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Aquatic and riparian plant management: controls for vegetation in watercourses

Case study report

Project: SC120008/R3

Flood and Coastal Erosion Risk Management Research and Development Programme

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Miranda Kavanagh

Director of Evidence

Executive summary

This report presents five detailed case studies carried out to provide evidence on which to develop updated guidance on the management of aquatic and riparian vegetation for use by practitioners in the operating authorities responsible for flood risk and water level management in catchments where the desired watercourse functioning relies upon the periodic removal of aquatic plants. A number of legislative changes have occurred and new management techniques have been developed since the existing guidance, *Aquatic Weed Control Operation - Best Practice Guidelines*, published by the Environment Agency in 1999.

The case study sites were selected to:

- provide exemplars of good practice
- demonstrate how the decision-making spreadsheet tool can be applied
- cover a range of typical sites and management approaches
- identify lessons that can be learnt

The five sites chosen for case study analysis were:

- Moretons Leam, Cambridgeshire
- River Mole, Surrey
- Nafferton Beck, East Yorkshire
- Boating Dike, Thorne, South Yorkshire
- River Lee, Luton

The case studies are detailed in separate chapters with information on problem identification, current and historical management practices, application of the decision-making framework and lessons learnt. The results of a re-visit to each site conducted one year from the first are also detailed.

The new guidance incorporates a technical guide, field guide and a decision-making spreadsheet tool to help watercourse managers select the most appropriate management method based on their watercourse type and problem species. There is also a literature review report.

The technical guide contains factsheets for the five case studies presented in this report to demonstrate how the decision-making spreadsheet tool can be applied. Shorter case studies from different sites are used throughout the guide to illustrate specific topics.

Acknowledgements

JBA Consulting would like to thank all those who suggested potential case study sites, provided information and accompanied its staff on site visits.

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1 Introduction

1.1 Project background

Watercourses are managed for a variety of, and often multiple, purposes which can have conflicting aims. In many watercourses, the management of aquatic and riparian plants is essential to ensure their efficient functioning. It is important that this is conducted in a cost-effective manner, taking account of relevant legislation and restrictions, and meeting the objectives of a greatest number of watercourse users while minimising any negative environmental impacts.

The existing guide relating to the management of aquatic and riparian vegetation is *Aquatic Weed Control Operation: Best Practice Guidelines* (Barrett *et al.* 1999). Since its publication by the Environment Agency in 1999 a number of legislative changes have occurred and new management techniques have been developed.

This case study report provides evidence on which the revised guidance has been developed. The updated guidance is aimed at practitioners, both technical staff and field operatives, in the operating authorities responsible for flood risk and water level management in catchments where the desired watercourse functioning relies on the periodic removal of aquatic plants.

The guidance incorporates a technical guide, field guide and a decision-making spreadsheet tool to help watercourse managers select the most appropriate management method based on their watercourse type and problem species. There is also a literature review report.

1.1.1 Aims and objectives

The project's overall aim was to develop good practice guidance on the management of aquatic plants in, and vegetation alongside, watercourses through the comparison of a number of management techniques in different watercourses. To achieve this aim, five case study sites were selected to:

- provide exemplars of good practice
- demonstrate how the decision-making framework can be applied
- cover a range of typical sites and management approaches
- identify lessons that can be learnt

1.2 Report structure

The report begins by outlining the process used to select the five case study sites. The case studies are then detailed in separate chapters with information on problem identification, current and historical management practices, application of the decision-making framework, lessons learnt and the results of re-visits conducted one year on.

The technical guide contains factsheets of the five case studies, demonstrating the application of the decision-making spreadsheet tool. Short case studies from a number of other sites are used in the technical guide to illustrate specific aspects of aquatic and riparian plant management.

2 Case study site selection

The original aim had been to produce six detailed case studies but unforeseen issues meant that only five were produced (see section 2.5).

2.1 Initial collation of sites

A wide range of stakeholders across England and Wales were contacted to request information on possible sites to develop a database of potential case study sites.

The Project Advisory Group was used as a first point of contact to suggest sites. Members were then asked to circulate the request for case studies among their organisations. Stakeholders were asked to provide a range of data for each potential site including the location, the rationale for management, the problematic species and the method of management. From this process, 40 possible sites were initially put forward (Appendix A and Figure 2.1).

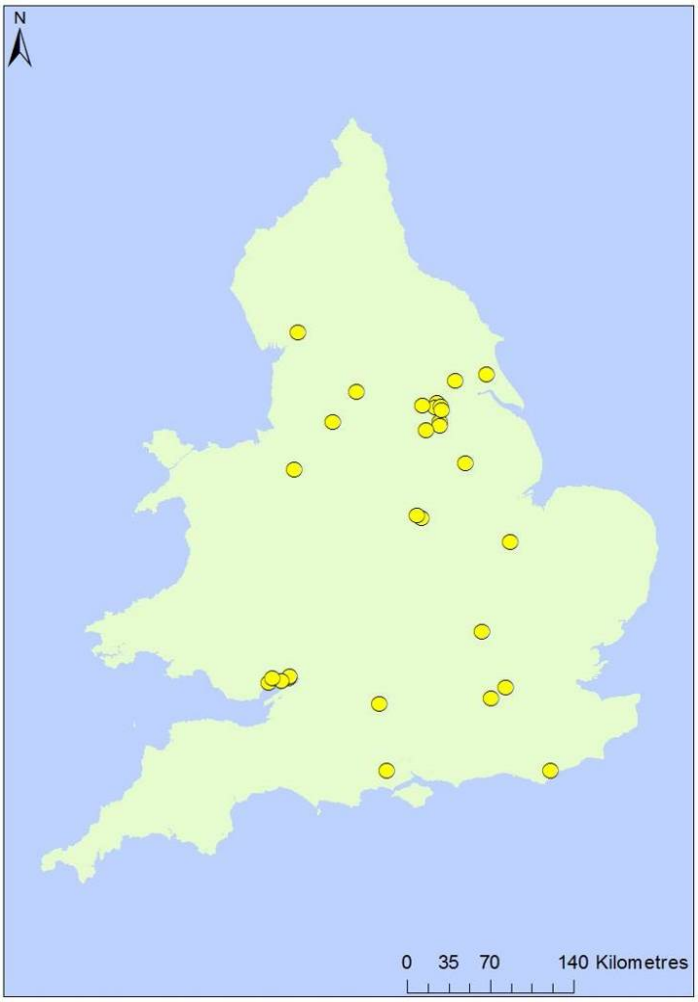


Figure 2-1 Distribution of proposed case study sites

Sites were suggested by a number of organisations including the Environment Agency, a small number of Internal Drainage Boards (IDBs), the Canal & River Trust (formerly British Waterways), Natural England and a wildlife trust (Figure 2.2).

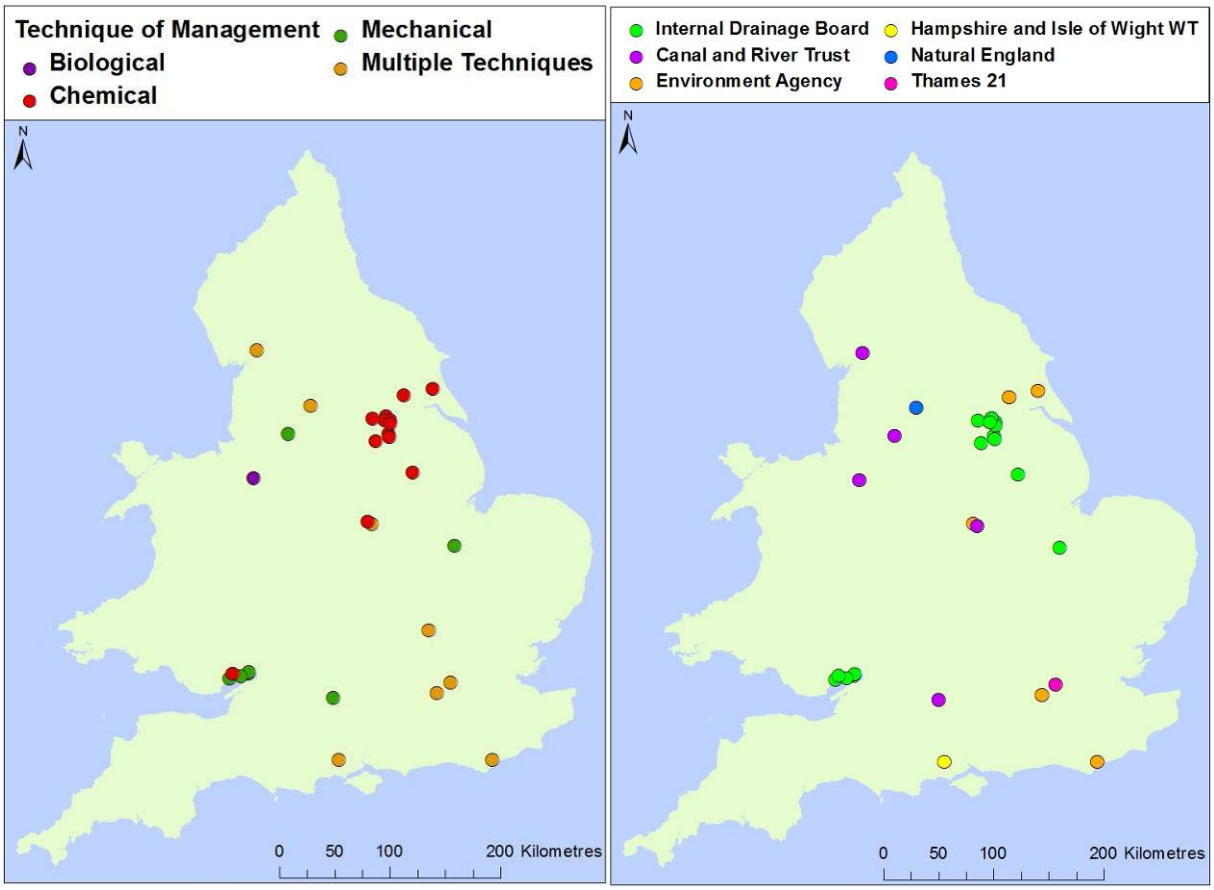


Figure 2-2 Potential case study sites by operating authority (left) and management technique (right)

Sites where chemical control techniques were proposed to be used were the most numerous, followed by mechanical techniques. This was not surprising given that chemical and mechanical techniques are the most frequently used methods of control across England and Wales. The implementation of multiple management techniques was also proposed for a small number of sites. No sites for environmental techniques of aquatic and riparian plant management were proposed. This was not unexpected as these techniques tend to be long-term solutions associated with capital works rather than usual management operations (Figure 2.2).

The sites suggested covered a wide range of rationales for management, with several having multiple purposes. Ecological reasons were the most frequent driver for management; this was due to the large number of case studies suggested where non-native invasive species were a concern and therefore the primary driver for management. However, flood risk management was also an issue in a number of these cases. Flood risk management and land drainage were also frequent primary drivers of management for the suggested case study sites (Figure 2.3).

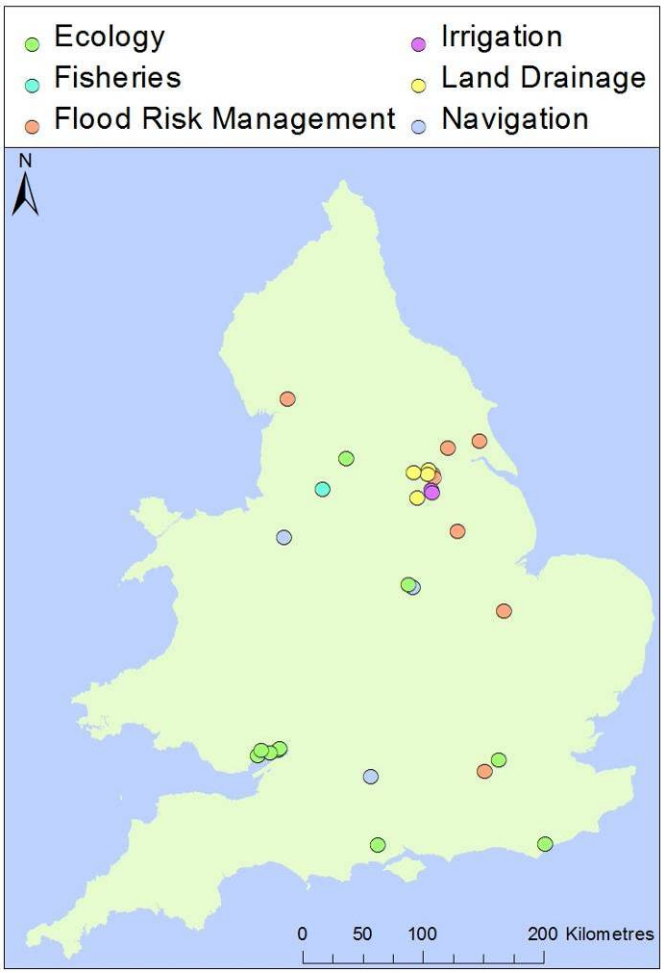


Figure 2-3 Rationale for management

2.2 Screening protocol

Once information on the suggested sites had been collated, a review and screening process was conducted to select the preferred six sites for detailed assessment. The Project Board and Project Advisory Group agreed the case study sites should cover:

- a wide geographical area
- a number of plant groups/species
- different drivers for management (for example, flood risk management, navigation, fisheries)
- different operating authorities responsible for aquatic and riparian plant management (for example, Environment Agency, IDBs, Canal & River Trust, wildlife trusts)
- a range of management techniques (for example, physical, chemical, environmental, biological, novel)
- both native and non-native invasive species

This list was used to guide and develop a series of selection criteria. The following process was used to screen the 40 suggested sites to select the six preferred.

(1) As a number of operating authorities/managers needed to be covered by the case studies, the sites proposed by the Environment Agency, IDBs, the Canal & River Trust and other authorities were considered separately. Two case studies were selected from each of these operating authorities/groups of operating authorities.

(2) A scoring system was applied to assess the information provided and help in identifying which sites had the most detailed and useful information. The scoring system was as follows:

   (a) Specific information on geographical location provided (1 = grid reference or location information provided; 0 = no specific information provided on location). If a whole river was named as a geographical location, this was classed as 'unknown' unless relating to drains which tend to be shorter in length and therefore their location is more specific.

   (b) Knowledge of problem species present (1 = species known; 0 = species unknown).

(3) Scoring was applied on the basis of whether the problem species was a native or non-native species. As non-native invasive species are only one element of this project, whereas native species management is a larger aspect, sites where native species are a problem were weighted more highly than those sites where non-native species are a concern (2 = native species; 0 = non-native, invasive species).

(4) The scores from stages 2 and 3 were added together, with only those given a score of 2 or more taken forward for further consideration. The other sites were screened out at this stage.

(5) If more than two sites remained following this initial screening, a qualitative assessment was conducted to select the most suitable sites. This took into account geographical location (that is, whether the site was near any other possible or previously chosen sites), management technique (that is, to ensure that a variety of management techniques would be considered) and rationale for management (that is, to ensure that a variety of reasons for management would be considered).

2.3 Site selection

This section details the results of the screening protocol. It is broken down into Environment Agency sites, IDB sites, and Canal & River Trust and other operating authority sites as per stage 1 of the screening protocol.

2.3.1 Environment Agency sites

Table 2.1 summarises the screening results for the proposed sites where the Environment Agency is the operating authority. From this screening, three sites were carried through for further consideration by qualitative assessment:

- Black Delphin in East Yorkshire
- Monk Dyke in East Yorkshire
- River Ember/Mole in Surrey

Given the requirement for a wide geographical coverage, it was proposed that only one site from East Yorkshire be considered further. Also as both sites located in East Yorkshire, were managed by the same Environment Agency team, and were both proposed to be managed by chemical means, it was felt that considering both sites would not be representative. Which East Yorkshire site to select was decided following discussions with the site managers.

The two selected Environment Agency case studies were:

- Black Delphin or Monk Dyke, East Yorkshire
- River Ember/Mole, Surrey

Table 2-1 Screening of case study sites proposed by the Environment Agency

Site	Grid Ref	Operating Authority	Problem Species		Major Management Issue	Management Method Proposed	Screening Criteria			
			Plant Group	Plant(s) Name (if known)			Geographical location known (1); unknown (0)	Species known (1); unknown (0)	Native Species (1) or NNIS (0)	Total
Back Delphin, East Yorkshire	tbc	Environment Agency	Tall Emergent Plants	tbc	Flood Risk Management	Chemical	1	0	2	3
Monk Dyke, East Yorkshire	tbc	Environment Agency	Tall Emergent Plants	tbc	Flood Risk Management	Chemical	1	0	2	3
Derwent Catchment	tbc	Environment Agency	Non-native Invasive Species		Ecology	Chemical	0	0	0	0
River Hull	tbc	Environment Agency	Non-native Invasive Species		Ecology	Chemical	0	0	0	0
Pevensey Levels	Various sites	Environment Agency	Non-native Invasive Species	Hydrocotyle ranunculoides	Ecology	Multiple Management Techniques	0	1	0	1
River Soar		Environment Agency, in partnership with Canal and River Trust and Leicester City Council	Non-native Invasive Species	Hydrocotyle ranunculoides	Ecology	Chemical	0	1	0	1
River Ember/River Mole	From Hersham to East Molesey, Surrey	Environment Agency	Non-native Invasive Species	Hydrocotyle ranunculoides	Flood Risk Management	Multiple Management Techniques	1	1	0	2

	Screened In
	Screened Out

2.3.2 IDB sites

The majority of sites proposed by IDBs scored more than 2 and were therefore put forward for further assessment. However, a number of the proposed sites were concerned with non-native invasive species and one of the Environment Agency selected sites was concerned with floating pennywort *Hydrocotyle ranunculoides*. As discussed above, non-native species were only one aspect of this project and so a second case study site dealing with a non-native invasive species was not desired; these sites were therefore discounted from further assessment.

To further refine the 11 remaining sites, only those with the highest score (that is, 4) are considered. This left the following sites:

- Boating Dike & Durhams Warping Drain (Black Drain Drainage Board)
- Dadsley Well Stream (Doncaster East IDB)
- Ings Dike (Danvm Drainage Commissioners)
- Moretons Leam (North Level IDB)
- Reen banks – Peterstone and Clifton Common (Caldicott and Wentlooge Levels IDB)
- Reen banks – Mireland Pill, Prat Reen and Collister Pill (Caldicott and Wentlooge Levels IDB)

From this list, the sites suggested by the Caldicott and Wentlooge Levels IDB were discounted as management was conducted in relation to rare riparian species (for example, corn parsley *Petroselenium segetum* and corky fruited water-dropwort *Oenanthe pimpinelloides*), which is a relatively specific and unique situation and not likely to be applicable to many stakeholders. It was considered this these sites were more suited to a smaller vignette within the technical report rather than a full case study.

Of the remaining four sites, three are managed by the Shire Group of IDBs and located in the South Yorkshire area. Therefore only one of the three was taken forward for further consideration. The Moretons Leam site was also selected.

Table 2-2 Screening of proposed IDB sites

Site	Grid Ref	Operating Authority	Problem Species		Major Management Issue	Management Method Proposed	Screening Criteria			
			Plant Group	Plant(s) Name (if known)			Geographical location known (1); unknown (0)	Species known (1); unknown (0)	Native Species (1) or NNIS (0)	Total
Snow Drain, Highwater Drain & Misson Bank Drain	470859, 400770 471352, 398385	Doncaster East IDB	Tall Emergent Plants	tbc	Irrigation	Chemical	1	0	2	3
Boating Dyke & Durhams Warping Drain	468803, 417049 467406, 413267	Black Drain DB	Tall Emergent Plants	Sparganium erectum, Carex species	Land Drainage	Chemical	1	1	2	4
Thorne Waste & Boating Dike	472092, 413678 472585, 410965	Doncaster East IDB	Tall Emergent Plants		Flood Risk Management	Chemical	1	0	2	3
Dadsley Well Stream	459266, 394192	Doncaster East IDB	Broadleaved Emergent Plants	Rorippa nasturium-aquaticum	Land Drainage	Chemical	1	1	2	4
Ings Dike	456306, 415404	Danvm Drainage Commissioners	Tall Emergent Plants	Typha latifolia	Land Drainage	Chemical	1	1	2	4
Various	tbc	CWLIDB	Floating Plants	wolffia arrhiza (rootless duckweed)	Ecology	Mechanical	0	1	2	3
Reen banks, Mireland Pill, Prat Reen and Collister Pill	ST 3782, ST438848, ST447863	CWLIDB	Riparian Plants	Petroselenium segetum. Corn Parsley	Ecology	Mechanical	1	1	2	4
Reen banks - Peterstone and Clifton Common	ST266808, ST374826	CWLIDB	Riparian Plants	Oenanthe pimpinelloides, Corky fruited water-dropwort	Ecology	Mechanical	1	1	2	4
Scattered throughout drainage district (e.g.Mill, Cross, Skinners, & Chapel Reens)		CWLIDB	Submerged Plants	Potamogeton trichoides	Ecology	Mechanical	0	1	2	3
Pontycwcw Branch Reen	330082m, 184722m	CWLIDB	Non-native Invasive Species	Impatiens glandulifera (Himalayan Balsam)	Ecology	Chemical	1	1	0	2
Various	various	CWLIDB	Tall Emergent Plants	Phragmites (Phragmites Australis)	Flood Risk Management	Mechanical	0	1	1	2
Various		CWLIDB	Non-native Invasive Species	Hydrocotyle ranunculoides (Pennywort)	Ecology	Multiple Management Techniques	0	1	0	1
Tyn-y-Brwyn	326942m, 183084m						1	1	0	2
Little Penning Reen	326917m, 182715m						1	1	0	2
Blacklands Reen	326756m, 183086m						1	1	0	2
Various		CWLIDB	Non-native Invasive Species	Fallopia japonica (Japanese knotweed)	Ecology	Chemical	0	1	0	1
Newlands Reen	323699m, 179434m						1	1	0	2
Longcross Reen	322595m, 178624m						1	1	0	2
Rhosog fawr	324229m, 178968m						1	1	0	2
Peterstone Watercourse	326825m, 180269m						1	1	0	2
Green Lane Reen	325213m, 181349m						1	1	0	2
Summerway Reen	327433m, 181736m						1	1	0	2
Sea Wall Reen	330057m, 185291m						1	1	0	2
Moretons Leam	539730 302903, 520925 297433	North Level IDB, EA, NE	Multiple Plant Types		Flood Risk Management	Mechanical	1	1	2	4
Pike Drain		Upper Witham IDB	Non-native Invasive Species	Japanese Knotw	Flood Risk Management	Chemical	0	1	0	1

Screened In
Screened Out

2.3.3 Canal & River Trust and other operating authority sites

Screening of the remaining sites resulted in four potential sites as case studies:

- Manchester, Bolton & Bury Canal (Canal & River Trust)
- Kennet & Avon Canal (Canal & River Trust)
- Lancaster Canal - Northern Reaches (Canal & River Trust)
- River Thames/London area (Thames 21)

From these four sites the River Thames project was discounted as again this related to a non-native invasive species already covered by one of the Environment Agency case studies.

Of the remaining three sites, it was recommended that the Kennet & Avon Canal was selected plus one of the remaining two canal sites as both were located in north-west England. It was proposed that Manchester, Bolton and Bury Canal should be the preferred site as this case study was concerned with submerged species management – a group of plants not covered by any of the other selected case studies.

Table 2-3 Screening of Canal & River Trust and other proposed case study sites

Site	Grid Ref	Operating Authority	Problem Species		Major Management Issue	Management Method Proposed	Screening Criteria			
			Plant Group	Plant(s) Name (if known)			Geographical location known (1); unknown (0)	Species known (1); unknown (0)	Native Species (1) or NNIS (0)	Total
New Forest	Various sites	Isle of Wight and Hampshire Wildlife Trust	Non-native Invasive Species	Various	Ecology	Multiple Management Techniques	0	1	0	1
Manchester,Bolton & Bury Canal	tbc	Canal & River Trust	Submerged Plants	elodea, plus pondweeds	Fisheries	Mechanical	0	1	2	3
Shropshire Union Canal	tbc	Canal & River Trust	Floating Plants	azolla	Navigation	Biological	0	1	0	1
River Soar	tbc	Canal & River Trust	Floating Plants	pennywort	Navigation	Multiple Management Techniques	0	1	0	1
Kennet & Avon Canal	tbc	Canal & River Trust	Tall Emergent Plants	Common reed	Navigation	Mechanical	0	1	2	3
Lancaster Canal - Northern Reaches	tbc	Canal & River Trust	Tall Emergent Plants	mixed	Flood Risk Management	Multiple Management Techniques	1	1	2	4
River Thames/London area		Thames 21	Non-native Invasive	Himalayan Balsam Giant Hogweed Japanese Knotweed Floating Pennywort	Ecology	Multiple Management Techniques	1	1	0	2
Rochdale Canal		Natural England	Non-native Invasive Species	Crassula helmsii	Ecology		0	1	0	1
										Screened In
										Screened Out

2.4 Sites selected by screening process

Although none of the selected sites (Table 2.4) was concerned with biological control methods, it was felt that this control technique was relatively specialised and therefore more appropriate for inclusion in the guidance as a shorter case study.

Table 2-4 Selected case study sites from screening process

Site	Operating authority	Plant group	Plant name	Major management issue	Proposed management method
One of: Black Delphin/Monk Dyke, East Yorkshire	Environment Agency	Tall emergent	Specific species not known at screening stage	Flood risk management	Chemical
River Ember/River Mole, Surrey	Environment Agency	Non-native invasive species	Floating pennywort	Flood risk management/ ecology	Multiple management techniques
One of: Boating Dike & Durham's Warping Drain/ Dadsley Well Stream/ Ings Dike	Shire Group of IDBs	Tall emergent	Branched bur-reed, tall sedges/ water-cress / reedmace	Land drainage	Chemical
Moretons Leam	North Level IDB (in partnership with the Environment Agency and Natural England)	Multiple plant types	Specific species not known at screening stage	Flood risk management	Mechanical
Manchester, Bolton & Bury Canal	Canal & River Trust	Submerged plants	Water-weeds *Elodea* spp, plus pondweeds	Fisheries	Mechanical
Kennet & Avon Canal	Canal & River Trust	Tall emergent	Common reed	Navigation	Mechanical

2.5 Post-screening developments

Once the Project Board had ratified the choice of the six preferred case study sites, liaison began with each of the operating authorities to discuss the sites in more detail and to arrange site visits. As this liaison work began, however, a number of changes had to be made to the selected list.

- Monk Dyke and Black Delpin. When the Environment Agency looked into the sites in the Hull catchment allocated for spraying, it was found that

these two sites were not included in the 2013 spraying programme. An alternative, similar site – Nafferton Beck – within the same catchment was therefore selected instead.

- Boating Dike in Thorne, South Yorkshire, was the site selected from those proposed by the Shire Group of IDBs.
- Due to staff changes within the Canal & River Trust, it was not possible to proceed with the original proposed sites and no detailed investigation of a canal site was undertaken.
- As the majority of the proposed sites were rural in nature it was felt the analysis should include a more urban situation. The Project Board identified a site in Luton – the River Lee – for inclusion as an additional site.

The final five sites chosen for case study analysis were:

- Moretons Leam, Cambridgeshire (Section 4)
- River Mole, Surrey (Section 5)
- Nafferton Beck, East Yorkshire (Section 6)
- Boating Dike, Thorne, South Yorkshire (Section 7)
- River Lee, Luton (Section 8)

Figure 2.4 shows their location.

Figure 2-4 Location of final chosen case study sites

3 Methodology

3.1 Desk-based assessment

Before making a site visit, a desk-based assessment was conducted to gather relevant background information on each of the sites such as designated status, management plans and site photographs. This information was collected through a search of readily available internet sources and liaison with the site operators/managers.

3.2 Site visit

Each of the case study sites were visited by a member of the project delivery team. Where possible, the site visits were scheduled before implementation of the management programmed for 2013 so as to assess the problem at its greatest extent. The general site visit protocol involved the following.

- On-site discussions were held with the site operator/asset manager covering a range of issues including site history, the problem created by the vegetation, the management technique and method proposed, how the management technique is selected and success/lessons learnt from previous management.
- Discussions were held with the site operator/asset manager as to how the draft decision-making framework could be applied to the site.
- A survey of the aquatic and riparian vegetation was conducted and a species list compiled.
- Fixed point photography locations were established (at easily accessible locations) with a photographic record taken of watercourse and vegetation conditions prior to management. Where possible, a second visit was made following maintenance to compile a photographic record of the watercourse response post-maintenance. If possible, the watercourse managers were asked to take regular photographs from the established fixed points throughout the weeks/months following management to determine recovery rates and response to management.

The survey method was designed to be relatively straightforward and easy to implement so that it could be developed into a monitoring protocol as part of the adaptive management approach.

3.3 Return site visits

As part of an extension to the project, return site visits were conducted for each site one year after the management work was performed, and prior to management operations being conducted in 2014. The purpose of these visits was to help:

- determine if the management carried out had been effective
- test the adaptive monitoring approach proposed in the technical guide
- discover if any adverse impacts had arisen

This report contains the results of the return site visits conducted throughout 2014.

4 Moretons Leam, Cambridgeshire

4.1 Introduction

Moretons Leam is located to the east of Peterborough in Cambridgeshire, with the upstream reaches situated within the boundary of Peterborough City (Figure 4.1).

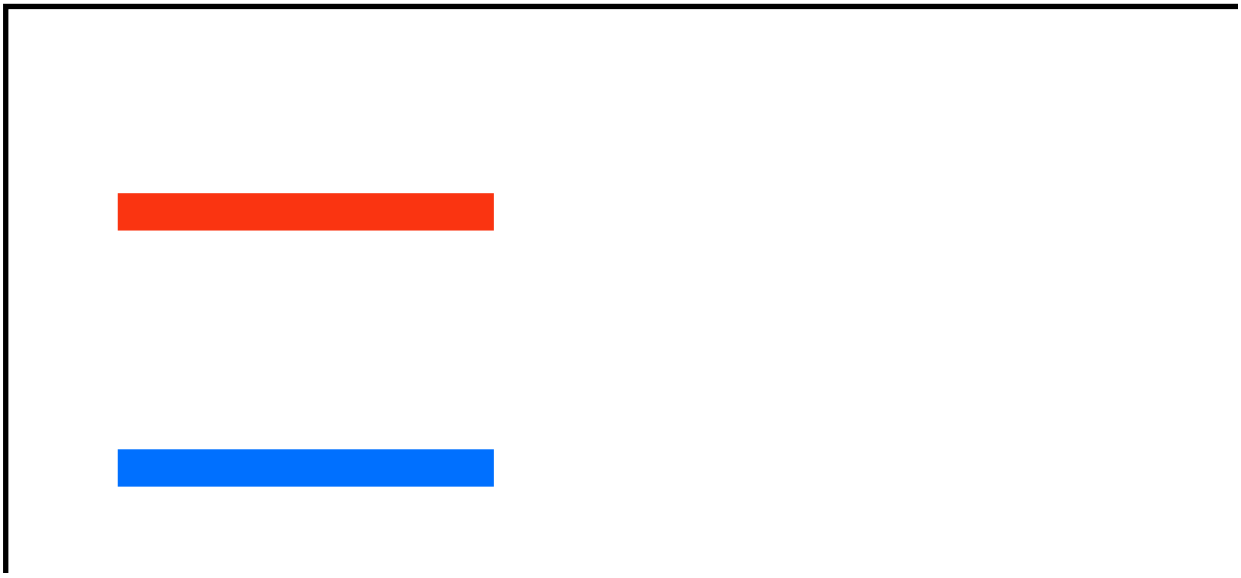


Figure 4-1 Moretons Leam location map

An initial site visit was conducted by Laura Thomas of JBA Consulting and Jonathan Newman of the Centre for Ecology and Hydrology (CEH) on 17 July 2013. The watercourse is a designated main river and therefore the responsibility of the Environment Agency. However, from 2013 onwards it will be managed by the North Level IDB (see section 4.3 for more details). Consequently, the site visit was made with representatives of the IDB.

During the site visit, two sections of Moretons Leam were assessed in more detail. This included the section immediately up and downstream of Little Bridge and the section immediately up and downstream of the sluice at Eldernell (Figure 4.1).

4.2 Watercourse description

4.2.1 General

This artificial watercourse is approximately 20 km long, flowing from the outskirts of Peterborough to the sluice at Guyhirn (Figure 4.1). There are numerous sluices, weirs and water control structures along the length of the watercourse. Throughout flow rates are slow.

In general, the central part of the channel is relatively deep and dominated by algae, floating-leaved rooted species and submerged species. The margins are frequently lined with a narrow fringe of tall emergent species.

Moretons Leam is designated as part of the Nene Washes Ramsar site, Special Protection Area (SPA), Special Area of Conservation (SAC) and Site of Special Scientific Interest (SSSI). The watercourse also contains the highest recorded density of spined loach *Cobitis taenia* in the UK (JNCC 2013). Maintenance activities can have a direct adverse impact on spined loach as they bury themselves in bed substrates and also indirectly through damaging the habitats they rely on, including spawning gravels and feeding areas.

4.2.2 Little Bridge

At Little Bridge, the channel was approximately 4–5 m wide, with water approximately 1.5–2 m deep. The banks were relatively low at this location, only 0.5–1 m above the water level. A weir was present within this section, downstream of the road bridge.

Adjacent land use generally consists of rough, unimproved pasture on both banks. However, on the right bank there are also areas of tall herb/rank vegetation with broadleaved plantations on the left.

4.2.3 Eldernell

At Eldernell the channel was approximately 5 m wide, with water 1.5 m deep when surveyed. The banks here were higher than at Little Bridge, measuring approximately 2–2.5 m in height above the water level. The watercourse, in places, has a gravelly bed although in other places it is quite silty. A sluice is also present at this location.

At Eldernell it is likely, given the trapezoidal nature of the channel, that some resectioning has been carried out. The southern barrier bank is also present in relatively close proximity to Moretons Leam at this location.

Land use adjacent to the right bank included improved/semi-improved pasture and tall herb/rank vegetation. Adjacent to the right bank land use consisted of pasture – both rough, unimproved and improved/semi improved.

4.3 Watercourse management

4.3.1 Problem species

Multiple species were growing at Little Bridge that were considered to require management including:

- frequent floating-leaved rooted yellow water-lily *Nuphar lutea*
- frequent tall emergent branched bur-reed *Sparganium erectum* and greater pond-sedge *Carex riparia*
- abundant algae (*Cladophora* and *Enteromorpha*)

Submerged perfoliate pondweed *Potamogeton perfoliatus* was also present in relatively large patches. Other species recorded within the channel at this location included:

- curled pondweed *Potamogeton crispus*
- fennel pondweed *P. pectinatus*
- spiked water-milfoil *Myriophyllum spicatum*
- common duckweed *Lemna minor*

In the marginal areas gypsywort *Lycopus europaeus*, great willowherb *Epilobium hirsutum,* reed sweet-grass *Glyceria maxima,* yellow iris *Iris pseudacorus* and meadowsweet *Filipendula ulmaria* were recorded. Figure 4.2 shows vegetation at the site.

Figure 4-2 Vegetation at Little Bridge

Multiple species were also present within the channel and riparian zone at Eldernell which were considered to require management. These included:

- frequent fennel pondweed
- occasional floating-leaved rooted yellow water-lily
- frequent tall emergent branched bur-reed and reed Sweet-grass
- dominant *Cladophora* algae (Figure 4.3)

Other species present within this reach included water mint *Mentha aquatica*, great willowherb and common reed *Phragmites australis* along the margins.

Figure 4-3 Extensive algae (*Cladophora*) cover at Eldernell

4.3.2 Rationale for management

Discussions with North Level IDB identified that Moretons Leam is a critical watercourse in the water level management system of the area. This is because it is the only means of getting water off the Nene Washes following a flood event. To do this good conveyance of water is required. Vegetation management is therefore considered an important aspect of ensuring that the conveyance of water is adequate.

During a flood event, urban areas such as Whittlesey are also potentially at risk of flooding should further rain fall and the Nene Washes are already flooded to capacity. A large, four-year scheme is currently being implemented to strengthen the southern barrier bank to maintain the structural stability of the embankment; this is a requirement under the Reservoirs Act 1975 (Environment Agency 2013a). New residential development is also proposed for Whittlesey and so Moretons Leam may also have a crucial role in protecting new developments from flooding.

As the system is controlled by tidal influences further downstream, when the tide turns water cannot be discharged from Moretons Leam if the tide is high and the fluvial River Nene is also at high flows. In this situation areas of Peterborough could potentially be at risk of flooding.

Management of water through Moretons Leam is also required for to meet the demands of the ecological interests of the Nene Washes. This is managed in partnership with the RSPB and Natural England. The level of water and the timing, depth and duration of flooding are critical for many species of interest within the designated site and also for the cattle grazing regime. Flooding of too greater depth or too long a duration can have an adverse impact on some features of interest of this site (for example, nesting birds and botanical interests); ensuring water can be drained from the washes is therefore important. In previous years, excessive vegetation growth in the watercourse during the summer months has impacted on water levels on the Nene Washes and had a detrimental impact on nesting birds (Environment Agency 2013b). During dry periods, water from the River Nene is also let onto the washes for ecological reasons.

4.3.3 Current management practices

The current management of Moretons Leam is in line with an agreed management plan (Environment Agency 2013b) developed by the Environment Agency, North Level IDB, Natural England and the RSPB.

To minimise the ecological impact of vegetation management works, the watercourse has been divided into nine sections. Management prescriptions can then be targeted to the areas of greatest need and a specified percentage of the channel can be cut to maintain marginal habitat and to create a mosaic of habitats along the watercourse. Depending on the specified section, between 50% and 75% of the channel width is cut by weed boat or hydraulic excavator. The IDB proposes using a long-reach hydraulic excavator with a weed cutting basket, as opposed to a weed boat; it considered the excavator to be a more efficient and economical means of maintaining the watercourse as weed boats can generate a lot of arisings which require collection.

The full length of Moretons Leam will be cut annually by the North Level IDB, although sections that do not have extensive vegetation cover will be left. This work will take place between August and November to avoid impacts on breeding birds and then populations of overwintering birds; management in 2013 was proposed for the first week of August.

Tree and shrub management will occur should this be required to minimise flood risk or if vegetation restricts maintenance activities.

Desilting will be required regularly due to the low gradient and slack flows, which are insufficient to mobilise silts; however, this is not performed as a vegetation control operation. A hydraulic excavator will be used and, to minimise disturbance to ecological interests, will be carried out on a maximum length of 3 km in any one year. It will be conducted after the bird breeding season but before the arrival of large numbers of wintering birds (that is, September to November). Following desilting, appropriate bank management including reseeding, mowing and vegetation control may be required.

The new management plan proposes that maintenance is carried out using purely mechanical methods. The use of chemical control was discussed but is not permitted within the designated site.

4.3.4 Historical management practices

Previously Moretons Leam was managed entirely by the Environment Agency. As detailed in Environment Agency (2013b), the following maintenance activities were carried out.

- Desilting took place to remove accumulated sediment and to maintain channel capacity. This was required on a regular basis due to the low gradients and controlled flows through Stanguard Sluice. Desilting was carried out by a long-reach hydraulic excavator. Removed sediment was spread behind the machine on the banks.
- Aquatic vegetation control was carried out by hydraulic excavator and weed boat to maintain channel conveyance. Insufficient vegetation cutting can restrict the channel and trap silt.
- Banks were grazed or mown.

4.4 Post-management assessment 2013

Moretons Leam was managed by the North Level IDB in August 2013, using an excavator fitted with a weed cutting bucket. All management was conducted in accordance with the agreed management plan (Environment Agency 2013b).

Figure 4-4 Management of Moretons Leam, August 2013 (courtesy Paul Sharman, North Level IDB)

4.5 Application of decision-making tool

Table 4.1 summarises the data inputs to the spreadsheet tool.

Table 4-1 Input parameters for Moretons Leam

Parameter	Input
Is the watercourse a designated site or is it adjacent to a designated site?	Yes – Moretons Leam is designated as part of the Nene Washes Ramsar site, SPA, SAC and SSSI
Does the watercourse support populations of protected species (for example, water vole, otter, white-clawed crayfish)?	Yes – the watercourse also contains the highest recorded density of spined loach *Cobitis taenia* in the UK
Problem species	Yellow water-lily Submerged pondweeds Filamentous green algae
Watercourse type	Artificial drainage channel
Length of watercourse to be managed (m)	4700 m. The section visited stretches from Little Bridge to Eldernell.
Channel width (m) (that is, wetted width)	Channel width varies from 4 to 5 m (minimum value of 4 m inputted)
Water depth (m)	Water depth varied from 1.5 to 2 (minimum value of 1.5 m inputted)
Machine access possible?	Yes
Boat access possible?	Yes

As this site contains multiple problem species, the spreadsheet tool was run three times, once for each species. The outputs are compared in Table 4.2.

Table 4.2 Comparison of outputs from decision-making tool for Moretons Leam

Technique	Yellow water-lily	Submerged pondweeds	Filamentous green algae
Glyphosate-based herbicide with adjuvant (boat and lance application)	1=		
Waterfowl	3		

Technique	Yellow water-lily	Submerged pondweeds	Filamentous green algae
Glyphosate-based herbicide (boat and lance application)	4=		
Weed boats	4=	2	5=
Channel narrowing to increase velocity (two-stage channel)	7=		
Shading through tree/ hedgerow/ bankside planting	7=	3	3
Amphibious vehicles	9=	4=	8=
Hand cutting	9=	4=	
Buffer strips	11=	7=	5=
Diffuse and point source pollution management	11=	7=	5=
Shading with native, broad-leaved floating species		1	2
Native fish species		4=	4
Hand pulling		7=	
De-weeding with a weed bucket		10	10
Hand raking		11=	8=
De-weeding with a solid bucket		11=	
Barley straw extract			1

Given the complexity of this site, including the multiple problem species, designated status, rare fauna and current open landscape, a site-specific analysis was applied to the list of techniques. This site-specific analysis concluded that:

- glyphosate-based herbicide application, with and without an adjuvant, would not be permitted within this designated site
- shading through tree/ hedgerow/ bank side planting would create predator perches which would threaten the bird interest of the Nene Washes and is not advised
- waterfowl, channel narrowing to increase velocity (two-stage channel), native fish species, hand pulling, de-weeding with a solid bucket and barley straw extract are not advised as they would only be effective in managing one of the three problem species
- the native fish populations should not be manipulated given the presence of the rare spined loach
- although hand cutting and hand raking were returned as options for this 4.7 km section of watercourse between Little Bridge to Eldernell, this reach needs to be placed in the context of the full 20 km that requires management, a distance over which manual techniques are not feasible

The number of possible management techniques at this site are therefore limited, with weed boats and amphibious vehicles being the highest ranked techniques effective on all three problem species. However, these were not highest ranked technique for any of the three problem species and this case study highlights the importance of taking site-specific considerations into account.

De-weeding with a weed bucket is also returned as a possible option, although with a relatively low ranking considering the sensitivity of artificial drainage channels to sediment mobilisation and the amount of sediment that this technique can generate. However, given the site-specific considerations detailed above, this method was selected as the most appropriate for this watercourse. A stringent management plan, agreed with Natural

England was followed to limit the potential adverse impacts of using this technique, including retention of wide vegetated margins so that the weed bucket did not come into contact with the banks, thereby limiting sediment mobilisation.

A number of long-term management strategies may also be effective for these species, including buffer strips and diffuse and point source pollution management to manage nutrient inputs and encouraging broad-leaved floating species to create shading (this would not be effective for yellow water-lily).

Figure 4.5 shows an example output for submerged pondweed.

Watercourse Name
Moretons Leam

Location
Cambridgeshire

WFD Watercourse number GB105032050382
Start Grid Reference TL27289846
End Grid Reference TL31869924

Prepared by Laura Thomas
Date 11/08/2013

Is the watercourse a designated site or is it adjacent to a designated site? Yes - site is of national importance (eg SSSI, NNR)

You must contact Natural England/Natural Resources Wales prior to undertaking any vegetation management as a site management plan may already be in place and/or appropriate techniques/working methods will need to be agreed. Consent must be obtained under the Wildlife and Countryside Act 1981 (as amended). See section 4.5.1 of the Technical Guide.

Does the watercourse support populations of protected species (eg Water Vole, Otter, White-clawed Crayfish)? Yes

Contact Natural England/Natural Resources Wales/Environment Agency for further advice and follow appropriate species guidance. See section 4.5.2 of the Technical Guide.

Select Species
Submerged Pondweeds Potamogeton spp. (e.g. Fennel Pondweed)

Data must be entered into all the white cells in this section before any recommendations can be made

Select Watercourse Type
Artificial Drainage Channel

Length of watercourse to be managed (m) 4700
Channel width (m) (ie wetted width) 4
Water depth (m) 1.5

Machine access possible? Yes
Boat access possible? Yes

Notes for selected species:
Species identification of submerged pondweeds is important as this group contains some relatively scarce species (e.g. Grass Wrack Pondweed Potamogeton compressus, Sharp-leaved Pondweed, P. acutifolius)

Recommended control options are (always consider site-specific factors in technique selection):

Rank	Control Technique	Relevant Section of Technical Guide	Means of Application (where more than one method)	Effectiveness for selected species (0 = low, 3 = high)	Damage to Watercourse Type (0 = low, 1 = high, -1 = N/A)	Technically feasible? (0 = No, 1 = Yes)	Score (0 = low, 3 = high)	Indicative Cost
1	Shading with native, broad-leaved floating species	7.5.1		2	0.00	1	2.00	£
2	Weed boats	7.3.2		2	0.17	1	1.67	£
3	Shading through tree/hedgerow/bankside planting	7.5.1		2	0.33	1	1.33	££
4=	Amphibious vehicles	7.3.2		2	0.50	1	1.00	£
4=	Hand cutting	7.3.1		1	0.00	1	1.00	£££
4=	Native fish species	7.6.4		1	0.00	1	1.00	£
7=	Buffer Strips	7.5.6		1	0.17	1	0.83	££
7=	Diffuse and point source pollution management	7.5.6		1	0.17	1	0.83	£££
7=	Hand pulling	7.3.1		1	0.17	1	0.83	£££ / £ (*)
10	De-weeding with a weed bucket	7.3.3		2	0.67	1	0.67	££
11=	Hand raking	7.3.1		1	0.50	1	0.50	£££
11=	De-weeding with a solid bucket	7.3.4		3	0.83	1	0.50	£££

Note: Score = (Effectiveness of technique) x (1 - Damage to watercourse type) x (Technically feasible) The maximum possible score is 3 (*) = low er cost if use volunteers

Figure 4-5 Example output from decision-making spreadsheet tool for submerged pondweed at Moretons Leam

4.6 Lessons learnt

Lesson 1: This case study provides an exemplar of how partnership working between a number of operating authorities and environmental organisations can be of benefit to achieve the requirements of multiple users (for example, land drainage, flood risk management and ecology). This has been particularly beneficial given the importance of the site ecologically and its designated status.

Action taken: The guidance will emphasise the importance of partnership working to achieve multiple goals.

Lesson 2: From discussions with the IDB it was apparent that species identification is not a major driver of management technique selection. This should be considered as part of the decision-making framework.

Action taken: Within the decision-making framework, generic species groups (that is, submerged, floating, tall emergent, algae) will be included as part of the species identification stage, alongside specific species for operators to select from. However, the guidance will stress the importance of correct species identification in selecting management techniques, where possible, and particularly in the case of non-native invasive species.

Lesson 3: At Moretons Leam it was apparent that more than one species/ group of species was problematic in this watercourse, with significant coverage of filamentous green algae, and also extensive populations of floating-leaved rooted species and submerged species.

Action taken: Protocols need to be developed to include sites where multiple species/ groups of species are problematic and discussed in the technical guide.

4.7 Post management assessment 2014

A return site visit to Little Bridge and Eldernell on Moretons Leam was conducted on the 22nd August 2014, approximately one year following the mechanical maintenance work carried out by the North Level IDB. Liaison was also undertaken with the North Level IDB to determine their views on the successes and limitations of the management conducted.

4.7.1 Results of post management assessment

Section 4.3.1 above discusses the species that were problematic in Moretons Leam in 2013. At Little Bridge, multiple problem species included frequent floating-leaved rooted yellow water-lily, frequent tall emergent branched bur-reed and greater pond-sedge, and abundant algae (*Cladophora* and *Enteromorpha*). Submerged species were also present in relatively large patches. Similarly, at Eldernell, multiple species were problematic, including frequent fennel pondweed, occasional floating-leaved rooted yellow water-lily, frequent tall emergent branched bur-reed and reed sweet-grass and dominant *Cladophora* algae. As at Little Bridge, tall emergent species were present along the margins.

In 2014, the species abundance and composition at both Little Bridge and Eldernell was broadly similar to that in 2013. However, a number of observations were made:

- The amount of algae in the channel in 2014 was significantly less than noted in 2013, when it was abundant/dominant in the channel. It is uncertain, however, if this is a result of the management undertaken or due to weather conditions, or to what extent each factor has influenced algal growth. When the survey was conducted in 2013 weather conditions were very hot which can cause excessive

algal growth. In August 2014 weather conditions were much cooler which may have limited algal growth in comparison. However, mechanical removal of filamentous green algae from the channel during the management operation in August 2013 may also have helped minimise its growth in the subsequent year.

- The extent of tall emergent vegetation along the channel margins was observed to be very similar between 2013 and 2014. Stands of branched bur-reed, reed canary-grass, reed sweet-grass and common reed were frequent at both Little Bridge and Eldernell, and there appeared to be no change in the extent or species composition. This result is expected as the management regime for the watercourse only cuts between 50% and 75% of the channel width, and some marginal vegetation will therefore be retained.
- The amount of in-channel submerged and floating vegetation, in particular yellow water-lily, observed in 2013 and 2014 was very similar. Although upstream of the bridge at Little Bridge less submerged vegetation was present, with more open water (see Figure 4-6).
- Frogbit, a relatively scarce species in the UK, was recorded at both Eldernell and Little Bridge in 2014, in relatively good proportions. In 2013, only a very small patch of this plant was recorded at Eldernell. This species appears to be thriving within Moretons Leam, and this could be a result of the management undertaken. This is a species of ponds, ditches and fens, but it will be rapidly out-competed by tall and broad-leaved emergent species; conducting annual maintenance will keep open water areas in which this species can grow.

Figure 4-6 Little Bridge in August 2013 (left) and August (2014) showing the significant decline in algae cover

Figure 4-7 Eldernell in August 2013 (left) and August 2014 (right) showing the significant decline in algae cover

4.7.2 Effectiveness of management

The purpose of aquatic plant management on Moretons Leam is to ensure effective water level management of the area and the conveyance through the system. Management is also important to meet the demands of the ecological interests of the Nene Washes. Liaison with the North Level IDB identified that the mechanical maintenance conducted by de-weeding with a weed bucket, as suggested by the decision-making spreadsheet tool (see section 4.5), was largely successful in terms of flood risk management.

The findings of the 2014 post management survey support this conclusion as the extent of the previously identified problematic species had not increased within the channel, and algae had significantly decreased. The tall emergent vegetation along the margins was retained, which provides ecological and bank stability benefits, but this had not increased from 2013 and therefore conveyance within the channel was maintained.

Given the rapid recovery of many species following physical maintenance operations, the management carried out on Moretons Leam is proposed to be part of an annual maintenance regime. Consequently, it would be expected that immediately prior to the repeat of the annual maintenance, vegetation within the channel should have recovered to a level where management is required again. This was found to be the case at both Little Bridge and Eldernell, with in-channel submerged and floating vegetation amounts in 2014 found to be consistent with the levels observed in 2013.

4.7.3 Application of adaptive monitoring approach

Whilst the physical maintenance operation conducted at Moretons Leam was considered to be largely successful by the North Level IDB, one issue noted in 2014 was that there was dense growth in the upstream length of watercourse early in the summer which limited conveyance. Following the adaptive management approach, it could be considered necessary to revise the management approach to ensure that this situation does not occur and contribute to increased flood risk in summer, prior to vegetation management. However, the very warm conditions in early spring of 2014 would have accelerated the growing season, resulting in the dense growth noted. Given that this is likely to have been a response to weather conditions it is unlikely to require adaptation of the management approach given the general successes of the management conducted in 2013.

In 2014 the implementation of the mechanical management technique was adapted as low dissolved oxygen levels in July/August raised concerns about the potential adverse impacts on fish and other in-channel fauna; the operation was therefore delayed until later in the year when temperatures were lower. This illustrates the importance of having flexibility in a management programme and being able to adapt based on site-specific conditions and issues.

5 River Mole, Surrey

5.1 Introduction

The River Mole, a tributary of the Thames, flows from its headwaters near Crawley to where it connects to the Thames at East Molesley in the borough of Elmbridge in south-west London (see Figure 5.1).

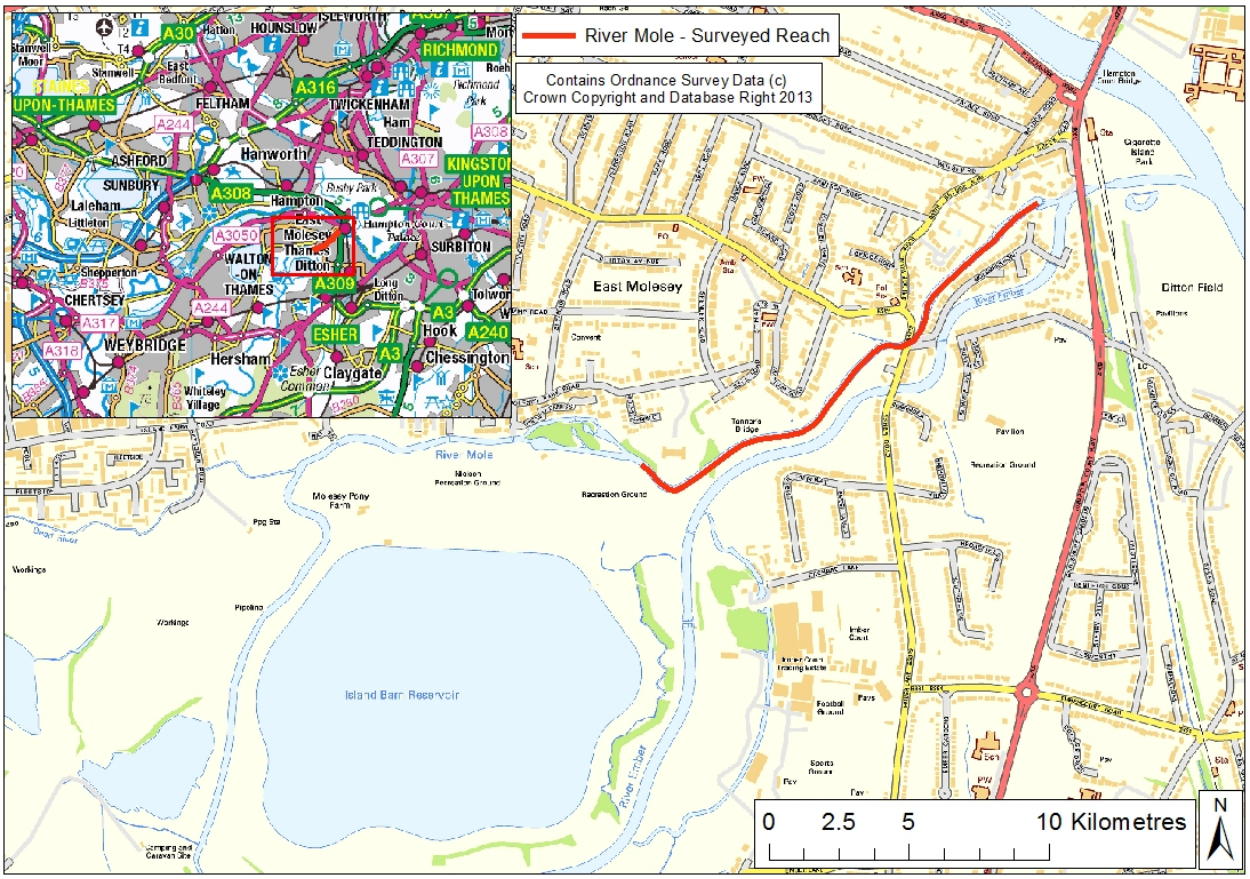


Figure 5-1 River Mole location map

An initial site visit was conducted by Laura Thomas of JBA Consulting on 24 July 2013 in conjunction with Environment Agency staff. The watercourse is a designated main river and therefore the responsibility of the Environment Agency.

During the site visit, the downstream section of the River Mole was surveyed by boat, both upstream and downstream of the Environment Agency's Spa Meadow depot at Aldersgrove, East Molesley.

5.2 Watercourse description

The watercourse flows from its headwaters near Crawley to where it joins the Thames at East Moseley. The section of concern is the very downstream section around the Island Barn Reservoir to the confluence with the Thames.

The watercourse at this location is relatively wide (10–15 m) (Figure 5.2). In places water levels are very shallow (less than 0.5 m), though moving downstream, water depths do

become deeper (over 1 m in places). The substrate, where visible, is a combination of silt, gravels and pebbles.

The river is heavily modified throughout the surveyed reach, which is unsurprising given the highly urbanised nature of the area. Both banks of the river have properties and gardens backing onto the river for a large majority of the surveyed reach with bank protection and modifications evident throughout. There are also numerous weirs, sluices and bridges across the river.

Figure 5-2 The River Mole

At this location a flood diversion channel, the River Ember, was constructed in the 1970s to alleviate flooding issues in this area. This carries water to the east and south of Island Barn Reservoir, whereas the River Mole carries water to the north and west of this reservoir.

5.3 Watercourse management

5.3.1 Problem species

On this stretch of the River Mole the non-native invasive species floating pennywort *Hydrocotyle ranunculoides* is a major problem. This species is listed in Schedule 9 of the Wildlife and Countryside Act 1981 (as amended) and it is an offence to plant this species or cause it to grow in the wild.

When the survey was conducted in July 2013, however, it was apparent that previous years of management had been successful, with very few areas of infestation found. Where this species was found it was only in small, localised patches, generally interspersed within stands of other species (generally branched bur-reed *Sparganium erectum*) and beneath structures that protruded into the river including decking and docking platforms (Figure 5.3).

Figure 5-3 Floating pennywort infestation on the River Mole

Historically the infestation of floating pennywort along this stretch of river has been much more extensive and problematic than what was evident during the 2013 site visit. Figure 5.4 shows the extensive rafts of this species that have formed in previous years.

Figure 5-4 Floating pennywort Infestation at Island Barn sluice (left) and Royal Mills (right) (courtesy Michele Cooper, Environment Agency)

The species-richness of this stretch of river was relatively high, with a number of other species recorded including extensive patches of yellow water-lily *Nuphar lutea*, dense beds of branched bur-reed and a number of other species including purple loosestrife *Lythrum salicaria*, arrowhead *Sagittaria sagittifolia*, common duckweed *Lemna minor*, great willowherb *Epilobium hirsutum*, hemlock water-dropwort *Oenanthe crocata*, water-cress *Rorippa nasturtium-aquaticum,* reed sweet-grass *Glyceria maxima* and algae (*Cladophora*).

There were also extensive areas where Nuttall's waterweed *Elodea nuttallii* was present within the channel and occasional patches of Himalayan balsam *Impatiens glandulifera* on the banks; these species are also listed on Schedule 9 of the Wildlife and Countryside Act 1981 (as amended). Throughout the surveyed reach, the bank sides also contained a number of exotic ornamental species, either escaped from gardens or deliberately planted where gardens backed onto the river. It was anecdotally reported that the reduced extent of floating pennywort in 2013 had resulted in a notably higher diversity of other aquatic and emergent species being observed within the channel (Environment Agency, personal communication).

Despite the relatively large numbers of species recorded, the central channel was relatively clear, with the vegetation generally most dominant along the margins. In places, the river was relatively shaded with some large crack willow *Salix fragilis* and ornamental

trees. Where this shading was present the growth of aquatic macrophytes was much reduced.

5.3.2 Rationale for management

Floating pennywort is controlled primarily for flood risk management purposes as it has a tendency to block structures when it forms large rafts. Although the flood relief channel (the River Ember) constructed in the 1970s has reduced flood risk for the area, the blocking of weirs and sluices can have a localised impact. Figure 5.5 illustrates this issue at Zenith Weir in 2002.

Figure 5-5 Zenith Weir in 2002 (courtesy Michele Cooper, Environment Agency)

5.3.3 Current management practices

The much reduced extent of floating pennywort in 2013 compared with previous years is believed to be a result of a successful control programme implemented in 2012 and the cold winter and spring which inhibited growth (Environment Agency, personal communication).

In 2012, management included spraying of stands with a glyphosate-based herbicide, alongside hand pulling. Management in 2013 was proposed to be conducted monthly from June onwards. It consisted of hand pulling the small localised infestations before they become too extensive and unmanageable.

It was also hoped that canopy raising (that is, trimming and cutting back of overhanging branches and vegetation) would be carried out in 2013 as this has not been done recently. Where there are overhanging branches it is very easy for the floating pennywort to become entangled in these and to become established.

5.3.4 Historical management practices

Floating pennywort has been problematic on this stretch of river for 13 years and many approaches to controlling have been adopted. In 2012, £38,000 was spent in trying to control this species on this stretch of river alone (Environment Agency, personal communication).

Mechanical methods, using weed boats (Figure 5.6) and long-reach excavators (Figure 5.7) have been tried but the level of fragmentation with these techniques, and the potential for downstream spread, was considered to be too high.

Figure 5-6 Control in September 2002 using weed boats and tugs to collect arisings at Zenith Weir (courtesy Michele Cooper, Environment Agency)

Figure 5-7 Control using long-reach excavators (courtesy Michele Cooper, Environment Agency)

In some years management has been conducted entirely by hand, either from a boat or with operatives in waders. This is time-consuming and onerous work.

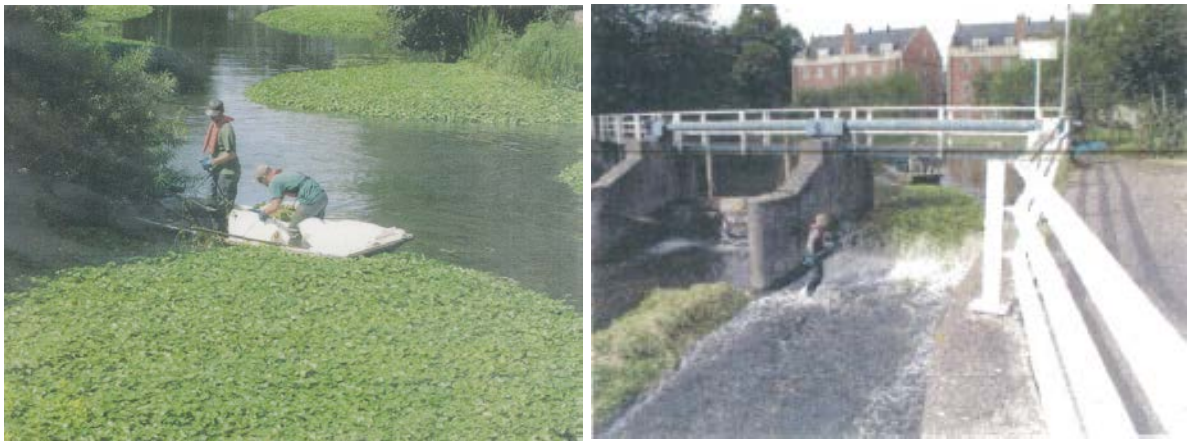


Figure 5-8 Hand pulling techniques at East Molesley (left) and at Zenith Weir (right) (courtesy Michele Cooper, Environment Agency)

Booms have also been regularly used to collect cut material, which was then loaded into tug boats for disposal off-site. In the past, arisings were removed from site. However, this was expensive so now the approach is to leave the arisings on the bank to decompose naturally where possible. However, this needs to be done carefully so that the material does not fall or

wash back into the river. In some cases it will begin to regrow on the banksides and so it needs to be monitored carefully.

As discussed above, canopy raising has also been conducted along the river in the past to remove overhanging branches where floating pennywort could potentially become entangled and re-establish.

5.4 Post-management assessment 2013

Updates on the management of floating pennywort throughout 2013 were provided by the local Environment Agency officer. Regular management by hand from a boat was conducted to keep on top of the infestations, which remained small and much more manageable with the adoption of this early intervention approach. It was estimated that one week to 10 days a month were spent hand pulling this species during the summer, with the work undertaken from a boat (Environment Agency, personal communication). This allowed the infestations to remain small and under control. This regular hand pulling approach is also proposed for 2014.

Figure 5-9 Floating pennywort on the River Mole, August 2013 (courtesy Michele Cooper, Environment Agency)

No herbicide applications were made in 2013 as the infestations remained small due to the regular monitoring and rapid response once found. None are proposed for 2014.

In 2014, it is proposed to carry out a canopy raising operation on one bank as many of the infestations encountered in 2013 were in the marginal areas, growing around overhanging vegetation. This canopy raising operation should ensure that there is little for the plant to become entangled with and make management by hand pulling easier.

5.5 Application of decision-making tool

Table 5.1 summarises the data inputs to the spreadsheet tool.

Table 5-1 Input parameters for the River Mole

Parameter	Input
Is the watercourse a designated site or is it adjacent to a designated site?	No
Does the watercourse support populations of protected species (for example, water vole, otter, white-clawed crayfish)?	No
Problem species	Floating pennywort
Watercourse type	Modified urban watercourse
Length of watercourse to be managed (m)	3,500 m
Channel width (m) (that is, wetted width)	10–15 m (minimum of 10 m inputted)
Water depth (m)	Water levels are variable. They are very shallow (less than 0.5 m) in some places, becoming deeper downstream (over 1 m in places) (minimum of 0.5 m inputted)
Machine access possible?	Yes
Boat access possible?	Yes

The output from the decision-making spreadsheet tool is shown in Figure 5.10. The highest ranked option returned is glyphosate-based herbicide with adjuvant, applied by either a boat or lance, followed by hand cutting and hand pulling. This supports the approach currently being implemented at this location as described in section 5.3.3.

As a longer-term strategy, increasing shading through additional tree planting on the river banks could be considered (output rank 4). However, site-specific issues including the large number of private residences and landowners that back onto the river could make implementation of this difficult. The issue of overhanging branches trapping fragments, allowing them to regrow has also been highlighted as a concern, with canopy raising undertaken as a result. Therefore this option may not be appropriate at this location.

Confirming the findings of previous management operations at this site, which resulted in fragmentation, use of a weed boat (output rank 6) or de-weeding with a weed bucket (output rank 10) are much lower ranked options.

Figure 5-10 Output from the decision-making spreadsheet tool for the River Mole

Watercourse Name

River Mole

Location

East Molesley, Surrey

WFD Watercourse number	GB106039017622
Start Grid Reference	TQ14346756
End Grid Reference	TA15266817
Prepared by	Laura Thomas
Date	16/12/2013

Is the watercourse a designated site or is it adjacent to a designated site? No

Does the watercourse support populations of protected species (e.g. water vole, otter, white-clawed crayfish)? No

Select Species

Floating pennywort Hydrocotyle ranunculoides

Data must be entered into all the white cells in this section before any recommendations can be made

Select Watercourse Type

Modified Urban Watercourse

Length of watercourse to be managed (m)	3500
Channel width (m) (ie wetted width)	10
Water depth (m)	0.5

Machine access possible? Yes

Boat access possible? Yes

Notes for selected species:

Floating pennywort is a non-native invasive species listed on Schedule 9 of the Wildlife and Countryside Act 1981 (as amended); it is an offence to plant or cause its spread in the wild.
Physical control techniques should be implemented with care; fragmentation can result in spread.

Recommended control options are (always consider site-specific factors in technique selection):

Rank	Control Technique	Relevant Section of Technical Guide	Means of Application (where more than one method)	Effectiveness for selected species (0 = low, 3 = high)	Damage to Watercourse Type (0 = low, 1 = high, -1 = N/A)	Technically feasible? (0 = No, 1 = Yes)	Score (0 = low, 3 = high)	Indicative Cost
1=	Glyphosate-based herbicide with adjuvant	7.4.1	boat	3	0.06	1	2.83	£
1=	Glyphosate-based herbicide with adjuvant	7.4.1	lance	3	0.06	1	2.83	£
3	Hand cutting	7.3.1		2	0.00	1	2.00	£££
4	Hand pulling	7.3.1		2	0.06	1	1.89	£££ / £ (*)
5	Shading through tree/hedgerow/bankside planting	7.5.1		2	0.11	1	1.78	££
6=	Glyphosate-based herbicide	7.4.1	boat	1	0.06	1	0.94	£
6=	Glyphosate-based herbicide	7.4.1	lance	1	0.06	1	0.94	£
6=	Weed boats	7.3.2		1	0.06	1	0.94	£
9=	Channel narrowing to increase velocity (two-stage channel)	7.5.5		1	0.11	1	0.89	£££
9=	Mechanical harvesters	7.3.2		1	0.11	1	0.89	££
11	Amphibious vehicles	7.3.2		1	0.17	1	0.83	£
12	De-weeding with a weed bucket	7.3.3		1	0.22	1	0.78	££

Note: Score = (Effectiveness of technique) x (1 - Damage to watercourse type) x (Technically feasible)

The maximum possible score is 3

(*) = lower cost if use volunteers

5.6 Lessons learnt

Lesson 1: This case study demonstrates that, in relation to floating pennywort, early intervention is key. Once a small infestation is spotted it is much easier and cheaper to carry out localised control rather than leave the infestation to spread and then have to control it. This case study also emphasises the importance of having well-informed site operatives who can identify this species and then highlight the urgent need for management.

Action taken: The importance of rapid intervention in controlling this species will be highlighted in the guidance and also in relation to other non-native invasive species. The value of having site operatives trained in accurate non native invasive species identification will be stressed.

Lesson 2: This case study highlighted the potential benefit of canopy raising in reducing the likelihood of re-establishment following management by removing potential overhanging branches where fragments could become entangled and re-establish.

Action Taken: The importance of canopy raising in relation to this species will be emphasised in the guidance.

5.7 Post management assessment 2014

A return site visit to the River Mole was conducted on the 1st October 2014. Liaison was also undertaken with the Environment Agency regarding their views on the successes and limitations of the management conducted.

5.7.1 Results of post management assessment

The return site visit identified that floating pennywort was still problematic within the River Mole, with some significant areas of this plant noted, and an increase observed from 2013 (see Figure 5-11). Rafts of floating pennywort were observed floating along the river, with some having accumulated around Zenith Weir (see Figure 5-11).

Figure 5-11 Zenith Weir in July 2013 (left) and October 2014 (right)

During the site visit this species was generally observed as only present in small patches alongside the margins of the watercourse. However, liaison with the Environment Agency indicated that earlier in the year the extent of the floating pennywort had been particularly severe, with the mild spring resulting in denser and earlier than anticipated growth. As a

consequence, the maintenance teams were not able to implement their early intervention approach which had been employed so successfully in 2013, and as a result the stands became extensive.

Figure 5-12 Extent of floating pennywort on the River Mole in summer 2014 (courtesy Mary Seabourne, Environment Agency)

Once the severity of the problem was identified, the management technique as employed in 2013 was implemented; this included manual removal of floating pennywort patches from the watercourse using hand rakes from both the bankside and boat.

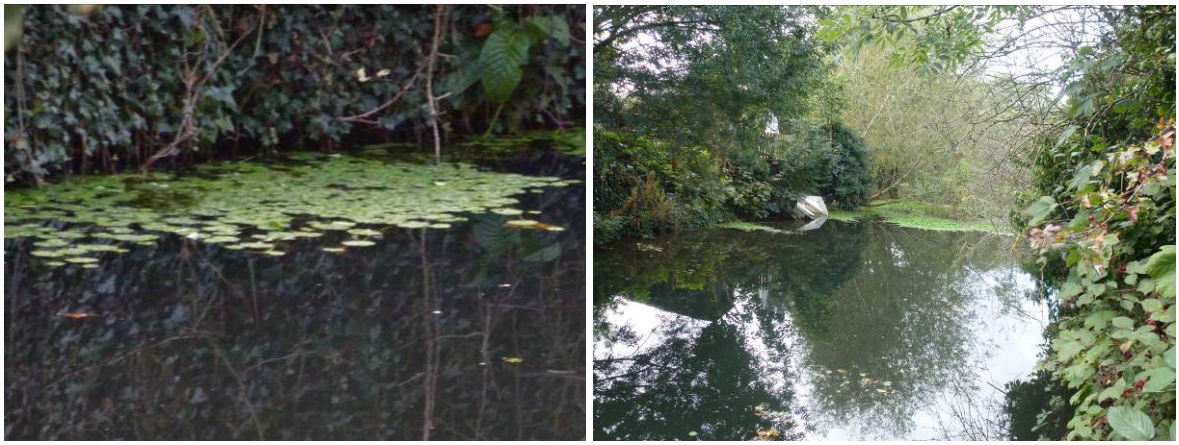


Figure 5-13 Patches of floating pennywort observed on the River Mole in October 2014

5.7.2 Effectiveness of management

As discussed above, the effectiveness of management conducted in 2014 was limited due to the mild spring which resulted in higher than anticipated growth rates of floating pennywort earlier in the year. This prevented an early intervention approach being implemented. This highlights the importance, particularly with rapidly growing non-native invasive species such as floating pennywort, of having flexibility in a management programme to be able to respond as soon as a problem is identified.

By October 2014, the extent of floating pennywort at the River Mole, although more than observed in 2013, was still in relatively small patches along the watercourse margins indicating that once the management had begun in 2014, it was relatively successful in limiting the extent of this species.

5.7.3 Application of adaptive monitoring approach

Figure 10.1 of the technical guide details the process for applying a monitoring and adaptive management approach to watercourse management. At the River Mole, the objective for management is to control the floating pennywort for flood risk management purposes. Given the difficulties encountered in 2014, with the rapid growth caused by unusual weather conditions, the flowchart indicates that the management approach should be adapted. Referring back to the output of the decision-making spreadsheet tool (Figure 5-10), the method of hand cutting employed at the River Mole is the third ranked technique, and considered very effective in relation to this species. A higher ranked technique returned is the use of glyphosate based herbicide with an adjuvant and the management method employed at the River Mole in 2015 could therefore be adapted to use this technique, either instead of hand cutting, or in-combination with it. Alternatively, the method of implementation of the hand cutting technique could be adapted to increase its success. Incorporating greater flexibility into the management programme to allow for rapid intervention as soon as floating pennywort begins to encroach into the river could be employed, so that management can be undertaken in advance of the original schedule if weather conditions require it.

6 Nafferton Beck, East Yorkshire

6.1 Introduction

Nafferton Beck is located to the east of Driffield, East Yorkshire. It flows south from the village of Nafferton to Driffield Canal (Figure 6.1).

Figure 6-1 Nafferton Beck location map

An initial site visit was conducted by Rachael Brady of JBA Consulting on 10 July 2013. The watercourse is a designated main river and therefore the responsibility of the Environment Agency. The site visit was made with the Environment Agency's contractor.

During the site visit, one section of Nafferton Beck was assessed in more detail. This was a section upstream of the road bridge as shown in Figure 6.1.

6.2 Watercourse description

Within the section surveyed, Nafferton Beck is a wide (approximately 4–5 m), shallow, slow-flowing watercourse, with relatively low banks (approximately 1–1.3 m in height) (Figure 6.2). The substrate is predominantly gravels with some silt.

Adjacent land use consists predominantly of arable fields. An intermittent hedgerow with some large, mature trees is present along the right bank. A public footpath is present along the top of the left bank

Figure 6.2 Fixed point photograph location: looking upstream (left) and downstream (right)

6.3 Watercourse management

6.3.1 Problem species

The main problem species is emergent branched bur-reed *Sparganium erectum*, which grows throughout the channel and in places covers the full width.

Other tall emergent species present include reed canary-grass *Phalaris arundinacea* and common reed *Phragmites australis* along the bank margins and on the banks.

6.3.2 Rationale for management

Land drainage and flood risk management are the primary drivers of watercourse maintenance. Tall emergent species can impede the flow of flood waters and cause an accumulation of debris.

6.3.3 Current management practices

The Environment Agency decided to use chemical control to manage the emergent vegetation in 2013. Mechanical control is difficult as there is a public footpath along the left bank and therefore the arisings cannot be placed on this bank. On the right bank there are sections of hedgerow and mature trees, and therefore the mechanical techniques involve the machine having to place all arisings on top of the right bank at the bottom of the hedge which is artificially raising the bank.

Chemical control was undertaken by the Environment Agency's contractor the week before the site visit. The spraying was undertaken by one operative from within the channel using a knapsack sprayer, which allowed for targeted control of the emergent branched bur-reed. Figure 6.3 shows the effects of spraying.

Figure 6.3 Extent of branched bur-reed (left) and effects of spraying (right)

6.3.4 Historical management practices

Nafferton Beck has in the past been managed by mechanical methods. The weed is usually cut by a machine with a weed cutting bucket from the left bank and the arisings placed on top of the right bank, as discussed above.

6.4 Application of decision-making tool

Table 6.1 summarises the data inputs to the spreadsheet tool.

Table 6-1 Input parameters for Nafferton Beck

Parameter	Input
Is the watercourse a designated site or is it adjacent to a designated site?	No
Does the watercourse support populations of protected species (for example, water vole, otter, white-clawed crayfish)?	Yes – water vole are present
Problem species	Branched bur-reed
Watercourse type	Artificial drainage channel

Parameter	Input
Length of watercourse to be managed (m)	525 m
Channel width (m) (that is, wetted width)	4–5 m (minimum of 4 m inputted)
Water depth (m)	Water depth varies but consistently shallow (0.2 m inputted)
Machine access possible?	Yes
Boat access possible?	Yes

The output from the decision-making spreadsheet tool is given in Figure 6.4. The highest ranked options returned are glyphosate-based herbicide and glyphosate-based herbicide with adjuvant. This supports the approach currently being implemented at this location. Hand cutting is also a highly ranked option, but due to the relatively high cost of this technique, it may not be feasible.

As a longer-term strategy, increasing shading through additional tree planting on the banks of the beck could be considered (output rank 4).

6.5 Lessons learnt

Lesson 1: This case study provides an example where the use of glyphosate-based herbicide may be more effective when managing tall emergent species and less environmentally damaging than mechanical techniques. In this particular watercourse, the herbicide application could be targeted due to the width and shallowness of the watercourse, reducing impacts on the adjacent public footpath and hedgerow.

Action taken: The guidance will emphasise the effectiveness of chemical control for tall emergent species. It will also highlight the importance of controlled application following best practice guidelines and with Environment Agency agreement.

Figure 6.4 Output from the decision-making spreadsheet tool for Nafferton Beck

Watercourse Name

Nafferton Beck

Location

Nafferton, East Yorkshire

Is the watercourse a designated site or is it adjacent to a designated site? No

WFD Watercourse number	GB104026067090
Start Grid Reference	TA06525669
End Grid Reference	TA06515722

Does the watercourse support populations of protected species (eg Water Vole, Otter, White-clawed Crayfish)? Yes

Contact Natural England/Natural Resources Wales/Environment Agency for further advice and follow appropriate species guidance. See section 4.5.2 of the Technical Guide.

Prepared by	Rachael Brady
Date	20/11/2013

Select Species

Branched Bur-reed Sparganium erectum

Data must be entered into all the white cells in this section before any recommendations can be made

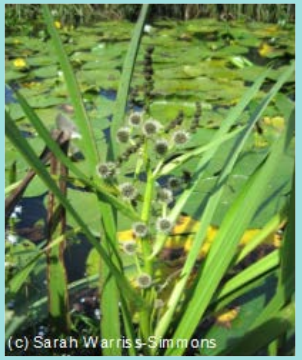
Select Watercourse Type

Artificial Drainage Channel

Length of watercourse to be managed (m)	575
Channel width (m) (ie wetted width)	4
Water depth (m)	0.1

Machine access possible? Yes

Boat access possible? Yes



Notes for selected species:

Tall emergent species are often very important in stabilising the toes of banks and management should aim to ensure that a protective fringe of tall emergent vegetation is retained.
Tall emergent species can often provide nesting sites for a range of bird species; management of large stands of tall emergent species should always be conducted outside of the bird breeding season (March-September).

Recommended control options are (always consider site-specific factors in technique selection):

Rank	Control Technique	Relevant Section of Technical Guide	Means of Application (where more than one method)	Effectiveness for selected species (0 = low, 3 = high)	Damage to Watercourse Type (0 = low, 1 = high, -1 = N/A)	Technically feasible? (0 = No, 1 = Yes)	Score (0 = low, 3 = high)	Indicative Cost
1=	Glyphosate-based herbicide	7.4.1	lance	3	0.17	1	2.50	£
1=	Glyphosate-based herbicide with adjuvant	7.4.1	lance	3	0.17	1	2.50	£
3	Hand cutting	7.3.1		2	0.00	1	2.00	£££
4	Shading through tree/hedgerow/bankside planting	7.5.1		2	0.33	1	1.33	££
5	Amphibious vehicles	7.3.2		2	0.50	1	1.00	£
6=	Buffer Strips	7.5.6		1	0.17	1	0.83	££
6=	Diffuse and point source pollution management	7.5.6		1	0.17	1	0.83	£££
6=	Excavator and tractor mounted cutter/flail	7.3.5		1	0.17	1	0.83	£
6=	Hand pulling	7.3.1		1	0.17	1	0.83	£££ / £ (*)
10=	Channel narrowing to increase velocity (two-stage channel)	7.5.5		1	0.33	1	0.67	£££
10=	De-weeding with a weed bucket	7.3.3		2	0.67	1	0.67	££
12=	De-weeding with a solid bucket	7.3.4		2	0.83	1	0.33	£££

Note: Score = (Effectiveness of technique) x (1 - Damage to watercourse type) x (Technically feasible) The maximum possible score is 3 (*) = lower cost if use volunteers

6.6 Post management assessment 2014

A return site visit to Nafferton Beck was conducted on the 8th August 2014. Liaison was also undertaken with the Environment Agency regarding their views on the successes and limitations of the management conducted.

6.6.1 Results of post management assessment

The return site visit identified that branched bur-reed was was still frequent within the channel although there appeared to be a greater area of open water than was present in 2013, and consequently improved water conveyance.

No submerged or floating species were found to have colonised the open water areas but this is likely due to the shallow depth of water and the high level of nutrients present.

Figure 6.4 Extent of branched bur-reed in summer 2014

6.6.2 Effectiveness of management

In the winter of 2013 it was discovered that weed cutting had been carried out by a third party following application of herbicide. It is unknown whether this was carried out because of an actual flooding risk, or whether it was a perceived risk due to a change to the usual management regime and/or the presence of dying vegetation within the channel.

Because of the subsequent de-weeding it is difficult to assess the effectiveness of the application of glyphosate-based herbicide as a management technique for this watercourse. Nevertheless, as shown in Figure 6-3, the stands of branched bur-reed were dying back following the application of the herbicide and subsequent re-growth in 2014 appears to be reduced, with a more open central channel present.

6.6.3 Application of adaptive monitoring approach

As described in section 6.6.2 above, it is difficult to assess whether the management technique employed was successful. It would appear that the watercourse is susceptible to extensive growth of branched bur-reed and due to the shallow channel depth, it may be that a combination of techniques is required to ensure that the flow of water is not impeded. For

example, herbicide may be effective to reduce the amount of growth of branched bur-reed but physical techniques such as de-weeding may still be required to remove the dead growth from the channel to prevent blockages. This operation would need to be carefully timed to ensure that the herbicide has sufficient time to translocate through living plant material to effectively control plant growth, prior to physical removal of dead plant material.

Consideration should be given in the future to longer term management techniques such as shading, nutrient/pollution management and/or channel narrowing/deepening to manipulate the environmental conditions to help to limit the growth of branched bur-reed.

7 Boating Dike, Thorne, South Yorkshire

7.1 Introduction

Boating Dike, within the Black Drain Internal Drainage District, is located within the town of Thorne, near Doncaster in South Yorkshire (Figure 7.1).

Figure 7-1 Boating Dike location map

An initial site visit was conducted by Laura Thomas of JBA Consulting on 17 October 2013. The drain is managed by the Black Drain DB.

During the site visit the section of Boating Dike within the Capitol Bark Business Park, off Omega Boulevard, was assessed.

7.2 Watercourse description

Boating Dike flows in a general westerly direction on the western outskirts of the town of Thorne. For its upstream reaches it flows alongside the Stainforth and Keadby Canal and Thorne Marina. It then passes through the Capitol Bark Business Park, off Omega Boulevard, before discharging under the M18 motorway and into the old course of the River Don. Where the drain passes under the railway and motorway, there is a large culvert. Where it passes

under Omega Boulevard, the culvert is fitted with a weed screen and cleaner to remove accumulated debris.

The section of Boating Dike that flows through Omega Boulevard is relatively wide (5–6 m), with shallow, sloping banks. When the industrial estate of Capitol Park was developed in the late 1990s, the watercourse was diverted. Further expansion of the industrial estate in 2006-2007 resulted in additional works to increase the capacity of this watercourse, along with the installation of the weed screen cleaner. During the second phase of engineering works on this watercourse a berm, below the usual water level, was included within the channel profile and extensive planting of marginal vegetation was carried out.

Water depth is variable, but is typically about 0.5 m. The length of watercourse requiring management through Capitol Park is 735 m.

Boating Dike discharges into the Thorne Watersides, Oxbows and Ings Site of Scientific Interest (SSI), the locally designated non-statutory site in the Doncaster district. It is an area of open water, reed bed and wetland habitat. The upstream end of the watercourse is located in close proximity to the Thorne Railway Delves SSI. Water vole *Arvicola amphibius* are also known to be present within this watercourse.

7.3 Watercourse management

7.3.1 Problem species

The species of concern at Boating Dike is currently common duckweed *Lemna minor* which, at the time of the survey, completely covered the water surface (Figure 7.2), potentially leading to impoverished submerged flora and fauna.

Figure 7-2 Boating Dike with extensive common duckweed coverage

Along the margins in places were also extensive stands of branched bur-reed *Sparganium erectum* and reed sweet-grass *Glyceria maxima*. A range of other tall emergent species were also frequent including reed canary-grass *Phalaris arundinacea*, reedmace *Typha latifolia*, and lesser pond-sedge *Carex acutiformis*. The marginal areas were relatively species-rich (likely a result of the planting scheme implemented during the works undertaken in 2006-2007) with fool's water-cress *Apium nodiflorum*, water-plantain *Alisma plantago-aquatica* and creeping bent *Agrostis stolonifera*.

False-oat-grass *Arrhenatherum elatius* dominated the banks, with great willowherb *Epilobium hirsutum,* red clover *Trifolium pratense* and tansy *Tanacetum vulgare* also frequent.

Within the common duckweed coverage across the water surface were occasional small patches of the non-native invasive species water fern *Azolla filiculoides* (Figure 7.3). Given the

extensive coverage of common duckweed, this non-native has not been able to dominate the watercourse as it can do in certain situations.

Figure 7-3 Water fern patches within Boating Dike

7.3.2 Rationale for management

Being in an urban and industrial setting, the primary driver of management of Boating Dike is flood risk management, although the watercourse is also part of the land drainage network of the Black Drain DB.

Most notably, in June 2007 the area suffered from extensive flooding as a result of overtopping of the banks (Figure 7.4). Consequently, there is a need to ensure that the conveyance and capacity of the watercourse is not impeded by tall emergent vegetation and that structures, including the weed screen cleaner, do not become blocked by the common duckweed.

Figure 7-4 Boating Dike flooding in June 2007

Management of the extensive infestations of common duckweed is also likely to lead to ecological benefits by allowing light into the channel, which should encourage submerged flora and fauna to increase.

7.3.3 Historical management practices

Historically, the problem species in this watercourse have been branched bur-reed and reed sweet-grass reducing conveyance and channel capacity, with common duckweed being much

less of issue. Other tall emergent species were also frequent, including reed canary-grass, reedmace and lesser pond-sedge. Figure 7.5 shows the extensive tall emergent vegetation found in earlier years.

Figure 7-5 Extensive tall emergent vegetation in 2010 (left) and 2009 (right

For many years the traditional management employed by the Black Drain DB in managing this watercourse has followed a dual approach.

- Vegetation was removed from one full bank, together with at least the lower 50% of the opposite bank, using a flail mower or hand tools. Cut material was removed from the watercourse immediately.
- Vegetation was removed from the bed of the drain using a weed cutting bucket to remove as much of the root as possible.

However, use of a weed cutting bucket has become difficult at this site over more recent years due to the shallow sloping banks, large width of this drain, the large volume of vegetative material requiring removal and the limited area for disposal of cut material on the banksides. Consequently, the use of glyphosate-based herbicide to control the tall emergent growth was trialled in 2012.

Figure 7.6 provides a chronological record of the vegetation issues in this watercourse, taken from a fixed point at grid reference SE67511331.

Photo	Year	Comment
	2009	Two years following the works to increase capacity of the watercourse, bankside vegetation is still establishing, although in-channel vegetation is beginning to be dominated by branched bur-reed and reed sweet-grass.

Photo	Year	Comment
	2010	In-channel tall emergent vegetation is very extensive, covering the majority of the channel width.
	2011	In-channel tall emergent vegetation is very extensive, covering the majority of the channel width, with increasing proportions of reed sweet-grass.
	2013	One year following glyphosate-based herbicide application, the sprayed central channel is now clear of tall emergent species, with a marginal toe retained, although common duckweed now completely covers the water surface.

Figure 7-6 Fixed point photography at Boating Dike (courtesy Black Drain DB)

7.3.4 Current management practices

Given the glyphosate-based herbicide application conducted in 2012 to control the tall emergent vegetation within this drain, management of the watercourse was not proposed for 2013. However, the extent of the common duckweed that subsequently developed, potentially as a result of the reduced tall emergent cover, resulted in management being carried out to prevent the common duckweed blocking structures further downstream. Due to the availability of resources held by the DB it was proposed that de-weeding with a weed cutting bucket would be conducted, although this is unlikely to be the most effective technique for this floating species.

7.4 Post-management assessment

Boating Dike was managed by the Black Drain DB using an excavator fitted with weed cutting bucket in winter 2013.

7.5 Application of decision-making tool

Table 7.1 summarises the data inputs to the spreadsheet tool.

Table 7-1 Input parameters for Boating Dike

Parameter	Input
Is the watercourse a designated site or is it adjacent to a designated site?	Yes – the watercourse discharges into the Thorne Watersides, Oxbows and Ings SSI
Does the watercourse support populations of protected species (for example, water vole, otter, white-clawed crayfish)?	Yes – the site is known to support a population of water vole
Problem species	Common duckweed
Watercourse type	Ditch/ small drain
Length of watercourse to be managed (m)	735 m
Channel width (m) (that is, wetted width)	5–6 m (minimum of 5 m inputted)
Water depth (m)	0.5
Machine access possible?	Yes
Boat access possible?	No

The output from the decision-making spreadsheet tool is shown in Figure 7.7. The highest rank output is shading with native, broad-leaved floating species, which would likely require planting to generate the shade and, given the issues with conveyance and channel capacity at this site, would not be an advisable option. Alternatively, shading with tree/hedgerow/bankside would be an effective control technique, but given the limited access along the bank top at this site and the presence of a public footpath, there is limited space available for planting.

The second ranked option returned is channel narrowing to increase velocity through creation of a two-stage channel. This is an option that the Black Drain DB has considered, though previously to reduce the extent of tall emergent vegetation. It wants to install toe piling within the channel in the hope of allowing marginal areas to develop where maintenance would not be required or required less frequently due to faster flows. This could be a long-term strategy to help reduce long-term management requirements of this watercourse. However, the flood risk implications of this would need to be carefully assessed given its urban and industrial setting to ensure that any channel narrowing does not have an adverse impact. Other longer-term options such as buffer strips and diffuse and point source pollution management may also have an impact, but would require extensive liaison and partnership working across the catchment.

The highest ranked options returned were generally longer-term options which would not result in a short-term solution to the issue. The highest ranked short-term option was the use of the novel suction harvesting technique. However, the option actually selected for management of common duckweed at Boating Dike was de-weeding with a weed bucket, which only returned as the 10th highest option, given its limited effectiveness on floating species and its potential to

damage ditches/small drains through silt mobilisation. However, given the availability of resources, this was the only technique available at the time.

Figure 7-7 Output from the decision-making tool for Boating Dike

Watercourse Name

Boating Dike

Location

Thorne, South Yorkshire

WFD Watercourse number: n/a
Start Grid Reference: SE67771338
End Grid Reference: SE67501340

Prepared by: Laura Thomas
Date: 18/10/2013

Is the watercourse a designated site or is it adjacent to a designated site? Yes - site is of local importance (eg LNR, LWS, etc)

Liaise with local planning authority/site owner or manager with regards to appropriate techniques/working methods and a site management plan may already be in place.

Does the watercourse support populations of protected species (eg Water Vole, Otter, White-clawed Crayfish)? Yes

Contact Natural England/Natural Resources Wales/Environment Agency for further advice and follow appropriate species guidance. See section 4.5.2 of the Technical Guide.

Select Species

Duckweeds Lemna spp

Data must be entered into all the white cells in this section before any recommendations can be made

Select Watercourse Type

Ditch / Small Drain

Length of watercourse to be managed (m): 735
Channel width (m) (ie wetted width): 5
Water depth (m): 0.5

Machine access possible? Yes

Boat access possible? No

Notes for selected species:

Care should be taken in identification as Rootless Duckweed Wolffia arrhiza is a rare species in this group.

Recommended control options are (always consider site-specific factors in technique selection):

Rank	Control Technique	Relevant Section of Technical Guide	Means of Application (where more than one method)	Effectiveness for selected species (0 = low, 3 = high)	Damage to Watercourse Type (0 = low, 1 = high, -1 = N/A)	Technically feasible? (0 = No, 1 = Yes)	Score (0 = low, 3 = high)	Indicative Cost
1	Shading with native, broad-leaved floating species	7.5.1		2	0.00	1	2.00	£
2=	Channel narrowing to increase velocity (two-stage channel)	7.5.5		2	0.33	1	1.33	£££
2=	Shading through tree/hedgerow/bankside planting	7.5.1		2	0.33	1	1.33	££
2=	Suction harvesting	7.7.4		2	0.33	1	1.33	£££
5	Native fish species	7.6.4		1	0.00	1	1.00	£
6=	Buffer Strips	7.5.6		1	0.17	1	0.83	££
6=	Diffuse and point source pollution management	7.5.6		1	0.17	1	0.83	£££
6=	Glyphosate-based herbicide	7.4.1	lance	1	0.17	1	0.83	£
6=	Glyphosate-based herbicide with adjuvant	7.4.1	lance	1	0.17	1	0.83	£
10	De-weeding with a weed bucket	7.3.3		1	0.67	1	0.33	££
11	De-weeding with a solid bucket	7.3.4		1	0.83	1	0.17	£££

Note: Score = (Effectiveness of technique) x (1 - Damage to watercourse type) x (Technically feasible) The maximum possible score is 3

7.6 Lessons learnt

Lesson 1: This case study provides an example of how management of one species can result in another species becoming problematic. In this case, management of branched bur-reed and other tall emergent species has led to dominance by floating common duckweed. This highlights the need to monitor the impacts of vegetation management.

Action taken: The impacts of vegetation management on the communities in a watercourse will be discussed in the technical guide. The importance of monitoring impacts will be stressed, particularly when traditional management techniques are altered.

Lesson 2: This case study demonstrates that it may not always be the highest ranked technique that is selected for management due to a range of site-specific issues.

Action taken: The guide will emphasise that selecting the highest ranked technique is a valid decision to make based on site-specific issues. The spreadsheet is a decision-support tool to help inform decisions; an alternative technique to those ranked highest can be selected so long as this is justified.

7.7 Post management assessment 2014

Boating Dike was re-surveyed on the 9th September 2014, prior to management being conducted.

7.7.1 Results of post management assessment

The re-survey of Boating Dike in 2014 found a similar situation to that observed in 2013, with common duckweed again dominating the channel, particularly within the downstream section. Water fern, which was noted in 2013 in very small patches, was however much more frequent in 2014, with it present in approximately equal proportions with the common duckweed in some parts of the channel.

Figure 7-8 Water fern within downstream part of channel in 2014 showing that it has become more frequent

A further change to in-channel vegetation observed in 2014 was a dense stand of water plantain *Alisma plantago-aquatica*, which was noted approximately 50m upstream of the culvert and weed screen cleaner. This stand of vegetation only extended for approximately 15m of channel, but was very dense. This species does not usually form dense stands, as has occurred at Boating Dike, and was therefore not specifically included within the technical guide as a problematic species.

Figure 7-9 Stand of water plantain at Boating Dike

The upstream section of the channel, which historically has been dominated by tall emergent vegetation, was again dominated by reedmace, tall sedges and branched bur-reed. This section of watercourse was treated with a glyphosate-based herbicide in 2012, which maintained an open central channel in 2013, however, by 2014 the vigour of plant growth again resulted in their dominance in this section.

Figure 7-10 Boating Dike in 2013 (left) and 2014 (right)

7.7.2 Effectiveness of management undertaken

Flood risk management and land drainage are the primary drivers for management of this watercourse, with the tall emergent vegetation impeding conveyance and the common duckweed potentially creating an issue in relation to structure blockage, in particular the weed screen cleaner. Analysis of the results from the case study visits shows that the glyphosate-based herbicide application to the tall emergent vegetation was particularly effective, resulting in effective control for 2 seasons, although in 2014 a repeat treatment is likely to be required.

Mechanical control of the common duckweed, whilst directly removing the plant from the watercourse, has not provided a long-term solution, with the plant again as dominant as previously, with water fern also frequent.

There is uncertainty over why water plantain would have become so abundant over the very short stretch of watercourse, as it has done in 2014.

7.7.3 Application of adaptive monitoring approach

The application of glyphosate-based herbicide to the tall emergent vegetation was successful at ensuring conveyance within the channel could be maintained by creating an open central channel, and the channel remained open for a period of 2 years. It can therefore be considered that the management technique employed is effective and it should therefore continue.

The use of a weed-cutting bucket to manage the common duckweed however has not had long-term success, although this is often the case with physical management techniques which can typically require annual intervention. In addition, water fern and water plantain have become more frequent within this stretch of watercourse and consequently adaptation of the management strategy for the downstream 200m section of watercourse should be considered. Given that there are now three species which are dominant/abundant within this portion of the channel, the decision-making spreadsheet was re-run for these species to ascertain the most effective management strategy. As water plantain is not specifically included within the tool, the generic 'broad-leaved emergent' species group was entered.

Table 7-2 Comparison of outputs from decision-making tool for the downstream section of Boating Dike

Technique	Common duckweed	Water Fern	Water plantain (broad-leaved emergent)
Shading with native, broad-leaved floating species	1	3=	
Channel narrowing to increase velocity (two-stage channel)	2=	9=	
Manipulation of flow characteristics	2=	5=	
Shading through tree/hedgerow/bankside planting	2=	9=	4=
Suction harvesting	2=	2	
Native fish species	6	3=	
Buffer Strips	7=	5=	6=
Diffuse and point source pollution management	7=	5=	6=
Glyphosate-based herbicide	7=	5=	2=
Glyphosate-based herbicide with adjuvant	7=	5=	2=
Shading with opaque materials suspended over water	11=	9=	4=
Water level manipulation	11=		8=
Invertebrates (e.g. Daphnia spp., weevils)		1	
Hand cutting			1
De-weeding with a weed bucket			8=
De-weeding with a solid bucket			10
Grazing of banks by cattle, sheep and horses			11

Consequently, and following the adaptive management approach, the management technique employed at Boating Dike could be revised. The outputs of the decision-making spreadsheet are varied in the techniques they recommend given that the species present are relatively diverse. However, it could be that an integrated technique of glyphosate-based herbicide (which is already recommended to continue for the tall emergent vegetation) is used in conjunction with another technique, such as weevils to control the water fern, or suction harvesting. Over the long-term, shading using vegetation and/ or nutrient management would be advised to try and minimise the growth of problematic species.

8 River Lee, Luton

8.1 Introduction

The River Lee rises at Rotten Corner on Leagrave Marsh within the town of Luton in Bedfordshire, and flows in a general south-easterly direction through the town (Figure 8.1).

Figure 8-1 River Lee location map

This watercourse was surveyed on 23 July 2013 by Laura Thomas of JBA Consulting. The site visit was conducted in conjunction with Environment Agency staff.

8.2 Watercourse description

The River Lee is a chalk stream (Figure 8.2) and therefore has low flows in summer, but potentially high winter flows. The section requiring management (Figure 8.1) is approximately 3–4 m wide, with water depths when surveyed of approximately 0.5 m, although bank heights tended to be significantly higher than this (approximately 1.5–2 m). Water flow was moderate and the substrate a combination of gravel/pebbles and sand.

A significant proportion of this stretch of the River Lee flows through parks, with amenity grassland, scrub and semi-improved grassland being the dominant adjacent habitats. Elsewhere, residential developments were located alongside the watercourse. The urbanised nature of this section of river means that there are numerous bridges, sluices, weirs, culverts and outfalls throughout.

Figure 8-2 The River Lee

The River Lee has a thriving water vole *Arvicola amphibius* population (Environment Agency undated) and chalk rivers are a UK Biodiversity Action Plan priority habitat.

8.3 Watercourse management

8.3.1 Problem species

Within the length of watercourse to be managed, two species types are problematic:

- tall emergent species, primarily branched bur-reed *Sparganium erectum*, but there are also some stands of reed sweet-grass *Glyceria maxima* and reed canary-grass *Phalaris arundinacea*
- broad-leaved emergent species, primarily fool's water-cress *Apium nodiflorum*, with occasional water-cress *Rorippa nasturtium-aquaticum*

Figure 8-3 River Lee showing problematic broad-leaved emergent growth (left) and tall emergent growth (right)

Other species within the channel included water-starwort *Callitriche* sp., brooklime *Veronica beccabunga*, great willowherb *Epilobium hirsutum* and in places quite large beds of water-crowfoot *Ranunculus* sp.

The banks throughout had particularly dense ruderal vegetation, with frequent false oat-grass *Arrhenatherum elatius*, hogweed *Heracleum sphondylium*, comfrey *Symphytum x uplandicum*, bramble *Rubus fruticosus agg*. and broad-leaved dock *Rumex obtusifolius*.

In places, shrubs – predominantly hawthorn *Crataegus monogyna* – were present on the banks, which limited the growth of in-channel aquatic macrophytes extensively.

8.3.2 Rationale for management

Flood risk management is the primary driver for watercourse maintenance along the River Lee. There are many houses in the north Luton area that are at serious risk of rapid flooding during periods of heavy rainfall, including properties that are located between the M1 and Toddington Road, along roads running parallel to the Luton Parks and at certain roads along New Bedford Road (Environment Agency undated).

Both the tall emergent and broad-leaved emergent species impede the flow of flood waters and cause the accumulation debris which can cause blockages. The broad-leaved emergent species can also cause blockages themselves if they become dislodged during high flows. As summer flooding can be an issue on this watercourse, the dense growth of these species during the summer can be problematic. However, prolonged rainfall in winter can also cause issues. The aim of maintenance on this watercourse is therefore to keep flood flow capacity at optimal levels by keeping the channels relatively clear of vegetation all year round.

The upstream sections of the River Lee have an urbanised catchment and surface water can be an issue as much of the flow is unattenuated. The topography also leads to flows rapidly accumulating in the river corridor quickly, giving a flashy nature. During peak flows the channel capacity is insufficient to convey the water and management is therefore required to ensure maximum flow capacity within the channel to minimise the number of times when flow exceeds capacity (Environment Agency undated). A number of significant tributaries also join the River Lee including Houghton Brook, Lewsey Brook, Cat Brook, Luton Millstream and Sundon Park Brook.

8.3.3 Current management practices

Current management is conducted in line with agreed maintenance principals, devised by the Environment Agency, to address the flood risk management needs while also ensuring that the habitat remains in optimum condition for water voles.

Mechanical control by a machine working from the bank is not feasible along many stretches of this river as the margins along the bank tops are in Countryside Stewardship Schemes and the use of machines is unlikely to be permitted under this agreement.

Therefore, the priorities for the current management regime for the River Lee are (Environment Agency undated):

- prevent and/or remove debris blockages affecting flow
- prevent growth of wood vegetation on lower banks and bed
- strictly limit unstable bed/channel vegetation (that is, broad-leaved emergent species)
- restrict growth of stable emergent bed vegetation (that is, tall emergent species) to less than 30% of the channel width
- remove siltation affecting flood flows
- manage soft bank side vegetation to enable woody vegetation control

To achieve these priorities the following management regime will be implemented on the River Lee.

- Remove unstable broad-leaved vegetation by hand in late April (before the main water vole breeding season) and early July (after the main water vole breeding season).
- Every five years a programme of mechanical control by excavator to remove the roots of the branched bur-reed will be carried out to reduce its presence in the channel. When this is conducted, the second phase of hand clearance (see above) is not implemented.
- Banks are trimmed once annually. This is carried out on one nominated bank six weeks after the July removal of the broad-leaved emergent vegetation to minimise disturbance to water vole. The other bank will be trimmed not less than six weeks later. This will be performed, where possible, with a tractor and flail mower and the cut height of vegetation will be 100 mm. Where tractor and flail mower is not accessible, it will be cut with hand tools.
- Where tall emergent vegetation exceeds 30% of the bed width, this will be cut and removed to clear 70% of the bed width. This will not be carried out at the same time as trimming of either bank or in May/June.

A trial using a glyphosate-based herbicide spray was carried out on 15 October 2013 to control the dense stands of branched bur-reed that dominate some sections. This was done selectively to keep a central channel clear, leaving a sinuous edge where possible.

Spraying was performed on a trial basis as there is concern that the speed of die-back may have implications for flood risk management. It is not yet known whether mechanical removal of the vegetation that has died back will be necessary to maintain conveyance. The long-term impacts of chemical control are uncertain and there is some concern that controlling the plants, particularly the branched bur-reed upstream, will reduce the amount of silt trapped by these stands. Furthermore, the transport of this silt and the nutrients within it downstream may encourage growth further downstream.

In addition, the river network is patrolled weekly to remove litter which is a significant problem in this area.

8.3.4 Historical management practices

In the past, the River Lee was managed much more intensively than it is currently. However, budgetary restrictions and the presence of water voles have resulted in changes to the way the watercourse is managed on an annual basis.

Previously, the banks would have been flail mowed to a very short grass height 2–3 times annually (in May and late August), with in-channel vegetation being regularly cleared by hand.

De-weeding operations, with a solid bucket, have also been conducted over previous years, with at least three operations undertaken since 1990 (Environment Agency, personal communication). This removed the rhizomes of the problem species and it took a significant period of time (up to 10 years) for the species to dominant the channel as they did prior to management by this method.

However, this technique had a number of problems. It was considered very damaging to the river's geomorphology and ecology. Arisings also had to be disposed of off-site as they were potentially contaminated and this was very expensive. Another issue encountered during these de-weeding operations was that they were carried out in late autumn (November) and, as the species had already begun to die back, it was difficult to see where the plant was and therefore not all the rhizomes were removed in every case.

8.4 Post-management assessment

The spraying of the River Lee through Luton was undertaken by the Environment Agency in early October 2013 (Figure 8.4). Due to conditions at the time not all sections originally intended for treatment were sprayed, with Fallowfields, Lewsey Brook and Houghton Brook not managed with glyphosate-based herbicide. Several sections of the River Lee through Luton were treated.

Figure 8-4 Spraying on the River Lee at Luton

8.5 Application of decision-making tool

Table 8.1 summarises the data inputs to the spreadsheet tool.

Table 8-1 Input parameters for the River Lee, Luton

Parameter	Input
Is the watercourse a designated site or is it adjacent to a designated site?	No
Does the watercourse support populations of protected species (for example, water vole, otter, white-clawed crayfish)?	Yes – the River Lee has a thriving water vole population
Problem species	Branched bur-reed Fool's water-cress
Watercourse type	Inactive single thread channel
Length of watercourse to be managed (m)	3,000 m
Channel width (m) (that is, wetted width)	The section requiring management is approximately 3–4 m wide (a minimum of 3 m inputted)
Water depth (m)	0.5 m
Machine access possible?	No

Parameter	Input
Boat access possible?	No

The problem species varies along the 3 km length of watercourse to be managed. Branched bur-reed is the main problem, with small patches of fool's water-cress interspersed between. As this site contains two problem species the spreadsheet tool was run twice, with the species changed on each run. The outputs given were then compared as shown in Table 8.2. Given the limitations for machine access, only eight possible techniques were returned for each species.

Table 8-2 Comparison of tool outputs for the River Lee, Luton

Technique	Branched bur-reed	Fool's water-cress
Glyphosate-based herbicide	1=	2=
Glyphosate-based herbicide with adjuvant	1=	2=
Hand cutting	3	1
Shading through tree/hedgerow/bankside planting	4	4
Buffer strips	5=	5=
Diffuse and point source pollution management	5=	5=
Hand pulling	5=	
Grazing of banks by cattle, sheep and horses	8	8
Hand raking		7

The ranked list of returned techniques for both problem species is very similar. In this case a common technique, or combination of techniques, can therefore be found which will be effective in managing both species. The top three ranked techniques for both species, although in differing orders, were glyphosate-based herbicide, glyphosate-based herbicide with adjuvant, and hand cutting.

The management approach on the River Lee currently consists of hand cutting dense stands of broad-leaved vegetation, such as the fool's water-cress, with the branched bur-reed managed approximately every five years using an excavator fitted with a solid bucket. However, the use of a glyphosate-based herbicide was trialled in 2013 due to access restrictions, expense, waste disposal issues and potential environmental damage caused by an excavator fitted with a solid bucket. This approach is supported by the outputs of the decision-making tool.

A longer-term strategy that could be considered is to increase shading of the watercourse through bank side planting. In this situation, tree and hedgerow planting is likely to be the most effective and could be undertaken in some places to reduce long-term management costs. Nutrient and pollution management may help reduce vegetation growth in the long term.

The output from the decision-making tool for branched bur-reed and fool's water-cress are shown in Figures 8.5 and 8.6 respectively.

8.6 Lessons learnt

Lesson 1: In complex urban situations such as this, there is often a number of conflicting requirements and constraints to management and an integrated approach may be the most effective way of managing the watercourse.

Action Taken: The potential effectiveness of an integrated management approach will be considered as part of the decision-making framework.

Watercourse Name
River Lee

Location
Luton

WFD Watercourse number: GB106038033391
Start Grid Reference: TL06192429
End Grid Reference: TL07692422

Prepared by: Laura Thomas
Date: 16/09/2013

Is the watercourse a designated site or is it adjacent to a designated site? No

Does the watercourse support populations of protected species (eg Water Vole, Otter, White-clawed Crayfish)? Yes

Contact Natural England/Natural Resources Wales/Environment Agency for further advice and follow appropriate species guidance. See section 4.5.2 of the Technical Guide.

Data must be entered into all the white cells in this section before any recommendations can be made

Select Species
Fool's Water-cress Apium nodiflorum

Select Watercourse Type
Inactive Single Thread

Length of watercourse to be managed (m): 3000
Channel width (m) (ie wetted width): 3
Water depth (m): 0.5

Machine access possible? No
Boat access possible? No

Notes for selected species:

Recommended control options are (always consider site-specific factors in technique selection):

Rank	Control Technique	Relevant Section of Technical Guide	Means of Application (where more than one method)	Effectiveness for selected species (0 = low, 3 = high)	Damage to Watercourse Type (0 = low, 1 = high, -1 = N/A)	Technically feasible? (0 = No, 1 = Yes)	Score (0 = low, 3 = high)	Indicative Cost
1	Hand cutting	7.3.1		2	0.00	1	2.00	£££
2=	Glyphosate-based herbicide	7.4.1	lance	2	0.17	1	1.67	£
2=	Glyphosate-based herbicide with adjuvant	7.4.1	lance	2	0.17	1	1.67	£
4	Shading through tree/hedgerow/bankside planting	7.5.1		2	0.33	1	1.33	££
5=	Buffer Strips	7.5.6		1	0.17	1	0.83	££
5=	Diffuse and point source pollution management	7.5.6		1	0.17	1	0.83	£££
7	Hand raking	7.3.1		1	0.50	1	0.50	£££
8	Grazing of banks by cattle, sheep and horses	7.6.1		2	0.83	1	0.33	£

Note: Score = (Effectiveness of technique) x (1 - Damage to watercourse type) x (Technically feasible) The maximum possible score is 3

Figure 8-5 Outputs from the decision-making tool for fool's water-cress on the River Lee, Luton

8.7 Post management assessment 2014

A re-survey of the River Lee in Luton was conducted, in conjunction with Environment Agency staff, on 26th August 2014. Discussions were held with Environment Agency watercourse managers regarding the successes and limitations of the management conducted.

8.7.1 Results of post management assessment

The re-survey identified that, on the sections of the River Lee that had been sprayed, a good level of control had been achieved, with the extent of in-channel growth of the problem tall emergent (branched bur-reed, reed sweet-grass and reed canary-grass) and broad-leaved emergent species (fool's water-cress, water-cress) considerably reduced.

Figure 8-6 The River Lee in Luton prior to management (left) and one year following treatment with a glyphosate-based herbicide

On those channels where spraying with a glyphosate-based herbicide had not been conducted, vegetation growth was consistent with that observed in 2013. This can be seen in Figure 8-7, below, with dense branched bur-reed evident across the full width of the channel in both. In the 2014 photo the branched bur-reed has already started to die-back, most likely due to the very early spring experienced in 2014 resulting in earlier than usual die-back.

Figure 8-7 Untreated section of the River Lee at Fallowfields (2013 on the left; 2014 on the right)

8.7.2 Effectiveness of management

As discussed above, the application of a glyphosate-based herbicide to some sections of the River Lee was very effective at controlling the growth the tall emergent and broad-leaved emergent species, with an open channel maintained throughout the growing season and no requirement for in-channel vegetation maintenance in 2014.

The Environment Agency watercourse managers also commented that the method of application was very effective at achieving the objectives for the watercourse, and was also sensitive to the ecological constraints present (the water vole population), as the targeted application with a knapsack sprayer enabled a margin of vegetation to be retained. This was given a scalloped edge to provide a more natural appearance and the retention of a margin retained food and cover for water voles and other species.

8.7.3 Application of adaptive monitoring approach

As the technique suggested by the decision-making spreadsheet tool was found to be effective, the management of the watercourse should continue as planned, with monitoring also continuing in case of any adverse impacts which are not yet evident.

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List of abbreviations

CEH	Centre for Ecology and Hydrology
DB	Drainage Board
IDB	Internal Drainage Board
JNCC	Joint Nature Conservation Committee
SAC	Special Area of Conservation
SPA	Special Protection Area
SSI	Site of Scientific Interest
SSSI	Site of Special Scientific Interest

Glossary

Riparian vegetation	The characteristic vegetation along watercourses that forms the link between the environments of water and land

Appendix A: Suggested case study sites

Site	Grid Ref	Operating Authority	Problem Species		Major Management Issue	Secondary Management Issue (if relevant)	Management Method Proposed	Details of Management Method	Proposed Date of Management	Additional Comments
			Plant Group	Plant(s) Name (if known)						
Snow Drain, Highwater Drain & Misson Bank Drain	470859, 400770 471352, 398385	Doncaster East IDB	Tall Emergent Plants	tbc	Irrigation	Land Drainage	Chemical	Glyphosate	tbc	
Back Delphin, East Yorkshire	tbc	Environment Agency		tbc	Flood Risk Management		Chemical			
Monk Dyke, East Yorkshire	tbc	Environment Agency		tbc	Flood Risk Management		Chemical			
Derwent Catchment	tbc	Environment Agency	Non-native Invasive Species		Ecology		Chemical			
River Hull	tbc	Environment Agency	Non-native Invasive Species		Ecology		Chemical			
Pevensey Levels	Various sites	Environment Agency	Non-native Invasive Species	Hydrocotyle ranunculoides	Ecology		Multiple Management Techniques			
New Forest	Various sites	Isle of Wight and Hampshire Wildlife Trust	Non-native Invasive Species	Various	Ecology		Multiple Management Techniques		tbc	
Boating Dyke & Durhams Warping Drain	468803, 417049 467406, 413267	Black Drain DB	Tall Emergent Plants	Sparganium erectum, Carex species	Land Drainage	Flood Risk Management	Chemical	Glyphosate	tbc	
Thorne Waste & Boating Dike	472092, 413678 472585, 410965	Doncaster East IDB			Flood Risk Management	Land Drainage	Chemical	Glyphosate	tbc	Not sure weed types but can cause obstruction to flow and flood risk
Dadsley Well Stream	459266, 394192	Doncaster East IDB	Broadleaved Emergent Plants	Rorippa nasturium-aquaticum	Land Drainage		Chemical	Glyphosate	tbc	
Ings Dike	456306, 415404	Danvm Drainage Commissioners	Tall Emergent Plants	Typha latifolia	Land Drainage	Flood Risk Management	Chemical	Glyphosate	tbc	
Manchester,Bolton & Bury Canal	tbc	Canal & River Trust	Submerged Plants	elodea, plus pondweeds	Fisheries	Amenity	Mechanical	Hand raking	tbc	
Shropshire Union Canal	tbc	Canal & River Trust	Floating Plants	azolla	Navigation	Amenity	Biological	weevils	tbc	
River Soar	tbc	Canal & River Trust	Floating Plants	pennywort	Navigation	Flood Risk Management	Multiple Management Techniques	herbicide & mechanical	tbc	
Kennet & Avon Canal	tbc	Canal & River Trust	Tall Emergent Plants	Common reed	Navigation	Amenity	Mechanical			
Lancaster Canal - Northern Reaches	tbc	Canal & River Trust	Tall Emergent Plants	mixed	Flood Risk Management	Fisheries	Multiple Management Techniques			
Various	tbc	CWLIDB	Floating Plants	wolffia arrhiza (rootless duckweed)	Ecology		Mechanical	Deweeding		Smallest flowering plant. Only know place in Wales
Reen banks, Mireland Pill, Prat Reen and Collister Pill	ST 3782, ST438848, ST447863	CWLIDB	Riparian Plants	Petroselenium segetum. Corn Parsley	Ecology		Mechanical	Banks where occurs flailed late season to allow seeding		Scarce species surviving on unimproved reen banks
Reen banks - Peterstone and Clifton Common	ST266808, ST374826	CWLIDB	Riparian Plants	Oenanthe pimpinelloides, Corky fruited water-dropwort	Ecology		Mechanical	Banks where occurs flailed late to allow seeding		Scarce species surviving on unimproved reen banks
Scattered throughout drainage district (e.g.Mill, Cross, Skinners, & Chapel Reens)		CWLIDB	Submerged Plants	Potamogeton trichoides	Ecology		Mechanical	Ensure reen de-weeded annually		Key SSSI species. Keeping channel open reduces competition from hardier, more dominant pondweeds
Pontycwcw Branch Reen	330082m, 184722m	CWLIDB	Non-native Invasive Species	Impatiens glandulifera (Himalayan Balsam)	Ecology	Flood Risk Management	Chemical	Spray before flowering	Early summer	
Various	various	CWLIDB	Tall Emergent Plants	Phragmites (Phragmites Australis)	Flood Risk Management	Navigation	Mechanical	Weed cutting/de-weeding on an annual basis	October - Feb	
Various		CWLIDB	Non-native Invasive Species	Hydrocotyle ranunculoides (Pennywort)	Ecology	Flood Risk Management	Multiple Management Techniques	Hand weeded and sprayed	Late spring through untill late summer	Eradication successful. Constant monitoring for re-appearance
Tyn-y-Brwyn	326942m, 183084m									
Little Penning Reen	326917m, 182715m									
Blacklands Reen	326756m, 183086m									
Various		CWLIDB	Non-native Invasive Species	Fallopia japonica (Japanese knotweed)	Ecology	Flood Risk Management	Chemical	Monitoring and spraying	Spraying 2-3 times per year	
Newlands Reen	323699m, 179434m									
Longcross Reen	322595m, 178624m									
Rhosog fawr	324229m, 178968m									
Peterstone Watercourse	326825m, 180269m									
Green Lane Reen	325213m, 181349m									
Summerway Reen	327433m, 181736m									
Sea Wall Reen	330057m, 185291m									
River Soar		Environment Agency, in partnership with Canal and River Trust and Leicester City Council	Non-native Invasive Species	Hydrocotyle ranunculoides	Ecology		Chemical	Previously all done by mechanical means, now using towards chemical control		Good example of partnership working
River Thames/London area		Thames 21	Non-native Invasive Specie	Himalayan Balsam Giant Hogweed Japanese Knotweed Floating Pennywort	Ecology		Multiple Management Techniques			Use of volunteers
Moretons Leam	539730 302903, 520925 297433	North Level IDB, EA, NE	Multiple Plant Types		Flood Risk Management	Ecology	Mechanical	Excavator and boat	tbc	Site is SSSI with maintenance agreement
Pike Drain		Upper Witham IDB	Non-native Invasive Species	Japanese Knotweed	Flood Risk Management	Ecology	Chemical		tbc	
River Ember/River Mole - from Hersham to East Molesey, Surrey		Environment Agency	Non-native Invasive Species	Floating Pennywort	Flood Risk Management	Ecology	Multiple Management Techniques		tbc	Significant progress on management made in 2012
Rochdale Canal		Natural England	Non-native Invasive Species	Crassula helmsii	Ecology					

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