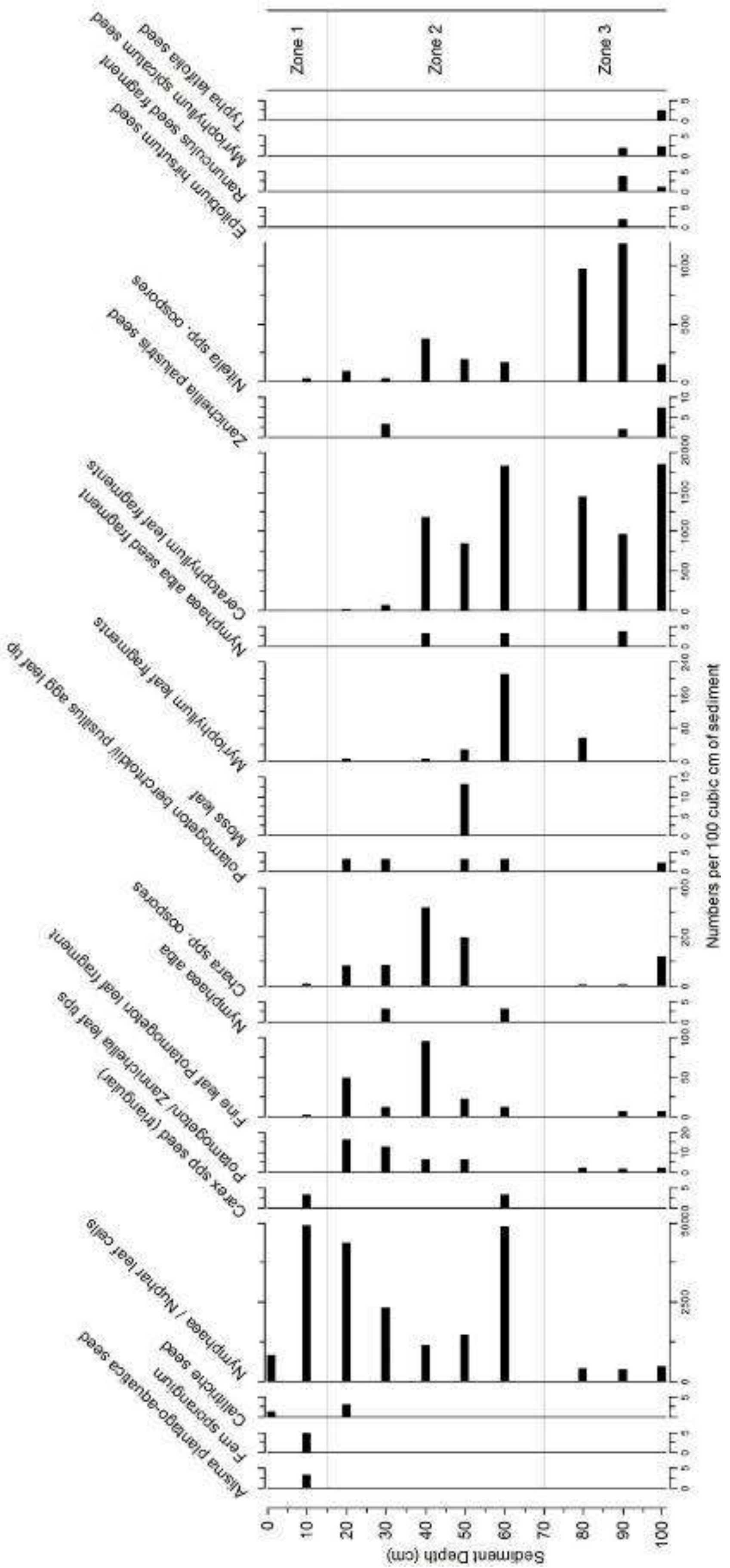

Figure 44 Summary diagram of plant macrofossils recorded in core BURT3

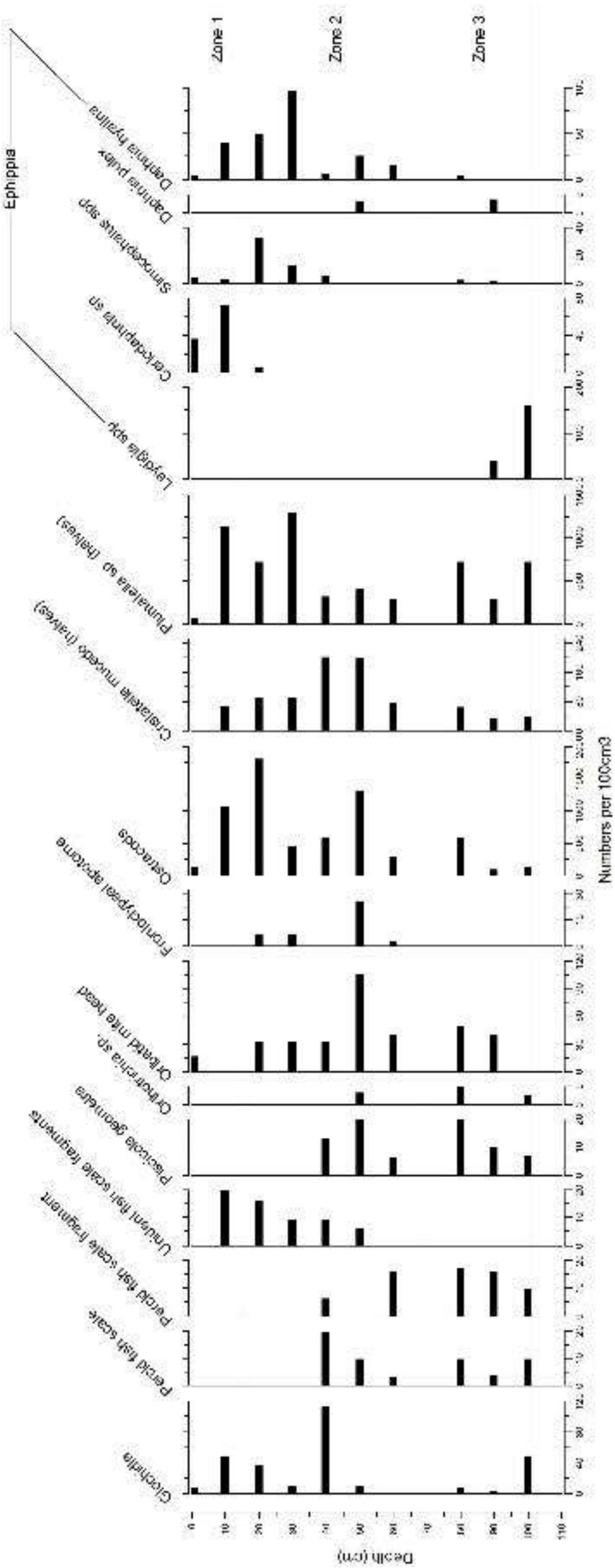

Figure 45 Summary diagram of animal macrofossils recorded in core BURT3

Zone 1: 0 – 15 cm. The uppermost two samples, taken at the sediment surface and from 10 cm, had low species richness. This is best explained by the recent dominance of shining pondweed *Potamogeton lucens* in the site; a plant that rarely leaves any identifiable remains in the sediment. We know this species to have dominated the open water since before 2003 (author surveys), but exactly when it colonised the site is unknown. There are records of it as early 1907 (Arnold 1907), yet it is not listed in the 1980 revision of the SSSI citation (NE 1986) which, given this is a very visible species and one of interest to botanists, it is safe to assume it must have been rare or absent from the site to have been overlooked. The dramatic drop in water lily leaf cells is also of note. It suggests that the relative cover of water lilies has reduced over this more recent period (approx. 30 years), presumably as a result of the active clearance noted by Griffiths (2012) and in the Favourable condition documentation (NE 2014).

This upper zone also sees subtle changes within the animal remains, and particularly within the zooplankton community (Figure 45). Ephippia (eggs) of *Ceriodaphnia* spp. are not seen in the core until the top 20 cm, where they appear and mostly to replace *Simocephalus* spp. and to some extent *Daphnia hyalina*. The reason for this is not clear from the ephippia alone. *Ceriodaphnia* are generally associated with water lilies and sites with high plant cover, but so too are *Simocephalus* and *Daphnia pulex*. It is possible, that the *Ceriodaphnia* spp. favour the larger leaved *Potamogeton lucens* which we know to have colonised the site over the period covered by the upper 20 cm, but it is thought unlikely that this alone would influence such a major shift.

Changes within the fish community may also account for observed shifts within the zooplankton community. Fish are a major predator of zooplankton, with certain types of fish favouring zooplankton and therefore having a more noticeable impact on the resultant community composition. Zooplanktivorous fish species such as Bream and roach in particular, are efficient predators of the larger pelagic zooplankton species, which are largely absent where these fish dominate. In order to unpick this any further, we would need to analyse the sediments for the chitinous remains of the zooplankton and determine the size range of individuals, relative abundance of adults and to detect species that are poorly represented by ephippia data (e.g. *Bosmina* spp.). This is beyond the original scope of this project.

Zone 2: 15 – 70 cm. There is some variation in the macrofossil remains in this central portion of the core, but generally it is more diverse and is characterised by the presence of *Chara* (and *Nitella*) oospores, fine-leaved pondweeds (*Potamogeton* and *Zannichellia*) species, water-lily leaf cells, rigid hornwort *Ceratophyllum spicatum* and *spiked-milfoil Myriophyllum spicatum,* an assemblage typical of shallow alkaline lakes, and similar to that described in the SSSI citation (NE 1986).

The presence of *Chara* and *Nitella* species is indicative of good ecological condition and their apparent reduction at the top of this zone is symptomatic of eutrophication. Stoneworts are particularly susceptible to nutrient enrichment, due in part to there requirement for clear water, but there is also evidence that increased nitrate can be toxic to some *Chara* species. In laboratory experiments, Lambert & Davy (2011) showed that mean annual concentrations greater than 2.0 mgl^{-1} of nitrate N inhibit the successful growth of *Chara globularis*.

There appears to have been a significant change within the site 30 – 40 cm; a period estimated to be AD 1930 – 1950. A dramatic decline in rigid hornwort *Ceratophyllum demersum* remains occurs here along with reduced numbers of stonewort oospores and an increase in water lily leaf cells. This may simply be a case of the water lilies dominating the site and out-competing the submerged flora, but there is evidence to suggest this observed change may not have been entirely natural. Within the sediments we also found fish scales. These are not always identifiable to species level, but Percid scales (in this case from perch *Perca fluviatilis*) were common in the deeper sediments, giving way to unidentified fish scale fragments in the upper 50 cm of the core. The general appearance of these scale fragments and their propensity to shatter is consistent to them being from Cyprinid species i.e. roach, tench, carp, rudd, bream.

Although perch are still found in the lake, the rather sudden switch observed in the sediments from Percid to unidentified (Cyprinid?) scales, suggests the balance within the fish community shifted away from a perch dominated system, to the Cyprinid dominated community reported by anglers today[7]. What caused this change is not clear. We know that the site to have been an active angling lake for many years, but can find no documented evidence of fish stocking since the site was designated as a SSSI. The presence of common carp and a range of other coarse fish is however evidence that fish stocking has occurred in the past. What is not possible to establish at this stage, is whether the change in the fish community caused a shift in the plants seen around the same time, or if there were other factors driving the observed changes in vegetation.

The first half of the 20th century also saw significant changes to the industrial management of the mill, which may also have impacted the pond. Hudson (1980) reports major chanced to the to the mill machinery and function between 1894 to 1942, and while no mention is made to changes to the dam, it is likely that water levels would have been periodically dropped, and possibly the lake drained completely to facilitate management. Any extended periods of drawdown could have influenced the aquatic flora significantly as well as the fish community. Some species of aquatic plants can tolerate exposure and drying better than others. Water lilies for example, have large tuberous stolons and can survive for many weeks out of water. Conversely, rigid hornwort *Ceratophyllum demersum* and stoneworts are very shallow rooted and cannot survive out of water for more than a few hours or days at most, and rely on the viability of seed-banks to re-establish after plants are lost.

Zone 3: 70 - 100 cm. Below 70 cm in the core we see much lower numbers of water lily leaf cells and higher numbers of *Ceratophyllum demersum* and *Nitella* spp. remains. Additionally, there are low numbers of *Potamogeton, Zannichellia, Myriophyllum, Chara* and *Ranunculus* species remains, suggesting the flora was relatively rich. The lower numbers of water lily leaf cells would suggest that water lilies were less abundant in the time represented by this section of the core (estimated to be in excess of 100 years ago), either due to active clearance or naturally lower abundance is unclear.

The abundance of *Nitella* oospores (seeds) is of particular note. The majority of *Nitella* species are more typically recorded in less alkaline waters and therefore there are few options for species with oospores of this size and structure. Based on photographs and measurements, Nick Stewart (BSBI Stonewort referee) suggested the most likely candidates to be *Nitella tenuissima*[8] or *Tolypella glomerata.* These are species only recorded from water bodies with high water quality and consequently relatively rare in the UK today, particularly in lakes of this size. Further analysis of these oospores would be required to determine species, including scanning electron microscopy (SEM) and

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[7] The Sussex Piscatorial Society has held the angling lease at the pond since 2014, and has reported catches of roach, rudd, tench, bream, pike and perch, with additional sightings of common carp and eels. Large pike have also been caught in the past (David Hayler, pers. comm.).

[8] *Nitella tenuissima* is UK Biodiversity Action Plan species and on the IUCN Endangered list. All recent records of this species are from East Anglia and Anglsey

germination trials. Oospores can remain viable within the sediments for many decades (even centuries) and can be germinated and grown to confirm identification (e.g. Goldsmith *et al.* 2014, Lambert *et al*. 2013).

Summary

Although the reasons for the observed changes within the sediment core remain speculative, it is nonetheless clear from the data that significant changes have occurred to both the aquatic flora and fish communities within Burton Mill Pond over the last c. 100 years. This is a period that has seen significant changes to the Mill Pond in terms of both the catchment and the site management.

The Nitrate-nitrogen concentrations in the chalk aquifers of the South Downs that feed the lake, have increased significantly over this period (Jones & Robins 1999) and there has been an almost universal increase in anthropogenic phosphorus concentrations in surface waters in lowland Britain and Europe (OECD 1982). In addition, the function and management of the lake has changed considerably over this period, from milling and power generation in the early 20^{th} century through to active conservation since 1954 as a SSSI. During this latter period, we know the site to have been partially dredged and water lilies periodically cleared as well as potential impacts from the breaching of Chingford dam above the lake. During this time, the site has been used for angling, and while we have no documented evidence of fish stocking, the presence of target species such as carp, tench and bream are however, indicative that fish have been introduced.

Even at this relatively coarse resolution, the macrofossil data show there to have been significant changes in species and habitat within the site, and provide a good insight into the open water habitat. Most striking is the evidence that in contrast to the present, stoneworts once formed a significant component of the aquatic flora, a clear indication that water quality was better in the past. Water lilies also appear to have become more prevalent in the site in recent years. While the number of leaf cells recorded in the sediment cannot be related directly to abundance, the relative proportion of these cells is good evidence that they were less common in the zone below 70 cm.

While it is clear that the open water environment has changed over the past 100 years, the extent to which the marginal habitats have altered is less clear. The macrofossil data do not reliably represent the marginal wetland flora. We know from early Ordnance Survey maps however (e.g. OS 1898), that the lake has had a well-developed wetland margin (backed by woodland) in the past, the extent of which is not dissimilar to that seen today. Species composition is unknown, but it is likely that Common reed *Phragmites australis,* Bulrush *Schoenoplectus lacustris* and Reedmace *Typha* spp. were all present. Old maps appear to show there to have been encroachment of the trees towards the lake over the past 100 years, but the accuracy of these older maps cannot be verified.

2.5. Surveys of Desmoulin's Whorl Snail *Vertigo moulinsiana* (Martin Willing)

Background

Desmoulin's whorl snail *Vertigo moulinsiana* was first discovered at Burton Mill and Chingford Ponds in 1992 (Willing 1992). *Vertigo moulinsiana* (Dupuy, 1849) is of high conservation concern as it is scheduled on Annex IIa of the EU Habitats & Species Directive and is an English Section 41 'Species of Principle Importance' (until 2006 UK BAP priority species). In the latest red data review (Seddon *et al* 2014) *V. moulinsiana* is categorised as 'Vulnerable'. Pertinent to this study, the snail is rare in Sussex, occurring at very few sites, having been lost from at least 3 since 1970; the population of the snail at Burton Mill Pond (BMP) is the largest in West Sussex and so of regional importance (the species has not been recorded in East Sussex).

The first full *V. moulinsiana* survey of BMP was undertaken in November 2011 (Willing 2012). This survey was partly undertaken to assess populations of the snail in advance of water level restoration works being undertaken at Chingford Pond, which might have had a negative impact on the large populations of *V. moulinsiana* living there (Willing 2011b). Following construction work at the pond in water levels at Chingford Pond were raised in autumn 2014; *V. moulinsiana* surveys at the pond in December 2014 showed that populations of the snail had declined sharply (Willing 2015a). Further surveys at sites around the pond in May 2015 (Willing 2015b) and then again in July 2016 (report in prep.) confirmed the total loss of the snail at Chingford.

Apart from monitoring populations of *V. moulinsiana* at BMP in order to assess the status of this important population in its own right, it is also hoped that some 'surplus' *V.moulinsiana* stock might be used to re-populate Chingford Pond once higher water levels have stabilised and suitable marginal fen has become re-established (particularly in newly cleared areas at the southern (inflow) end of the pond. In 2015 the Sussex Wildlife Trust undertook an invertebrate survey of the Trust's land around and adjacent to Burton Mill Pond (G. Lyons, personal communication; report in prep). This predominantly entomological study picked up very few *V. moulinsiana* during sweep sampling on the pond margins. These results raised the concern that *V. moulinsiana* populations around the pond may have crashed providing yet another reason to undertake this current study.

Methods

Survey areas were visited on 30th June 2016 (Sites 1 – 12) and 26th July 2016 (Sites 13, 14, 13/14). Live snails extracted in the lab from bulk samples collected on the first visit were returned to marginal fen at the pond on 2nd August 2016. Burton Mill Pond sites 1 -12 were accessed by boat. Survey site numbering follows that used in the first full *V. moulinsiana* survey of Burton Mill Pond in 2011. Survey locations are displayed on Fig 1.

Survey methodology broadly followed the 'level 1' survey techniques detailed in Killeen & Moorkens (2003). Therefore searches for *V. moulinsiana* climbing upon wetland vegetation were carried out by the well-established technique of beating herbaceous fen vegetation onto a gridded white plastic tray[9] (tray dimensions approx. 34 cm X 24 cm = 1/12th m^2) during dry weather (it is extremely difficult to undertake the 'beating technique' in wet conditions).

At each sampling location a total of six trays samples were taken at 2 or 3 locations each separated by about 3 – 4m (at each of these beating beneath a fresh and undisturbed area

[9] Trays have a surface area of about 0.082 m^2 so that 12 trays are approximately equal to 1 m^2.

of vegetation all within 1 – 2 m of a single sampling spot). Material on the tray was retained for later laboratory counting and when numbers of snails were high or when counting in the field was difficult because of excess litter debris on the tray. A close visual search was also undertaken of the bases of reed or sedge stems, although this technique only tends to disclose *V. moulinsiana* where it occurs at relatively high densities. At each of the survey sites, ground moisture levels were recorded on the 5-point scale as detailed in Killeen & Moorkens (2003):

1. DRY – no visible moisture on ground surface or detected if touched;
2. DAMP – ground visibly damp, but water does not rise if pressed;
3. WET – water appears under light pressure;
4. VERY WET – pools of water present but < 5cm in depth;
5. SUBMERGED – whole sample site under water > 5cm in depth

Removed samples were examined in the laboratory on gridded white trays and inspected microscopically using a x7 – x45 binocular microscope to allow counts of adult and juvenile *V. moulinsiana*. As the surveys were non-destructive all live material taken from the site was returned within 48 hours and replaced on suitable marginal fen at the pond.

The Ordnance Survey grid locations of survey stations were recorded using a Garmin GPS, and sites were also digitally photographed.

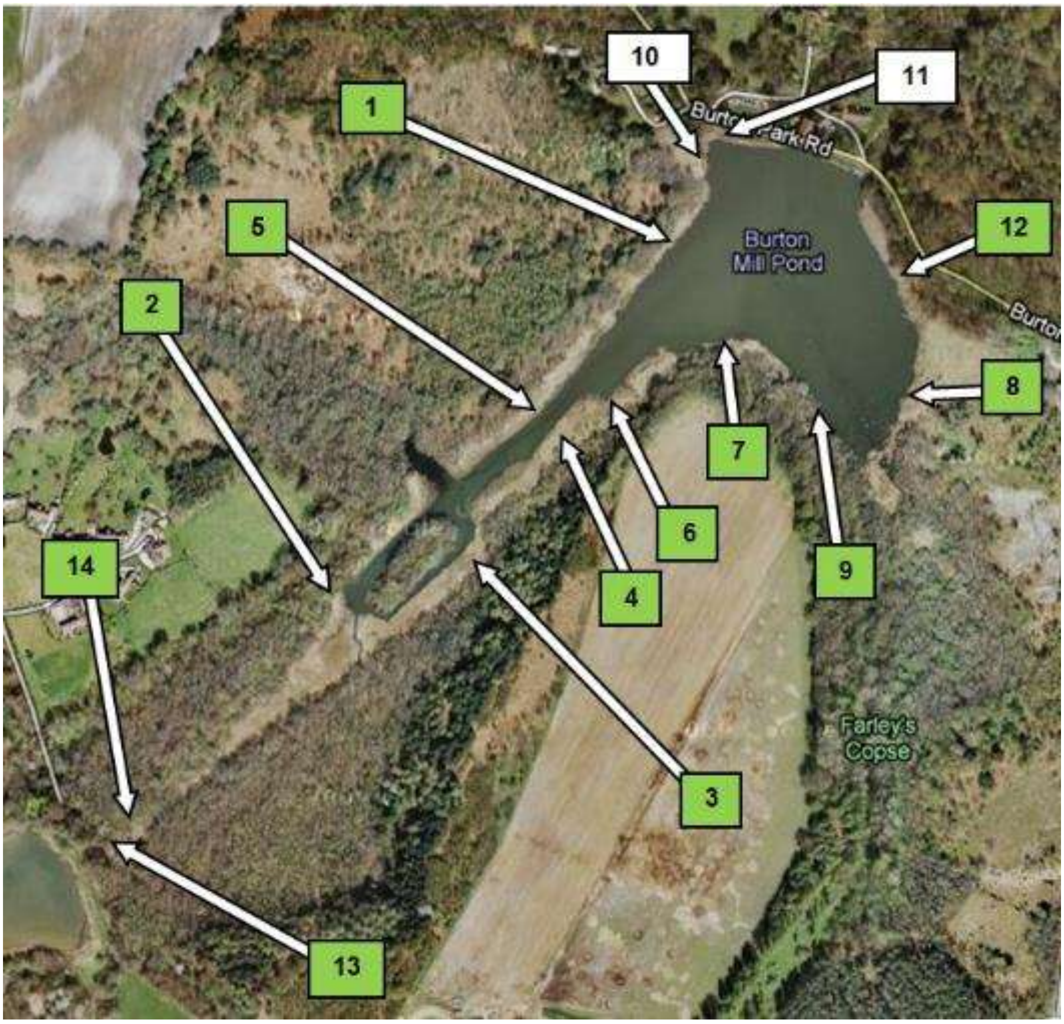

Figure 46 Aerial map of Burton Mill Pond displaying approximate 2016 survey locations (In-filled green boxes = *V. moulinsiana* present)

Results

The survey station locations and brief site descriptions are a shown in Table 6 and summary results in Table 7. The full survey results are given in Table 9.

Table 6 *Vertigo moulinsiana* survey station locations with brief site descriptions

Site & Grid Ref.	Brief site description & image reference	GM = ground moisture levels
S1 SU9776517892	10 – 12 m fringe of open *Sparganium* / *Carex* sp / *Typha* fen. *Alnus* encroaching into open fen from west so some slight lateral shading late in day.	5
S2 SU9754017625	Narrow fringe of *Phragmites* dominated open fen with some *Carex* spp & *Typha*; lateral shading from *Salix caprea* and *Fraxinus excelsior.*	5
S3 SU9763817673	Fringe (approx 20 m) of mixed open fen with some *Carex* spp, *Typha, Phragmites* & *Iris*; very slight morning lateral shading from *Salix caprea* and *Alnus* to east. .	5 (small areas 4)
S4 SU9769117749	Fringe (10 – 15 m) of *Phragmites, Sparganium, Carex spp, Oenanthe crocata.* (*Vertigo moulinsiana* readily visible in field on *Carex* and *Sparganium* leaves). Some lateral morning shading of *Alnus / Salix* to east. .	5 (small areas 4)
S5 SU9767217781	Fringe (10 m) of *Phragmites,* a little *Carex spp,* . Some lateral evening shading of *Alnus / Salix* to west. .	4 / 5
S6 SU9775817808	Fringe (10 m) of *Phragmites,* a little *Carex spp, Oenanthe crocata, Epilobium sp, Cicuta virosa, Eupatorium cannabinum*. (*Vertigo moulinsiana* readily visible in field on *Carex* and *Sparganium* leaves).Some lateral morning shading of *Alnus / Quercus / Betula* to east. .	4
S7 SU9786717852	Fringe (25 - 30 m) *Sparganium* / *Carex* sp / *Typha* fen.of . (*Vertigo moulinsiana* occasionally visible in field on *Carex* and *Sparganium* leaves). Some lateral shading of *Alnus* to south. .	4 / 5
S8 SU9798917795	A wide margin (width ca 50 m) of open fen only areas within 25 – 30 m of pond sampled. Mixtures of *Carex* spp, *Phragmites* and occasional *Oenanthe crocata.* No shading.	4 / 5
S9 SU9788717839	Very similar to site 7.	5
S10 SU9782317993	A wide margin (width ca 30 m) of open fen only with mixtures of *Carex* spp, *Eupatorium cannabinum, Typha*, and occasional *Oenanthe crocata;* some encroaching *Alnus.* No shading.	Mostly 3
S11 SU9783618029	A narrow margin (3 – 4 m) of open fen with *Phragmites, Typha* and *Carex* spp. No shading.	3 / 4
S12 Between SU9801217857& SU9798017940	A margin (10 - 15 m) of open fen with *Phragmites,* and *Carex* spp. No shading.	5
S13 SU9737517434	Similar to S14 but with additional *Glyceria maxima*.	3
S14 SU9737817440	Chiefly *Carex riparia* fen with moderate lateral shading from *Salix* spp and mature *Alnus* & *Fraxinus*	3 / 4

Site & Grid Ref.	Brief site description & image reference	GM = ground moisture levels
	excelsior (to both east & west)	
S13/14 SU9735217429	Similar to S 14 but lying about 10 m of newly created concrete cascade feature. (*Vertigo moulinsiana* readily visible in field on *Carex riparia* leaves).	3

Vertigo moulinsiana was present at twelve of the fourteen Burton Mill Pond sites. As in 2011, the snail was not found, at two sites lying at the north-west of the pond (S10 & S11), but had reappeared in large numbers at sample stations S13 and S14, located at the at the south-western extremity of the pond (Figure 46).

Table 7 compares the approximate *V. moulinsiana* density at the fourteen survey sites obtained in 2011 with those of the latest survey whilst Table 8 compares numbers of juveniles with adult snails recorded at the survey sites in 2016.

Table 7 A comparison of *approximate Vertigo moulinsiana* population density at Burton Mill Pond survey sites in 2011 and 2016

Survey sites	*Vertigo moulinsiana* m^{-2}	
	November 2011	June / July 2016
1	38	8
2	6	6
3	12	16
4	150	30
5	14	8
6	114	80
7	108	24
8	14	< 1
9	374	14
10	0	0
11	0	0
12	2	< 1
13	0	92
14	0	60
13/14	Not surveyed	174

Table 8 Comparison of adult / juvenile presence at survey sites 2016

Survey sites	*Vertigo moulinsiana* numbers in 2016	
	Adult	Juvenile
1	12	0
2	10	0
3	18	4
4	39	6
5	13	0
6	96	24
7	32	4
8	1	0
9	20	2
10	0	0
11	0	0
12	2	0
13	78	60
14	18	42
13/14	168	6
Totals:	**507**	**148**

Discussion:

Vertigo moulinsiana was found living in marginal fen around approximately 80% of the perimeter of Burton Mill Pond where open water is present (Figure 46). It was only absent, on the pond perimeter, at adjoining sites S10 and S11 and in very low numbers at adjoining sites S8 and S12. At all other perimeter sites the snail was quickly located. The largest populations on the main pond were recorded from fen lying on the western margins of a salient of land extending into the centre of the pond (sites S4, S6, S7) where populations ranged between 24 – 80 m^{-2}. These counts are lower than in 2011, but this is probably accounted for as a result of the earlier timing of the work occurring before the presumed main breeding period of the snail in early autumn. *V. moulinsiana* is a species where population numbers are often highest in the late summer and autumn (Drake 1999, Killeen 2003, personal observations), but also where population numbers fluctuate considerably from year to year for a series of reasons, many not fully understood (Baker *et al* 2007, Killeen, 2003, Tattersfield & Killeen, 2006; Willing, 2011a). It is not possible on the basis of very occasional sites visit to identify population trends.

Unexpectedly large populations of *V. moulinsiana* (the highest recorded during the 2016 surveys) were found at sites 13, 14 and 13/14 at the southern margins of the pond (peaking at 174 m^{-2} at S13/14). Surveys in this area produced very low numbers of the snail in 2010 (Willing 2011b), whilst *V. moulinsiana* was not recorded in this area in 2011 (Willing 2012) and the population there was feared extinct. It is possible that the reappearance of the snail in this relatively isolated fen compartment (separated from the main blocks of marginal fen vegetation lying on the margins of the main pond further north) may be due to live animals transported in on flood debris from Chingford Pond during two flooding events occurring between November 2014 and February 2015. The Chingford survey report documenting this period described the presence, in flood debris collected (in late February 2015) on the margins of Chingford Pond, of large numbers of freshly dead *V. moulinsiana.* Some of these snails will have been carried (when live) downstream and deposited with flood debris in the recolonised area (sites S13, S14 & S13/14). Many publications (e.g. Drake 1999, Killeen 2003) have suggested that *V. moulinsiana* colonises newly formed sites as a consequence of carriage of the animals in flood debris. Thus Drake (1999; p. 76) states, "*There is no information on the mobility of these small snails but it can be speculated that that they could be moved during floods ….. Support for the idea that the snail can disperse, perhaps moderately readily, along rivers comes from finding V. moulinsiana at many apparently suitable patches of habitat along the recently well surveyed rivers, and from the rapid establishment of colonies on newly created swamp. If there is some inter-change of individuals between sites along a river, then each river or catchment may represent a single population".* Such a situation does of course describe a 'metapopulation' and this is what may be considered to exist in the Chingford – Burton Mill Pond catchment.

Although the Burton Mill Pond sites 13 and 14 are not directly over-shaded, they are subject to indirect shading from tall trees (e.g. ash, sycamore and alder) lying on the slightly higher ground on either side of the fen at this location (Figure 48). It is possible that this slight shading (most significant in the morning and evening) may have a slight negative effect upon this areas long-term suitability for *V. moulinsiana*. *V. moulinsiana* is mostly found in open, un-shaded habitats (Kerney 1999, Drake 1999, Killeen 2003, Willing 2016). Unfortunately, these populations are at risk from water overspill from Chingford Pond leaving the pond via the newly reconstructed concrete cascade (lying about 10 m from S 13/14).

In the 2011 surveys (of both Chingford and Burton Mill Ponds), adult *V. moulinsiana* were outnumbered by juveniles. Thus, at Burton Mill Pond 57% of the total snails collected were juveniles (1:1.35 adult/juvenile ratio). The predominance of juveniles from both areas suggested 'healthy' recruiting populations where breeding was likely to have occurred in the early autumn. By contrast, the June/July 2016 survey produced a predominance of adult snails (Table 8) with a juvenile: adult ratio of 1:3.4 suggesting that the breeding was at a relatively low level and before the presumed period of reproduction in late summer / early autumn. It is suggested that if these surveys had been undertaken in autumn 2016 then numbers of *V. moulinsiana* would be higher at all sites where the snail is present and that the juvenile snails would then have outnumbered adults.

The absence or low numbers of *V. moulinsiana* at the northern Burton Mill Pond sites (survey stations 8, 10, 11 and 12) seems unusual. The fen at these sites has supported the snail in the past (personal observations) and environmental conditions (un-shaded fen dominated by sedges with suitable ground water levels) appears favourable for the snail. Reasons for the absence, or very low numbers, of the snail in areas are not clear.

To summarise *Vertigo moulinsiana* populations at Burton Mill Pond are judged to be in a **favourable condition** and with the recovery (since 2011) of populations at the southern extremities of the pond, may have increased in range since 2011. This highlights Burton Park SSSI as an important habitat for this Annex II species (EU Habitats & Species Directive). As such, *V. moulinsiana* should be included within the SSSI favourable condition tables for the site along with the reed-swamp habitat and its appropriate management.

Table 9 Full survey results for *Vertigo moulinsiana* at Burton Mill Pond, 2016

Site 1	Sub-samples (0.5 m^{-2})			Mean total for site $0.5m^{-2}$	Mean total m^{-2}
	1	2	3		
Adult	6	2	4		
Juvenile	0	0	0		
Total (adult + juv)	6	2	4	4	**8**
Site 2	**Sub-samples (0.5 m^{-2})**			**Mean total for site $0.5m^{-2}$**	**Mean total m^{-2}**
	1	**2**	**3**		
Adult	1	6	3		
Juvenile	0	0	0		
Total (adult + juv)	1	6	3	3	**6**
Site 3	**Sub-samples (0.5 m^{-2})**			**Mean total for site $0.5m^{-2}$**	**Mean total m^{-2}**
	1	**2**	**3**		
Adult	2	2	18		
Juvenile	0	0	4		
Total (adult + juv)	2	2	22	8	**16**
Site 4	**Sub-sample (0.5 m^{-2})**			**Mean total for site $0.5m^{-2}$**	**Mean total m^{-2}**
	1	**2**	**3**		
Adult	21	14	4		
Juvenile	1	0	5		
Total (adult + juv)	22	14	9	15	**30**
Site 5	**Sub-sample (0.5 m^{-2})**			**Mean for site $0.5m^{-2}$**	**Mean total m^{-2}**
	1	**2**	**3**		
Adult	12	0	1		
Juvenile	0	0	0		
Total (adult + juv)	12	0	1	4	**8**
Site 6	**Sub-sample (0.5 m^{-2})**			**Mean for site $0.5m^{-2}$**	**Mean total m^{-2}**
	1	**2**	**3**		
Adult	12	24	60		
Juvenile	4	6	14		
Total (adult + juv)	16	30	74	40	**80**
Site 7	**Sub-sample (0.5 m^{-2})**			**Mean for site $0.5m^{-2}$**	**Mean total m^{-2}**
	1	**2**	**3**		
Adult	6	10	16		
Juvenile	2	2	0		
Total (adult + juv)	8	12	16	12	**24**
Site 8	**20 minute search at various locations (none in sub-samples)**			**Mean for site $0.5m^{-2}$**	**Mean total m^{-2}**
Adult	1				
Juvenile	0				
Total (adult + juv)	1			< 1	**<1**

Site 9	Sub-sample (0.5 m^{-2})			Mean for site 0.5m^{-2}	Mean total m^{-2}
	1	2	3		
Adult	6	6	8		
Juvenile	2	0	0		
Total (adult + juv)	8	6	8	7	**14**
Site 10	**20 minute search at various points (none in sub-samples)**			**Mean for site 0.5m^{-2}**	**Mean total m^{-2}**
Adult	0				
Juvenile	0				
Total (adult + juv)	0			0	**0**
Site 11	**20 minute search at various points (none in sub-samples)**			**Mean for site 0.5m^{-2}**	**Mean total m^{-2}**
Adult	0				
Juvenile	0				
Total (adult + juv)	0			0	**0**
Site 12	**25 minute search at two locations**			**Mean for site 0.5 m^{-2}**	**Mean total m^{-2}**
Adult	2				
Juvenile	0				
Total (adult + juv)	2			< 1	**<1**
Site 13	**Sub-sample (0.5 m^{-2})**			**Mean for site 0.5 m^{-2}**	**Mean total m^{-2}**
	1	**2**	**3**		
Adult	18	18	42		
Juvenile	12	24	24		
Total (adult + juv)	30	42	66	46	**92**
Site 14	**Sub-sample (0.5 m^{-2})**			**Mean for site 0.5m^{-2}**	**Mean total m^{-2}**
	1	**2**			
Adult	6	12			
Juvenile	24	18			
Total (adult + juv)	30	30		30	**60**
'Site 13 / 14'	**Sub-sample (0.5 m^{-2})**			**Mean for site 0.5m^{-2}**	**Mean total m^{-2}**
	1	**2**			
Adult	48	120			
Juvenile	0	6			
Total (adult + juv)	48	126		87	**174**

Figure 47 *Vertigo moulinsiana* survey station photos 1-8 (2016)

Figure 48 *Vertigo moulinsiana* survey station photos 9 - 14 (2016)

3. Appraisal of the Evidence and Discussion

3.1. Current status of Burton Mill Pond

Burton Mill Pond is in unfavourable condition with respect to the updated Common Standards Monitoring for Freshwaters (JNCC 2015). The follow sections summarise the condition of Burton Mill Pond in light of the available evidence.

Siltation and water depth

Previous concerns about siltation were based on the breaching of Chingford Dam, and while at the time (1983) there was undoubtedly an influx of sediments to BMP, this problem was relatively short-lived, and in part dealt with by silt removal in 1985. Subsequent changes to the dam in 1991, are likely once again, to have caused sediment influx, but evidence from radio-nucleotides in the sediments show relatively slow accumulation rates over the past 50 years (estimated at 0.50 – 0.77 cm per year).

A previous attempt to calculate the loss of soil from the catchment (Atkins 2012) was alarmist in its conclusion that BMP would be completely infilled by 2026. This study was based on the inaccurate interpretation of Ordnance Survey data, and failed to provide any evidence of on-going sediment loss from the catchment.

Recent works to remove the sediments from Trout Pond and to reinstate the dam and historic water level at Chingford Pond, will play a major part in trapping catchment derived sediments before they reach BMP. There was no evidence of excessive soil erosion seen within the catchment. Current catchment management includes approximately 25% under arable production, and while the majority of this is on low gradients, best practice should be maintained to prevent soil loss under wet conditions.

The depth of water within BMP is not currently of concern in terms of the ecological function of the site. Most the open water area is between 1.0 – 2.0 m deep, with slightly shallower depths recorded around the island and along the reed front of the southeast shore (in front of Woodlands, see Figure 22). This is ideal for growth of aquatic plants, and consequently we find high plant biomass throughout the open water in all but the deepest areas. These plants provide vital habitat for zooplankton, invertebrates and fish, and under current trophic conditions, represent the best possible ecological scenario for the site (see Box 1 below).

Sediment removal has been used as a management tool for both increasing water depth and reducing internal phosphorus loadings, but this is only deemed to be appropriate where catchment sources have been successfully controlled or where there is a risk of losing open water due to excessive siltation (NE 2015). Furthermore, the current ecological status of BMP is dependent on the submerged aquatic flora; dominated by shining pondweed *Potamogeton lucens*.

Encroachment

Terrestrialisation of shallow lakes is a natural process whereby the emergent plants trap organic matter and silt and over time becomes drier and more suitable for terrestrial plants to establish. The rate of encroachment and quality of the new wetland habitats formed and open water habitats lost, requires careful assessment and management.

The loss of open water extent was one of the primary concerns cited by Natural England (2009, 2014) for Unit 1 of Burton Park SSSI was failing. This is a problem seen at many shallow lakes where there is active development of the surrounding wetlands, and it is an issue that has received active management in the form of reed cutting and tree cutting for many years (as described by Griffiths 2012). As a result, the actual area of open water in BMP is likely to have varied somewhat since the site was first designated in 1954, but, based on aerial photography, the overall change (measured between 1956 and 2013 is a reduction of approximately 16%. This is a significant loss of extent, but is considerably lower than previous estimates by NE (36% loss since 1982) and Atkins ((2012) a 54% loss since 1979).

Aerial photography (Figure 19) reveals that the rate of tree growth has exceeded the rate at which the wetland and reeds have grown out into the pond and thus there has been a net loss of open wetland habitats as well as the total areas of open water. The wet woodlands comprise mainly of alder and willow, but there is also regeneration of birch along the more acid north-western shore (bordering Newpiece Moor), where there is good potential for areas of wet heath within the existing mosaic of heathland habitats on Newpiece Moor. Loss of the wetland habitat, and particularly the dense shade caused by developing woodland pose a threat to populations of Desmoulin's whorl snail and Cowbane, both of which have nationally important population at BMP.

Encroachment is therefore a problem at BMP and requires continued management. It is likely that the rate of growth of wetland plants and trees is influenced in part by the availability of nutrients, thus a reduction in trophic status will help to reduce the rate of chance (see following section). Active management should focus on the sensitive removal of tree and scrub cover in line with historic boundaries (see Management plan and map below). Similarly, the cutting of reeds will be required to prevent any further loss of extent, and were possible, to regain areas of open water. All aspects of this management work will require sensitive work programmes to ensure target species are not significantly damaged within the site.

It should be stressed however, that where encroachment is occurring, it is likely that some of the new habitats formed will themselves be of conservation value, and it may therefore be appropriate to allow some succession to occur and this should be accounted for within the management programme (see Mainstone *et al*. 2016). Species and habitat monitoring should therefore be done in conjunction with the management plan, in order to best identify the key areas in which to intervene or leave.

Eutrophication

Based on Environment Agency water quality data, Burton Mill Pond is currently eutrophic and has mean annual concentrations of total phosphorus (TP) and total nitrogen (TN), well in excess of the expected values for natural waters. Furthermore, EA monitoring data show the levels of annual mean TP in the site to have almost doubled since 2004. There is clear 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.

While a lake remains plant dominated and clear during the summer months, the most effective management is to reduce the anthropogenic inputs of nutrients and in so doing increase the resilience of the lake to change.

In Burton Mill Pond, we see an aquatic plant community "typical" for eutrophic lakes (JNCC 2015). While there has been a two-fold increase in TP since 2003, the aquatic plant community shows very little change. Plants we consider to be indicative of eutrophication (e.g. *Potamogeton pectinatus* and *Zannichellia palustris*) have remained very stable over this period, suggesting the site has some resilience to change; at least in the short term.

The current plant assemblage does not reflect the original SSSI citation (NE 1986), but that too describes a flora more typical of eutrophic waters. Survey results from this earlier period are insufficient to make direct comparisons with the CSM methodologies applied since 2003. Where we do see significant changes in the flora is in the palaeoecological records spanning at least the past 100 years. Numbers of stonewort oospores (akin to seeds) were very high in the older sections of the core. Stoneworts are very sensitive to eutrophication, particularly *Nitella* species, which are only found in the older sediments. *Chara* species oospores remained prevalent until more recently, but although stoneworts are still found in the site, they have been very rare in the surveys since 2003, suggesting conditions have long since been unfavourable for their growth.

Without a better chronology on the sediment core, we are unable to attribute the decline in stoneworts to an exact timescale, but the decline we see in the BMP is typical of the patterns in other lowland lakes in England, that have a documented history of decline due to eutrophication over the past 150 year (Bennion *et al.* 2017). This is strong evidence of an ecological impact having occurred in Burton Mill Pond due to eutrophication, and from the descriptive flora in the SSSI citation, it is safe to assume that this change had already occurred by the time the site was designated as a SSSI in 1954.

Since 2003, there has been good water quality data available for BMP. The observation that the mean annual total phosphorus concentration has doubled over this period should be viewed with extreme concern and efforts to reduce nutrient inputs to the site should become the priority for future management. Part of this will be to establish the sources and of nutrients from within the catchment and place controls wherever possible, to prevent any further deterioration in trophic status.

This is pertinent not only to Burton Mill Pond, but to the wider area of River Rother catchment of which this forms an important headwater area. 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 the Rother and Arun river basins downstream.

Agricultural sources: Within the BMP catchment, the majority of agricultural land is managed under Environmental Stewardship schemes, including both Entry Level plus Higher Level Stewardship and Organic Entry Level plus Higher Level Stewardship, both of which should help to reduce agriculturally derived nutrient inputs to the freshwaters. The catchment walkover and water quality survey did not show any significant phosphorus pollution coming from agricultural run-off. Nonetheless, agriculture by its very nature, will contribute to nutrients in the streams and ultimately into BMP, but under the current management, the impact should be minimised providing the Stewardships are adhered to and best practice is maintained.

The support of landowners and tenants farming 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 2017).

There is some evidence to suggest diffuse pollution is reaching the Black Pond sub-catchment to the north of Burton Park House. This warrants future monitoring to determine if there are any land management or stock-yard issues that may result in higher nutrients in this area, or in fact there are any potential domestic sources up stream of Black Pond.

While we did not find any further evidence of high nutrient run-off from agricultural sources, additional catchment monitoring is advised in order to quantify the full impact from farming. Monitoring should include an array of sites (similar to that used for the walkover) 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.

Domestic sources: The majority of domestic sewage within the catchment is treated at the Duncton sewage treatment works (STW) located at SU9611817271 (operated by Southern Water) and the private STW at Burton Park (package plant installed in 1996, operated by Petworth Management Company). Both STWs comply under their respective permits and discharge treated effluent directly into the BMP catchment. These permits do not however cover phosphorus directly, but focus on the levels of organic pollution, suspended solids and ammoniacal nitrogen, as well as microbiological quality.

Duncton sewage treatment works (STW) discharges to a surface water drain within the catchment of BMP, but we were unable to trace the flow over ground during the catchment walk over. Further work is required to trace the exact route of the discharged waters, but it must be assumed that they reach BMP, probably via Trout Pond and Chingford Pond. Given the extremely high phosphorus content of the discharge, it is imperative that Southern Water are engaged to determine the exact quantity and quality of the effluent, and the fate of the P loading through to BMP. This information is required to determine what, if any, additional treatment is required in order to prevent any further damage to Burton Park SSSI.

The treated sewage effluent from the Burton Park package plant, is discharged directly into the surface drain that flows directly into BMP; the discharge point being less than 200 m from the boundary of the Burton Park SSSI. While the discharge meets the specified criteria listed in the consent permit (EA ref. P.6634L/S/CH/97, issued under the Water Resources Act 1991), we are not satisfied that it meets section 5 of the consent as follows:

> 5. As far as is reasonably practicable the works shall be operated so as to prevent:
>
> (a) any matter being present in the discharge, other than matter specifically covered by numerical conditions in this consent, to such an extent as to cause the receiving waters, or any waters of which the receiving waters are a tributary, to be poisonous or injurious to fish in those waters, or as to the spawning grounds, spawn or food of fish in those waters, or otherwise cause damage to ecology of those waters; and
>
> (b) the treated effluent from having any other adverse environmental impact.

Effluent draining to the lake is extremely high in phosphorus, a pollutant which we present good evidence has caused ecological change to the site and thus has an adverse environmental impact. Given the relatively volume of treated effluent being discharged (estimated from PMC figures to be in the region of 5000 m^3), this is likely to be significantly lower that the contribution from the Duncton STW (no discharge volume given). This is nonetheless a significant source of P within close proximity of the SSSI and Burton Mill Pond, and we recommend addition controls are put in place to prevent this source of P causing further ecological damage.

In addition to the two STWs within the catchment, there are a number of rural dwellings 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. In reality, older septic tanks are rarely efficient, and there is a significant body of evidence to suggest they can make a significant contribution to nutrients in receiving waters (May et al. 2015). We recommend that a full review of the location and function of all individually maintained septic tanks within the catchment is made.

The control of nutrients within the catchment will be a key priority for the restoration and sustainability of Burton Mill Pond. Other aspects of management, particularly the control of encroachment will also be required, but this focus should be on the catchment rather than just the lake. It will be crucial for the success of the Vision, that the site owners and managers bring together and involve a wide stakeholder group to include: farm owners and tenants, local residents, South Downs NP, Arun and Rother Rivers Trust, West Sussex CC, Natural England, Sussex Wildlife Trust (and LNR Committee), Petworth Management Company, Southern Water and Environment Agency.

SSSI Favourable Condition Tables

The Favourable Condition Tables (FCT) set out the target condition for the designated features within the SSSI. In the case of Burton Mill Pond, this includes both the habitats and notable species therein. The FCT are based originally on the SSSI citations and are periodically reviewed by NE though a process of evidence gathering, expert opinion and condition assessment.

Waterbody type: Burton Mill Pond is classified as a “Mesotrophic Lake” within the SSSI Favourable Condition Tables (NE 2014) with the explanatory description being “Formed over Folkestone sandstone – one of the best West Sussex examples”. This classification, is somewhat optimistic for what is, in reality, an artificial, lowland lake lying within a historically agricultural setting with a mix both of acid and alkaline geologies within the catchment. The targets laid down for very shallow mesotrophic lakes are for low nutrients (<20 $\mu g l^{-1}$ for mean TP), and a mixed flora including a range of broad-leaf *Potamogeton* species as well as *Isoetids* such as *Littorella uniflora, Isoetes spp. and lobelia dortmanna.* Box 2 presents the general descriptions for mesotrophic and eutrophic standing waters, as defined by Mainstone *et al.* (2016).

Lake types **Box 2**

The following descriptions are taken from the Natural England publication: *A narrative for conserving freshwater and wetland habitats in England,* by Chris Mainstone, Ruth Hall and Iain Diack - Published 18 March 2016

Mesotrophic standing waters are the most botanically diverse, often supporting a range of both the rosette forming species common in oligotrophic standing waters and a range of taller growing species including a number of pondweeds (*Potamogeton* spp.). They can also support rare species such as slender naiad and least water-lily (*Nuphar pumilla*). The fish assemblages in these lakes are often a mixture of those found in eutrophic and oligotrophic lakes; in addition shelly, vendace and Arctic charr are all found in this lake type within the Lake District. Mayflies and caddisflies associated with aquatic vegetation are more abundant in mesotrophic than oligotrophic water bodies, as are the freshwater shrimps (*Gammarus* spp.) and water hoglouse (*Asellus aquaticus*) and a range of molluscs, along with a large number of chironomid species. This diverse species assemblage of flora and fauna is possible due to moderate nutrient concentrations, clear water, suitable oxygen levels, sufficient carbon dioxide, and a mix of substrates and emergent vegetation providing habitat for a range of fauna.

Eutrophic standing waters characteristically support a range of pondweeds and floating vegetation such as frogbit (*Hydrocharis morsus-ranae*) and greater bladderwort (*Utricularia vulgaris*). Such floating vegetation is particularly prominent in smaller water bodies with less exposure. The best remaining examples of this type of vegetation in the lowlands are often found in ditches as their nutrient concentrations are often kept low by spring-fed water and repeated removal of organic material. Such vegetation-rich habitats often support good numbers of macro-invertebrates, such as water beetles, water bugs and molluscs. Shallow, warm edges with a varied vegetation structure are of key importance. Other species rarely found in larger water bodes include Norfolk hawker (*Aeshna isosceles*) and fen raft spider (*Dolomedes plantarius*), which favour floating vegetation that is most frequently found in pools, ponds and ditches. Eutrophic standing waters typically support a cyprinid fish assemblage, many of which require submerged vegetation for spawning.

At the time of SSSI designation (1954) and revision (1980), the lake was not a typical mesotrophic lake. The aquatic flora comprised mainly of eutrophic species such as spiked water milfoil *Myriophyllum spicatum*, fennel pondweed *Potamogeton pectinatus*, hair-like pondweed *P. trichoides* and perfoliate pondweed *P. perfoliatus*. Looking further back in time, the palaeoecological record from the lake sediments, shows the site to have supported rigid hornwort *Ceratophyllum demersum* as far back as the 19th Century, and Arnold (1907) lists spiked water milfoil *Myriophyllum spicatum,* fan-leaved water crowsfoot *Ranunculus circinatus,* mare’s tail *Hippurus vulgaris,* shining pondweed *P. lucens* and soft hornwort *Ceratophyllum submersum*[10]*.* These older records, while subtly different from today in their species composition, nonetheless are more typical of a good quality natural eutrophic shallow lake, than a mesotrophic lake. When compared at a national level, the current and historic flora in BMP corresponds most closely to groups F, G and I (Duigan *et al.* 2006), which are the natural eutrophic and high alkalinity lakes.

The presence of *Nitella* oospores in the lower portion of the sediment core is perhaps indicative of more mesotrophic conditions, but some species of *Nitella* (and closely related *Tolypella*) are also recorded in good quality eutrophic waters. More work would be required to identify the oospores to species level (which is taxonomically very complex), but we consider the most likely reason for their loss at the site to be related to nutrient enrichment and in particular, increased nitrate which has been shown to be toxic to stoneworts (Lambert & Davy 2011).

Considering the past species assemblages, the artificial nature of the pond and its setting in an agricultural landscape, we would recommend that the Favourable Condition Tables are updated to include BMP as a “eutrophic lake” rather than “mesotrophic”. This in no way lessens the conservation status of the site, nor does the slight shift in ecological targets place the site in favourable condition. The change in status will however allow for site management to be focussed on more realistic goals and thus help to achieve the Vision.

Desmoulin’s Whorl Snail: The occurrence of Desmoulin’s Whorl Snail (DWS)*Vertigo moulinsiana* was first recorded within Burton Park SSSI (in Burton Mill and Chingford Ponds) in 1992 (Willing 1992), which is after the latest revision of the SSSI citation (1980). The snail is rare in Sussex, and has been lost from at least three sites since 1970 and the population at Burton Mill Pond is the largest recorded in West Sussex (see Section 2.5) and so of regional importance. Given the high conservation concern for DWS (scheduled on Annex IIa of the EU Habitats & Species Directive and is an English Section 41 ‘Species of Principle Importance’), its inclusion in the Favourable Condition Tables is strongly recommended.

Shining Pondweed: The extensive beds of shining pondweed *Potamogeton lucens* provide excellent open water habitat for zooplankton, aquatic invertebrates and fish. We know the species to have been present in BMP for over 100 years (Arnold 1907) and although not mentioned in the SSSI citation, it forms an important part of the characteristic flora of the site. Although not uncommon in the UK, eutrophication is thought to have resulted in an overall decline of *P. lucens,* and o the best of our knowledge this is the most extensive population within West Sussex. The abundance of *P. lucens* is important within the site for helping to maintain water clarity and thus it provides additional resilience to the lake from the impacts of eutrophication.

Furthermore, the presence of at least one broad-leaved *Potamogeton* species is a prerequisite of favourable condition for eutrophic (and mesotrophic) lakes, and we therefore recommend the Favourable Condition Tables be updated to include *P. lucens* as a long-standing and important component of the aquatic flora. Based on five cycles of CSM surveys at BMP between 2003 to 2016), the frequency of *P. lucens* has fluctuated between 45 to 65 % (54 % in 2016). Any significant loss of abundance should give rise to concern and steps taken to investigate possible causes.

[10] *C. submersum* is an unusual record for this site, but a species confined almost entirely to eutrophic lakes (Preston *et al.* 1997).

Climate change

When focusing on the long-term vision of a lake, one needs to consider the possibility of this being achieved within a changing climate. While we can only predict how climate will change in the future, it is generally accepted that restoration targets and baselines need to take climate into consideration; i.e. achieving past conditions under different climate conditions may not be possible.

In order to ensure lakes achieve the highest possible conservation status into the future, it is vital that they function as naturally as possible. Lakes that retain a diverse assemblage of characteristic species and are free from major disturbance, invasive species and pollution, provide the best and most sustainable habitats. Where anthropogenic pressures are placed on a lake, this resilience is weakened and the status lake is at greater threat of declining under changing climate conditions.

Restoring Burton Mill Pond to its most natural condition not only meets the conservation objectives, but also provides the best defence against climate change by ensuring the ecosystem has resilience and can adapt to change.

3.2. Policy drivers for lake restoration

In addition to the local concerned with regards to the condition and restoration of BMP, there is a national framework in place to provide leverage and justification towards protected sites. Apposite to Burton Mill Pond 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 Burton Mill Pond. These drivers, in conjunction with evidence-based monitoring of the site, provide the over-arching legislative pathways through with the vision may be realised.

4. Burton Mill Pond – A Vision for the future

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.

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 is presented below which targets the primary drivers of environmental change at the site and when implemented.

4.1. Burton Mill Pond – The Vision

The vision is focussed on both the open water and the array of wetland habitats that surround the pond; a site of rich historical, cultural and environmental interest, lying within the South Downs National Park.

Our Vision is of a future in which the waters of Burton Mill Pond remain clear and are dominated throughout the summer months by a diverse community of submerged aquatic plants, interspersed with white and yellow waterlilies. Shining 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 pond, there will be extensive areas of reed-bed grading gently into wet alder woodland and greater tussock sedge fen or areas of acid lowland heath, with *Sphagnum* mosses present in the wetter areas. Cowbane will flourish within the reeds and frogbit will grow in the sheltered areas where the reeds thin. 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, and Burton Mill Pond will remain a stronghold for the rare Desmoulin's whorl snail. Swan Mussels and Duck Mussels will inhabit the lake bed, where their filter feeding will help to remove suspended algae and sediments. The quality and diversity of habitats will support a host of other invertebrate species, and thus the pond will be an important feeding ground for both birds and bats, with acoustic monitoring revealing at least ten species of bat using the site to feed.

The fish population will consist of native species, such as pike, perch, eels, tench and rudd. Non-native fish species, such as common carp and rainbow trout, 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 pond will not be compromised by obstructions within the wider catchment.

The expanse of open water and extensive 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 others such as bittern and osprey will use the site as a feeding stop-off on migratory routes. The pond will attract many other species of waterfowl 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 < 30 µgl-1), both in the pond, 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. Beyond the reeds, water depth will, in the most part, exceed 1 m, reaching a maximum of 2 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.

Public access to Burton Mill Pond 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 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 nationally important site, and other wetlands, into the future.

5. Management plan

5.1. Controlling encroachment

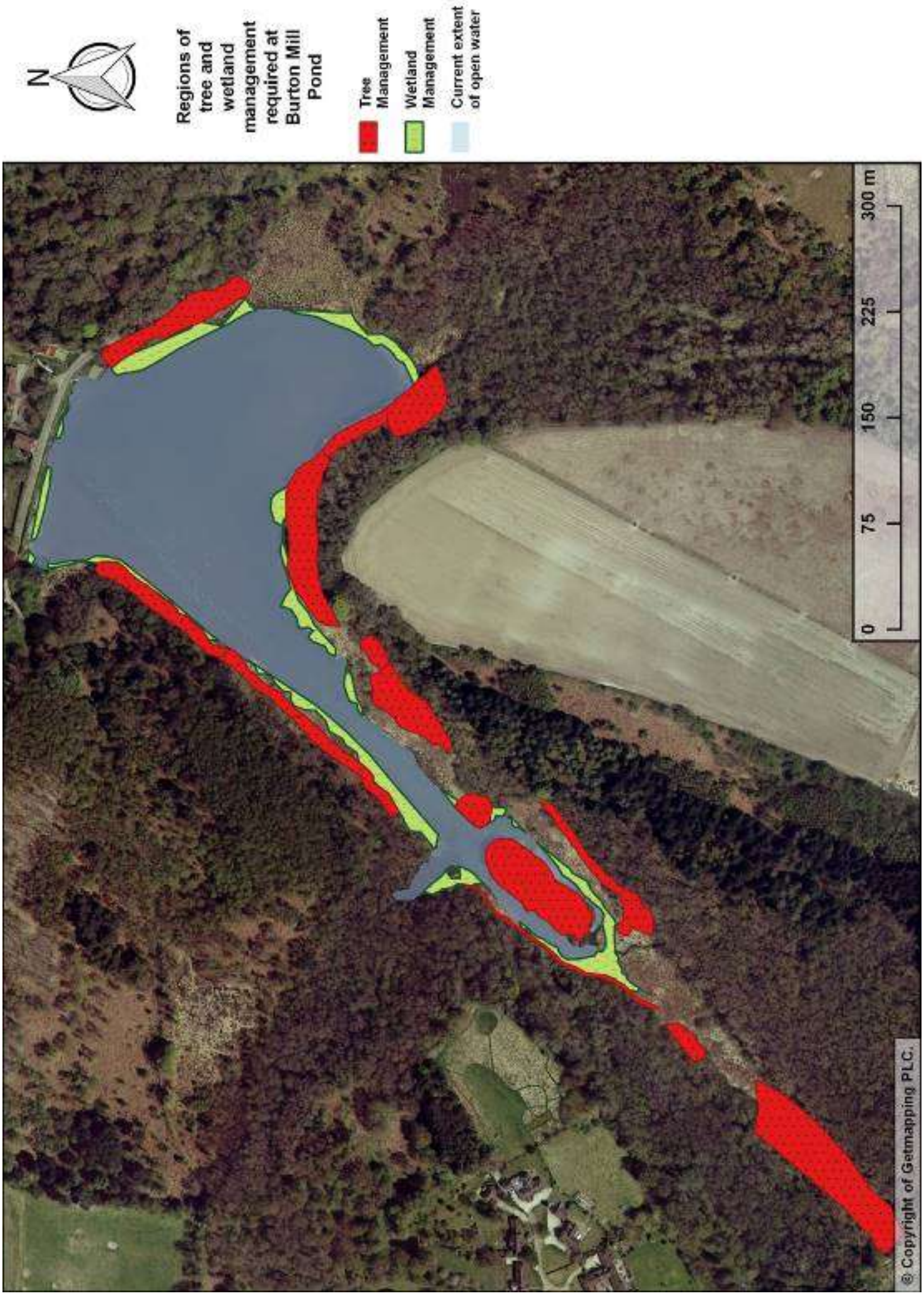

Figure 49 Map of key management areas for reed and tree cutting

This management plan is a response to the evidence gathered for and presented within this report. It uses this information to provide details of when and where specific management activities are required, and where possible provides cost estimates for undertaking this management. It should be noted however, that some additional work may be required to provide specific detail for gaining Assent from Natural England to undertake such works before the prescribed management may be implemented.

It must also be stressed, that the Burton Park SSSI falls within an area of multiple land ownership. While WSCC owns Burton Mill Pond, the necessary management required to bring about the Vision, encompasses adjacent land under separate ownership. As such, where areas of management are identified within this report, which fall outside of WSCC ownership, it will be important to work alongside the relevant land owners to facilitate the associate works necessary to achieve effective management of the site as a whole.

Figure 49 shows the potential areas for reed cutting, and, more crucially, for the management and removal of tree growth and the wetland scrub. The boundaries used are, in part, based on the extent of tree and reed cover recorded from aerial photography in 1956.

This section of the Management Plan is specific to the areas where encroachment of the marginal reed-beds and tree cover have been demonstrated to be impacting on the lake since SSSI designation in 1954, as evidenced from aerial photography. These areas fall under multiple ownership, and as such WSCC will need to work closely with other land owners and managers to achieve a practical solution to achieving the work. There are a wide range of habitats beyond those identified in Figure 49, which are not covered within this Management Plan, because they do directly impact the lake, and therefore fall outside the remit of this project.

Tree / scrub clearance: once the initial clearance of trees is achieved, this can be done on a 5-year rotation, or more frequently where deemed necessary if re-growth starts to increase shade to the adjacent wetlands. We recommend tree cutting is performed throughout the site during the autumn or winter months if water levels allow:

- along the north-west shore (bordering Newpiece Moor), where extensive areas of *Sphagnum* moss occur, the birch should be cleared up to the marginal Holly zone, with disturbance to the moss flora taken into consideration during work.
- larger trees along the southwest shore have areas with Greater tussock sedge *Carex paniculata* understory. The tussocks should be afforded care where possible during management work.

It is important not to clear all scrub habitat from the site. The JNCC's Common Standards for Monitoring guidance for lowland wetlands (JNCC 2004) recommends that up to 10% of open fen be allowed to remain as scrub vegetation and that tree clearance should not be undertaken within scrub and woodland communities which are now more valuable in conservation terms, than the original fen habitat, or the type of habitat, which could be restored.

Where practical to do so, cut timber may be left on site, including some deliberate felling into the pond. This latter action aims to provide habitat for *Lophopus crystallinus,* a freshwater bryozoan, present in BMP, that is thought to have undergone a worldwide decline in numbers over the past century[11]. Assent (or consent) will need to be sought

[11] The Invertebrate Site Register of *L. crystallinus* by Natural England lists 10 sites within England, but only three of these records have been made since the 1970's. As a consequence of this decline, *L. crystallinus* was placed in the British Red Data Book of Invertebrates Other than Insects

from Natural England for all tree management work. The quantity and location of timber that is to remain on site will need to be discussed with NE staff, and potentially this will need to take into consideration habitats and species not covered within this report (e.g. terrestrial habitats). Storage and disposal of timber and other organic waste generated by clearance will need to be permitted by the Environment Agency. Short-term storage and burning on site, will require the permission of the respective land-owners where the activity is to take place, and may be achievable under Exemption D7[12], providing the timber is not removed from site and is handled / burned in quantities of less than 10 tons per 24 hours.

Further provision to remove cut timber and dispose of it off site is unlikely to be practical, and should be avoided. The extent of the tree and scrub clearance that can be achieved at any one time will therefore be limited by the D7 exemption and suitable areas to dispose of cut material; either by burning or storage.

Mature trees may provide extant or potential habitat for bats. Given that the majority of trees requiring removal are less than 60 years old, and that the wider area has a significant number of older, larger trees, the better habitats are more likely to be outside of the management area. A habitat survey of the mature trees should nonetheless be conducted prior to management work being undertaken. If applicable, single large trees, or groups of trees, may be left standing if they are shown to have significant conservation value in their own right.

Reed Cutting: this should be managed to ensure the extent of open water is maintained at or above current levels into the foreseeable future. Due to the importance of the reed habitat for priority species, management should be done at a rate no greater than 25% of the total management area (marked in light green in Figure 49) in any one year. In practice, the cutting of 10-15% of the encroaching area per annum, should be sufficient to maintain good habitat and minimise encroachment. A 7-10 years rotation will allow the movement and re-establishment of metapopulations of Desmoulin's whorl snail *Vertigo moulinsiana* within the reed habitat, and for Cowbane *Cicuta virosa,* a perennial wetland plant, to form mature seed-bearing individuals in managed areas.

Reed management / cutting should aim to avoid removing Cowbane where possible and the location of plants may be used to define where best to “scallop” the reed front to produce a more dynamic habitat within the managed areas. Additional information on the best practice for the management of wetland habitats can be sought from the Fen Management Handbook (McBride *et al.* (Eds.) 2011). When selectively cutting reed from the reed / water interface, material will need to be removed and ideally composted off site.

Removal of the cut reeds to one of the WSCC recycling facilities (e.g. Coach Rd, Chichester) is suggested as the best method of disposal (thus removing nutrients with the biomass). Transportation of cut reed for composting in batches of less than 7.5 tons may be undertaken without environment permitting, which is covered by the recycling facility. Disposal charges of approximately £70 per ton apply.

The timing of the management will impact the long-term outcome. Cutting in winter will maintain the dominance of reedbeds, whereas cutting in summer reduces the competitive ability of reeds and encourages a more diverse mix of marginal species to develop. At Burton Mill Pond, selective cutting in late summer will be most effect at controlling

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in 1991 and given a designation of Rare (Bratton 1991). *L. crystallinus* is also listed as a priority species in the UK Biodiversity Action Plan, and a Species Action Plan was produced for *L. crystallinus* in 1998. Carl Sayer, (UCL, pers. Comm.) discovered a number of colonies in January 2004. All colonies were associated with submerged wood and branches.

[12] See https://www.gov.uk/guidance/waste-exemption-d7-burning-waste-in-the-open

encroachment and maintaining floral diversity, but must only be conducted outside of the breeding season for reed-nesting (e.g. reed warbler and water rail). The specific timing and location of reed cutting will require discussion with Natural England as part of gaining necessary Assent for the work.

Management cost – controlling encroachment

Table 10 Cost estimates for managing tree and scrub encroachment

Tree and Scrub Management - 5 year plan			
Item	**Rate (£)**	**Days**	**Total (£)**
Year 1 woodland species and bat species / bat habitat survey (inclusive of reporting).	500	6	3,000
Year 1 tree management – focussed on clearing the bulk of overhanging and marginal trees and scrub to achieve 1956 baseline (on site disposal of wood).	750	20	15,000
Year 1 – sundry costs: Administration, planning and project management – inclusive of SSSI Assent and Environmental waste permitting / exemptions.	300	5	1,500
Year 2 tree management – focussed on clearing the bulk of overhanging and marginal trees and scrub to achieve 1956 baseline (on site disposal of wood).	750	10	7,500
Year 2 – sundry costs: Administration, planning and project management.	300	2	600
Year 3 – Trimming re-growth and final tree clearance to achieve 1956 baseline tree cover.	750	5	3,750
Year 3 – sundry costs: Administration, planning and project management.	300	2	600
Year 4 – Assessment and monitoring of tree cover.	500	2	1,000
Year 5 – Trimming re-growth to maintain 1956 baseline tree cover.	500	5	2,500
Year 1-5 T & S estimate based on Contractors and WSCC staff travel and accommodation			5,000
5-year total			**£41,450.00**
Projected annual cost for sustainable tree and scrub management after initial 5 years (inclusive of management and administration)	500	6	3,000
T & S estimate			500
Annual total			**£3,500.00**

Table 11 Cost estimates for managing reedbed encroachment

Reedbed Management – 5 year plan			
Item	**Rate (£)**	**Days**	**Total (£)**
Year 1 - Administration, planning and project management – inclusive of SSSI Assent	300	4	1,200
Annually – Cut and remove reed by hand in late summer at a rate of 10 – 15 % per year.	500	5	2,500
Annually – Remove reed to a local composting facility.	250	3	750
Annually – Cost of disposal (composting facility)			700
Annually – Administration, planning and project management.	300	1	300
Year 1-5 T & S estimate based on Contractors and WSCC staff travel and accommodation			2,500
5-year total			**£29,750.00**
Projected annual cost for sustainable reedbed management after initial 5 years (inclusive of management and administration)	650	5	3,950
T & S estimate			500
Annual total			**£4,450.00**

5.2. Catchment management and pollution control

One of the key components to any lake restoration plan and vision is the recognition and acknowledgement of on-going pollution sources from the catchment and addressing these as a priority to ensure future management is sustainable (NE 2015). There is a clear and well recognised approach to shallow lake management, that there is little point in addressing internal sources of nutrients (e.g. lake sediments), until external sources have been identified and reduced to a sustainable level (Moss *et al.* 1996, NE 2015)

Agriculture: within the BMP catchment, agricultural practices and management are relatively good, and include a high proportion of areas within Stewardship schemes (HLS and Organic). This will in no way eliminate agricultural sources of nutrients reaching BMP, but will help to minimise the impact through best practice. Farmyard manures and slurry for example, are particularly high in phosphorus, so poor management of stockyards and poorly timed field applications can result in excessive runoff to surface water.

We would strongly encourage the full engagement of all farms (arable, livestock and equine) within the catchment to ensure best practice is adhered to. This process is best facilitated through the ongoing work conducted by Natural England's network of Catchment Sensitive Farming Officers (CSFO). An up-to-date list of CSFOs is available online at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/618625/csf-contacts.pdf .

Within the context of agricultural run-off, Burton Mill Pond and the surface water inflows, are generally well buffered from agricultural land throughout the catchment by adjacent areas of wetland, woodland and non-agricultural land. The buffering will help to slow the passage of diffuse nutrients to BMP, and alleviate sediment loads in all but extreme rainfall events. Future management should ensure these buffers remain, and work with landowners to ensure inputs are kept to a minimum and that best agricultural practice is followed.

Any cost implications to the site owner (WSCC) should be administrative only and involve liaising with Natural England Catchment Sensitive Farming Officers (CSFO) and local stakeholders, to ensure an effective and inclusive local network is established and the site vision effectively communicated. This is based on cost of £300 per day.

Management cost – Agricultural and catchment liaison

Table 12 Cost estimates for agricultural catchment liaison.

Agricultural and Catchment Liaison – 5 year plan			
Item	Rate (£)	Days	Total (£)
Year 1 – Engage and meet NE CSFO to identify and contact the key stakeholders.	300	2	600
Year 1 – Meet the stakeholders with the CSFO to communicate the Vision and ensure best practice is communicated to manage and reduce catchment sources of N & P.	300	5	1,500
Annually – Liaise with CSFO and stakeholders.	300	5	1,500
5-year total			**£8,100.00**
Projected annual cost for stakeholder and CSFO liaison.	300	5	1,500

Domestic sewage: despite good agricultural management, this study has highlighted the increasing problem of nutrient enrichment within BMP. Rather than coming from agricultural sources, two sources of treated domestic sewage pollution have been identified as contributing a significant phosphorus loading to the freshwaters in the SSSI. Within the legal framework of discharging consents, both the Duncton STW (Southern Water) and Burton Park package plant (PMC) comply in terms of public health and gross organic pollution. The discharge of high levels of phosphorus to the surface waters and ultimately Burton Park SSSI, does however require further review, particularly in light of the evidence of declining water quality in BMP.

The catchment sources of pollution have been identified as the major pressure on the lake. In such cases, a catchment-based approach (CaBA[13]) has been acknowledged as a valuable forum for exploring the evidence and involving the stakeholders to ensure the best possible outcomes for all parties. The current catchment partnership is hosted by Arun and Rother Rivers Trust (http://arunwesternstreams.org.uk). For the vision to be achieved through restoration, this partnership should have clear objectives and a long-term outlook to ensure the goals are met. The stakeholders involved should include:

- West Sussex CC
- farm owners and tenants;
- local residents
- South Downs NP
- Arun and Rother Rivers Trust

[13] More information and contacts for CaBA can be found online at http://www.catchmentbasedapproach.org/south-east/arun

- Sussex Piscatorial Society (current angling lease)
- Natural England
- Sussex Wildlife Trust
- LNR Committee
- Petworth Management Company
- Duncton Parish Council
- Southern Water
- Environment Agency.

It will be necessary to gather further evidence and undertake additional water quality monitoring; in particularly to determine the exact volumes and quality of discharge from the two sewage treatment works within the catchment. Currently, the fate of discharge from the Duncton STW (managed by Southern Water), is not known beyond the point of outfall. The volume of discharge would also help in assessing the final impact of nutrients reaching the Lake.

In addition, working with the community and the Environment Agency, identifying all properties within the catchment that are not on mains sewerage would help with better understanding. Septic tank systems, and to a lesser degree, cesspits, are only efficient in containing nutrient pollution (and other pollutants) when fully functional and in a good state of repair (May *et al.* 2015). We also recommend that residents using off-line sewage treatment are provided with information on the correct usage of their septic tanks (national information available online at: http://www.theseptictankguide.info/information).

Management cost – domestic sewage

The cost of identifying and managing domestic sources of nutrients from private sewage treatment facilities (SSDs – Small sewage discharges) is complex, due to multiple property ownership and a reliance on the property owners for the upkeep of off-line sewage treatment facilities. Given the relatively low number of properties thought to have individual sewage treatment facilities, the initial cost implication will be to identify properties with SSDs.

With respect to the larger domestic discharges (Duncton STWs and Burton Park Package plant), the cost implication for WSCC will be best directed to providing additional evidence of the quality and quantity of discharges. Both treatment works comply under their current discharge permits, but nonetheless are demonstrated within this report to be polluting the surface waters within Burton SSSI with high levels of inorganic nutrients.

The installation of discharge gauging equipment (stilling well and pressure sensor) is recommended at the outlet points of the Duncton STWs and Burton Park Package plant. Servicing and water quality assessment will form part of the catchment monitoring programme (see below). The methods and costs of tertiary treatment (for P removal) vary depending on the type of treatment works, but for a package plant discharging 5-10 m^3 per day, dosing systems can be installed for between £5,000 -£25,000. For large STW’s the cost would be higher.

Table 13 Cost estimates for facilitating control of domestic pollution.

Identifying and managing domestic sewage – 5 year plan			
Item	Rate (£)	Days	Total (£)
Year 1 – Meet the stakeholders to communicate the Vision and ensure best practice is communicated to control domestic sewage outlets.	300	4	1,200
Year 1 – Identify all off-line SSDs (cesspits, septic tanks, package plants, etc.) within the Burton Mill Pond catchment (desk exercise).	300	5	1,500
Year 1 – Liaise with owners of properties / businesses with off-line sewage treatment facilities, provide information on best practice and arrange access for inspection.	300	2	600
Year 1 – Inspect all offline SSDs and commission a report on function and condition.	600	15	9,000
Year 1 – Liaise with Southern Water and Petworth Management Company with respect to installing discharge monitors (volume) at the respective outlet points.	300	2	600
Year 1 - Install discharge monitoring equipment at the outlet points from Duncton STW and Burton House package plant.	500	2	1,000
Year 1 – Pressure level sensors and installation units. 2 at £2500			5,000
Year 1 – monitor catchment water quality			See below
Year 2 – Liaise with property owners and NE and EA staff with respect to any failing SSDs	300	5	1,500
Year 2 – Liaise with Southern Water and Petworth Management Company with respect to additional evidence of nutrient pollution.	300	2	600
Year 2 – monitor catchment water quality			See below
Year 3 – Liaise with Southern Water and Petworth Management Company with respect to all additional evidence of nutrient pollution (see monitoring below).	300	5	1,500
Year 3 – Liaise with NE and EA with respect to STW and Package plant discharges. Present all evidence and work with NE / Ea and Site operators to find the best outcome to alleviate nutrient pollution.	300	10	3,000
Year 3 – monitor catchment water quality			See below
Year 4 – monitor catchment water quality			See below
Year 5 – monitor catchment water quality			See below
Year 1-5 T & S estimate based on Contractors and WSCC staff travel and accommodation			2,500
5-year total			**£28,000.00**
Projected annual cost for managing domestic waste. Data collation and stakeholder liaison.	300	2	600

5.3. Dredging / sediment removal

There is no evidence that Burton Mill Pond is currently undergoing excessive siltation within the open water area. Sediment accumulation rates calculated from radiometric markers within the sediment core, show deposition rates to be between 5-10 mm per year, which is typical of productive lowland lakes in the UK (Rose *et al.* 2011). During the natural sedimentation process, the older sediments are compressed over time, and thus the actual rate of sediment accrual is likely to be less than 5 mm per year.

In the work programme for Burton Mill Pond, we would strongly recommend that the focus is directed towards achieving the vision through addressing the wider issues within the catchment, before any further efforts are made to remove sediments. This follows best practice and the evidence-based advice laid down for shallow lake management by Natural England (see Section 3.43 in Mainstone *et al.* 2016).

The case against dredging is particularly pertinent at BMP, where the current flora, dominated by shining pondweed *Potamogeton lucens*, provides additional stability and reliance to the site, despite the high trophic status, by providing refuge to zooplankton from fish predation, which in turn help to prevent high algal turbidity (See Box 1 above). If sediment were removed, so would many of the vegetative propagules (mainly rhizomes) of *P. lucens* as well as viable seeds and propagules of other aquatic plant species. Given the current nutrient levels, there is a high risk that disruption to the viability and distribution of the current macrophyte flora would result in a switch from the clearwater conditions we see today, to algal-dominated turbid waters. There is a strong evidence base demonstrating that shallow eutrophic lakes rarely recover after switching from plant-dominated to algal-dominated conditions, without major and costly interventions (Moss 2010).

Going forward into the future, there will hopefully be a time when catchment monitoring shows nutrient pollution to have fallen to acceptable levels. When this is achieved, it can be demonstrated that high levels of nutrients are being liberated from the lake sediments, there may be cause to consider sediment removal. Similarly, if areas of the open water become shallower over time, it may be deemed appropriate to deepen them to avoid any loss of open water extent. At this stage, major intervention such as sediment removal are not deemed to be appropriate. Future monitoring of lake and catchment water quality will inform appropriate management within the site and should be integral with achieving the vision.

Management cost – Sediment removal
The cost of dredging is estimated within the Atkins report (2012) as being between £3.7-£18.1 million, at 2012 costs. Based on best practice of shallow lake management (see Mainstone *et al* .2016), we can see no justification in spending this amount of money while there is clear evidence of nutrient inputs being a major factor in the decline in quality of the SSSI.

5.4. Fisheries management

The current level of angling is low and focussed on native fish species. Access to the site is primarily from the dam or via one small boats, thus minimising disturbance to the natural marginal habitats.

In terms of management, there is no recent history of fish stocking and any licence to change this would require review by the Environment Agency and Natural England. Non-native fish species should be excluded and live bait strictly prohibited. We would recommend that no “weed cutting” is undertaken without assent from Natural England.

Angling forms an important part of the cultural and social history of Burton Mill Pond and if managed sustainably and in conjunction with the conservation objectives can be integral with the Vision. Anglers should be encouraged to form an active role within the catchment partnership, and to feed in catch records to add to the evidence database.

The knowledge of many anglers is an excellent resource that can be harnessed to collect useful data and potentially act to highlight any problems with water quality or conservation concerns. The potential benefits of this so-called “citizen science” are well recognised within the catchment based approach to facilitate both engagement and data gathering (see http://www.catchmentbasedapproach.org/resources/volunteer-monitoring).

Management cost – Fisheries management
Any financial commitments relating to up-keep and facilities for anglers will be broadly covered by the inclusion of the fisheries leaseholder (Sussex Piscatorial Society) within the wider stakeholder discussions. It remains important that the Sussex Piscatorial Society work alongside WSCC and NE in order to ensure their management and actions are in keeping with the wider SSSI management and work towards the Vision.

5.5. SSSI Designation and Condition

Waterbody type: We recommend that Burton Mill Pond is classified as a “eutrophic” instead of “mesotrophic” standing water body. This is more in line with the historical data from the site and allows for more realistic and achievable targets to be set for site management.

Species additions: Desmoulin’s whorl snail *Vertigo moulinsiana* and shining pondweed *Potamogeton lucens* are “site-specific standards defining favourable condition” and “Indicators of local distinctiveness” and their respective populations should be included in site monitoring to ensure they remain viable within the site.

Management for DWS should take into account their preference for unshaded areas of emergent reed bed, and therefore ties in with the management recommendations for controlling encroachment by trees and scrub vegetation. The fluctuation of water levels can also negatively impact DMS (as at Chingford Pond). Periods of high water (causing inundation) in winter or low water in summer (resulting in loss of standing water within the reeds) should be avoided, and any management work requiring water level changes, should only be done through an informed process of Assent where the potential impact on DWS can be assessed. The populations should be monitored periodically (3-5 year interval), and consideration be given to disturbance during management operations within reed bed habitat.

The current extent of shining pondweed is best shown by vegetation mapping (see Figure 25). Monitoring is more easily achieved by repeat surveys using the Common Standards Monitoring methods (JNCC 2015) which have shown the frequency of *P. lucens* to have remained at approximately 50% since 2003 (Figure 24). It is suggested that CSM monitoring should be conducted on a 3-year cycle and concerns raised if the frequency of *P. lucens* falls below 40%, triggering additional investigation as to potential causes.

Cowbane: The occurrence of cowbane *Cicuta virosa* is highly notable and additional distribution maps are appended to the 2014 tables (NE 2014). It is recommended that a threshold figure of at least 50 individual plants (approximately half the 2016 population) be quoted as the minimum population size. Should monitoring show the total number of plants to fall below this (or a consistent decline over 3 monitoring cycles), management action should be taken to determine the causes.

Floristic composition: The current "comment" field in the 2014 SSSI unit describes the vegetation composition as:

> "Open water dominated by Yellow water lily (*Nuphar lutea*), spiked water milfoil (*Myriophyllum spicatum*), and uncommon species of pondweed, such as; fennel pondweed (*Potamogeton pectinatus*), perfoliate pondweed (*P. perfoliatus*) and hair-like pondweed (*P. trichoides*)."

This description is outdated, and fails to mention some of the characteristic species important in defining the SSSI condition. A more accurate description might be:

> "Open water dominated by shining pondweed (*Potamogeton lucens*), yellow water lily (*Nuphar lutea*) and fennel pondweed (*Potamogeton pectinatus*), with other notable species present, including: fan-leaved water crowsfoot (*Ranunculus circinatus*), perfoliate pondweed (*P. perfoliatus*), hair-like pondweed (*P. trichoides*), frogbit (*Hydrocharis morsus-ranae*), small pondweed (*P. berchtoldii*), rigid hornwort (*Ceratophyllum demersum*), arrowhead (*Sagittaria sagittifolia*) and stoneworts (*Chara* spp.).

Sediment load: Reference to the 2012 report (Atkins 2012) which suggests the "open water will be lost in 14 years [2026]" is inappropriate. The data used to obtain these figures were based on the incorrect interpretation of maps and there is no field evidence to substantiate this rate of siltation. Furthermore, the restoration of Trout Pond and Chingford Pond, will help to reduce catchment derived silts reaching BMP.

Any reference to de-silting should be caveated by NE advice on best practice, which is to first deal with external nutrient sources before re-assessing the need for sediment removal.

Water quality: There is relatively good sequence of water quality available for BMP from 2003 to 2016 (EA 2017) showing TN and TP to exceed CSM limits, with the latter doubling since 2003. This data source is key and the TP and TN values made readily available. Using the target values for natural eutrophic lakes set out in the CSM guidance (JNCC 2015), we suggest the maximum levels for TP and TN are set at 50 μgl^{-1} and 1.5 mgl^{-1} respectively.

5.6. Monitoring

A key aspect to the success of the Vision, will be to monitor the environment in and around BMP to assess progress and, if necessary, to adjust management accordingly to ensure the most favourable trajectory is followed.

Monitoring water quality from strategic points within the catchment (including Duncton STW and Burton House package plant) will be essential to provide the necessary evidence and track the reduction of both point-source and diffuse nutrient pollution. This should be arranged via the catchment partnership, with the lead being taken by the EA. Monthly sampling within the catchment at points 2, 3, 7 and 8 (Figure 4 and Table 1) should be considered as a minimum, with two additional samples added at the Duncton STW and Burton House package plant outfalls. Water quality parameters should include a minimum of: total phosphorus, orthophosphate, total nitrogen, nitrate, suspended solids, pH, specific conductance and (outflow only) chlorophyll a. This monitoring should be in place before, during and after any actions are taken to reduce nutrient inputs from these sources.

Species monitoring should follow standard SSSI protocols, with Common Standards Monitoring methods (JNCC 2015) used to establish changes within the aquatic vegetation assemblage (to be assessed against data presented in Section 2.3). Species monitoring should be supplemented to address key species such as cowbane *Cicuta virosa* and Desmoulin's whorl snail *Vertigo moulinsiana*, with additional invertebrate, bird, mammal and habitat surveys considered to ensure the most complete information is included within the Vision and site management plans. Comprehensive vegetation monitoring should be conducted on a 3 or 5 year cycle, with more frequent surveys undertaken if concerns are raised about particular features or to inform specific management actions where high levels of disturbance is will be necessary (e.g. reed cutting and scrub and tree clearance).

Management cost – Monitoring

Table 14 Cost estimates for water quality monitoring

Water quality monitoring - 5 year plan			
Item	**Rate (£)**	**Days**	**Total (£)**
Year 1 – Monthly water quality monitoring, Catchment, STW outlets and lake (including reporting).	250	15	3,750
Year 1 – Cost of analysis. 12 x 6 samples, inc courier			4,950
Year 1 – T & S			900
Annually – Repeat monitoring as above			9,550
5-year total			**£47,750.00**
Projected annual cost for water quality monitoring after initial 5 years (inclusive of analysis, reporting, and T&S)			9,600

Table 15 Cost estimates for aquatic species monitoring

Species monitoring - 5 year plan			
Item	**Rate (£)**	**Days**	**Total (£)**
Year 1 – Conduct CSM survey of aquatic vegetation.	500	1	500
Year 1 – Conduct Desmoulin's whorl snail (*Vertigo moulinsiana*) survey.	500	1	500
Year 1 – reporting	500	4	2,000
Year 1 – T & S			250
Year 2 – Commission and undertake additional surveys to include aquatic and wetland invertebrates, birds, bats, mammals.	500	5	2,500
Year 2 – Reporting.	500	10	5,000
Year 2 – T & S			1,000
Year 4 – Conduct CSM survey of aquatic vegetation.	500	1	500
Year 4 – Conduct Desmoulin's whorl snail (*Vertigo moulinsiana*) survey.	500	1	500
Year 4 – reporting	500	4	2,000
Year 4 – T & S			250
Year 5 – Undertake a species appraisal based on all available data and relate to ongoing management.	500	10	5,000
5-year total			**£20,000.00**

Timescales

Whist the physical management actions for lake restoration can be implemented relatively quickly (over a few years), it is important for stakeholders and funding bodies to understand that the time taken to achieve the Vision may take decades. Natural recovery processes offer the most reliable and sustainable means of achieving the vision and even if nutrient pollution is stopped, the natural processes by which these nutrients are lost from the catchment and sediments are very slow.

Thus, looking to the future success of the vision, it will be important to secure strong local support through the catchment partnership and to promote Burton Mill Pond and other local wetlands by raising awareness of their importance within the natural landscape. Playing to the strengths of the site, Burton Mill Pond already has the advantage of facilities that can be used to encourage more people to experience and learn about the aquatic environment through good access. Investing in education, and effectively communicating the benefits that the Vision will bring, will help to ensure the local and national support required to deliver the Vision and maintain it into the future.

An excellent way to engage with the local community, communicate the value of environment and discover more about the site, is to run a “Bioblitz”. By involving a good range of knowledgeable volunteers as well as WSCC staff, NE, SWT and local wildlife groups, a wide range of information can be gathered about the area, as well as engaging local interest and support. Information on setting up and running a “bioblitz” is available at: http://www.bnhc.org.uk/bioblitz/free-downloadable-resources/

5.7. Appraisal of management cost

Table 16 Cost estimates for all management (two and five year plans).

Management action	2 year total (£)	5 year total (£)
Tree and Scrub Management	27,600.00	41,450.00
Reedbed Management	11,900.00	29,750.00
Agricultural and Catchment Liaison	3,600.00	8,100.00
Identifying and managing domestic sewage	22,000.00	28,000.00
Water quality monitoring	19,100.00	47,750.00
Species monitoring	11,750.00	20,000.00
Total	**£95,950.00**	**£175,050.00**

Table 17 Management actions (two- and five-year plans).

Management action	Year 1	Year 2	Year 3	Year 4	Year 5	Environmental permit	SSSI Assent ?	Project lead	Project Partners	Target
Tree and Scrub Management	x	x	x	x	x	No. T6 not required if wood is cut and left in situ	Y	WSCC	NE, SWT, Contractor	To reduce current tree and scrub growth back to 1956 baseline and control.
Reedbed Management	x	x	x	x	x	Small quantities (<75 tons) can be removed from site and composted at a registered facility without permit	Y	WSCC	NE, SWT, Contractor	To abate encroachment of the reed front into open water and maintain good habitat for DWS and *Cicuta virosa*.
Agricultural and Catchment Liaison	x	x	x	x	x	No	N	WSCC	NE, EA SWT, LC	Ensure best practice is followed and reduce and maintain low inputs of silt and nutrients to surface waters.
Identifying and managing domestic sewage	x	x	x	x	x	No (PMC and SW may require additional planning / permitting for upgrading work)	N	WSCC	EA, NE, PMC, SW, LC, Contractor	To ensure off-line SSDs are in good order and function correctly and reduce P outputs from Duncton and Burton house STWs to < 100 $\mu g l^{-1}$ TP
Water quality monitoring	x	x	x	x	x	No	N	WSCC	EA, SW, PMC, Contractor	To reduce P to below 50 $\mu g l^{-1}$ in the lake and inflows. Target of 30 suggested for long-term sustainablility.
Species monitoring	x	x		x	x	No	Y	WSCC	NE, SWT, contractors	To ensure no species loss (or significant reduction). To provide baseline data and inform management success.

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