Water Vole Conservation and Management: Lessons From Four Case Studies

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SUMMARY

Water voles *Arvicola amphibious* have seen a significant decline in numbers and distribution across England and Wales since the 1960s, a situation that continues to the present day. As a consequence they were adopted as one of the original UK BAP species, with the most recent targets being to halt their decline and subsequently to increase their range and numbers. With a view to contributing to these objectives, this research project was conceived in 2004, with the aim of determining the effectiveness of habitat creation and enhancement design methods for promoting the conservation and expansion of water vole populations both at colony and metapopulation levels. Subsequently Landfill Tax Credit Scheme funding was sought and won for a two year period, which provided seed money for the project. Four research sites were identified and baseline surveys undertaken. From this initial work, relevant programmes were established for each of the sites, which included as appropriate: habitat enhancement and creation; water vole release and introduction; and mitigation for loss due to development of a commercial park. Following the implementation of these programmes during 2011 and 2012, each site was monitored both with regard to the maintenance of habitat suitability and the water vole population. The conclusions from this research following, on average, two years of post works monitoring, were that through employing appropriate design procedures, water vole habitat creation and enhancement schemes were viable, but required long term management plans to be put in place and implemented. The field studies at three of the sites have contributed towards the understanding of vole metapopulation dynamics and a system was developed for classifying habitat suitability for water voles.

KEY WORDS:-

Arvicola amphibious, habitat enhancement and creation, metapopulation dynamics, mink control, water vole introduction.

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CHAPTER 1 INTRODUCTION

1.1 Background

Once common and widespread, water voles, *Arvicola amphibius,* have suffered a significant drop in numbers and distribution since the 1960s. The startling statistics of the actual decline of the water vole became apparent after two national surveys were undertaken by the Vincent Wildlife Trust (VWT), the first in 1989-90, and the second in 1996-98. These revealed that there was a loss of 67.5% of previously occupied sites and 88% of the remaining population, in only eight years (Jefferies, 2003; Strachan *et al,* 2000).This rapid decline of water voles can be attributed to various factors.

Changes in land use was deemed a main factor, with farming methods becoming more intensive leading to minimal, if any, field margins alongside the ditches/watercourses running through the farmland. This, in addition to more intensive crop spraying, resulted in the reduction, and sometimes the complete loss, of the marginal vegetation along the ditches/watercourses, together with the tall ruderal vegetation and rough grassland within the field margins. These vegetation zones would previously have provided the necessary food source for water voles.

Livestock were often allowed to roam into the watercourses and ditches associated with the fields, resulting in heavy poaching which has a devastating effect on the bank structure and subsequently the vegetation. This reduced the food sources available to water voles, and indeed the banks which they burrow into.

Structural engineering on river and canal banks through the 80’s and 90’s were often a cause of habitat destruction. Replacing the natural banking of meandering rivers with straight often concrete lined channels resulted in that specific section of water course no longer being suitable for water voles. Canals were often seen to have wooden or metal pilling along the banks, with only the smallest amount of well mown amenity grassland alongside. Again this maintenance gave no habitat in which water voles could reside.

During the 1970’s, the mink, *Mustela vison*, population increased rapidly throughout the UK. The habitat loss discussed above increased water voles’ vulnerability to predators, and especially mink.

Together the factors cited above led to an increase in fragmentation of the suitable riparian habitats which water voles require. This habitat loss isolated water vole colonies, increasing their vulnerability to other factors, such as drought or flooding, from which the colonies might recover from if other connecting habitats were available for them to escape to.

1.2 Water Vole Characteristics and Ecology

Much has been written about water voles, their biology, habitat requirements and habits, so only a thumbnail description is provided here. The reader is referred to Stachan *et al* (2011) for a more in depth discussion.

1.2.1 Description

The water vole found in the UK is the northern water vole, *Arvicola amphibius*, and is the largest of the British voles, weighing between 140g-350g with males usually being slightly larger than females (Strachan & Moorhouse 2006). The water vole characteristics are the same as for other voles: small round ears which often appear hidden under the dense fur; a rounded muzzle and body (see Fig 1.1).

Fig 1.1 The Northern Water Vole, *Arvicola amphibious*.

Water voles live in loose colonies of up to 10 breeding individuals, and their life expectancy is seldom more than 2 winters, though some survive 3. They can also experience high over-wintering mortality rates, with some colonies experiencing a loss of up to 70% of voles, but this is compensated for by females producing up to five litters a year (Strachan et al, 2011; Nottingham Wildlife Trust, no date).

1.2.2 Habitat

Water voles are found in rivers, streams, ditches, dykes and lakes. Although they have been found in less than optimal situations, for the purpose of this study, the habitat description, and thus that which this project will aim to create, will be for optimal conditions.

Water voles generally prefer channels with slow flowing water and steep sided banks, ideally around 45-60 degrees, to enable them to burrow successfully into them. They burrow up to two meters into the banks, and usually have more than one entrance. One is often at the water level to give access to the burrow quickly for refuge, with a second often located higher up to allow access should the water level increase. Water voles are very sensitive to changes in water levels and the need to escape when they rise.

Only the breeding female water voles are territorial (Strachen & Woodhouse 2006), and water vole home ranges are generally comprised of a male overlapping several females (and sometimes other males). The size of the territory varies depending upon the suitability of the habitat, with the higher quality the habitat the less territory required, but can be up to 300 m for males and 150 m for females.

Water voles generally prefer watercourses with swards of dense vegetation along the banks and within the channel, to provide both refuge and food. Although they are omnivorous, the diet of water voles is almost completely vegetarian, and comprises a wide range of grasses, reeds, tall ruderal, marginal and emergent vegetation. In addition berries, and scrub species, including hawthorn and willow leaves, are also eaten, although water voles will also eat molluscs, invertebrates, crustations and fish. It is important that a variety of the food plants are present to enable water voles to feed all year round.

1.2.3 Breeding

Water voles start marking the territory for breeding in spring time through to early autumn, depending on temperature. This period is generally considered to be March-September, but can run into October. If conditions are suitable (i.e. food sources and weather) water voles can have 2 to 5 litters each year containing on average from 5 to 8 young (Strachan & Moorhouse 2006).

1.3 UK Biodiversity Action Plan

In 1992 at the Earth Summit, which was took place in Rio de Janeiro (now known as the Rio Conference), the Convention on Biological Diversity (CBD) was signed by 159 governments. It was the basis for the legal framework for biological conservation, and called for each nation to create and enforce a national strategy and action plans to conserve, protect and enhance biological diversity (Joint Nature Conservation Committee, 2014).

The UK Biodiversity Action Plan (UKBAP) was formulated in 1994 as the government's response to the CBD. This was implemented by forming a UK Biodiversity Steering Group (also created in 1994), which established the framework and criteria for identifying species and habitat types of conservation concern. This work was to be undertaken at both national and local levels. The recommendations of the steering group were endorsed by the government, and led to the establishment of the UK Biodiversity Group creating the UKBAP.

The UKBAP structure on a basic level is split into three types: species, habitat and local. How a species or habitat is selected as needing an action plan is based on a list of criteria, which are as follows:

Criterion 1 – Subject to international threat

Criterion 2 – International responsibility and moderate decline in the UK, specifically:

- Species where the UK has more than 25% of world or appropriate biogeographical population;
- Species where numbers or range have decline more than 25% in the last 25 years.

Criterion 3 – Marked decline in the UK, specifically:

- Species which have declined 50% or more over the past 25 years

Criterion 4 – Other important factors , specifically

- Where a species does not qualify under Criteria 1, 2 or 3, its inclusion in the UKBAP could be justified if it met one or more from a list of 5 conditions

Following the application of this procedure, the water vole was chosen as one of the original species for the UK Biodiversity Action Plan, which called for restoration of their former widespread distribution by 2010. Restoration and re-creation of extensive areas of riparian vegetation (with mink trapping if necessary) were suggested as the best mechanisms for increasing water vole numbers and distribution.

The UK BAP targets for water voles were updated in 2006 to:
T1: Maintain the current range (730 occupied 10km squares) of the water vole in the UK;
T2: Achieve an increase in range by 50 new occupied 10km squares in the UK by 2010.
Since that time, the Third Edition of the *Water Vole Handbook* (Strachan et al, 2011) has been published, which observes that:

> "The 2008 review of BAP targets demonstrated that majority of the 2010 targets had already been exceeded. This was largely, however, due to more extensive survey data being available."

The Handbook goes on to summarise the findings of the review, noting that water voles were slowly expanding their ranges, primarily due to concerted conservation efforts, but that fragmentation of populations was still a problem largely due to mink predation and catastrophic flood events. Section 1 of Chapter 11 Review of the UK Biodiversity Action Plan, ends by stating that:

> "This conclusion while broadly positive, underlines the fact that threats to water voles are still ongoing and that further conservation action is required for the species."

At a local level, a report on the status of water voles in Warwickshire (Warwickshire County Council, 2002), stated that:

> "The main meta-population in the county survives as a number of fragmented colonies in the Coventry / Nuneaton area (on the Rivers Sowe and Anker and their tributaries, plus the Coventry Canal). With the exception of a couple of isolated colonies recorded elsewhere, the water vole appears to have all but disappeared from the rest of the county."

At the time of this report, the local BAP targets were:

A.	Maintain the size of all populations known to be remaining in the sub-region in 2001-2.	by 2002-2015
B.	Increase population size and range by promoting expansion in the vicinity of existing key populations in the sub-region (i.e. in and around Coventry, Nuneaton and headwaters flowing off the Cotswold Hills).	by 2010

In response to the report and targets, the County Council proposed a series of 14 local actions, subsequently updated by the Core Steering Group in February 2008, which included under Site/Species Safeguard and Management:

SM4 Promote the expansion of existing populations through the sympathetic management and restoration of adjacent habitat. Provide habitat management / restoration advice for at least 50% of sites adjacent to water vole Site of Importance for Nature Conservation (SINCs).

and under Research and Monitoring:

RM4 Establish a means of monitoring the effectiveness and success of habitat enhancements and mitigation works undertaken.

The above demonstrates the need for greater efforts at habitat restoration and enhancement, and understanding of the effectiveness of such works. To this end an application for a Landfill Tax Credit Scheme funded project for research into water vole conservation was submitted by Middlemarch Environmental Ltd in 2004.

1.4 Landfill Tax Funding

The Landfill Tax Credit Scheme (LTCS), which was introduced in 2003, enables landfill operators and environmental bodies to work in partnership to create significant environmental benefits and jobs, and is a source of funding for organisations to undertake various types of environmental projects. The application for a 3 year part time programme (see Appendix 1), was made through Section 'da' which covers either:

i) the provision , conservation, restoration or enhancement of a natural habitat; or

ii) the maintenance or recovery of a species in its natural habitat, on land or in a water situated in the vicinity of a landfill site.

Choosing four sites within 10 miles of a landfill, qualified the project for application. The application was drafted around five core areas which included survey, research, habitat creation, habitat management and education.

Input was also gained from key stakeholders and parties including the Environment Agency, Severn Trent Water and Wildlife Trusts. Severn Trent Water agreed to undertake the role of independent third party and provide 10% of the total funding, since the tax credit claimed by landfill operates only covers 90% of the money they can give to the environmental bodies.

The funding was initially delayed by 14 months, but awarded in 2006, and the project was completed in 2008. At that time, with respect to the 4 sites selected, Hartshill Severn Trent Water (STW), Brandon Marsh Nature Reserve, Netheridge STW, and Kirkby in Ashfield STW (see Chapter 4), baseline data collection had been completed with existing hydro-ecological conditions ascertained and water vole surveys undertaken. Based on this information, initial research had also been undertaken to determine suitable habitat creation areas, profiling of watercourses and bodies and vegetation planting species mixes. The subsequent plan was to design and implement habitat creation/enhancement schemes on each of the sites, commencing in 2009.

1.5 Aim and Objectives

In 2005 the researcher enrolled for a part time higher degree by research, with the overall aim:

> to determine the effectiveness of habitat creation and enhancement design methods for promoting the conservation and expansion of water vole populations.

In order to achieve this aim, the following objectives were formulated:

Objective 1: undertake a review of current knowledge and guidance regarding habitat creation, restoration and enhancement for water vole conservation.

Objective 2: identify suitable field sites and undertake baseline studies to understand the current water vole population and site characteristics,

Objective 3: design and implement habitat creation, restoration or enhancement schemes as relevant for the selected sites, including a programme of water vole reintroduction if appropriate;

Objective 4: design and undertake a survey programme to monitor the response of the water vole populations to the habitat schemes;

Objective 5: analyse the data collected and use the results to make recommendations regarding the effectiveness of such schemes for enhancing water vole populations.

1.6 Structure of the Thesis

Following this Introduction, Chapter 2 provides a literature review which briefly explores theoretical considerations of species decline and metapopulation dynamics. The Chapter then continues by reviewing past research into water voles, their ecology, habitats and distribution, together with an overview of current design recommendations for habitat creation and renovation schemes.

Chapter 3 builds on this, covering the research methodology adopted both with regard to the study site selection and enhancement, and the water vole monitoring programme. The four study sites are described in Chapter 4, with Chapter 5 reporting on the monitoring programmes and their results.

The thesis ends with Chapter 6 providing a discussion and evaluation of the research, with the conclusions drawn and recommendations presented in Chapter 7.

CHAPTER 2 LITERATURE REVIEW

Although much research has been undertaken and reported with regard to water voles, the document which encapsulates the water vole history, research, ecology and management of habitats is the Water Vole Conservation Handbook. Since the first edition in 1998 (Strachan 1998), there have been two further editions (Strachan and Moorehouse, 2006, Strachan *et al*, 2011). The Water Vole Conservation Handbook is a comprehensive general guide to all aspects of water voles including:

- Law/legislation;
- Survey techniques;
- History/threats to water voles; and,
- Management/mitigation techniques including mink control.

It lays out a broad guide to working with water voles including a number of case studies varying in scheme size and different types of mitigation.

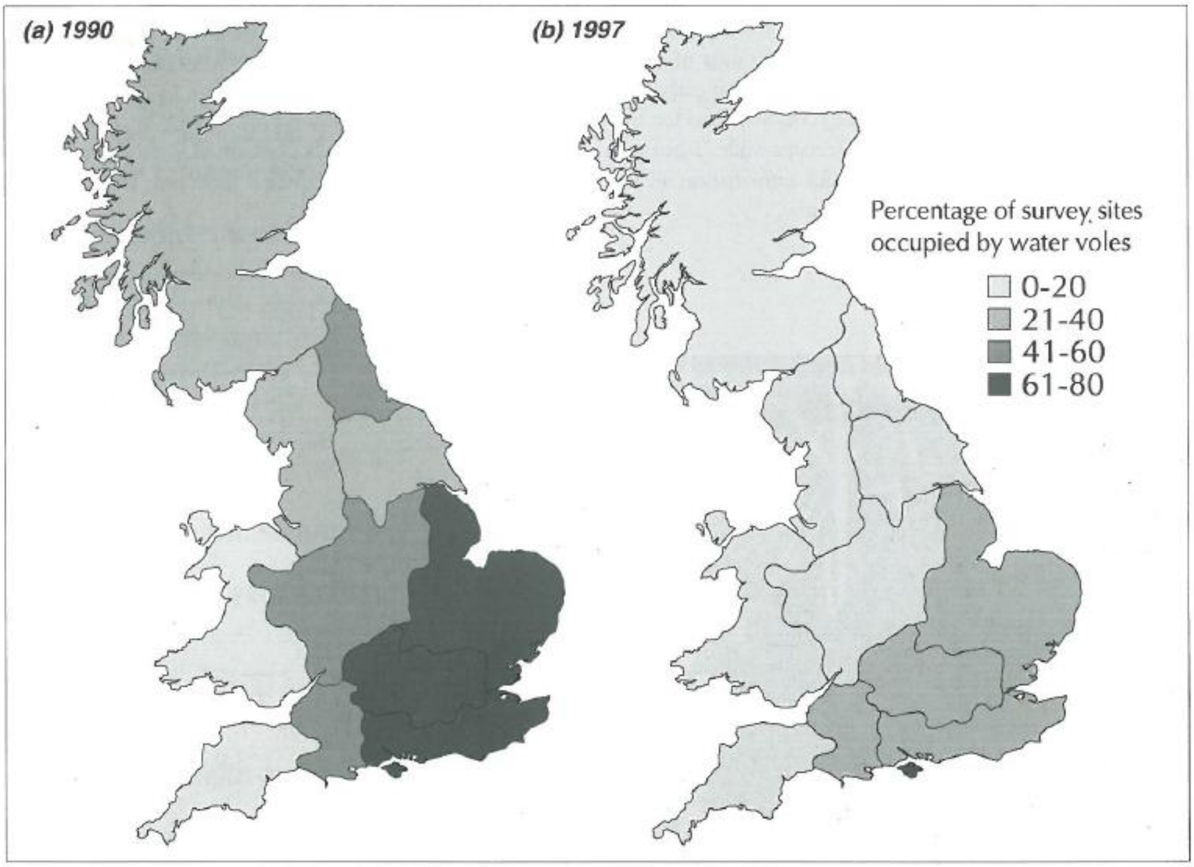
As consequence of the above, this literature research will focus primarily on those aspects of direct relevance to the study undertaken, and the reader is referred to the 3 editions of the Water Vole Conservation Handbook and its Bibliography, for more in depth study.

2.1 HISTORY

The requirement for the protection and mitigation of water voles has stemmed from the results of a nationwide water vole survey initiative undertaken by the Vincent Wildlife Trust at the end of the 1980's and the 1990s (Vincent Wildlife Trust, no date). The first survey undertaken in 1989-1990 showed that the water vole population had majorly declined and that populations were "scarce and fragmented in the north and west and strongest and most widespread in the south and east" (Strachan 1998) – see Fig 2.1.

The results of this survey and a subsequent number of studies, led to a prediction in 1998, that there would be a 94% loss of water voles from former sites by the year 2000. This in turn led to an initiative from which a steering group for the water vole was established and its inclusion in the UK Biodiversity Action Plan, as it was identified as one of the 11 priority species for the UK.

The handbook also identified that this decline continued rapidly throughout the 90's, and gave an example of the River Thames catchment where in 1995 a decline from 72% to 23% of the occupancy was reported.



<u>Fig 2.1</u> Change in Distribution of Water Voles in 1989-90.

(from Strachan, 1998)

Since it is the decline in water vole population across the UK, and the potential for extinction in many locations, it is worth considering the theoretical thinking behind ecological conservation with respect to population decline.

2.2 THE THEORY UNDERPINNING ECOLOGICAL CONSERVATION AND THE MANAGEMENT OF POPULATION DECLINE

In a seminal paper published in 1994, Caughley reviewed developments in conservation biology over the previous 20 years, and explored in depth two paradigms that run parallel, but do not interact. The first of these, the 'small-population paradigm' deals with the risk of extinction faced by an isolated population with small numbers. He concluded that the theoretical basis underpinning the paradigm was strong, but it had only limited application to isolated populations as it stands.

The second paradigm, ‘the declining-population paradigm’, considers that external factors have caused a population to become at risk, rather than issues relating to its current size. Research in this area was focused on the diagnosis of the causes of decline, and through understanding these factors, managing them to arrest the species decline and risk of extinction. As a consequence this paradigm was judged to be of more relevance to practical conservation problems, and in the course of his discussion, Caughley distilled the application of the declining-population paradigm to wild populations down to the following five stages:

“1. Use scientific method to deduce both why the population declined and which agent caused the decline.
2. Remove or neutralize the agent of decline.
3. Release a probe group to confirm that the cause of decline has been deduced correctly.
4. If so, restock unoccupied areas by translocation or, if the remnant population is too low to risk further reduction, breed up a protected stock as fast as possible, as near to the problem site as possible, and release it as soon as possible.
5. Monitor the subsequent re-establishment.”

A useful tool in identifying the agents of decline produced by Diamond (1984, 1989), was cited by Caughley, and referred to as ”The Evil Quartet”:

1. Overkill – hunting at a rate above the maximum stainable yield.
2. Habitat destruction and fragmentation.
3. Impact of introduced species, either through preying on the species of at risk or through the destruction of their habitat.
4. Chains of extinction – the decline in one species as the result of the loss of another on which it depends.

Caughley concluded that the bulk of work around the declining-population paradigm was empirical, fragmented and related to individual studies of specific populations, and that a generic underlying theoretical base had yet to be developed.

Ten years after the publication of Caughley's 1994 paper, Norris (2004) discussed the status of the declining-population paradigm. In his paper he reviewed the three classes of model predominant in the field: statistical models, demographic models and behaviour-based models. He found that the statistical and demographic models were relevant to static environments providing adequate data were available, but inappropriate when there was environmental change that rendered redundant the historic patterns on upon the models were based. On the other hand providing that future parameters were predicted adequately, behaviour-based models could be used to explore future population trends in order to inform management decisions. Norris made no challenge to Caughley's 5 stages in the application of the declining-population paradigm or to Diamond's Evil Quartet. However, he concluded that, contrary to Caughley's assertion at the end of his paper, the declining-population paradigm was underpinned by appropriate theory, but its application within the field was lacking.

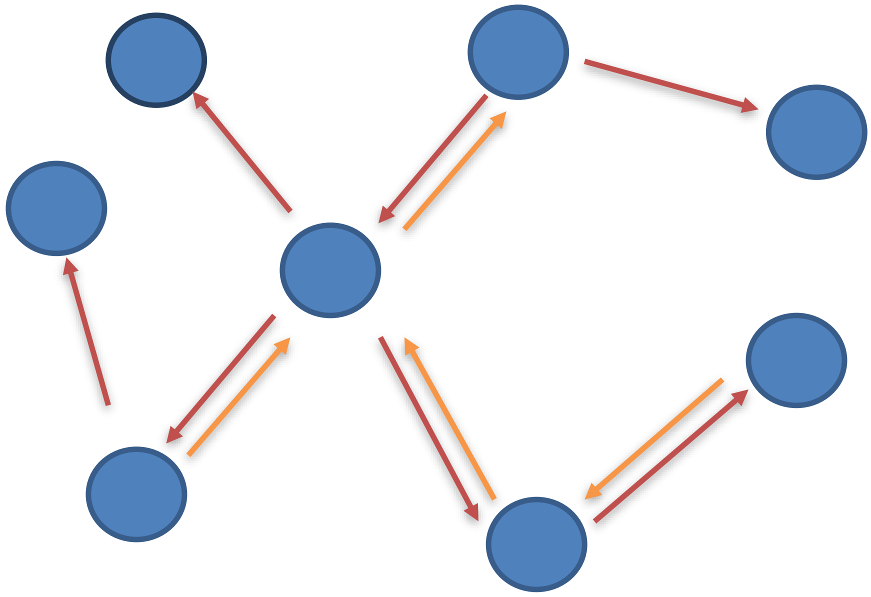
2.3 WATER VOLE HABITATS AND ECOLOGY

Early studies on water voles, such as that by Stoddart (1970), identified that water voles were "strictly herbivorous". This has been proven to be incorrect as future studies found water voles to be omnivores, however a high percentage of their diet is indeed herbivorous. A further early study undertaken by Perry in (1943) examined water voles captured in Britain and concluded that both sexes were capable of breeding in the same year of their birth. In addition the study found post-partum oestrus, which means that water voles can produce continuous litters throughout the breeding period. This capability for high levels of fecundity is further supported by Moorhouse *et al* (2008), who studied the effects of foraging availability. This study found that areas which had high amounts of vegetation resulted in water voles gaining weight quicker and therefore reaching sexual maturity quicker (112 g for female and 115 g for male water voles). This study also identified that denser populations of water voles also influence the time that it takes for water voles to gain weight and therefore sexual maturity, the more competition for food the longer time taken for water voles to gain weight. In addition it was identified that female water voles took longer to gain sufficient weight for sexual maturity than males.

It is important to understand how water voles behave and interact within habitats when working to enhance/manipulate the habitats. Water voles live in colonies which are spatially separated. Individuals from these colonies will migrate from one to another, thereby maintaining genetic diversity - this type of population interchange is referred to as a "meta population dynamics".

A metapopulation can be defined as a group of spatially separated populations/colonies of the same species which interact at some level. The basic premise of metapopulation theory is that, although individual populations in a metapopulation may suffer high extinction risks, regional long-term persistence is achieved through the processes of dispersal and recolonization (Telfer 2001).

Figure 2.2 gives an example of the structure of a metapopulation flow, and shows a number of colonies, which individual water voles immigrate and emigrate between. To make a self-sustaining population, this has been identified as between clusters of 8-9 colonies of water voles (Strachan, 2009).



Water vole colony
Immigration movement
Emigration movement

<u>Fig 2.2</u>   A Self-sustaining Metapopulation

Figure 2.3 shows an example of how negative influences can impact on colonies of water voles. These manmade and natural influences including the following:

- Intensive farming (including use of pesticides and heavy grazing);
- Canalisation/engineering works leading to fragmentation of habitat;
- Introduction of Mink;
- Rats; and,
- Flooding.

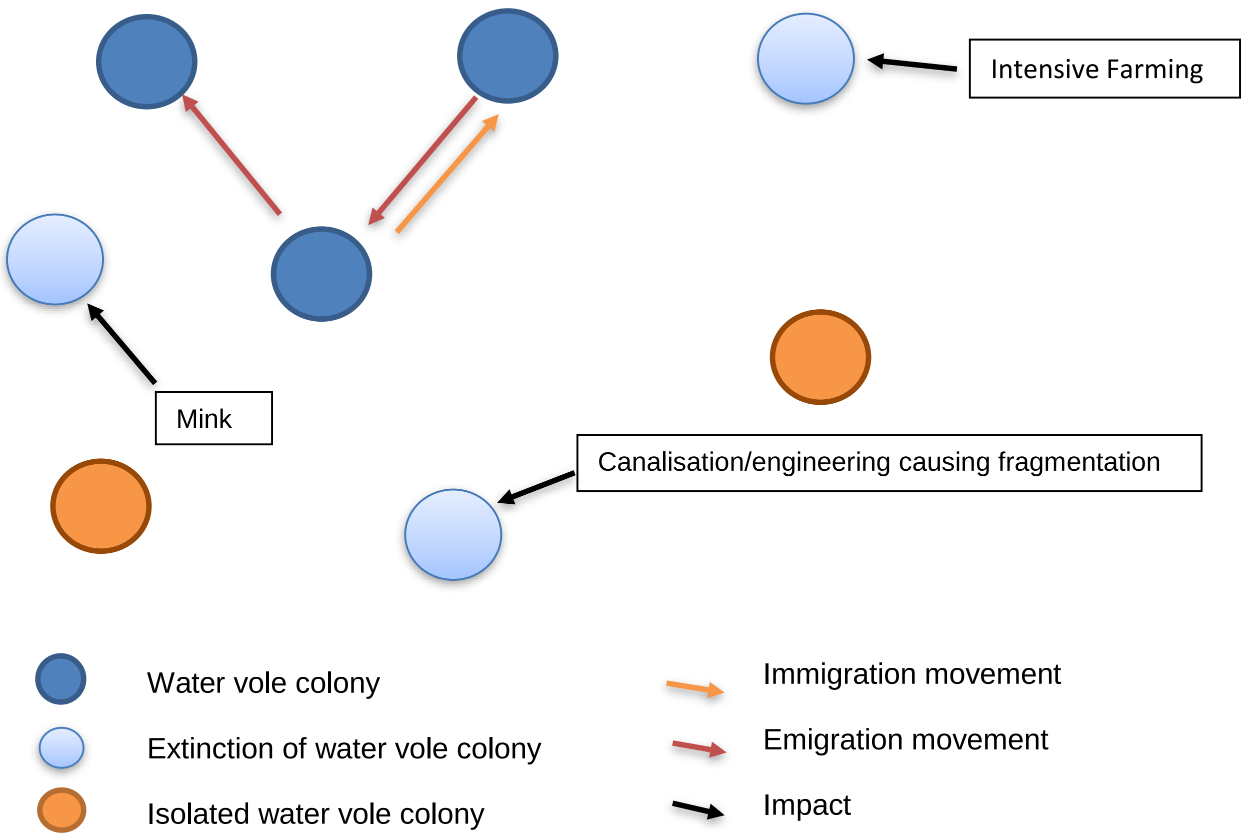


Fig 2.3 **Metapopulation with Impacts Leading to the Loss of Water Vole Colonies.**

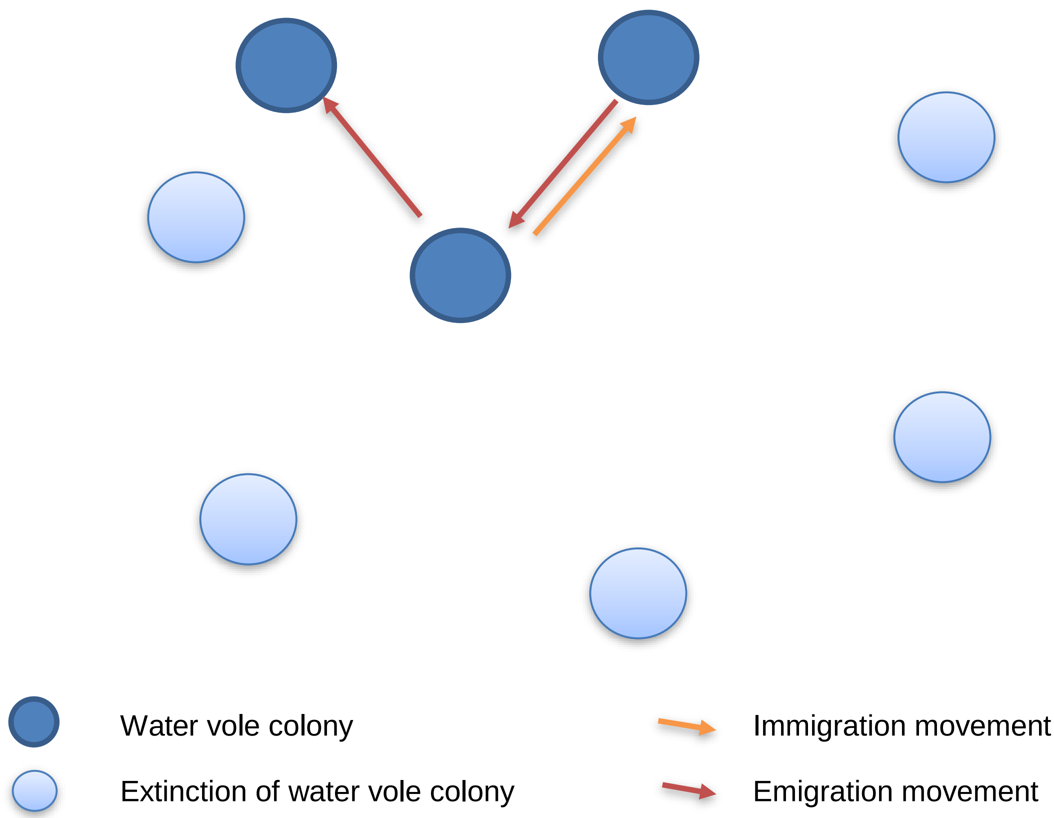
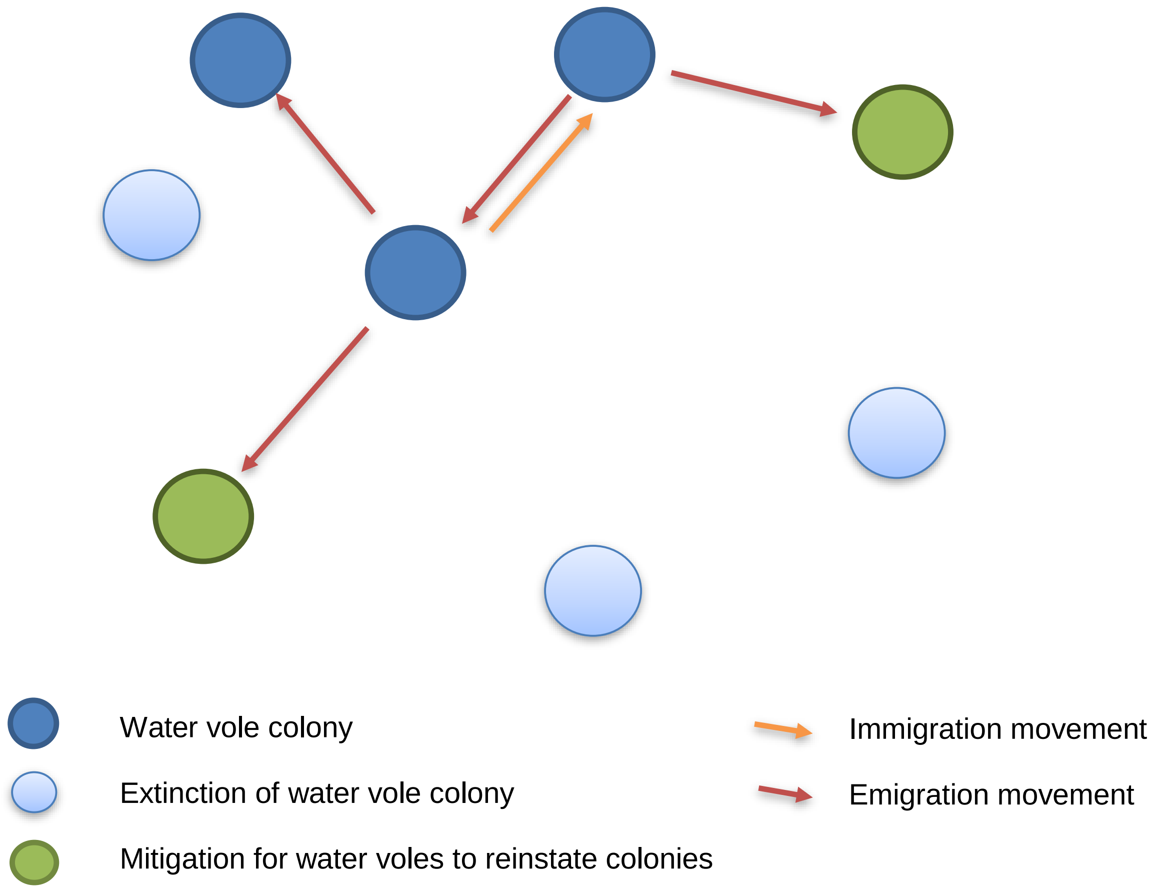


Fig 2.4 **Unsustainable Metapopulation Leading to the Loss of Isolated Water Vole Colonies.**

As previously discussed water voles populations have become extinct through the impact of these negative influences, leading to the isolation of outlier colonies with the consequence that there is an insufficient number of water vole colony clusters to be sustainable, leading to the extinction of the population – Fig 2.4.

Figure 2.5 indicates how timely reinstatement of the lost colonies through habitat enhancement/manipulation or mink control, will start to increase the cluster size again. However, unfortunately, if colonies are not constantly monitored/managed this is often not achieved within the time required to prevent the water vole population from becoming extinct. Although, without outside influence, colonies of water voles may naturally become extinct, if there are no the outside impacts new colonies will naturally form in new areas, with the result that the population is rejuvenated.



<u>Fig 2.5</u>   Rejuvenation of Metapopulation through Colony Reinstatement.

Much has been written about metapopulation theory (e.g. Hanski and Gilpin, 1997; Hanski, 1998), but field studies are often short-term with the data gained subsequently employed to calibrate and prove models, that are then used to explore the relationship between species and their environment.

The validity of applying the metapopulation concept to water voles was confirmed by Fedriani et al (2002) following their study of some 185 ponds in and around the Donana National Park in southwest Spain. At a landscape scale voles were found to be more prevalent in pools outside the National Park, where there are many predators and competitors (rabbits in particular), and close to ponds occupied by other voles. Habitat quality was a dominant influence on pond occupancy at a local scale.

This theme of habitat quality, often linked to hydrology, is one that permeates many metapopulation studies.

In an early study, Gibbs (1993) found that the loss of small wetlands from an area of 600 km^2 in Maine, USA, which increased the inter-wetland distance by an average of 67%, had a greater impact on the metapopulation dynamics of certain animal species than the small area of the individual wetlands might suggest. This was confirmed through a sensitivity analysis using a computer model.

Over a two year period, Schooley and Branch (2009), studied the occupancy of the rare semi-aquatic nocturnal round-tailed muskrat in 457 wetlands in central Florida. Between years the overall occupancy of the wetlands was consistent at approximately 26%, but this masked a substantial turnover of patch occupancy, with 38.5% of the wetlands occupied in 2002-3 becoming extinct in 2003-04, whilst 13.5% of the wetlands vacant in 2002-3 were colonised in 2003-04. Utilising the data collected in a stochastic patch occupancy model (Incidence Function Model or IFM), they also found that two specific land uses influenced turnover dynamics: habitat quality degradation due to cattle grazing, and the introduction of pine plantations decreasing connectivity. From this it was recommended that the metapopulation approach provided a useful conservation framework providing landscape heterogeneity was incorporated together with the effects of local land-use practices.

Subsequently Schooley and Branch (2011), explored the influence of habitat quality of source patches and connectivity in fragmented landscapes. In a review of 20 papers (15 from 1998 to 2000, and 25 from 2005 to 2008) where IFM models had been employed, they found that only 12.5% of the papers incorporated habitat quality, whereas the remainder simply used the source patch area and connectivity distance. Again using the data from their round-tailed muskrat field studies and modelling of the data collected it was found that the inclusion of habitat quality gave superior results when source areas was weighted according to habitat quality, rather than simply taking the area alone.

Ovaskainen et al (2015) modelled the effect of spatial structure in habitat loss on equilibrium metapopulation size. They showed that persistence of a metapopulation was a function of the spatial arrangement of the remaining habitat after loss, with the habitat loss being felt more by species with a short-range dispersal than those with a long range dispersal.

Through the application of individual-based models, rather than local-population models, Uchmanski (2016) explored the influence of individual growth on dispersal and metapopulation dynamics. He found that dispersion rates were fundamentally a function of resource availability, although his studies did not take into account the mortality of the dispersing individuals.

Van der Merwe et al (2016) used marsh rice rat data collected between 2011 and 2013 from two wetland areas in southern Illinois to explore the effects of hydrology on metapopulation dynamics. Populations were found to fluctuate as a function of the habitat quality as influenced by the hydrology, rather than patch area and degree of isolation as employed in many modelling studies.

With particular regard to water vole populations in the UK, an IFM model supported by extensive field surveys, was used by MacPherson and Bright (2011) to demonstrate that a large protected core site, such as several of the recently created reed beds and marsh grazing sites in the UK, was essential for maintaining the long term viability of water vole metapopulations in the surrounding landscape. The core reedbeds and wetlands of MacPherson and Bright's study provide refuge areas for water voles from the predation of mink and "sustain metapopulation in the surrounding landscape where conditions are less favourable". Linear habitats were found to be more vulnerable, with an increased probability of mink predating upon the entire colony of water voles. It was also observed that the viability of these metapopulations could be enhanced through habitat creation and restoration works. Moreover, they suggested that the minimum effective size of these created or restored habitat should be in the region of 1.5 to 2 km.

The importance of reedbeds are further emphasised by Carter and Bright (2003). Their study identified that large populations of water voles have persisted at some reedbed sites, as in the case of Stodmarsh National Nature Reserve in Kent, where water voles and mink have been on site for past 30 years. Water voles in reedbeds create nests in summer and burrows in winter. The study demonstrated that water voles, which are active over 150m from the main linear channel, had a 50% less chance of predation from mink/otter.

Regarding water vole populations, Daniel *et al* (2014) found that: “Habitat restoration of floodplain wetlands could help to reverse the decline, but detailed habitat preferences of water vole in these environments have not been well studied, and the impacts of restoration practices on water vole populations are not known”. The reduction in wetlands results in the decline of water voles due to the relationship of water voles and mink. Macdonald *et al* (2002) and Carter and Bright (2003) showed that water voles can survive in wetlands (i.e. dense reedbeds) despite the presence of mink as the wetland habitats provide areas of refuge from mink predation. The latter study showed water voles prefer wider water bodies with taller vegetation and greater plant diversity, and stated that, wetlands provide “wider water bodies that can therefore provide greater area of suitable habitat within the same distance from the burrows, providing that it is sufficient cover and foraging in the centre of the water body”.

2.4 HABITAT REQUIREMENTS

A number of studies have looked at the habitat requirements of water voles. They are generally associated with slow flowing-static water with dense marginal/emergent vegetation as detailed by Strachan (1998).

The study undertaken by Lawton and Woodroffe (1991) identified “core sites” used by water vole for breeding colonies, and “periphery” sites which water voles visit but do not breed within. These core sites are characterised as having a high percentage of grass, on steep banks and a high density of vegetation as described by Strachan (1998). The most suitable location for core habitats is where they are not isolated and where there are no predators.

Fragmentation of habitat is one of the most important factors with regard to water voles. A study undertaken by Rushden *et al* (2000) undertook to model the effect of mink and habitat fragmentation. This studied the “ effects of mink predation and habitat fragmentation on future viability of water vole populations on the River Windrush”. The results were analysed after the artificial manipulation of habitat fragmentation on the river, and running the model in the presence and absence of mink. The model was for the “correlation and coefficient, to estimate how the predicted size of water vole population and extinction were determined by life history parameters”. The results showed that as fragmentation increases the reproduction output and adult /juvenile mortality becomes increasingly important. The study also identified that “high levels of fragmentation demographic stochasticity has a substantial influence on population size”. The extinction of water voles increased with habitat fragmentation, in addition the presence of mink doubled the probability of extinction

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Bright (1993) undertook a study to review the reasons that make mammals susceptible to habitat fragmentation. This study also provided three potential responses to habitat fragmentation:

(1) gradual decrease in population followed by rapid extinction when a threshold of habitat fragmentation is reached;
(2) initial small populations increase then gradually decreases followed by extinction at the same threshold (e.g. edge species);
(3) marked increase in population to gradual decline for species which utilised several habitat types.

Water voles were classed as being in the first grouping - that is the most vulnerable group. Habitat fragmentation and poor management was argued to be a more important factor than mink (predator) control.

A study by Moorhouse and Macdonald (2007) found that male water vole ranges are smaller in size in an area with higher population density. Male weight also was found to be higher where ranges were larger. These range sizes are determined mainly by vegetation density, but also partially determined by social factors, with the ranges remaining intra and inter sexually overlapping.

One of the useful tools presented in the Water Vole Conservation Handbook (Strachan, 1998) is an equation which enables a population of water voles to be estimated from the number of latrines, as follows:

$$y = 1.48 + 0.683x \qquad \text{- Eqn 2.1}$$

where x = the number of latrines, and y = the number water voles.

This equation has made possible to determine from a survey of latrines, the required amount of habitat mitigation for number of water voles identified.

The social behaviour of water voles has been the subject of a number of studies. Benge’s thesis (2004) reports on research into water voles in Southern England. This study, undertaken across five sites, involved various techniques for investigating the social organisation of water voles. It was found that relationships between water voles and the number of latrines were generally lower than figures reported in previously published literature, with the numbers of latrines peaking in spring time and summer, which was accredited to breeding and population size. The research further identified that springtime is the optimal time to undertake population assessments for water voles, as later surveys would include latrines of non breeding juveniles which might skew the results. The results, however, did not show significant differences from the equation given in the water vole handbook - concluding that the equation is still viable.

Benge's study used radio tracking as a method to track the movements of water voles, the results showing male water vole observed range lengths (in m) were longer than females but there was no difference in home ranges size (in m^2). However a number of water voles fitted with collars died during the study, and although the cause of death could not be ascertained, the collars themselves may have been the cause.

2.4 MINK

One of the most important factors affecting water voles, other than habitat fragmentation/loss, was the introduction of the invasive species American mink, *Neovison vison,* in the 1960's. Early studies (eg. Woodruffe *et al*, 1990) found mink to be a key factor in the presence/absence of water voles. Following the escape and release of mink from fur farms around the country, the subsequent predation of British wildlife, especially vulnerable wild fowl and water voles, was catastrophic. Once the impact of this had been identified, a number of studies were undertaken to ascertain how mink interact with water voles and the consequences of this alien species being released into the wild.

Halliwell and MacDonald (1996) undertook a study on the Upper Thames catchment area. Unlike the other prey of mink (i.e. moorhen, coot), Halliwell and MacDonald showed that there was a correlation between the abundance of mink and water vole numbers. The mink numbers were higher where appropriate den sites were available and vegetation cover was reduced. However, as discussed within this study the habitat requirements of the two species differ, and so it could be asked whether water voles can co-exist with mink if there is adequate vegetation cover, which would result in reduced predation and increased water vole protection. As mink control can be expensive, in both monetary and time terms, this study suggested a different strategy for conserving water vole colonies.

The findings of Halliwell and MacDonald were further reinforced by Barreto *et al* (1998), who also undertook a study in the Thames catchment area, researching the variables in habitat types with regard to water vole distribution. Their results suggested mink was the determining factor in water vole distribution in the study area, but that water vole recovery could be achieved by the restoration and recreation of habitat. Guillermo et al also stated that: “It is hypothesised that mink control will be necessary only while the water vole population is small, once population starts to increase both species could co-exist provided that the habitat is suitable”.

A study by Bryce (2010) was undertaken with the aim of achieving large scale eradication of mink in an area of Scotland, whilst protecting the existence of water voles. The mink capture rate within the various sub-catchments increased with greater connectivity and with proximity to the coast, where there was a more productive habitat.

As water voles are a UK Biodiversity Action Plan priority species, part of the plan states that “where necessary employ appropriate mink control as a conservation tool to protect large breeding water vole populations”. Consequently, Reynolds (2003) undertook as study in an attempt to determine whether was it possible to achieve significant conservation benefits by culling mink on a local scale rather than to suppress the population within a whole river catchment. The study installed 36 mink rafts along a study site, and of these mink signs were recorded on 20 of the rafts (see Sect 3.5.2 for a description of mink rafts). Since field signs had previously been recorded on only 12 of these sites, it proved that the use of rafts increased the success of identifying presence/absence of mink on a watercourse, in comparison to conventional survey methods (i.e. natural field signs such as footprints, scats and dens). It was also found that rafts had value with regard to managing mink control and monitoring.

Reynolds study also looked into the use of scent for attracting mink to the rafts for trapping. It was found that the use of the rafts by mink did not increase at the time of year the field surveys commenced (summer time), which may not be the case at other times of the year (i.e. during the mating season in autumn). The scent lures used were milk lures, and as observed in the study, other scents based on mink scent glands could be more successful in attracting mink and deterring water voles.

Harrington et al (2008) quoted the UK legislation “obligated to eradicate or to control alien species including American mink”, in their paper, which reported that “mink removal could be effective in reducing mink population with four months or less trapping per year over 2-3 years”. In addition, it was strongly recommended that sites are monitored, as further control measures may be required. Their study concluded that this methodology was sufficient for the protection of water voles. However, was this judged to be very simplistic, as other studies have shown the type of habitat will determine the impact of mink. Water voles in linear habitats (i.e. canals) are more vulnerable to predation than mosaic habitats such as wetlands, therefore the effort and length of time/effort required for mink control will vary vastly between sites. Harrington et al's study can however be used as a guideline.

Barreto and Macdonald (1998) undertook an experimental design to identify water voles response to predator odours. Mammalian predators, especially mustelids secrete social odours for intraspecific communication (Macdonald 1985). The study tested water voles response to mink and brown rat odours, by setting up feeding cages with and without the odours and observing water voles response. The results of the study found that water voles avoided mink odours and also avoided the odour of brown rat, but to a lesser extent than that of mink. This was even with water voles which had not come into contact with mink before.

Macpherson and Bright (2010) studied the movements of radio tracked mink in the UK. They found an "observed correlation between spread of mink and the decline of water voles". Large wetlands (i.e. reedbeds) appeared to mitigate the impact of mink predation of water voles due to the way mink hunt: "More than 60% of mink foraging activity occurs within 10m of a main channel (>10m wide)". Where mink entered reedbeds the study showed that they navigated using scrub, it can therefore be concluded that scrub within reedbeds can have a negative effect on water vole population and supports the management regime of scrub removal within reedbeds.

The studies of the relationship between water vole and mink do all agree that this predator is one of the main factors in the loss of water vole populations within the UK. Some studies, however, identify that habitat type can lead to the successful co-existence of water vole and mink. Wetland and reedbeds which create dense mosaic habitats aid the protection of water voles from mink predation, as mink favour more linear habitats with den sites located along the banks or adjacent habitat. Barreto *et al* (1998) in particular identified that a suitable habitat is sufficient for water vole populations to co-exist with mink, however they argued that the presence of mink in itself is sufficient for a colony of water voles to become extinct, and this is further exacerbated by habitat fragmentation.

Studies have also shown that mink control can be successfully achieved with the right resources in 2-3 years, however, eradication using mink rafts is labour intensive and costly.

2.5 WATER VOLE REINTRODUCTION

Moorhouse et al (2009) studied the effects of habitat quality with regard to reintroduction programmes for water voles in the UK, and observed that reintroduction of water voles is an “important tool” in conservation, but such actions can fail. Their results showed that water voles were higher in number and density where vegetation was abundant. Where failure occurred it was generally attributed to insufficient mink control. The post release movements and dispersal of the water voles were dependent upon sex and vegetation density, with males found to disperse double the distance of females. Poor quality habitat increased the range of dispersal from the release location. Moorehouse et al’s research: “highlights the need to ensure that any habitat selected for a reintroduction programme is the best obtainable”.

Gelling et al (20102004) undertook a study to measure health and welfare of reintroduced water vole. They found captive bred animals had lower fat reserves (probably due to better quality of nutrition) and higher weight/length ratio than wild ones. The research identified the need for possible changes in release protocol, including hydration of the water voles. Some release protocols just have apple and carrot refreshed to supply the required water, whereas a water source in the pens may need to be considered. In addition, it was found that releasing water voles in less than high quality habitat at the optimal time of year will result in dehydration and subsequent health issues.

2.6 RADIO TRACKING

A methodology used to track water voles which has been used in a number of studies is to employ a radio collar. The released or trapped water vole is fitted with a collar (plastic tie), which incorporates a transmitter that emits a specific radio frequency which is picked up by a receiver. Studies have suggested water voles as being lost (assumed predated upon), however, it needs to be considered that the collars may increase the probability of mortality due to predation or death due to the collar become caught on branches etc. Indeed, as noted in Sect 2.3, Benge (2004) lost water voles fitted with collars during his study.

Moorhouse and Macdonald (2005) showed that water voles fitted with radio collars resulted in a substantial decline in female water voles born in their colony. Hypotheses commonly invoked to explain the mammalian sex-ratio manipulation, refer to the condition of the mother. Moorhouse’s results led to the conclusion that the radio collaring of female water voles caused a male skewed sex ratio and thus questioned the previous assumptions that radio-collars do not fundamentally affect the biology of collared water voles.

2.7 THE CURRENT STATUS OF THE WATER VOLE

The latest results from the National UK Water Vole Database and Mapping Project (McGuire, 2014) indicate a decline in water vole presence in 10km squares across the UK of 22% between 2008 and 2012 (The Wildlife Trusts, 2013), with the distribution shown in Fig 2.6. Table 2.1 demonstrates the decline since the first numbers for water vole distribution were published in 1998.

Year	Number of Occupied 10km Squares
1989 – 1990 #	1418
2004 – 2008 *	874
2007 -2011 *	683

Table 2.1 **Number of 10km Squares Occupied by Water Voles in England, Scotland and Wales**
(# Vincent Wildlife Trust: * National Water Vole Database and Mapping Project)

Paul Wilkinson, The Wildlife Trusts' Head of Living Landscape, warned (The Wildlife Trusts, 2013):

> "The benefits of targeted and sustained projects are clear. We have many examples of where recovery has been recorded and the water vole has extended its range due to the efforts of conservation professionals and enthusiastic trained volunteers. We must ensure that this kind of targeted work is extended. Otherwise there is a risk that we will lose water voles altogether from large areas of the country."

Fig 2.6 Water Vole Presence (2008-12): 689 Occupied 1km Squares

(McGuire et al, 2014)

The Wildlife Trusts (2013) map of current water vole strongholds, Fig 2.6, identifies the Ashby Canal and Coventry Waterways as one of these, evidencing the success of the 5 year Coventry Water Vole Project (Warwickshire Wildlife Trust, no date). However, the report also observes that in other areas of the West Midlands “the species remains vulnerable to further decline and extinctions”.

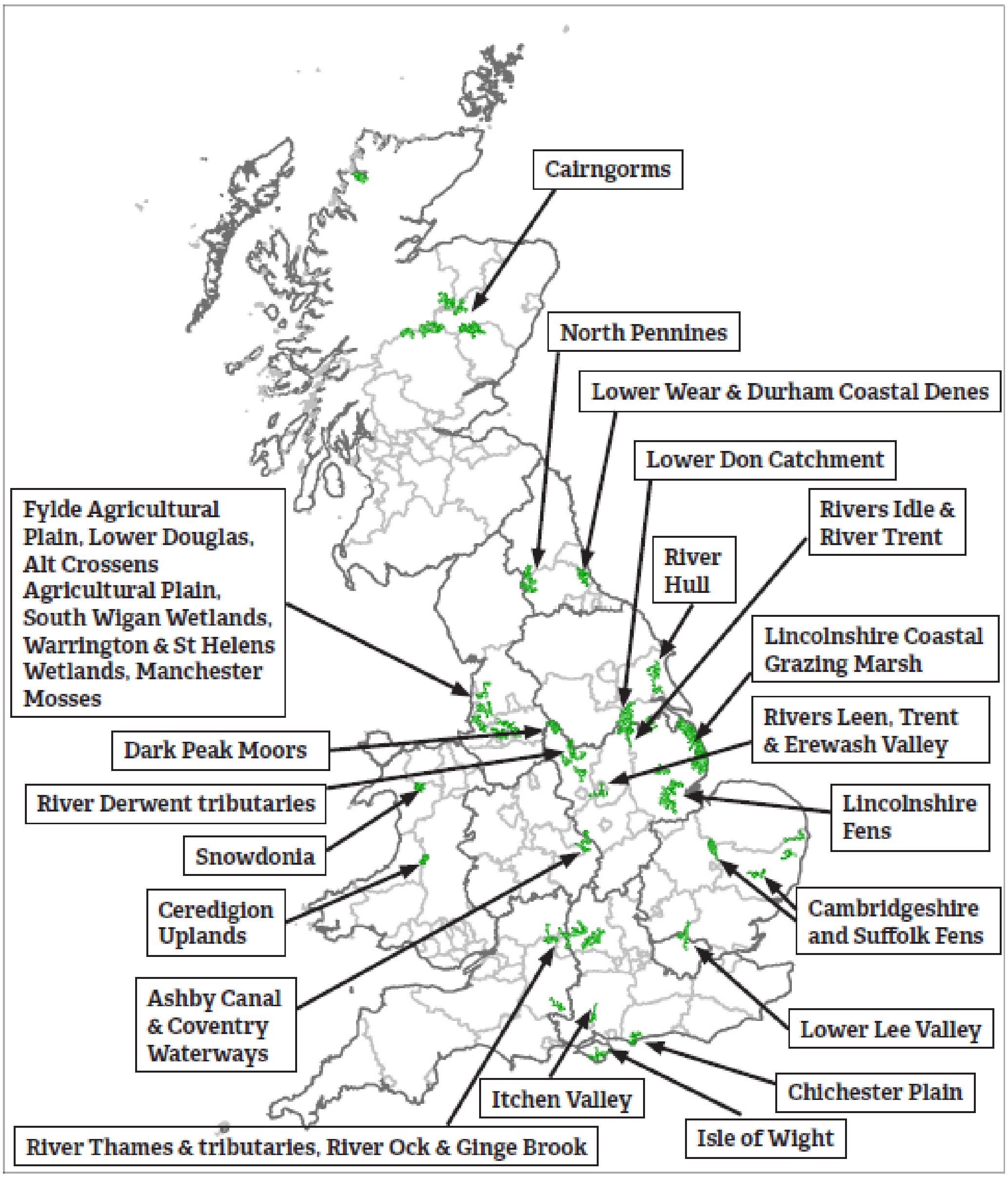

Fig 2.7 Key Areas for Water Voles 2008-11

(The Wildlife Trusts, 2013)

CHAPTER 3 RESEARCH METHODOLOGY

Once the overall Aim and Objectives of the project (see Sect 1.5) had been established, the next practical step was to identify suitable research sites. The conditions of the Landfill Tax Credit Scheme (Sect 1.4) and the wishes of the key stakeholders, particularly Severn Trent Water with their financial contribution, imposed constraints on the choice of potential sites.

Initially four locations were selected: Severn Trent Water's Sewage Treatment Works (STW) at Hartshill, Netheridge and Kirkby in Ashfield, and the Warwickshire Wildlife Trust's Brandon Marsh Nature Reserve. However, at the end of the Landfill Tax funded project the decision was taken to abandon the Hartshill STW site.

This decision was taken on the grounds that at Hartshill STW, Severn Trent Water only owned land on one bank of the adjacent River Anchor, a tributary of the River Tame. Since the potential research site was relatively small, and mink were prevalent on the river, it was not deemed feasible to implement effective mink control measures. In 2010 therefore, Kingsnorth, a 37 ha development site in Kent, that Middlemarch Environmental Ltd had been engaged with, was substituted for Hartshill STW.

Once study sites had been located, the research methodology adopted followed a similar pattern at each, though the habitat management undertaken differed according to the specific site characteristics. The general methodology and research principles, which were loosely based on the theoretical five step process proposed by Caughly (1994) in his considerations of the declining-population paradigm (see Sect 2.1), are discussed below, with site characteristics and the works undertaken at each described in Chapter 4.

The overall research process, largely followed the guidance given in the Water Vole Conservation Handbook (Strachan and Moorehouse, 2006), which at that time incorporated the most up to date knowledge and thinking. The sequence adopted is as illustrated in Fig 3.1, and comprised: a desk study; site surveys both topographical and eco-hydrological; the decision on whether and what form of enhancement and vole management was required; detailed design and implementation of site works and planting; mink control measures and water vole release if appropriate; water vole population monitoring.

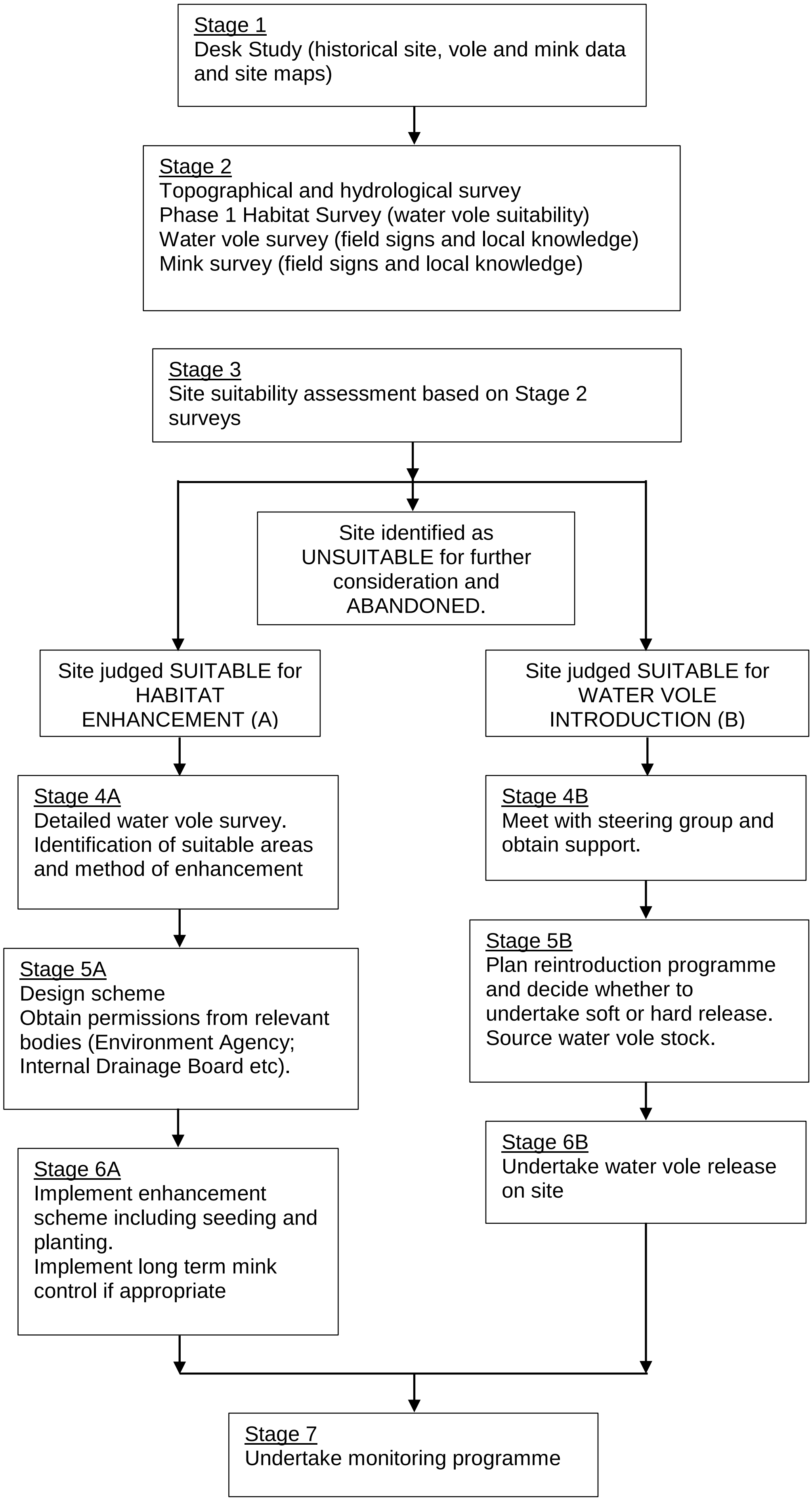

Fig 3.1 Research Methodology

Once the decision had been taken that a site was suitable for enhancement, then a decision also had to be taken regarding water vole release and mink control. The former is shown as path B in Fig 3.1, with the latter included under Stage 6A. Paths A and B can be followed independently or in parallel as appropriate.

As the procedures involved in topographical and hydrological surveys, together with construction processes, are commonplace, the discussion below is focused on those aspects of particular relevance to water vole conservation. Details of the construction/enhancement works undertaken at each site are given in Chapter 4.

3.1 DESK STUDY

Before any site visit was undertaken each site was subject to a desk study. This involved obtaining any available data relating to the site and its history, together with site plans. Records of water vole and mink on site and in the surrounding area were obtained from the Biological Records Centre (BRC, no date).

3.2 HABITAT SURVEY

At each site a baseline habitat survey undertaken. This comprised a Phase 1 Habitat Survey, which follows the methodology of JNCC (1993) as modified by IEA (1995). This survey is a standard technique for classifying and mapping British habitats, and involves undertaking the identification of plant species, which in turn indicates the soil type present (acidic, neutral or alkaline). These habitats are then mapped out, with target notes entered onto the map identifying specific notable features which are too small to map.

3.3 HABITAT SUITABILITY FOR WATER VOLES

In order to determine quickly and consistently the suitability of a site's habitats for water voles, an assessment system employing the key elements which they require was developed. To facilitate the process a check list of elements was drawn up as shown in Table 3.1, this was based on the habitat requirements and suitability for water voles described in the 2nd edition of the Water Vole Conservation Handbook (Strachan and Moorehouse, 2006). The system employed a simple traffic light grading. If all of the elements in Table 3.1 were present the habitat was classed as “green” – highly suitable. If one or two of the elements are missing the habitat was classed as “amber” (moderately suitable), and if more than two elements were missing the classification was “red” (unsuitable). If there was evidence that the water feature had been dry for a period of time it was automatically classified as red, as this was considered the most important element on the check list.

The assessment method should only be undertaken by someone who has enough experience to identify the relevant features in Table 3.1. It should also be noted that the system was designed to assess habitats and does not take the presence/absence of mink into account, since this is an additional factor that needs to be considered independently when deciding on a site’s water vole suitability.

The Water Vole Habitat Assessment system was used throughout the project, both for initial site assessment associated with habitat surveys, and during the monitoring programme for tracking any changes in vegetation quality. Traffic light system (Table 3.2) had the advantage that the results could be presented visually on site maps for ease of communication.

Key Elements
*Water present all year round of adequate depth
Suitable food source all year round (marginal vegetation, pockets of scrub grassland etc) of a sufficient density
Either burrowing or nest building habitat present
No disturbance (poaching, human impact)
Connected to other suitable habitats (not isolated or fragmented)
*key element

Table 3.1 Water Vole Habitat Assessment - Check List

Subsequent to the development of the Water Vole Habitat Assessment system and its application to this research, it was found that Harris et al (2009) had published “A Method for Assessing Habitat Suitability”, specifically for coastal and riparian grazing dyke systems. This is discussed further in Chapter 6, Sect 6.2.

Habitat Category	Water Vole Habitat Suitability Score
Unsuitable (no potential for enhancement) (*Shown Red on site map*)	Loss of more than two elements
Sub-optimal (potential for enhancement) (*Shown Amber on site map*)	Loss of one element
Optimal (*Shown Green on site map*)	All elements present

Table 3.2 Water Vole Habitat Assessment – Suitability Categories

3.4 WATER VOLE FIELD SURVEYS AND MONITORING

The water vole field survey methods employed in this research, are those identified in the Water Vole Conservation Handbook (Strachan and Moorehouse, 2006), and are tried and tested techniques. They are applicable to both initial site surveys and monitoring, and there is thus no differentiation below. Furthermore, the approach adopted at each of the research sites is identified in Chapter 4.

The field signs employed in water vole surveys include:

- Latrines;
- Feeding/grazing;
- Footprints;
- Burrows;
- Runways; and,
- Nests.

These are detailed below.

In addition to using field signs for monitoring programmes, radio tracking and trapping can also be employed (see Sects 3.4.8 and 3.4.9).

3.4.1 Latrines

Water vole droppings (Fig 3.2) are deposited near to the burrows, the droppings in a latrine can vary in number. Droppings are usually brown-green in colour and blunt at both ends. Their size is approximately 8-12mm and they have the texture of putty when fresh. Fine plant material can be seen when the droppings are squashed, and they have no odour. In a latrine, droppings are trampled down and fresh ones deposited on top. Water voles also use the latrines for territory marking.

Other latrines/droppings which may be found within the same habitat as water voles include: bank/field voles whose droppings are noticeably smaller in size; and, rat droppings which are generally larger, have a point at one end and have an unpleasant odour.

Fig 3.2 Water Vole Latrine

3.4.2 Feeding Characteristics

Grazing/feeding is usually found within the shelter of vegetation. The feeding pattern of water voles consists of a variety of plant species which are cut into up to 10cm pieces, each piece of cut vegetation has a 45 degree angle. As bank/field voles also cut vegetation with a 45 degree angle, although they are generally smaller pieces, the feeding remains of water vole and other bank voles can be similar hence difficult to differentiate.

The grazing around the burrow entrances are known as “lawns”. Lawns are often found when females have dependant young and they need to keep near the burrow.

3.4.3 Footprints

Often found in soft mud along watercourse edges, water vole footprints are 26-34mm (Fig 3.3). Water vole footprints are very difficult to distinguish from other rodents, especially those of the brown rat, unless the surveyor is experienced. It is not usually recommend that footprints are used as a positive confirmation of water voles presence, but as supporting evidence.

<u>Fig 3.3</u> Water Vole Footprints

3.4.4 Runways

Runways are found along the banks often near the water’s edge. These take the form of tunnels within the vegetation, which water voles used repeatedly to access areas along banks thereby maintaining cover from predators.

3.4.5 Burrows

Burrows are approximately 4-8cm in diameter, but can appear larger especially along the water's edge where entrances can erode (Fig 3.4). Other species which burrow/nest along water course to be aware of are rats (usually larger, 8-10cm, and can have a spoil heap outside), kingfisher, sand martins and sometimes mole tunnels which have been exposed. The burrows of other vole species are a lot smaller (between 2-3 cm).

Water vole burrows often have two or more entrances, one at water level and ones higher up (Fig 3.5), especially where high water levels are experienced (see Sect 1.2.2).

Fig 3.4 Water Vole Burrows at Water Level

<u>Fig 3.5</u>   Water Vole Burrow High on a Bank

3.4.6 Nests

Bedding is taken underground into the burrows, however where there are habitats with dense vegetation or high water levels, water voles can make woven nests the size of a rugby ball. These are found at the base of rushes, sedges or reeds.

3.4.7 Population Assessment

A population assessment of water voles can be undertaken within an area by counting the number of marker latrines within a water vole colony, and using Equation 2.1 given in Sect 2.3. This equation by Morris et al (1998) is cited in Strachan and Moorhouse (2006),

$$y = 1.48 + 0.683x \qquad \text{- Eqn 2.1}$$

where x = the number of latrines, and *y* = the number water voles.

By employing Eqn 2.1 an approximate colony number can be ascertained, which, besides being important for monitoring purposes, is particularly important when new areas of mitigation are to be created to support a given number of water voles. In addition if water voles are being trapped and translocated, or over wintered in a suitable location, an approximate number is required for planning purposes.

3.4.8 Radio Tracking

Radio tracking was a method proposed for monitoring at two of the sites, Brandon Marsh Nature Reserve and Kingsnorth (see Chapter 4), when the water voles were released.

Radio tracking entails a collar (plastic zip) fitted with a transmitter, placed around the neck of the water vole(s). The transmitters each have a unique frequency number which is programmed into the receiver before fitting onto the water voles, subsequently ‘beeps’ are emitted which are picked up by the receiver and aerial. For monitoring purposes, once the voles are released, the ‘beeps’ transmitted are picked up and followed, with the ‘beeps’ getting louder as the source is approached, until the water vole wearing the collar is found.

The batteries last between 4 and 12 weeks depending on the frequency of the beeps per minute which is selected (i.e. the more beeps per minute the less battery lifetime).

Although radio tracking was planned and collars and receivers purchased, monitoring by this method could unfortunately not be employed, due to a number of unforeseen issues.

Due to the inclement weather, the water voles releases at Brandon Marsh and Kingsnorth sites had to be delayed, and consequently only juveniles were available (generally under 160g). Water voles rapidly increase in weight and size, and this would have resulted in the collar becoming too tight and needing to be replaced/removed within two weeks to prevent choking the water vole. This was further complicated by the habitats the water voles were released into. As these habitats were not contained, but connected to ditches/rivers the water voles could disperse rapidly to areas beyond which access was permitted. It was therefore deemed that there was too great a risk to the health of the water voles to attempt to use radio tracking.

3.4.9 Water Vole Trapping

Trapping water voles entails the baiting of a trap to tempt the water voles into the trap. Traps are comprised of are a wire mesh cages with a nest box attached and a trigger mechanism, which shuts the trap when the water vole treads on it (Fig 3.6). The nest box is packed with straw to ensure any water vole (or other mammal) trapped has an area to nest and is protected from the elements. Food which contains a high water content (i.e. apples/carrots) is placed inside the cage. Small pieces of apple chips were also placed just outside the trap entrance to enhance the scent and entice the water voles into the trap.

Fig 3.6 Water Vole Trapping Cage

3.5 MINK MANAGEMENT

3.5.1 Mink Field Survey

As with a water vole survey, a mink field survey involves looking for field signs along river banks/watercourses. The signs are as follows:

- Scats;
- Footprints;
- Dens; and
- Sightings.

Since these are similar in principle to those of the water vole, they will not be discussed in further detail.

Mink rafts are also employed in monitoring mink populations, as discussed below.

3.5.2 Mink Control

Mink rafts were used on Brandon Marsh to control the mink population entering into the site. The raft employed is a tried and tested design by the Game and Wildlife Conservation Trust, and has been successful in projects such as the River Monnow project in Herefordshire where mink were eradicated and water voles reintroduced into the habitat. The raft design involves a floating platform with a tunnel created in the centre (Plate 1). Beneath the tunnel is a clay tray. The rafts are placed in suitable locations, which are hidden from the general public (ideally the rafts are placed on private land to reduce interference). They are spaced along the watercourses/waterbodies of interest, with the locations generally chosen for key habitat features associated within mink, such as culverts, oxbows and the junction of watercourses.

The idea of the raft is first establish if mink are within the area and then to trap them. As many mammals including mink are curious by nature, the animals will naturally investigate the tunnel, in the process imprinting their footprints onto the clay. Once the mink prints are identified, a baited trap is installed into the tunnel to replace the tray. The trap is a live capture trap, as only the mink are to be eradicated. The trap is checked a minimum of twice a day, dependent upon weather conditions (i.e the more extreme the weather conditions the greater the number of times traps are checked so no animal captured suffers unnecessarily). Any native animals captured (polecat/otter) are released, and the mink are disposed of humanely by a suitability qualified person, such as a game keeper.

<u>Fig 3.7</u> A Mink Raft

3.6 WATER VOLE RELEASE/INTRODUCTION PROGRAMME

The number of water voles released into a site for reintroduction, will depend on the size of the site and whether or not there are any water vole colonies within the vicinity, which could add to the genetic material and keep the colony going.

As Brandon Marsh was a large site with limited water vole populations in connecting habitats, 200 individuals were released in September 2011 with a view to creating meta-populations within the site.

At Netheridge 70 water voles were released in 2005 as part of a reintroduction programme in partnership with Severn Trent Water and Derek Gow Consultants. A further 60 were released in 2007, after a flood event which saw the entire site and surrounding areas inundated

There are two approaches to water vole release: soft release for juveniles and hard release for the more mature voles.

3.6.1 Soft Release

The water voles for soft release are initially kept in pens (Fig 3.8). These pens are positioned around the water bodies of interest, approximately 100 m apart. Each pen is comprised of a wooden frame with chicken wire to keep the water voles in and any predators out, and have a section of uPVC or wood over a portion of one side to provide shade. The water voles are placed in family groups into each of the pens, with numbers varying depending on family size, but generally a maximum of ten so as not to crowd the pen out. The water voles are provided with bedding and food, which comprises carrots and apples to provide them with the necessary water content.

Fig 3.8 A Soft Release Water Vole Pen

In the case of Brandon Marsh and Netheridge, the water voles were fed for three days, with the pens closed to acclimatize them to the habitat since they were juveniles of between 50g and 120g. On the fourth day one side of the pen was folded back and a baton cable tied to it, with two burrow size holes cut into the baton (one in each bottom corner). The aim of attaching these batons is the so the water vole can exit and return to the pens of their own accord until they are confident enough to enter the new environment naturally. On the sixth day the pens were collapsed as all the water voles had dispersed into the water bodies.

3.6.2 Hard Release:

Water voles weighing 120g to 160g are hard released. This simply involved releasing the water voles directly into the water body, since they are larger they can survive without the need to acclimatize.

3.7 DATA ANALYSIS

As the initial survey and subsequent monitoring data are limited in volume, it was not possible or appropriate to conduct any in-depth statistical analysis. Instead descriptive statistical methods, such as graphs and visual inspection, were initially employed to explore whether any potential relationships existed.

When considering the influence of habitat quality on vole populations, where scatter graphs suggested that a relationship existed, the non-parametric Spearman's Rank Correlation test was applied (Pentecost, 1999; Laird Statistics, 2013). Subsequently, when Spearman's Rank Correlation Coefficient confirmed a sensible relationship, the linear correlation coefficients were determined, and since the sample sizes were very small the significance of these was assessed (Koosis, 1997).

3.8 COMPLIANCE WITH LEGISLATION

Every five years the statutory nature conservation agencies (English Nature, Countryside Council for Wales and Scottish Natural Heritage), working jointly through the Joint Nature Conservation Committee (JNCC), are required to review Schedules 5 and 8 of the Wildlife and Countryside Act 1981, and to make recommendations to the Secretary of State for the Environment, Food and Rural Affairs for changes to these schedules. Schedule 5 lists animals (other than birds) which are specially protected, and Schedule 8 lists plants which are specially protected (JNCC). From April 6th 2008 water voles gained increased protection against intentional killing, injury or taking from the wild. In addition, the possession or selling of water voles was made an offence (DEFRA, 2008).

The Wildlife and Countryside Act 1981 (as amended) was updated on April 6th 2008 to give full legal protection to water voles, making it an offence to:

Intentionally kill, injure or take water vole from the wild;
Possess or control live or dead water voles or derivatives;
Intentionally or recklessly damage, destroy or obstruct access to any structure or place which water voles use for shelter or protection;
Intentionally or recklessly disturb water voles whilst occupying a structure or place used for that purpose; or
Sell water voles or offer or expose for sale or transport for sale.

The Act provides a defence against the above, where the action is the incidental results of an otherwise lawful operation and could not have been avoided (s.10(3)9c)).

Section 16 of the Act, allows licences to be issues to qualified individuals, which permits them to undertake activities that would normally be offences – this includes: for scientific and educational purposes; ringing and marking; and, for conserving wild animals or introducing them into a particular area. All activities reported in this thesis were carried out under licence.

CHAPTER 4 STUDY SITES

4.1 INTRODUCTION

As explained in Sect 1.4, the research commenced with a successful bid to the Landfill Tax Credit Scheme and the subsequent Biffaward. Initially 4 sites were selected for investigation, Hartshill STW, Brandon Marsh Nature Reserve, Netheridge STW, and Kirkby in Ashfield STW. However, at the end of Biffaward, the Hartshill site was abandoned (see Ch 3), although considerable preliminary work had been undertaken including the habitat survey in Appendix 2, and it was replaced by Kingsnorth.

Chapter 4 provides a description of each of the sites that have contributed to this thesis. For each site the focus is on the relevant baseline surveys and enhancement works that were undertaken.

4.2 KIRKBY IN ASHFIELD

The STW is located at Grid Reference SK484549, to the South West of Kirkby in Ashfield. It is bisected by the River Erewash, and the site is bounded to the East by the B6018 (Park Lane), which also provides access. The operational and larger of the two components of the works lies to the North of the river, with the research site located to the South in the smaller of the two areas, whose works had been abandoned about some 15 years previously. – see Fig 4.1.

The Northern part of the works comprises amenity grassland surrounding the operational works, these habitats generally have a poor species diversity and are well managed. The north eastern and northern boundary is maturing scrub, where species include hawthorn *Crataegus monogyna* and willow *Salix* sp. A parcel of grassland in the north-eastern corner has been left unmanaged creating a tussocky sward of grassland, and a more species diverse area.

The river corridor (River Erewash) which passes through the works, consists of steep banks ranging from 0.5-1.5m high, predominantly vertical with bedrock visible jutting out in places. The water was generally of a moderate to slow flow with areas of faster riffles along the shallower gravel beds. Deeper silted pools also existed along the river. The river bed substrate was silty with gravel and occasional pebbles.

The banks had a majority of vertical areas of bare ground and exposed bedrock with the vegetation over hanging. The bank side vegetation consisted of a field layer containing nettle, lesser celandine, bramble, cock's-foot *Dactylis glomerata*, perennial rye grass *Lolium perenne* and ground ivy *Glechoma hederacea*. The shrub layer was dominated by hawthorn with occasional crack willow *Salix fragilis*.

The abandoned Southern treatment component of the works operational area was surrounded by hard standing. The parcel of land to the North West (bounded by the River Erewash) was an area of improved grassland dominated by perennial rye grass with dock *Rumex s*p., dandelion *Taraxacum officinale* and clover *Trifolium alba*. Lining the river tall, ruderal species become more dominant, primarily nettle, *Urtica dioica*.

To the East of the Southern portion of the works lay twelve disused drying beds in various conditions ranging from good, with all concrete walls exposed and standing water with only duckweed covering the surface, to completely overgrown and engulfed with tall ruderal and scrub vegetation. These drying beds were approximately 25m x 12m running in a consecutive line.

The research area lies within the large area of ground South and East of these drying beds, as shown on Figs 4.1, and includes five water bodies – 4 lagoons in a row along Ditch 2, and a large pool.

4.2.1 Phase 1 Habitat Survey

Fig 4.1 provides a summary of the Phase 1 Habitat Survey, and illustrates the locations described below.

Boundaries

The Western boundary consisted of an unmanaged mature hawthorn, *Crataegus monogyna,* hedgerow which merged into scrub where the site had become overgrown. Remnants of woodland ground flora existed, with species including bluebell *Hyacinthodies non-scripta,* greater stitchwort, *Stellaria holostea*, red campion, *Silene dioica,* fern and herb robert, *Geranium robertianum*.

The River Erewash splits the Sewage Works site in two, hedgerows and fencing form the northern boundaries. However the study site is only within the southern half as specified by the red line in Figure 4.1. The Western stretch of the river's the Southern banks was dominated by scrub; predominantly hawthorn and bramble *Rubus fruticosus* agg., with occasional elder *Sambucus nigra*, and tall ruderal vegetation. Species along the Eastern stretch of the banks were dominated by nettle, with occasional hogweed *Heracleum sphondylium* and great willowherb *Epilobium hirsutum*.

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<u>Fig 4.1</u> Kirkby in Ashfield – Phase 1 Habitat Survey

Along a steep bank, in which a ditch runs, along the West of the site's Southern boundary was an area of dense scrub - dry at the time of survey within the Western section, but becoming wetter to the East. Eastwards along this boundary, the scrub thinned and four lagoons existed in a row leading from the ditch. These four lagoons varied in size (the largest being 25m x 8m; the smallest being 12m x 7m) and possessed a similar structure (all having steep sided banks to the South and North), but varied slightly in botanical composition.

The Eastern boundary of the site comprised the B6018 road, with hedgerow to the southern end and grassland either side of the entrance driveway to Severn Trent Water STW.

Scrub

Scrub within the site was predominantly hawthorn and bramble with willow, elder *Sambucus nigra* and blackthorn *Prunus spinosa*. It was dense along the Western and Southern boundaries and more scattered to the East of the site.

Tall Ruderal

A majority of the site was dominated by tall ruderal vegetation. Table A3.1 in Appendix 3 details the species recorded. Nettle covered the highest percentage of ground cover in dryer areas (Fig 4.2) and greater willowherb *Epilobium hirsutum* in wetter areas around the open water and ditches.

Fig 4.2 Tall Ruderal Habitat on the Kirkby Site

Grassland (calcareous semi-improved)

In areas where substrate appears dryer and better drained the habitat converted to grassland, and appeared to range from neutral to slightly calcareous in nature. This area had an increase in species diversity, and species recorded included; common spotted orchid *Dactylorhiza fuchsii* , perforated St Johns wort *Hypericum perforatum*, bird's-foot trefoil *Lotus corniculatus* and fairy flax *Linum catharticum*. The grassland had tussocks of tufted hair grass *Deschampsia cesputosa* with sweet vernal grass *Anthoxanthum odoratum* mixed with more course species, such as cock's-foot and false oat grass *Arrhenatherum elatius*. Table A3.2 in Appendix 3 details the species recorded within the grassland onsite, which existed along the steep banks of the ditch and in pockets along the middle to Eastern part of the site.

Standing water

A number of water bodies existed on site. These included four rectangular lagoons on the Southern boundary, a ditch which ran along the Southern boundary, a large pool to the West of the site and disused sludge beds/lagoons.

The four lagoons were similar in size and shape, with a variation of vegetation species and cover. Lagoon one had approximately 30% vegetation cover consisting of soft rush, spiked rush *Eleocharis palustris* and reedmace *Typha altifolia*. Lagoon two had approximately 45% vegetation cover comprising of branched burweed *Spraganium erectum*, soft rush, great willowherb and jointed rush *Juncus articulatus*. Lagoon three has a slightly more linear shape to it, and had almost 50% vegetation cover of reedmace and pondweed, *Potamogeton* sp. Lagoon four had 60 % reedmace cover. Surrounding the lagoons was a mixture of scrub, tall ruderal vegetation and grassland. Banks were generally steep sided with underground culverts connecting the lagoons.

The ditch connecting the lagoons, Ditch D1, started to the West within the scrub and hedgerow, and at the time of the survey was dry. It continued East, where it moved into the open land and was engulfed by vegetation, including reedmace figwort *Scrophularia nodosa*, great willowherb and bittersweet (Fig 4.3). Water was present at this point within the ditch.

The large pool was approximately 40m x 14m (Fig 4.4). The Southern edge had areas of bare ground with tussocks of soft rush/hard rush and reedmace, brooklime *Veronica beccabunga*, bittersweet *Solanum dulcamara* and duckweed *Lemna minor*. The Northern banks were completely dominated by tall ruderal species, and the Western section of the pool had been completely engulfed by a mixture of reedmace, rushes and great willowherb.

Fig 4.3 **Ditch D1 Choked by Vegetation**

Fig 4.4 **The Large Pool at Kirkby**

Marginal Vegetation

Located to the West of the large pool was a large area of marginal vegetation. This was where the vegetation had engulfed a section of the standing water. Species were dominated by false reedmace and sedges *Carex* sp., with Great willowherb abundant in drier areas.

4.2.2 Water Vole Survey

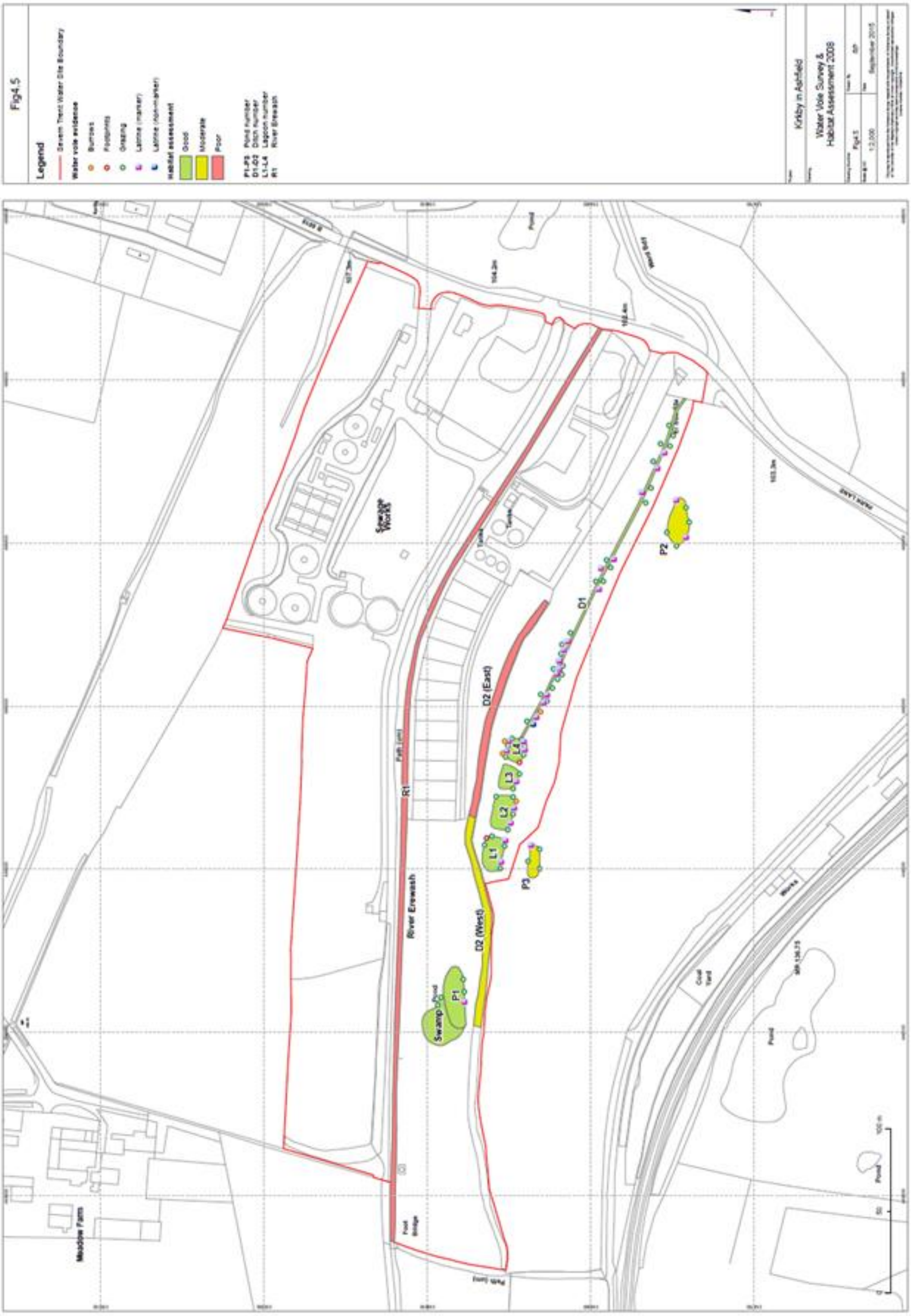
Background

The water vole survey was undertaken in September 2008 to establish the current status on site. It was understood (Warren, 2008) that Severn Trent Water commissioned the introduction of water voles to the site in 2005 by David Gow Associates (see David Gow Consultancy, 2012). Although approximately 80 water voles were released, no monitoring data were available prior to the time of the 2008 survey, but it is believed that there had been no water voles on site prior to the release. Furthermore, it is also not known whether any enhancement works had been undertaken, but at the time of the 2008 survey there was no visible evidence of any site management.

Field Survey

All of the monitoring surveys both pre- and post-enhancement were limited to the site boundary, which was in Severn Trent Water's ownership, and the public footpaths which run either side of the site. The water vole habitat on site (see Fig 4.5) comprised two ditches D1 and D2, four Lagoons (L1 being the most westerly lagoon through to L4 being the easterly most lagoon) and one large pond in the centre of the site (Pond P1). Forming the northern boundary of the study site is the River Erewash and adjacent to the southern boundary are two small ponds (P2 and P3).

The survey (se Fig 4.5) found signs of water vole activity only on the Southern bank of the large pool (P1) (Fig 4.4), where four fresh latrines and several grazing sites were recorded along. A significant constraint to the completion of a full survey was deep siltation to areas to the West of the large pool, which was colonised with dense vegetation, which was deemed too unsafe to enter. The Habitat Assessment found Ditch D1, all four lagoons and Pond P1 assessed as green habitat. Ditch 2 (west) was classified as amber due to loss of standing water due to being choked by vegetation and shaded. Ponds 2 and 3 had limited food source due to the size. Ditch D2 (east) was red due to being dry and shaded resulting in bare ground. The River Erewash was assessed as red due to heavy shading resulting in insufficient food sources.



<u>Fig 4.5</u> Kirkby in Ashfield Water Vole Survey 2008

Running parallel to the Southern boundary was a ditch (D1) and lagoons. The Southern banks of this ditch had areas of exposed soil with patches of shale. Vegetation was sparse in places (although species diverse) with loose shale providing poor establishment potential for vegetation. These areas were generally considered to be unsuitable for water voles to utilise as burrowing areas, although the vegetation would provide habitats for foraging and refuge. Evidence of water voles was recorded along the north banks of this watercourse and within the lagoons. Latrines, feeding station/remains and burrows were found along this section. In addition two ponds to the south of the site outside the STW boundary also had signs of water voles. A second ditch, Ditch 2 (D2), running parallel to Ditch 2 was choked with vegetation, primarily bittersweet. No evidence of water voles was recorded along this ditch.

The River Erewash provided minimal suitability for water voles to inhabit. Banks had numerous areas of exposed bedrock and bare soil, which is unsuitable for burrowing and provides no cover for refuge. The flow of the River Erewash fluctuates and can be fast flowing, features also not favoured by water voles.

4.2.3 Enhancement Design and Implementation

Subsequent to the water vole survey and habitat quality assessment, the decision was taken to undertake enhancement works along a section of Ditch D2 (west), as shown on Fig 4.6. Ditch D2 (west) was chosen due to is being amber and connected to green areas. The eastern section was dry and overgrown with dense scrub, the amount of work which would be required to increase this feature to green was not feasible.

As the site was within the flood zone area of the River Erewash, initial plans for habitat enhancement, which involved using any removed spoil from the ditch as bunds to increase the burrowing areas for water voles was not an option. The Environment Agency (EA) were contacted for advice, and stated that any spoil would have to be deposited outside the flood zone area. Subsequent discussions with Severn Trent Water identified the area shown on Fig 4.6 for the spoil’s deposition. The EA had also advised that drainage consent was required, and the application for this delayed the start of works from October 2010 to March 2011.

The site enhancement was to reduce the element which was the main factor in the ditch being amber not green within the habitat assessment, this was lack of standing water and shading of the channel due to the vegetation especially bittersweet *Solanum dulcamara* engulfing the channel. The enhancement involved clearing out Ditch 2 so that it was no longer choked with vegetation and silt, in order to provide deeper standing water for the water voles. Where it was possible, the East side of the ditch was re-profiled to reduce the steepness of the bank and provide optimal habitat conditions.

The existing vegetation structure along the banks was dominated by tall ruderal vegetation (predominantly nettle, creeping thistle, bitttersweet and great willowherb) with rank grasses including false oat grass and cock's-foot. Although water voles would eat this rank type of vegetation, the range of vegetation along this ditch and re-profiled bank areas was sown with a wider range of food sources to support a water vole colony and encourage them to colonise this area of the site. It was planned that a management programme would be implemented for the cutting of the vegetation, to suppress rank species and encourage a more diverse structure to form.

Once the works were complete, the area was enhanced by re-planting/seeding along the channel in part with appropriate vegetation translocated from other areas of the site, and in part by the combination of plug planting and seed mixture. The planting regime, detailed in Table 4.1, was selected as appropriate to the soil type along the banks in to increase biodiversity.

Latin Name	Common Name	Planting Location
Sparganium erectum	Branched burweed	Channel
Veronica beccabunga	Brooklime	
Iris pseudacorus	Yellow flag	
Juncus effusus	Soft rush	Banks/margins
Juncus inflexus	Hard rush	
Filipendula ulmaria	Meadowsweet	
Angelica sylvestris	Wild angelica	
Scrophularia nodosa	Water figwort	
Deschampsia cesputosa	Tufted hair grass	

<u>Table 4.1</u> Planting Regime for Habitat Enhancement at Kirkby in Ashfield

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<u>Fig 4.6</u> Kirkby in Ashfield Enhancement Works

<u>Fig 4.7</u>   Ditch 2 Before and After the Enhancement Works

4.3 NETHERIDGE

The Netheridge nature area is located within land owned by Severn Trent Water to the North of the Netheridge STW operational area. The STW is located off Rea Lane to the South of Gloucester, at National Grid Reference SO810160, with the River Severn lying to the West and the Sharpness Canal the East, as can be seen in Fig 4.7.

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Fig 4.8 Location of Netheridge Research Site

The nature area itself, as can be seen from Fig 4.8, is bounded to the South by the operational area of the STW, the North and East by arable land, and the West by residential housing and Rea Lane. A ditch runs along the entire boundary with the exception of the Southern side. Netheridge nature area is surrounded by a network of ditches which link into surrounding ponds on site and ditches off site, which support a variety of species.

<u>Fig 4.9</u>   Netheridge STW Nature Area and Habitat Survey

Some 70 water voles were released onto the Netheridge nature area in 2005, with a further release of 60 in spring 2008 to compensate for the population loss during flooding of the site in the winter of 2007 (Warren, 2008). When the site flooded, there was no high ground on site to act as a refuge for the water voles.

For three years prior to the initial water vole release in 2005, the site “was surveyed, managed, cultivated and monitored” as part Severnside Project of Gloucestershire City Council (2012). The site has been managed as part of the project ever since.

4.3.1 Phase 1 Habitat Survey

The survey identified the 6 broad habitats as shown on Fig 4.9:

- Broad leaved woodland
- Scrub
- Grassland
- Tall ruderal
- Standing water
- Reedbeds

These are discussed below.

Broad Leaved woodland

A block of secondary woodland existed in the south west corner of the site, which had a diverse shrub/canopy layer with little age structure. The woodland had been managed recently, areas of dense understory had been thinned out in places, with the dead wood left behind creating habitat piles. The canopy layer almost merged with the shrub layer creating dense shade when the canopy closed in summer. The field layer was dominated by tall ruderal vegetation and course grassland. Species including nettle *Urtica dioica* and creeping thistle *Cirsium arvense* were present along the glades where shading was minimised. Species recorded within the habitat are listed in Table A4.1 of Appendix 4.

Scrub

Large blocks of mature scrub exist throughout the site. The scrub species recorded are detailed in Table A4.2 in Appendix 4. Site management on this habitat included cutting areas back the prevent it from encroaching on the grassland areas.

Tall Ruderal

The tall ruderal species, listed in Table A4.3, Appendix 4, were dominated by large patches of nettle in the open areas merging into the swards of coarse grassland. In places the expanse of nettles stretched the length of the site especially along the banks of the ditches.

Grassland

A majority of the grassland consisted of rank swards of grassland with tall ruderal species mixed in. A small area of grassland to the South West of the main pool had a more diverse species composition, with the more dominant tall ruderal species and coarse grasslands being minimal. The grassland had a majority of the species detailed in Table A4.4, Appendix 4.

Standing water

Two large pools existed on site, which were connected by a narrow channel (see Fig 4.9). A large island was present in the southern pool (Fig 4.10), which was dominated by scrub species, predominantly willow *Salix* sp.. The pools had a well-established marginal layer of common reed *Phragmites australis* and iris *Iris pseudacorus* with scrub areas of willow, blackthorn *Prunus nigra* and dogwood *Cornus* sp.. The pools had duckweed *Lemna minor* and algal blooms present during the summer months.

Fig 4.10 The Large Pool at Netheridge

Two smaller ponds exist to the North East and South West of the larger pools. The former, was a kidney shaped pond with a marginal vegetation layer consisting of reedmace *Typha latifolia*, hard rush *Juncus inflexus* and iris. The latter pond no longer had an open area of water and had been engulfed by common reed.

Wet ditches

The site was almost completely surrounded by a wet ditch separating the site from the adjacent farmland and residential gardens (Fig 4.11). The ditch was approximately 3m across at the top, reducing to 1.3m at the channel. Banks were steep on both sides and between 1 and 1.5m high.

The water depth ranged from 0.3m to 0.4m, with a layer of silt at the bed. The banks on the site side were dominated by tall ruderal species at the top with scattered emergent/marginal vegetation at the water's edge. Species included meadowsweet, cow parsley, nettle, lesser celandine *Ranunculus ficaria* and watercress *Nasturtium officinale*. The farmland side of the ditched had scattered trees and hedgerows in places, which created a more shaded bank with areas of bare ground. To the Northwest and South of the site the ditch became overgrown by dense impenetrable bramble *Rubus fruiticosus* agg..

<u>Fig 4.11</u>   Ditch Forming the Boundary to Netheridge Nature Area

Reedbed

A treatment reedbed existed in the South East of the site which was adjacent to the Sewage Treatment Works. The reedbed consisted of concrete steep sided channels lined with plastic and common reed planted in lines.

4.3.2 Water Vole Survey

A habitat assessment and trapping survey was undertaken in April 2008 to establish the current status of water voles on site. It was understood that 70 water voles were released in August 2005 and 60 in May 2008 as part of a water vole introduction scheme by Derek Gow Consultants. A water vole monitoring programme using trapping was subsequently undertaken three times a year, in April, June and October by the Severnside Project team. Each water vole was marked (using tipex) on differing places to check for re-capture. The surveys in 2006 and spring early 2007 showed a healthy population of water voles breeding after the release.

Unfortunately the floods during the summer of 2007, and a cold April in 2008 resulted in the wetlands area being over waist high in water for a number of days. With no high ground within the site as refuge for the water voles, the impact on the on-site colony and within the adjacent ditch was devastating. This was revealed by the April 2008 monitoring survey, during which no water voles were trapped, with just a few signs of grazing on root bulbs along the edges of the southern and eastern edges of the large pool (Wilmot, 2008).

Subsequently 60 water voles were released to reinforce the low population on site in May 2008. The September/October 2008 monitoring survey and habitat assessment, captured 23 water voles (one re-capture so 22 in total) from 22 traps over a five day period Fig 4.12. These were marked and weighed, with a combination of juvenile and adult water voles being recorded, which suggested that the water vole population had started to recover. A preliminary habitat assessment identified the main water bodies and ditches to the north as green, ditches to the east and west amber due to shading and reduction of food sources and red to the south due to shading and areas of drying.

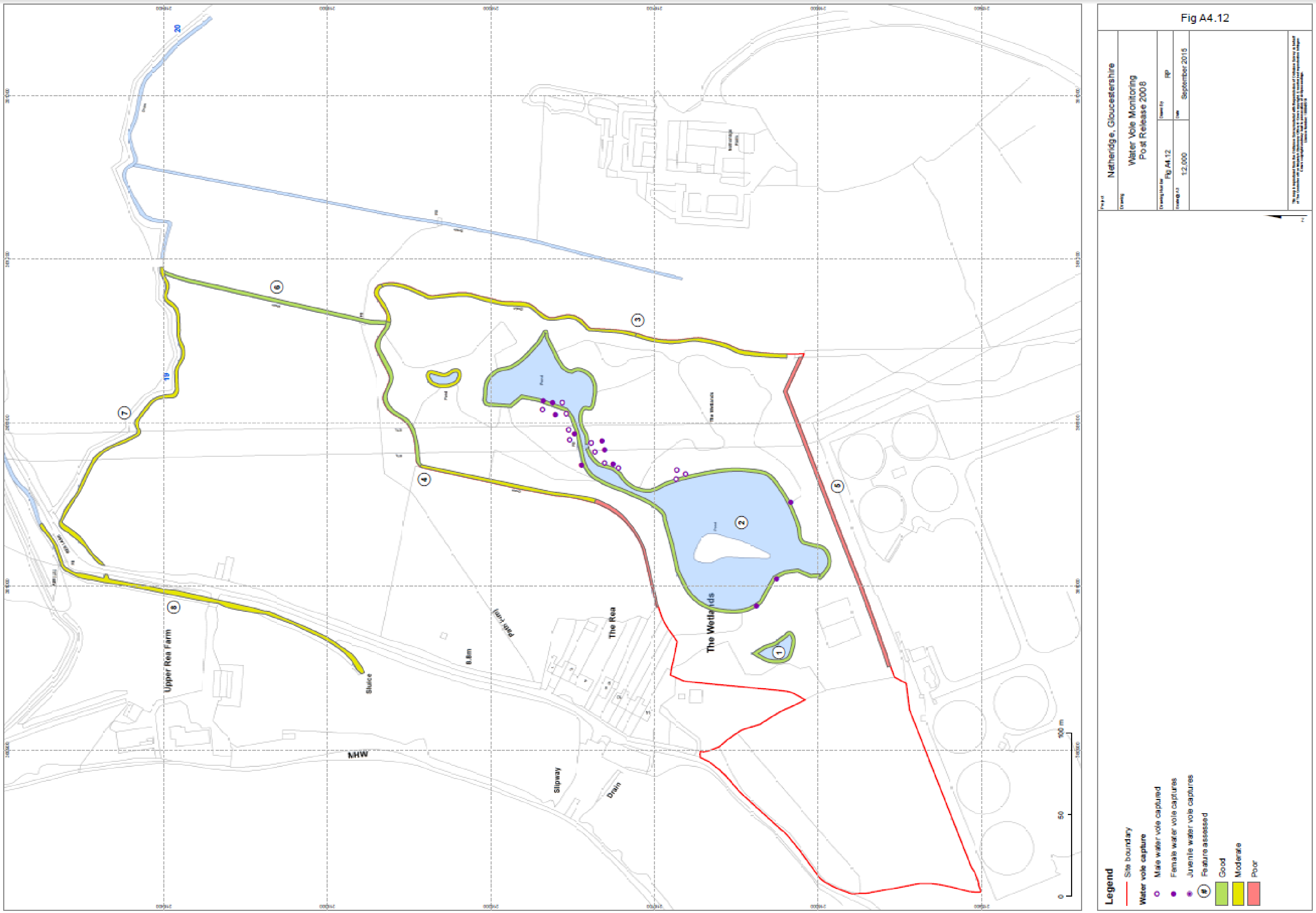

Fig 4.12 **Water Vole Survey September/October 2008**

4.3.3 Enhancement Design and Implementation

After undertaking the botanical survey of the site and assessment of habitat suitability, and analysing the water vole monitoring records, the ditch running along the Eastern boundary was been targeted for habitat enhancement – see Fig 4.13. No water voles burrows had been recorded along this section the 2009 survey, thus no mitigation works would be required.

A levelling survey was undertaken to ascertain the existing profile the chosen ditch section. This showed, as with the botanical description, that the ditch banks had steep banks on the West and East sides. The farmland (East) side had a defunct hedgerow and scattered trees abutting the bank. The proposal for this side of the boundary was to infill gaps in the hedgerow to improve habitat connectivity. Therefore, only the West side of the ditch was to be re-profiled. Fig 4.11 shows the ditch prior to re-profiling.

The ditch redesign reduced the steepness of the Western bank to provide an optimal habitat potential for water voles. The bank would be re-profiled to a 45 degree slope (Fig 4.15) with a shelf in some sections at the base to create a larger bank surface area for water voles to burrow into. Marginal vegetation will also be established along the shelf area. The ditch was also to be de silted during the re-profiling work It was planned that the excess spoil from the re-profiling would be used to create bunds along the ditch, these however were sited a short distance from the ditch to avoid any shading to the area. The purpose of the bunds was to provide areas of refuge for the water voles in times of flood.

With the formal approval of Severn Trent Water and the Internal Drainage Board (IDB), funding was obtained and the enhancement works were undertaken and completed in January 2010. Fig 4.15 shows the ditch after re-profiling.

The existing vegetation structure along the banks was dominated by tall ruderal vegetation (predominantly nettle, creeping thistle and great willowherb *Epilobium hirsutum*) with rank grasses, including false oat grass and cock's-foot. Although water voles will eat such vegetation, by increasing the biodiversity along the ditch and bank areas a wider range of food sources would be provided to support a water vole colony and encourage them to colonise this area of the site - it would also attract invertebrates, birds and mammals. The bank and any areas of bare ground were seeded with Emorsgate seed mixes EM2 (general purpose meadow mixture), EM5 (meadow mixture for loamy soils), EM10 (tussock mixture) and EP1 (pond edge mix) (Emorsgate Seeds, 2015).

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Fig 4.13 **Location of Enhancement Works at Netheridge**

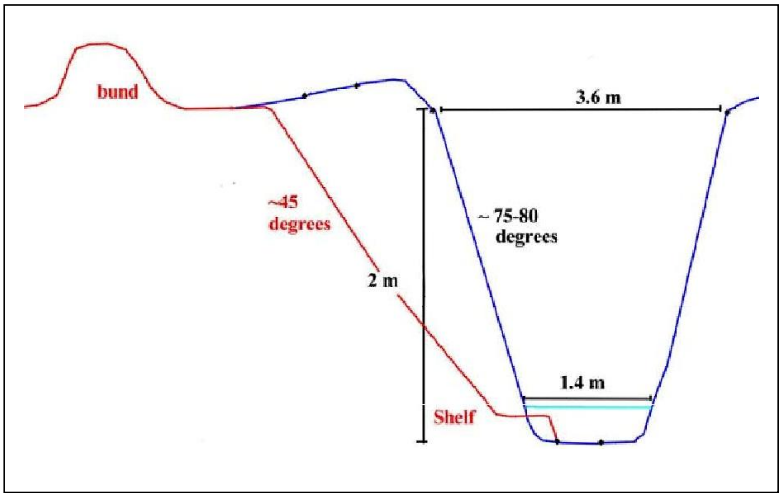


Fig 4.14 **Netheridge Ditch Section Design**

Fig 4.15 The Netheridge Ditch following Re-profiling

Once implemented, it was essential that in the first couple of years after the enhancement works had been undertaken, that the vegetation establishment was monitored and re-seeding undertaken where required, in order to ensure a thick sward established as a food source and refuge for the water voles. Thus a management plan was required.

The IDB who manage the ditch, required it to be dredged periodically to meet their flood management obligations. However in addition, the IDB has legal obligations regarding biodiversity:

- Section 28G of the Wildlife and Countryside Act (W&CA) 1981 as amended, to take reasonable steps, to further the enhancement and conservation of flora/fauna;
- Land Drainage Act 1994: Section 61 in which it is the duty of every IDB to exercise its power to further the conservation and enhancement of natural beauty and the conservation of flora and fauna.
- Natural Environment and Rural Communities Act 2006, Section 40(1); It is the duty of the IDB to exercise its power to further the conserve biodiversity. Section 40(3) states

that conserving biodiversity includes restoring or enhancing population or habitat. Consequently, a management plan was therefore designed, in consultation with the IDB, which would both ensure the medium term sustainability of enhancement scheme for water voles and the flood management obligations of the IDB. To facilitate this, costs for two years of site management had been included in the funding.

4.3.4 The Management Plan

The aim of the Management Plan was to incorporate both conservation/biodiversity and drainage requirements. It had therefore to take into account that the management of the enhanced ditch and the adjacent nature area, together with other connecting ditches both on and off site, should be undertaken in an appropriate manner for biodiversity and to maintain successfully working drainage system. In particular it was envisaged that the ditch network would become linking corridors for water voles and other wildlife species, both aquatic and terrestrial.

The Management Plan for the two years following the completion of the enhancement works is shown in Table 4.2. It includes the siting and monitoring of mink rafts as, although none had previously been observed, the potential for their incursion was always present due to the proximity of the River Severn and the Sharpness Canal. The key points of the Management Plan were as follows.

The cutting of vegetation to maintain the reduction of the rank species and encourage a more diverse structure to form. Since nettles occur in dominant pockets around the site, where necessary they should be treated by spraying.

Bank side vegetation strimming would only be on one side at any time to allow water vole connectivity on the other banks. This should be undertaken in March-April time before water voles start breeding, but after their torpid state through the winter months. This would also suppress the more dominant species (i.e. nettles, hogweed *Heracleum sphondylium*) from dominating the vegetation structure.

Additional seeding would be undertaken where required, this also encourages an increase in biodiversity and enables the establishment of a dense sward of grasses and wildflowers.

It was important that the hedgerow present on the eastern banks of the site were maintained. Although this provides suitable nesting areas for birds and has been identified as being utilised for pathways by badgers *Meles meles*, the hedgerow would shade out the ditch if it were not cut back. This should be achieved by leaving the West side of the hedgerow and cutting back the East side and top, in order to minimise disturbance. All cutting should be removed from and around the ditch to prevent debris build up and potential flooding. Hedge laying should also be a viable management type for the hedgerow.

When drainage maintenance is undertaken, this would have to be carried out from the Western bank side by a skilled driver, scooping out the silt from the channel without damaging the banks. As the plan is for the establishment of good quality marginal vegetation, selected areas should be left to ensure sufficient vegetation cover for water vole refuge and food availability. Immediately prior to the works, a water vole survey should be undertaken to establish where the burrows are. Any burrows located should be marked and those areas avoided. If it becomes necessary to disturb these burrow (i.e. the ditch needs to be clear to prevent flooding) then a suitably qualified ecologist should be consulted and engaged.

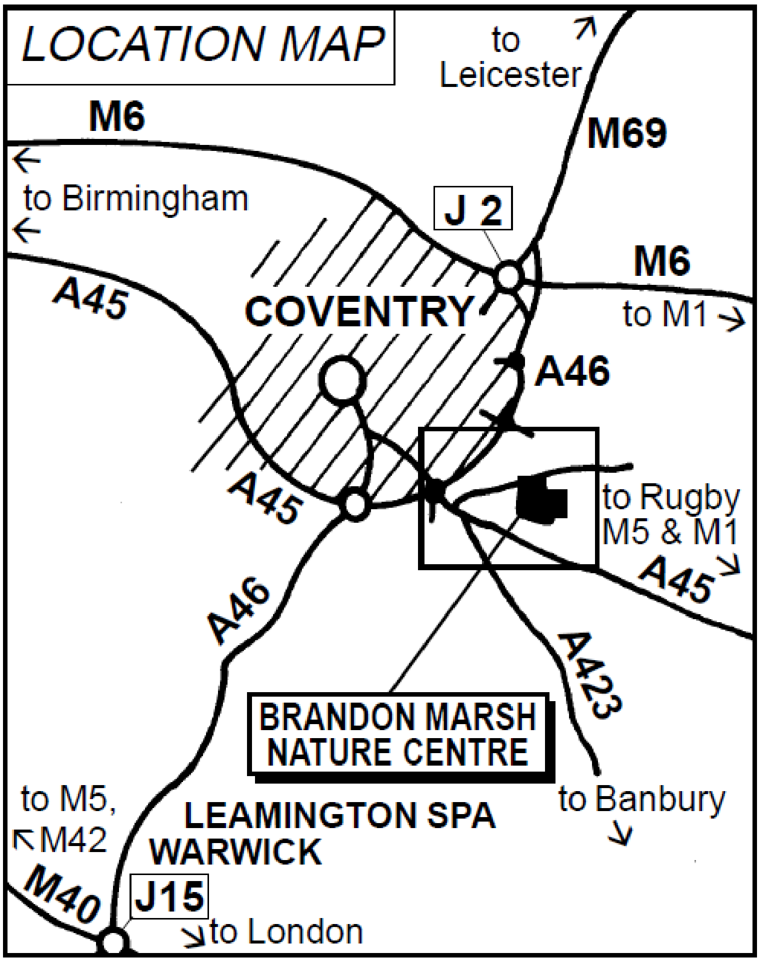
A water vole monitoring survey should be undertaken at twice a year ideally, once in spring and once in the autumn, however if only one survey is undertaken it should be in Autumn after breeding season to identify successful breeding.

Element	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Re-profiling of bank along targeted ditch	✓ (green)											
Re-seeding/plug planting and re-profiled bank				✓ (green)	✓ (green)							
Hedgerow maintenance	✓ (red)	✓ (red)										
Nettle control				✓ (green) ✓ (red)					✓ (green) ✓ (red)			
Mink rafts	✓ (green) ✓ (red)	✓ (green) ✓ (red)	✓ (green) ✓ (red)	✓ (green) ✓ (red)	✓ (green) ✓ (red)	✓ (green) ✓ (red)	✓ (green) ✓ (red)	✓ (green) ✓ (red)	✓ (green) ✓ (red)	✓ (green) ✓ (red)	✓ (green) ✓ (red)	✓ (green) ✓ (red)
Water vole monitoring				✓ (green) ✓ (red)					✓ (green) ✓ (red)			
N.B: green for 2010, red for 2011												

Table 4.2 Netheridge Management Plan for 2010-11 and 2011-12

4.4 BRANDON MARSH

Brandon Marsh Nature Reserve is the location of the headquarters of the Warwickshire Wildlife Trust. It is located to the South East of Coventry at Grid Reference SP386761, and is reached via Brandon Lane off the A45 – see Fig 4.16.



<u>Fig 4.16</u> Location of Brandon Marsh Nature Reserve
(Warwickshire Wildlife Trust, 2014)

The Reserve is a 87 ha Site of Special Scientific Interest (SSSI), and is bounded to the North West by Brandon Lane and the River Avon to the South, with agricultural land to the West and a golf course to the East.

Originally grazing and arable land, excavation for sand and gravel commenced in 1955. Subsequently over the next 34 years, the quarry and subsidence from the Binley Colliery galleries, which had previously closed, resulted in the formation of an extensive wetland habitat. Quarrying ceased in 1989 and subsequent renovation works and management, by both the quarry company and Warwickshire Wildlife Trust and its team of Voluntary Conservation Team led to the Reserve found today, whose layout is shown in Fig 4.17. The history of the site is well documented and the reader is referred to the Warwickshire Wildlife Trust (2015) and the volunteers (Brandon birding, No date).

<u>Fig 4.17</u>   Brandon Marsh Site and Habitat Plan
(Brandon Marsh Voluntary Conservation Team, 2006)

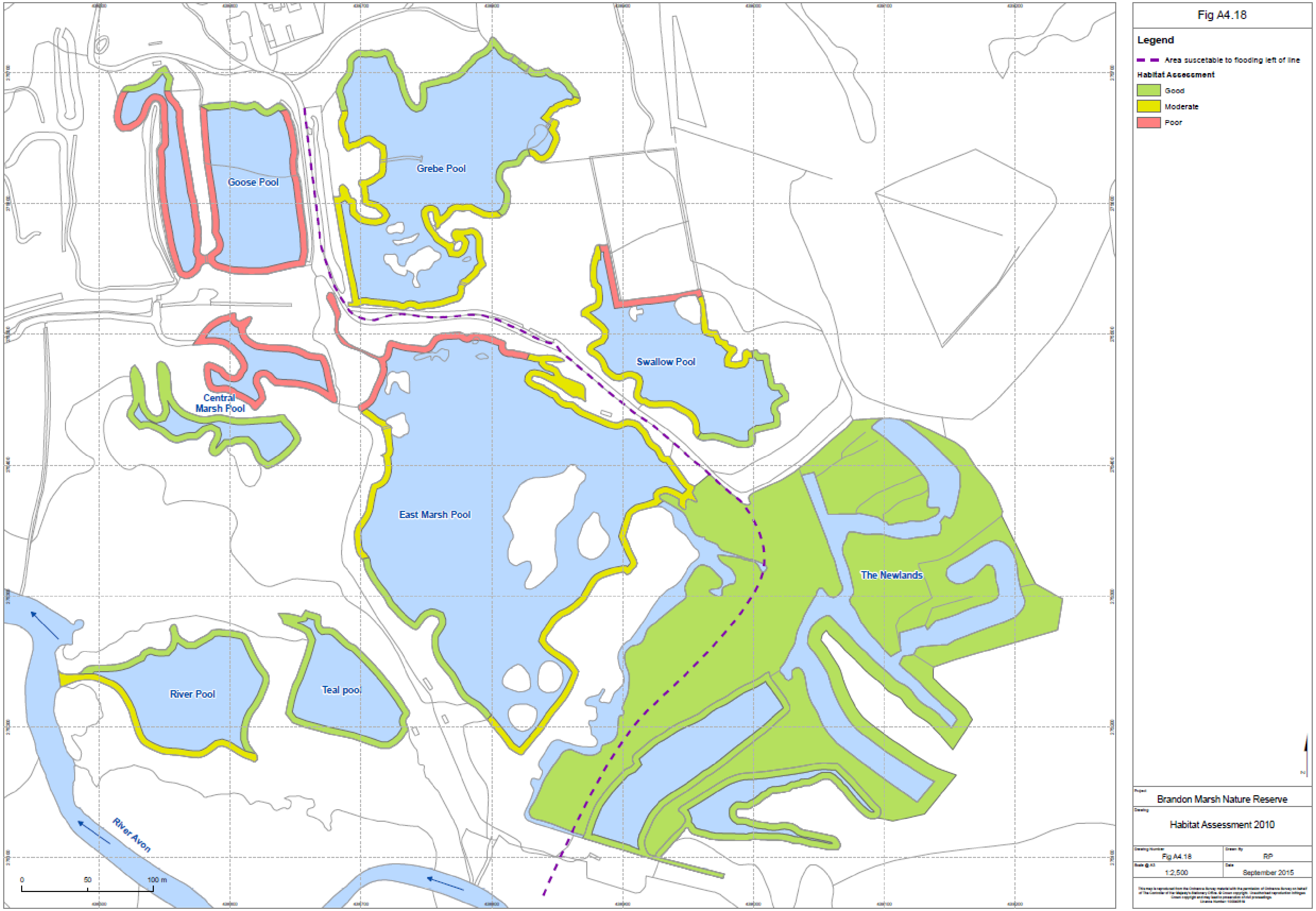


Fig 4.18 Brandon Habitat Assessment 2010

The reserve currently comprises 10 main pools and a mosaic of habitat types including: reedbed, wet woodland, wet grassland and scrub. The Unofficial Guide to Brandon (Brandonbirding, No date) states that the reserve is host to more than: 230 bird species (60 of which nest on site; 480 plant species; 550 fungi species and '1000s insects'.

Brandon Marsh Nature Reserve has had a Management Plan in place over a number of years, with the main focus being on birds. In recent years this has involved the expansion and creation of reedbeds with the object of attracting Bittern *Botaurus stellaris* and reed warblers *Acrocephlaus scirpaceus*.

Although there was no indigenous population of water voles, it was considered that Brandon Marsh held areas of highly suitable habitat for water voles (especially the Newlands, and Goose Pools). They provided dense areas of reedbed mixed with a mosaic habitat of marsh lands and grassland, which would provide sufficient food sources throughout the year. It was also considered that the management in place for the nature reserve tied in with water vole habitat requirements. A release programme was therefore planned, which was endorsed by both Rob Strachan (Environment Agency and Author of the Water vole Handbook) and Derek Gow of Derek Gow Consultants.

4.4.1 Habitat Survey

For the purpose of the proposed released programme only the habitats which were considered for the release were surveyed – see habitat map Fig 4.18 and habitat assessment Fig 4.19. The main factors deciding the release sites, therefore habitat assessment was being outside of the flood plain and not within the angling ponds.

Reedbed

To the north of the reserve is a large area of reedbed *Phragmites australis,* Top Pools Reedbed. Management involved pumping in water from other areas of the reserve to prevent the area drying up, and scrub control.

The Newlands was an area of approximately 20 hectares, which was once grassland. Extensive habitat management and creation had been undertaken on this area to create an area of open water with extensive reedbeds establishing around the edges. Additional planting of reeds was planned in the new reedbed creation to the south of Newlands excavated in August 2011.

Other reedbeds existed in and around the margins of several of the pools, as described below

Standing Water

A number of different sized pools existed around the site (see Fig 4.17 and 4.18) These were generally old gravel pits which had been managed to produce suitable habitats for a variety of water fowl and bird species. A majority of the pools had willow scrub/carr grassland and reedbeds surrounding the edges.

- Grebe Pool, located to the South East of the Visitor Centre and to the north west of the reserve, was managed and utilised by Brandon Angling club. This contained a number of fishing platforms around the perimeter. The North end of Grebe Pool comprises a well-established, moderately extensive reedbed.
- Goose Pool, to the West of Grebe Pool, had Lombardy poplar *Populus nigra* 'Itailica' lining its West and East banks. The water levels of this pool were maintained by piped supply from the neighbouring Grebe pool, and the .
- Swallow pool, South of new Hare Covert contained dense areas of submerged willows and areas of marginal vegetation, including reedmace *Typha latifolia* and greater pond sedge *Carex riperia*. Management of this pond included the cutting of willow scrub to the Northern edge where common reed was establishing itself.
- East Marsh Pool, located to the South of Grebe Pool, is the largest of the pools. It has pockets of reedbed to the South East and West. Management of this pool had extended the area of water and a series of islands had been created to provide areas attractive to wildfowl. A flood bank protected the pool from flood waters from the River Avon flood, which lay to the South.
- Central Marsh Pool, as the name suggests, lies in the centre of the reserve to the West of East Marsh Pool. This pool had undergone management in the form of willow removal from the Southern edge, which had allowed common reed to establish. Central Marsh Pool was connected to West Marsh Pool by a ditch/water body.
- West Marsh Pool lay on the southern edge of the reserve. Management of this pool included the excavation of areas to create low level reedbeds within the flood plain. Scrub species (hawthorn, willow) and wet meadow species (meadow-sweet *Filipendula ulmaria*, reed-sweet grass *Glyceria maxima*) had established in areas where the standing water had become engulfed by vegetation.

- River Pool is directly connected to the River Avon, which results in a fluctuation of water levels and expanses of mud flats in summer, when water levels are low. Again management of this pool involved the removal of dense willow stands.
- Teal Pool is adjacent to River pool. Between these two water bodies was a low bund which provided Teal Pool with partial protection from flooding of the River Avon. Management included the removal of dense willow to create areas of mud for wading birds.
- Kingfisher Pool a small pool North of West Marsh Pool was unmanaged at the time of the survey. Willow scrub was encroaching into the water, and reedmace and reed sweet-grass colonised the edges.

4.4.2 Mink Control

Mink have been recorded at Brandon Marsh at least since 1990, however mink control is also well established in the form of mink rafts. Brandon Marsh has a good core of volunteer workers on site daily, whether bird watching or site management. This dedication results in the constant good management and enhancement of the site and vigilance of spotting mink, and once spotted, the mink is generally captured within a couple of days. This is undertaken by setting a live capture trap within the tunnel of the mink raft, as described in Sect 3.5.2.

Downstream of Brandon Marsh, a local gamekeeper managed approximately 6 km of the River Avon and its tributaries from SP34358 72361 to SP36551 74446, and has kept records of mink captured over the last 20 years. He had identified an influx of mink numbers in the mid to late 90's, but could also demonstrate that over the recent 3-4 years numbers had dropped, with only 5 captured between 2010 and 2013. This agreed with the pattern of mink spotted/captured on the Brandon Marsh reserve.

Throughout this project, with the aid of local farmers/game keepers/anglers, mink control was undertaken on a regular basis, both upstream and downstream of Brandon Marsh along the River Avon – their location is shown in Appendix 5. The checking of the mink rafts was a very time consuming process. They had to be installed (Fig 4.19) in areas away from public access to minimise interference and at the best available locations (i.e. by potential den sites/near junction of watercourse), which were not always close or easily accessible.

<u>Fig 4.19</u>   Mink Raft on the River Avon

4.4.3 Water Vole Release

As Brandon Marsh had no population of water voles it was important to release a suitable number so that a success full breeding population could be established. This would require a core colony with a population which would disperse to form the required meta-populations for genetic variability. A release of 200 water voles was therefore planned for 2011, at the optimal time between June and August.

Unfortunately the extension of the reedbed at Newlands, as detailed within the Management Plan, failed to follow the planned schedule, and since this was adjacent to one of the water vole release sites the works had to be completed first. The original programme was to obtain planning permission in January 2011, with the four week work programme, including the excavation of the reedbed areas and planting, were to be completed in January-February. However a delay in the planning by a couple of months resulted in the excavation works being delayed. This was further exacerbated by the nesting bird season (specifically those ground nesting birds within the area of scheme) and ultimately the works were not be undertaken until August 2011.

As the water voles had already been “ordered” and bred ready for the site release in spring 2011 and had been paid for, it was not possible to put this off until the summer of 2012. As the weather conditions during the summer of 2011 were good, the vegetation density and abundance was high after and on site meeting and discussions with Derek Gow (Derek Gow Consultants and Steve Trotter (Chief Executive Warwickshire Wildlife Trust) is was decided that the water voles could be released in early September.

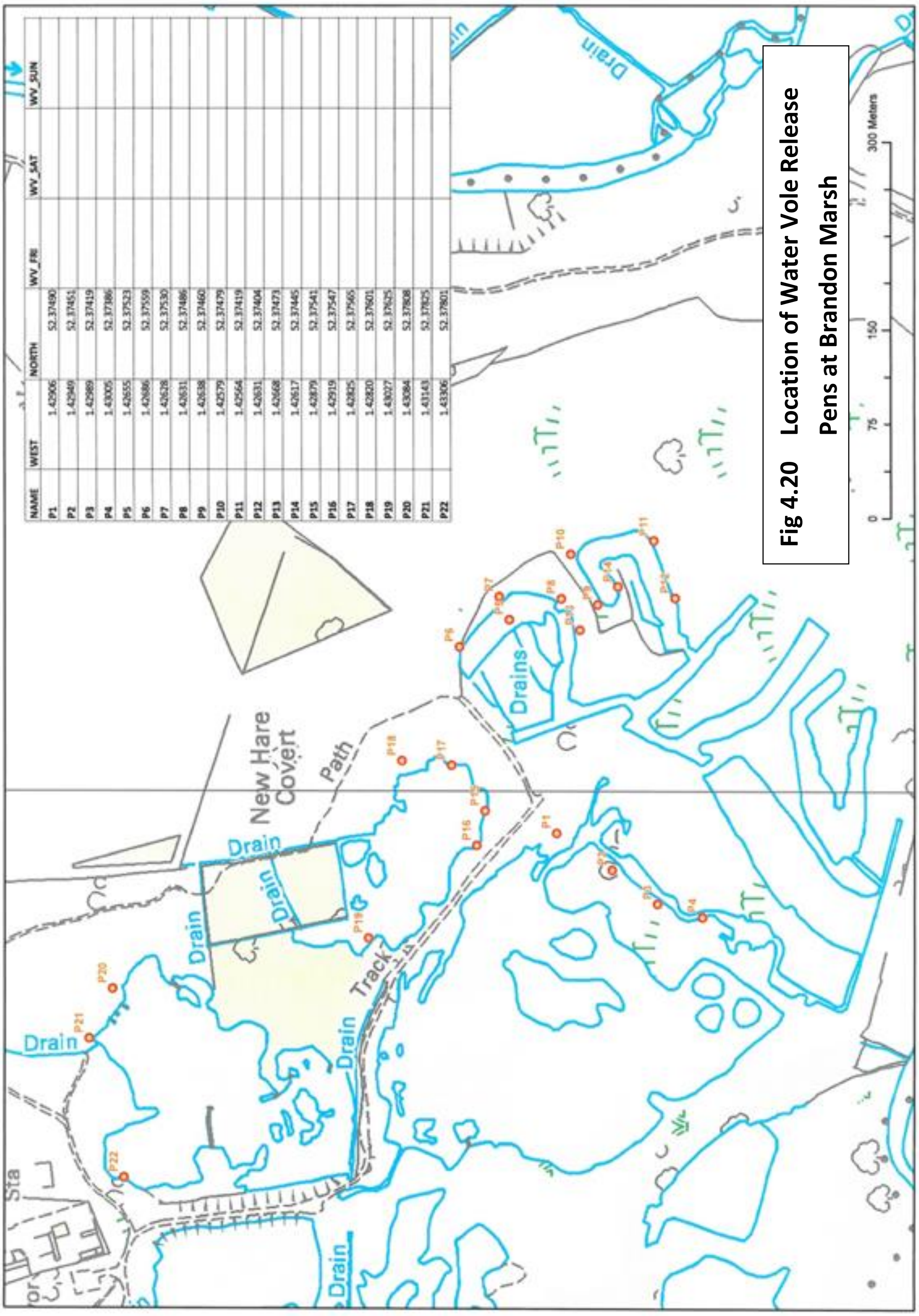
This created a further problem - the age the water voles. If the water voles bred for release in July were released in September, in all probability it would result in a low population and an unsuccessful reintroduction as these would be older and an unlikely number to survive the winter for breeding next year. As water voles have a high fecundity and produce litters constantly throughout the breeding season, they generally only have one year of breeding during their lifetime, and consequently releasing an aging population would not be advisable. The water voles were therefore bred again so a younger population was released which could breed during the next season - the spring/summer 2012.

As a result of the delay, the 200 water voles released at the beginning of September 2011 were all juveniles and only 15 were 120g or over. This late release was considered to be a risk as at this is the time of year. As the food source is always reduced and a risk of high mortality over winter before breeding. In addition the water voles may disperse onto the River Avon, the original programmed July release would have ensured that they had found territories during the breeding period. In addition, at that time the vegetation (food source) was at its densest, enabling the water voles to gain and maintain weight for over wintering.

Since the voles were juvenile at the time of their release, soft release was employed (see Sect 3.6). The pens were placed approximately 100 m apart or more to ensure that territory and foraging sizes areas were appropriate. Had the pens been placed too close together, territories/foraging areas could have overlapped, resulting in unnecessary competition for food. The pen locations are shown on Fig 4.20, with Fig 4.21 showing the handling method for checking vole weight prior to release.

4.4.4 Water Vole Monitoring

Prior to the change in timetable it had been planned that a number of the mature water voles near their maximum weight would be fitted with radio tagged collars. This would have enabled the dispersal of the water voles, both within the site and along the River Avon, to be monitored over the life of the transmitter batteries. Collars together with a receiver were



NAME	WEST	NORTH	WV_FRI	WV_SAT	WV_SUN
P1	1.42906	52.37490			
P2	1.42949	52.37451			
P3	1.42989	52.37419			
P4	1.43005	52.37386			
P5	1.42655	52.37523			
P6	1.42686	52.37559			
P7	1.42628	52.37530			
P8	1.42631	52.37486			
P9	1.42638	52.37460			
P10	1.42579	52.37479			
P11	1.42564	52.37419			
P12	1.42631	52.37404			
P13	1.42668	52.37473			
P14	1.42617	52.37445			
P15	1.42879	52.37541			
P16	1.42919	52.37547			
P17	1.42825	52.37565			
P18	1.42820	52.37601			
P19	1.43027	52.37625			
P20	1.43084	52.37808			
P21	1.43143	52.37825			
P22	1.43306	52.37801			

Fig 4.20 Location of Water Vole Release Pens at Brandon Marsh

therefore purchased. However, as the timetable was altered, juveniles were released on site instead of mature adults, and they would have rapidly gained weight and bulked up. As a consequence, the collars would become very tight within two weeks or less, and if they had not been trapped within this period to replace or remove their collars, they would have been strangled. Since, in practical terms, less than two weeks data could have been collected and, more importantly, the welfare of the water voles was at risk, it was decided to abandon the use of the collar radio tracking system.

Another method of tracking mammals electronically is by using Passive Integrated Transponder (PIT) tags. This involves a small pellet shaped tag coated in glass being inserted under the skin of the mammal. Each tag contains an "integrated circuit with a digital ID code and antenna that transmits the code when it is activated by the electric field of the transceiver." (Feldhamer et al, 2007). Although this is a good way to track animals in burrows and their use of regular runways (Harper and Batzli, 1996), in the case of this research, since transceivers are places in static locations rather than moving with the surveyor, PIT would have been impractical since neither burrows nor paths/runways had been established. Furthermore, although this option was considered, the cost of the required equipment was beyond the available budget.

Consequently, monitoring of the water voles following release had to rely on conventional field methods (Sect 3.4).

Fig 4.21 **Water Vole Handling for Weight Checking**

4.5 KINGSNORTH

4.5.1 Site Description

The Kingsnorth Commercial Park site is a large flat area of 97.4ha located approximately 2 km east of Hoo St Werburgh, Medway, Kent, to the North East of Kingsnorth powerstation and centred at Nation Grid Reference TQ815 374 (Fig 4.21). Planning permission had been granted for approximately 19,000m^2 of commercial development (VolkerWessels UK, no date). Prior to development, the area comprised a mosaic of irregular shaped fields used for farming, along with sections of marsh. The works included 300,000m^3 of earthworks, together with contaminated ground remediation, construction of 3km of roads, landscaping and 36.6ha of ecological mitigation measures. The development plan is shown in Fig 4.22.

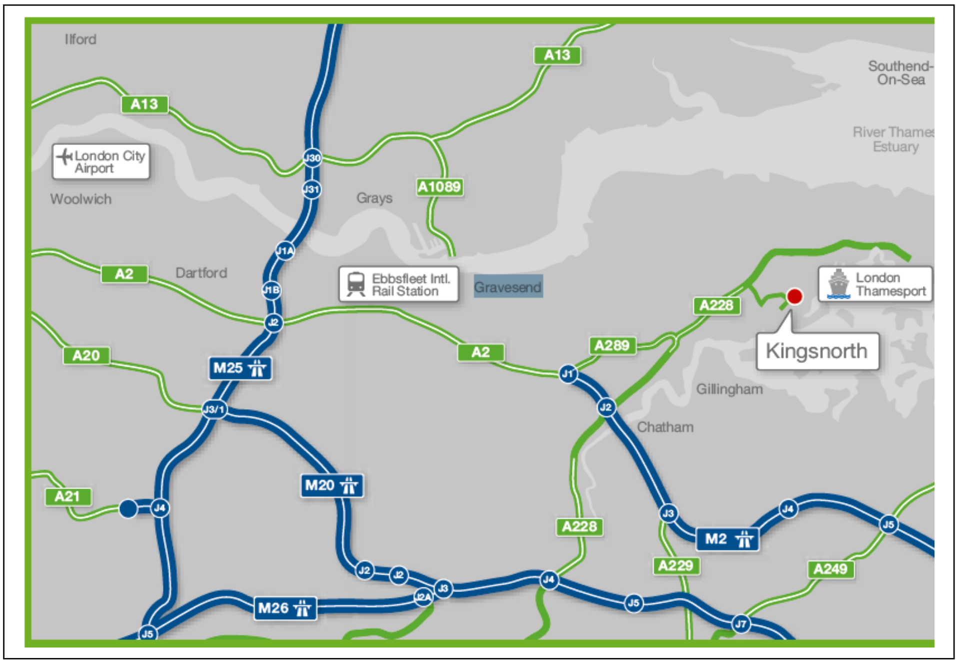


Fig 4.22 Location of Kingsnorth Commercial Park
(Goodman, no date)

The surrounding area comprises arable land, hedgerows, woodland, running /standing water salt marshes/estuary and structures associated with the Scottish Power's power station. Adjacent to the boundaries are a number of mitigation areas, previously created as nature conservation areas during the development of the power station, these were to remain

The site has been separated into 8 separate Plots, as shown on Fig 4.25. In addition the development area included a strip of land either side of the access road, Ropers Lane.

Aston University

Illustration removed for copyright restrictions

Fig 4.23 **Kingsnorth Commercial Park Development Plan**

Within the surrounding area five statutory sites designated for nature conservation were found:

- Medway Estuary and Marshes which is adjacent to the east of the site, and is a Ramsar Ramsar Site, an SSSI, a Special Protected Areas (SPA) and Important Bird Area (IBA);
- Chattenden Woods SSSI located 3.5 km East;
- Dalham Farm SSSI and National Nature Reserve (NNR) located 1.6 km Northeast;Northward Hill and High Halslow SSSI and NNR 2.4 km East:
- Tower Hill Cockham Wood SSSI 3.2 km southeast.

Non-statutory sites included four ancient woodlands (Deangate Wood, Fisher's Wood, Wybomes Wood and an unnamed woodland) located between 0.9 and 2 km from the site.

In total, the site itself contained four ponds, a reedbed, a scrape and a network of ditches of relevance to the research (Fig 4.25). Historical data from the desk study had also shown there to be water voles within the ditches of the site. Kingsnorth differs from the other three research sites, due to the fact it was a new development, where areas of water vole habitat would be destroyed and these required mitigation.

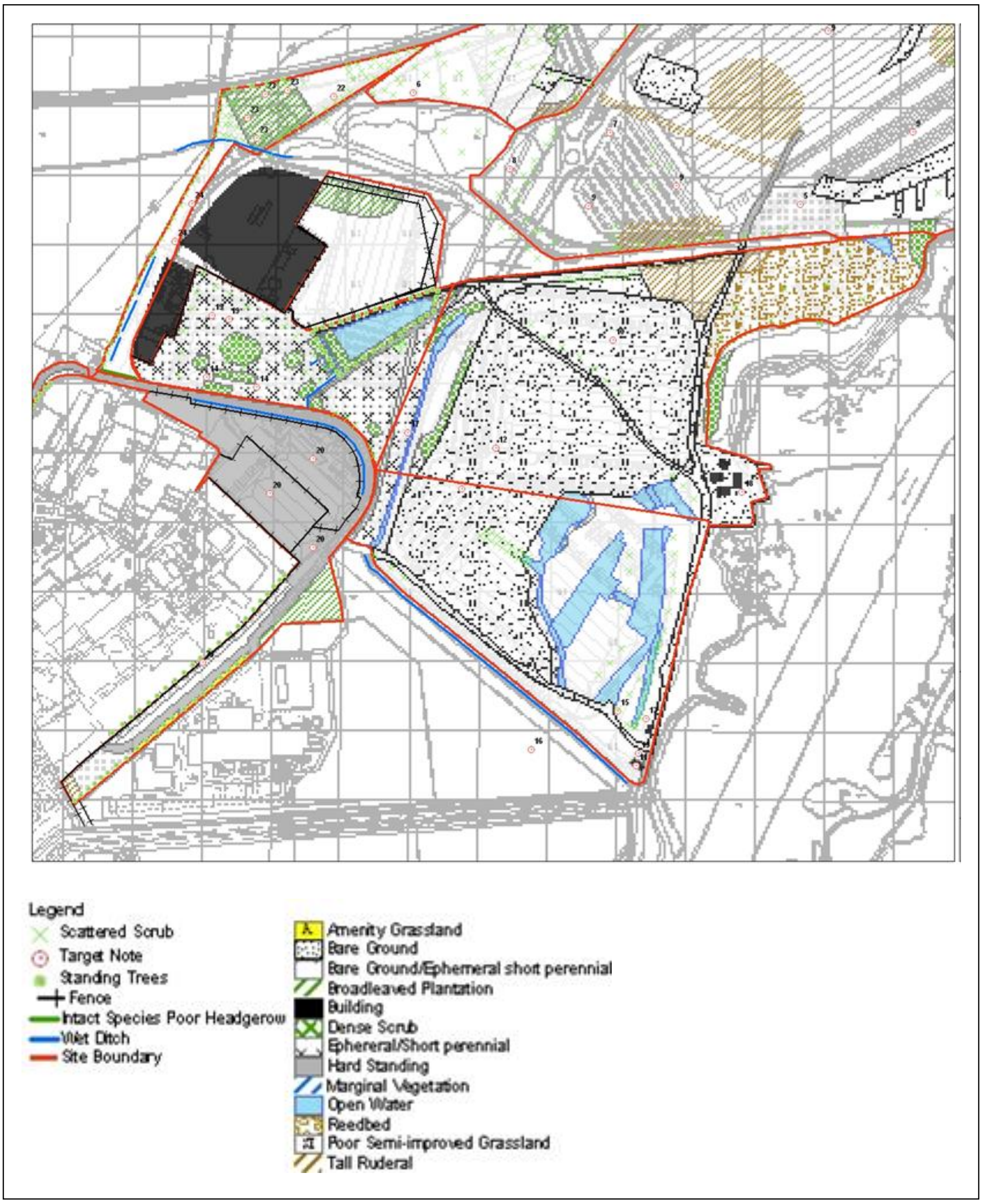
In 2007, Middlemarch Environmental Ltd were commissioned by the developer (Goodmans) and the construction company (VolkerFitzpatrick) as ecological consultants for the project, and produced a Habitat Management Plan (MEL, 2010a) and an Ecological Mitigation Strategy (MEL, 2010b). The Mitigation Strategy was to compensate for the loss of two of the ponds on the site, Pond 1 and Pond 2 (Fig 4.23). Subsequently, a 'Water Vole Survey and Mitigation Strategy' was prepared (MEL, 2011).

4.5.2 Phase 1 Habitat Survey

The following key habitats were noted at the time of Phase 1 survey.

- Bare ground
- Dense and scattered scrub;
- Ditch;
- Ephemeral / short perennial;
- Marshy grassland;
- Poor semi-improved grassland;
- Tall ruderal.

Fig 4.27 (from MEL, 2007) shows majority of the Phase 1 survey, and Table 4.3 is a summary of the habitats recorded within the various Plots. A brief summary of the main features of each of the habitats is given below



<u>Fig 4.24</u> Kingsnorth Phase 1 Habitat Survey
(from MEL, 2007)

Habitat	Ecological Value	Habitat Present in Plots						
		1	2A/ 2B	3	4	5	6/7	8 to 11
Amenity grassland	Low			✓				
Bare ground	Moderate	✓	✓	✓	✓			✓
Broadleaved woodland	Moderate							✓
Buildings	Low		✓					
Dense scrub	Moderate	✓	✓		✓	✓	✓	✓
Ditch	Moderate	✓		✓	✓	✓	✓	✓
Ephemeral/short perennial	Moderate	✓	✓	✓				
Fence	Low	✓	✓	✓	✓	✓	✓	✓
Hedgerow	Low to moderate						✓	
Marginal vegetation	Low to moderate		✓		✓			
Marshy grassland	Moderate	✓				✓	✓	✓
Open water	Moderate to high		✓		✓			
Plantation woodland	Moderate			✓				
Poor semi-improved grassland	Moderate	✓	✓	✓	✓	✓	✓	✓
Scattered scrub	Moderate	✓	✓		✓		✓	✓
Scattered trees	Low			✓	✓		✓	✓
Tall ruderal	Low	✓	✓					✓
Track	Low		✓					

Table 4.3 Presence of Habitat Types within the Kingsnorth Development Plots
(MEL, 2007)

Bare Ground

Bare ground dominated Plots 2A and B, but was present closely associated with Ephemeral/short perennial in most plots.

Dense Scrub

Where found, dense scrub was characterised by bramble *Rubus fruticosus* agg. hawthorn *Crataegus monogyna*. and broom *Cytisus scoparius*

Ditch

A network of ditches crossed the site, and were typically 1 to 1.5 m wide, with a 0.2 to 0.5 m depth of water, the majority were observed to be flowing at the time of the survey. Many of the ditches had no aquatic vegetation, but those within Plot 1 contained common reed *Phragmites australis*, reedmace *Typha* sp., fools water cress *Apium nodiflorum*, water plantain *Alisma plantago-aquatica* and branched bur-reed *Sparganium erectum*. Seversl of the ditches were heavily shaded by hawthorn *Crataegus monogyna* dominated scrub.

Ephemeral / Short Perennial

A wide variety of species were recorded within the various areas of ephmemeral/short perennial habitat present. These included grasses *Festuca* sp., mosses, common ragwort

Senecio jacobea, plantain *Plantago* sp., dove's-foot crane's-bill *Geranium molle,* flea bane *Pulcaria sp.,* bristly oxtongue *Picris echiodes*, teasel *Dipsacus* sp., and clover *Trifolium* sp.

Hedgerow

The only hedgerow found on site was in Plots 4 and 6/7. Plot 4 possessed a 2 m high planted hedgerow along the boundary between the area and the road. Species included hawthorn *Crataegus monogyna*, willow *Salix* sp, alder *Alnus glutinosa*, dog rose *Rosa canina*, gorse *Ulex europaeus*. Ash *Fraxinus excelsior* and alder *Alnus glutinosa* standards were noted planted within the line of the hedgerow. That in Plot 6/7 was a newly planted hawthorn *Crataegus monogyna* dominated hedge adjacent to the road.

Marginal Vegetation

Marginal vegetation was recorded in Plot A and 2B predominately around the edges of the open water areas. Species included common reed *Phragmites australis* with some reedmace *Typha* sp. also noted. The vegetation extended up to 4 m in width from the edge of the pools. Another small rectangular area was located in Plot 4 comprising reedmace reedmace *Typha* sp. and willowherb *Epilobium* sp.

Marshy Grassland

Two areas of marshy grassland were noted within Plot 1, with others in Plots 5 and 6/7. These areas were dominated by soft rush *Juncus effusus*, common couch *Elytrigia repens*, cocks foot *Dactylis glomerata* and field wood-rush *Luzula campestris*.

Open Water

Open water was found in Plots 2A, 2B and 5. Within Plot 2A/2B, five areas of open water were recorded. The first significant area was in the north-western corner of the area and comprised a linear feature approximately 30m x 7m. A second large area of open water was noted in the central section of this area, approximately 100 m x 30 m. In addition, a number of channels totalling 400 m in length were found, which had predominately straight sides and were approximately 5 m in width and during the survey contained standing water with occasional patches of marginal vegetation. In the north-eastern section of the area the waterbody had steep sides with marginal vegetation around the edge. The water body in Plot 5 appeared to be relatively deep and had no floating vegetation

Poor Semi-Improved Grassland

Areas of poor semi-improved grassland were observed in all Plots. Dominant species included common couch *Elytrigia repens*, false oat-grass *Arrhenatherum elatius*, cock's-foot

Dactylis glomerata, plantain *Plantago* sp. and clover *Trifolium* sp. Additional species found included cleavers *Galium aparine*, a number of vetch species *Vicia* sp., and tall ruderal species such as ragwort *Senecio jacobaea*, thistle *Cirsium* sp. nettle *Urtica dioica*, cow parsley *Anthriscus sylvestris*, sea beet *Beta vulgaris* subsp. *maritima,* teasel *Dipsacus* sp. and alexanders *Smyrnium olusatrum*. There was no apparent management of this habitat, apart from grazing by rabbits.

Scattered Scrub

Scattered scrub found only in Plots 2A and 2B, predominately along the banks next to the open water habitats and along the bank slopes surrounding the area. Species included bramble *Rubus fruticosus* agg. hawthorn *Crataegus monogyna* and gorse *Ulex europaeus*, dog rose *Rosa canina* in addition to butterfly-bush *Buddleia davidii*.

Tall Ruderal

An area of tall ruderal species was noted in Plot 1 associated with the semi-improved grassland in the north-eastern corner of the area. This included species such as ragwort *Senecio jacobaea*, thistle *Cirsium* sp. nettle *Urtica dioica*, cow parsley *Anthriscus sylvestris* and sea beet *Beta vulgaris* subsp. *maritime.* A second area was found in Plot 8/9/10/11, which was dominated by cow parsley *Anthriscus sylvestris*, hogweed *Heracleum* sp., nettle *Urtica dioica* and alexanders *Smyrnium olusatrum*.

Trees and Woodland

The development site possessed very few trees, and where they occurred they were scattered. They included elder *Sambucus nigra*, hawthorn *Crataegus monogyna*, willow *Salix* sp. and alder *Alnus glutinosa.* There was a line of poplars *Populus* sp. Aling the railway which formed the Northern boundary to Plot 7

An area of recently planted, plantation broad-leaved woodland (trees to 1.5 m high) was noted to the north of the power station. Species include oak *Quercus robur*, dog rose *Rosa canina*, willow *Salix* sp., ash *Fraxinus excelsior* and hawthorn *Crataegus monogyna*.

4.5.4 Water Vole Surveys

In 2007 water vole surveys were conducted for the 4 ponds shown on Fig 4.25, together with the surrounding ditches, the focus of these surveys was to provide mitigation area for the 2 ponds that were to be destroyed (P1 and P2 Fig 4.25). An updated water vole survey was undertaken in the spring of 2011 to establish the current population of water voles in the areas to be lost and retained. This was undertaken using conventional field survey technique , with population estimates made using Eqn 2.1. Table 4.4 details the characteristics of each pool together with the observed water vole signs, and Table 4.5 provides the water vole population estimates. Appendix 6 contains plans showing the locations of the survey field observations.

Reference	Dimensions of water-bodies in Metres (Approximate)	Water	Vegetation	Evidence of Water Voles Recorded and number of recordings	
P1	Dimensions: 200m x 30m Depth: 1.0 m Slope angle: 45-55°	Depth: 60 – 80cm Clarity: moderate-poor Flow: none	A large area of open water with approximately 5% cover of marginal vegetation comprising reedmace. No aquatic vegetation was noted within the waterbody. Bankside vegetation included greater willowherb, fleabane and gypsywort.	Latrines: yes Grazing: yes	Burrows: 0 Footprints: 0
P2	Dimensions: 300m x 40m Depth: 12 m Slope angle: 45-55°	Depth: 20cm – 100cm Clarity: moderate-poor Flow: none	A large area of open water with a narrow area at the southern end. Within the southern area there are large beds with reed-mace, with smaller clumps throughout the rest of the water-body. Aquatic vegetation included small pondweed. The eastern bank is vegetated with gorse and bramble, of varying density. The remaining habitat comprises unimproved grassland.	Latrines: 1 Grazing: 4	Burrows: 1 Footprints: 0
P3	Dimensions: 400m x 30m Depth: 2.0 m Slope angle: 45-55°	Depth: 60cm-150cm Clarity: moderate-poor Flow: none	A large area of open water with a narrow area at the southern end. Within the southern area there are large beds with reed-mace, with smaller clumps throughout the rest of the water-body. Aquatic vegetation included small pondweed. All the banks are vegetated with gorse and bramble with some interspersed tall ruderal species.	Latrines: 1 Grazing: 15	Burrows: 4 Footprints: 0

Table 4.4 – continued below

P4	Dimensions: 80m x 30m Depth: 2.5 m Slope angle: 45º	Depth: 40cm – 200 cm Clarity: moderate Flow: none	A large area of open water. There were no areas of marginal vegetation and emergent vegetation was sparse. It was not possible to identify the submerged vegetation as access to the water was not safe. The surrounding habitat to the east and south was bare ground and unimproved grassland. To the north and west was bramble and gorse scrub with interspersed tall ruderal species.	Latrines: 2 Grazing: 8	Burrows: 2 Footprints: 0
Ditch 1	Width: 1.5m Depth: 1.0m Slope angle: 45º	Depth: 40cm Clarity: moderate-poor Flow: none	A small section of ditch extending south-west from Waterbody 1. Species included reedmace, fleabane, willowherb, bristly ox-tongue and sea club rush.	Latrines: yes Grazing: yes	Burrows: 0 Footprints: yes

Table 4.4 Water Vole Survey Details for Each Pool at Kingsnorth in 2011

Pond Reference	Number of marker latrines recorded	Estimated number of water voles
Pond 1 P1 (to be lost)	3	4
Pond 2 P2 (to be lost)	78	55
Pond 3 P3 (retained)	24	18
Pond 4 P4 (retained)	8	7
Ditch 1 D1 (retained)	2	3

Table 4.5 Estimate of Water Vole Numbers at Kingsnorth in 2011

4.5.4 Pond Creation and Mitigation Works

The mitigation works that were undertaken to compensate for the loss of Ponds P1 and P2 are shown on Fig 4.24. These works comprised Ponds X,Y and 3(created) created in 2010/11, Pond 1 created in 2011 and Ponds 2A, 2B and H all of which were completed during the period November 2011 to April 2012. Ponds 3(retained) and 4 had been retained from the pre-development period as they had been deemed suitable as water vole habitats. Due to the high amount of pulverised fly ash (PFA) within the topsoils, artificial liners were used for the created ponds to minimise the risk of water seepage from the pond bottoms. Photographs of the Ponds are provided in Appendix 7.

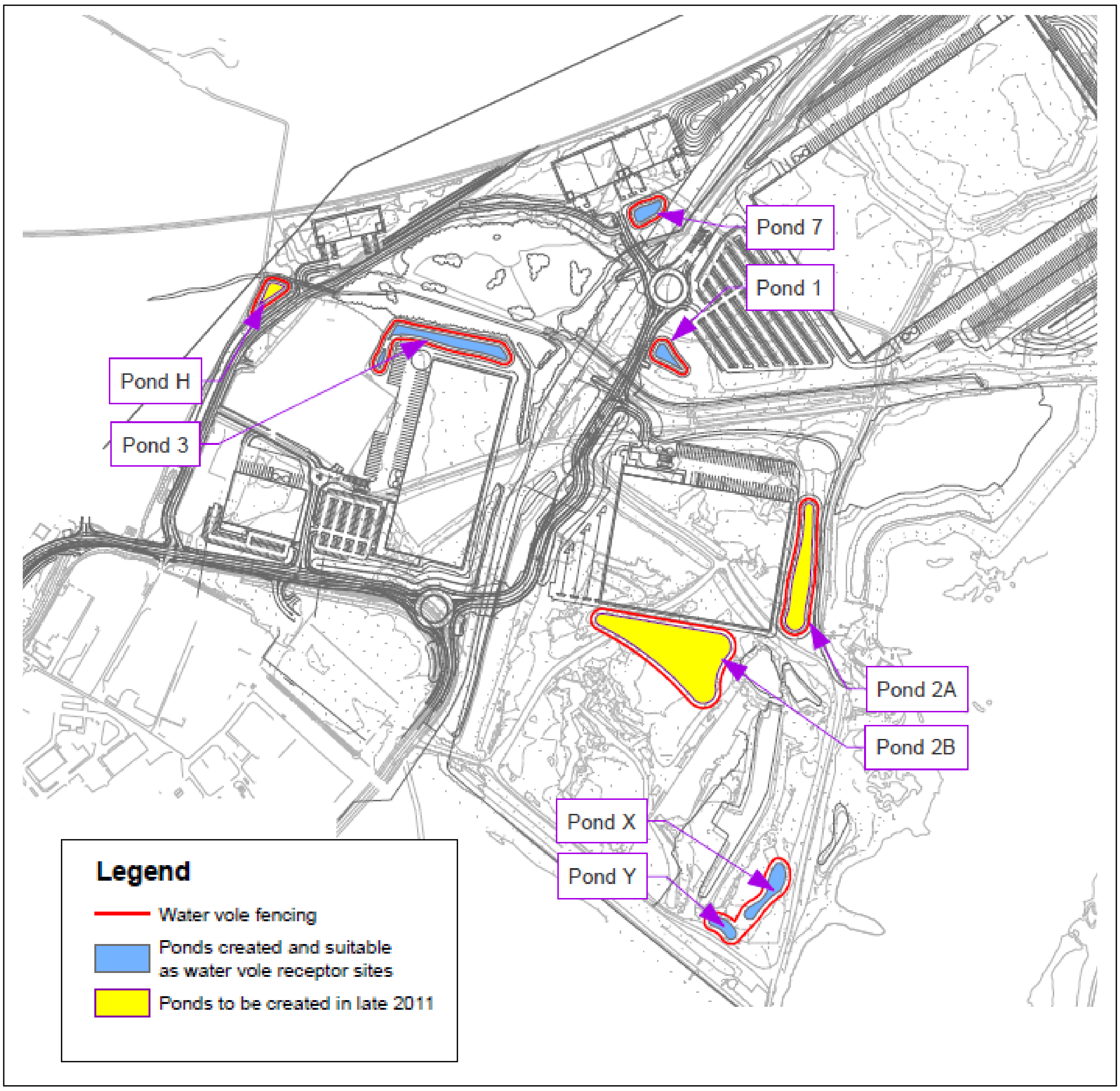


Fig 4.25 Kingsnorth Water Vole Mitigation Scheme Status Early in 2011
(MEL, 2010b)

Southern Bank Emergent Species:		
70%	Common reed*	*Phragmites australis*
10%	Flowering rush*	*Butomus umbellatus*
10%	Pond sedge*	*Carex riparia*
5%	Sea club rush	*Bolboschoenus maritimus*
5%	Soft rush	*Juncus effusus*
	* species to be planted in mono-specific stands	
Southern Bank Marginal Plants (planted in coir rolls):		
13%	Amphibious bistort	*Polygonum amphibium*
10%	Brooklime	*Veronica beccabunga*
6%	Fool's water-cress	*Apium nodiflorum*
13%	Greater spearwort	*Ranunculus lingua*
10%	Gypsywort	*Lycopus europeus*
10%	Marsh marigold	*Caltha palustris*
10%	Water cress	*Rorippa nasturtium-aquaticum*
10%	Water forget-me-not	*Myosotis scorpioides*
10%	Water mint	*Mentha aquatica*
8%	Water plantain	*Alisma plantago-aquatica*
Northern Bank Emergent Species:		
8%	Burr-reed*	*Sparganium erectum*
44%	Common reed*	*Phragmites australis*
4%	Common spike-rush	*Elocharis palustris*
8%	Flowering rush*	*Butomus umbellatus*
8%	Pond sedge*	*Carex riparia*
4%	Purple loosestrife	*Lythrum salicaria*
8%	Reed canary grass*	*Phalaris arundinacea*
4%	Sea club rush	*Bolboschoenus maritimus*
4%	Soft rush	*Juncus effusus*
8%	Yellow flag iris*	*Iris pseudacorus*
	* species to be planted in mono-specific stands	
Northern Bank Marginal Species:		
13%	Amphibious bistort	*Polygonum amphibium*
10%	Brooklime	*Veronica beccabunga*
6%	Fool's water-cress	*Apium nodiflorum*
13%	Greater spearwort	*Ranunculus lingua*
10%	Gypsywort	*Lycopus europeus*
10%	Marsh marigold	*Caltha palustris*
10%	Water cress	*Rorippa nasturtium-aquaticum*
10%	Water forget-me-not	*Myosotis scorpioides*
10%	Water mint	*Mentha aquatica*
8%	Water plantain	*Alisma plantago-aquatica*
Floating-Leaved Vegetation:		
-	Yellow Water-Lily	*Nymphaea lutea*
-	White Water-Lily	*Nymphaea alba*
Aquatics / Oxygenators:		
-	Common water starwort	*Callitriche stagnalis*
-	Hornwort	*Ceratophyllum demersum*
-	Water crowfoot	*Ranunculus hederaceaus*
-	Broad-leaved pondweed	*Potamogeton natans*
-	Water milfoil	*Myriophyllium spicatum*
-	Water soldier	*Stratiotes aloides*

Table 4.6 Planting Regime Employed in the Kingsnorth Mitigation Pond Creation Works

The design of the mitigation ponds was in accordance with the guidance provided in the Water Vole Conservation Handbook (Strachan and Moorehouse, 2006). In the pond creation works, shelves were incorporated into the design to provide a range of water level conditions, and coir rolls were employed to aid rapid vegetation establishment. The coir rolls were planted with the species detailed in Table 4.6 and banks were seeded with a wildflower mix. As part of the mitigation strategy, reedbed turves were removed from Pond 2 during its destruction and temporarily stored on site. These were subsequently replanted along selected edges of the ponds. These measures were designed to ensure suitable water vole habitats were created.

4.5.5 Water Vole Release

The water vole survey of 2011, was subsequently complemented by a further survey in 2012 of the ponds which were retained and those that had been created that did not have exclusion fencing. Using these survey results and employing Eqn 2.1, estimates were made of the numbers of water voles present. Although Eqn 2.7 gives an estimate of the total water vole population, in terms of translocation and release it is important to understand the number of breeding units (i.e. breeding female territories), given the fact that male and offspring water vole territories overlap with breeding female territories. Thus the number of territorial adult female water voles, and thus breeding units, within the ponds was assessed based on the assumption that each adult female water vole’s territory will contain 6 marker latrines (after Woodroof et al.,1998, cited in Strachan and Moorhouse, 2006).

Table 4.7 provides a summary of the number of marker latrines that were recorded at each pond, and the estimated number of breeding units in each. Two of the ponds on the site (P3 and P4) were retained and the others shown in Table 2.2 were created in 2010 / 2011.

Table 4.7 clearly shows that within the development site, water voles were using the following retained and created ponds: Pond P3, Pond P4, Pond 3, Pond 7 and Pond X.

A pre-release assessment of the various ponds, including the use of the habitat assessment system described in Sect 3.3, was undertaken to evaluate their capability to support the planned water voles release. It was found that the banks of Pond 2A were still bare ground and it was therefore judged to have inadequate vegetation to support a population of water voles, and was excluded from the 2012 release programme. The vegetation in and around all of the other ponds was well established.

Pond Reference	Number of Marker Latrines Recorded	Estimate of Number of Water Voles	Estimate of Number of Breeding Units
Pond P3 (retained)	17	13	3
Pond P4 (retained)	10	8	2
Pond 1 (created)	1	1	1
Pond 3 (created)	18	14	3
Pond 7 (created)*	0	0	0
Pond X (created)	3	4	1
Pond Y (created)	0	0	0

* No evidence of water voles were noted at Pond 1 during the surveys in May 2012, however, during the pre-release assessment works in August 2012, one recently active latrine was noted around this pond.

Table 4.7 Estimate of Number of Water Voles and Number of Water Vole Breeding Units

Ponds P3 and P4 had been retained from the original water bodies present on site, and previous surveys had indicated that they could support additional water vole population.

Ponds 1, 7, X and Y had been used as receptor sites during the 2011 trapping and translocation programme. Ponds X and Y were deemed suitable for inclusion in the release programme, and although Pond 1 had limited evidence of habitation, because it had good connectivity with neighbouring water bodies it was also included.

Water vole exclusion fencing was erected around Ponds 2B and H following their creation to prevent colonisation prior to the release.

Table 4.8 gives the length of water vole habitat that the pre-release assessment showed to be available for the 2012 water vole release, together with notes on the status of each pond. The length of water vole habitat given in Table 4.8, totalled 945 m, of which 665 m was habitat that contained no water voles.

During the pond creation and mitigation operations in 2011, a number of the trapped water voles had been taken off site by Derek Gow Consultancy Ltd (2012) to form the base stock for the breeding programme. By August 2012 a total of 54 water voles were deemed to be of suitable weight for release at the site at Kingsnorth: 31 males and 23 females. Of these individuals, 17 were of sufficient weight for hard release (Figure 4.25) with the remainder subject to soft release (see Sect 3.6).

Plot Ref.	Pond/Ditch Ref.	Length of Potential Water Vole Habitat (m)	Pond Suitable for Water Vole Release	Notes
Plot 1	Pond 1 Balancing Pond	100	Yes – low numbers of water vole recorded using this pond in August 2012 so only suitable for low numbers to be released	Pond to also form balancing function
Plot 2A	Pond 2A Balancing Pond	400	No. Bankside habitats not suitably established as water vole habitat.	Pond to also form balancing function
Plot 2B	Pond 2B Balancing Pond	390	Yes – completed, aquatic and bankside habitat suitable for water voles. No current population of water voles due to water vole exclusion fence.	Pond to also form balancing function
Plot 3	Pond 3 Balancing Pond	400	No – water voles already well established on this pond.	Pond to also form balancing function
Plot 5	Pond 7 Balancing Pond	100	Yes – pond and habitats well established. No water voles recorded at the pond in 2012.	Pond to also form balancing function
Plot 6/7	Pond H Balancing Pond	85	Yes – pond is well established. No current population of water voles due to water vole exclusion fence.	Pond to also form balancing function
Retained habitat area	Pond X	180	Yes – low numbers of water voles recorded using this pond in 2012.	Pond to also form GCN habitat
Retained habitat area	Pond Y	90	Yes – no water voles recorded using the pond in 2012.	Pond to also form GCN habitat
Total established water vole habitat length (August 2012)		**945**		

Table 4.8 Summary of Available Pond Edges for Water Vole Release in 2012

Pond Reference	Number of Water Voles Hard Released		Number of Water Voles Soft Released	
	Male	Female	Male	Female
Pond 1 (created)	1	1	0	0
Pond 2B (created)	0	3	8	3
Pond 7 (created)	0	0	4	2
Ponds X and Y (created)	2	5	1	1
Ponds P3 and P4 (retained)	5	1	5	1
Pond H (created)	0	0	3	3

Table 4.9 Details of August 2012 of Water Vole Release

<u>Fig 4.26</u> Hard Release of a Water Vole at Kingsnorth

CHAPTER 5 MONITORING PROGRAMME AND RESULTS

5.1 INTRODUCTION

Following the initial site surveys and subsequent enhancement scheme design and implementation, monitoring programmes were undertaken, which ranged in duration from between three to five years, depending on when the works were completed. These monitoring programmes focused on habitat suitability, using the scheme developed and described in Sect 3.3, and water vole presence, following the standard methods of Sect 3.4.

The following sections discuss the results obtained at each of the four research sites, which an overall discussion and evaluation presented in Chapter 6

5.2 KIRKBY IN ASHFIELD

5.2.1 Post-enhancement Monitoring

As described in Sect 4.2, the site comprised the former sewage treatment works and drying beds which had been abandoned for a number of years. The land was set aside by Severn Trent Water as part of their Biodiversity Action Plan commitments, in which water voles are a priority species. However, there has been no management on the site since enhancement works were undertaken and the water vole release in 2005.

Table 5.1 details the habitat suitability assessment throughout the research period, both pre- and post-enhancement. Table 5.2 provides the same information for water vole survey results.

The pre-enhancement water vole surveys and Habitat Assessment surveys undertaken in the late spring/early summer of 2008, 2009, 2010 and 2011 identified the presence of water voles in the following locations (see Fig 4.5):

- Southern boundary ditch (Ditch D1),
- Two ponds adjacent to the southern boundary (Ponds P1, P2 and P2 (2008/9 only));
- Four lagoons along the southern boundary (Lagoons L1(western most) to L4); and,
- Large pond within centre of the site Pond P1.

	Year					
Water Vole Habitat Assessment	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Good (Green)	D1, P1, L1, L2, L3, L4	D1, P1, L1, L2, L3, L4	D1, P1, L1, L2, L3,	P1, D1 (west), D2 (west), L2, L3	P1, D2 (west), L3, L2	P1, L3
Moderate (Amber)	D2 (west), P2, P3	D2 (west), P2, P3	D2 (west), P2, P3, L4	D1 (west) L1, L4	D1 (west)	D1 (west), D2, P2, L2
Poor (Red)	D2 (east), *R1	D2 (east), *R1	D2 (east), *R1	D2 (east), *R1	D1 (east), D2 (east), *R1, L1, L4	D1 (east), *R1, P3, L1, L4
D1= Features surveyed on site. *Features outside of study area.						

Table 5.1 Summary of Water Vole Habitat Assessment at Kirkby in Ashfield

Year	Number of Marker Latrines	Estimated Population of Water Voles
2008	28	21
2009	25	19
2010	14	11
2011	16	12
2012	12	10
2013	4	4
Bold: Year of habitat enhancement (February) 2011		

Table 5.2 Water Vole Survey Results for Kirkby in Ashfield

From the preliminary survey undertaken in the spring of 2008, as discussed in Sect 4.2 and the subsequent 2009 and 2010 surveys (see Figs A8.1 and A8.2 in Appendix 8), the majority of the water vole evidence was observed along ditch D1 and lagoons L1-L4 with burrows, grazing, latrines and footprints recorded. Latrines and grazing were found within the ponds adjacent to the Southern boundary (P2 and P3) suggesting that the water voles moved up to 20m over open ground to inhabit in these areas. Only a small amount of grazing was observed within the large central pond P1. As explained in Sect 4.2 there was an area to the west of P1 which was unsafe to monitor due to deep silt levels, this thus provided a constraint to producing a fully comprehensive survey.

The evidence (Table 5.2) identified from the pre-enhancement surveys showed a healthy, though possibly declining colony of water voles concentrated along the wet ditch to the South and the four lagoons. No evidence was recorded along the second ditch (D2), which was chocked with vegetation, and minimal evidence within the pond P1.

The first monitoring survey was undertaken in spring 2011. The results of the survey found a shift in the evidence of water voles within the site, Figure A8.3 in Appendix 8 shows the location of water vole evidence and Table 5.2 details the water vole latrine count. Water vole evidence was found within the following locations on site:

- Southern boundary ditch,
- Two lagoons along the southern boundary; and,
- Large pond within centre of the site.

A higher number of grazing sites were located with the central pond (P1) than in previous years, but the latrines had reduced in number overall. The evidence along the southern boundary ditch (D1) was concentrated in the western portion rather than along the entire length as in the 2009 and 2010 surveys. The water vole evidence had also reduced along the lagoons, with latrines found in only two of the four lagoons.

The second monitoring survey was undertaken in spring 2012, the results of which showed a further shift in evidence of water voles within the site, as demonstrated in Fig A8.4 in Appendix 8 and a noticeable decline in numbers (Table 5.2). Water vole evidence was found within the following locations on site:

- One lagoons along the southern boundary; and,
- Large pond within centre of the site.

As with the 2011 survey there were a good number of grazing sites within the central pond, but latrines had reduced further. The evidence along the southern boundary ditch (D1) within this monitoring year comprised of grazing only, and no latrines or burrows were recorded. Indeed the only latrines recorded were within the eastern most lagoon.

The third post monitoring year 2013 found that the water vole evidence had shifted in further (see Fig A8.5 in Appendix 8) with the dominant evidence recorded within the central pond (P1) with a large amount of grazing areas - however no latrines were recorded. In fact only three latrines were recorded in the fourth lagoon (eastern most lagoon (L4)) all other evidence was predominantly grazing and runs. No water vole evidence was recorded within the three other lagoons and the Southern boundary ditch. In total as shown in Table 5.2, only 4 latrines were observed across the entire site

Table 5.2 summarises the water vole habitat classification at Kirkby-in-Ashfield over the full study period. A study of this table indicates that most influential factors relating to the decline in water vole numbers within this site were loss of standing water and shading through scrub/vegetation dominance. The table demonstrates the decline in vegetation quality of Ditch 1 and the lagoons due to these factors resulting from a lack of any management plan being implemented.

5.2.2 Conclusions

The initial water vole surveys undertaken in 2008 and 2009 identified a healthy colony of water voles. These were located predominately along ditch D1 and Lagoons L1-L4. The survey also identified an area of habitat which was recorded as having minimal usage by water voles (Pond P1 and Ditch D2). Ditch D2 was therefore de-silted and cleared to provide an increase in water vole habitat and connectivity into other areas.

The lack of any management has resulted in the siltation of the ditches (D1 and D2) and lagoons L1, L2 and partial siltation of L3, which have lost standing water and started drying up. Within 5 years of the initial survey being undertaken in 2008, since there has been no management, approximately 20m of the eastern ditch had dried up to a point where vegetation was growing within the channel, in addition one of the four lagoons had dried up completely and a second had partially dried. This in turn has reduced the suitable habitat available to the water voles. It is not known if a change in drainage within the surrounding area, which feeds into the ditches, has occurred. However, even throughout the extensively wet winter of 2012 and in spring 2013, the ditches/lagoons were susceptible to drying. The human impact on the ditches, which included dumping large amounts of hay into them, was also noted during the two monitoring years.

The ditch to the west of the site was however choked with reedmace, and bittersweet completely covered the ditch. Since on the two years surveyed, no evidence of water voles were recorded along this ditch, it is assumed that the dense vegetation and shading has reduced the suitability of the habitat for water voles. The results identified that the majority of the water voles were utilising the eastern ditch and four lagoons with only a small amount of grazing within the central pond. This would indicate that the western ditch was potentially limiting the movement of water voles on site.

Consequently the western ditch was de-silted to both improve the corridor between the water bodies and to create connection with habitat of a suitable quality for water voles. The amount of suitable habitat was thereby increased by 120 m.

The water vole monitoring surveys found from the evidence of the post manipulation works that water vole activity had shifted westwards. Interpretation of the monitoring results indicated that this was due to two factors: the improved connectivity of the western ditch; and the partial drying up of the eastern most section of the southern boundary ditch.

As the study site was small in area, with the relevant land ownership only covering a small portion of the total available habitat, the potential for enhancement was limited. This is often the case for sites where mitigation is undertaken, especially when wider scale works are not possible due to either cost or land ownership issues.

The enhancement on site only had a limited effect on the population of water voles. The natural succession on site from the increasing scrub along the southern boundary ditch and around the lagoons, together with the gradual siltation and eventual drying up of the ditch and lagoons on site resulted in the loss of a significant amount of suitable water vole habitat.

The evidence from the water voles surveys, shows that the total population has reduced from over 20 in 2008 to 4 in 2013. Although this colony has connection to adjacent wet ditches, and thus judged to be part of a wider metapopulation, the drying out on site of the ditch has hindered immigration/emigration to neighbouring colonies. It is therefore concluded that long term ongoing management of sites with an existing colony of water voles is of great importance in order to maintain the required habitat. In addition, the management needs to be long term in order to maintain the quality of the habitats, so that they are sustainable for water voles, and thereby prevent their loss from a location.

However, the evidence also shows that small scale enhancement works do work. The water voles on site showed a response to the works, which in this instance was generally increased movement into other areas of the site, rather than using the ditch directly for burrowing.

The overall outcomes of the study suggests that the water vole colony was part of an overarching metapopulation connected to other colonies through a network watercourses.

The decrease in the habitat suitability, especially the wet ditch drying out, would suggest that this has fragmented the Kirkby water vole colonies from others and has resulted in the gradual drop in numbers due to the reduction in habitat quality and water vole no longer moving between other colonies of the metapopulation. The fragmented colony has thus become too small for a viable population to be maintained. To rectify this and re-connect the colony with the wider metapopulation would require additional enhancement works and an understanding of why the ditch has run dry. With the current low number left the eventual extinction of this colony is highly likely.

5.3 NETHERIDGE

5.3.1 Post-enhancement Monitoring

The habitat classification survey in 2008 (Fig 4.12) and 2009 (Fig A9.1 in Appendix 9) found a variety of habitat type on site, and in habitat classification terms, a majority were good (green) and moderate (amber) with occasional poor (red). The main factor reducing the habitat quality was shading from scrub and hedgerows, but in addition, a number of banks were steep, almost vertical, which resulted in a reduction of dense vegetation and an increase in bare ground resulting in erosion. The factors that increased the habitat quality included connectivity and dense marginal vegetation. Although not classed as a factor the absence of mink was also an important positive factor in favour of site.

The red features from the habitat classification showed no evidence of water voles as they were completely shaded by bramble scrub or suffered from an absence of regular standing water – it is assumed these features were still be used for commuting. Amber features were subject to partial shading, whereas Green features comprised dense swards of marginal/bankside vegetation and good connectivity. Thus the monitoring surveys identified that shading and scrub encroachment needed to be suppressed by management to ensure the continuation of suitable habitat. It was strongly emphasised in the site management plan for implementation following the enhancement works described in Sect 4.3.3.

The habitat enhancement work, which reduced the shade and re-profiled the banks of the ditch making them shallower (reducing the angle from 80 degrees to 50/60 degrees) increasing the surface area for establishment of grassland/marginal vegetation, along with seeding and plug planting to increase the vegetation coverage, shifted the habitat classification from amber to green.

Table 5.3 shows the results of the water vole habitat classification at Netheridge for the complete study period, with post-enhancement habitat classification results for 2010 to 2013 shown on Fig A9.2 to A9.5 in Appendix 9. The most influential factors within this site were the vegetation cover, and shading through scrub/vegetation dominance, and the table shows the fluctuation of the enhanced ditch (feature 3 on the surveys) from amber to green as a result of management prescriptions being implemented.

Monitoring in 2008, 2012 and 2013 comprised trapping, whereas monitoring in 2009, 2010, 2011 was by field survey. The change in monitoring method was due to licencing changes and changes in the site manager. Although the field surveys identified similar areas of water vole presence in similar location to the trapping data, a number of the features on and off site (eg. locations 8, part of 7 in Fig 4.12) could not be fully assessed due to health and safety issues (steep bank sides and deep silt). The high capture of water voles in 2008 was expected and due to the release earlier in the year.

It is recognised that the water vole monitoring surveys have used a combination of trapping and field surveys, and have thus not been consistent throughout. However, the results do show the colony scattered throughout the site in similar locations (survey results for post-enhancement, 2010 to 2013 are given in Fig A9.2 to A9.5 in Appendix 9). Water vole evidence (latrines and grazing) along the ditch was identified within five months of the enhancement works being completed, and in addition a water vole was trapped for the first time along that feature in 2012 (Fig A9.4, Appendix 9). The summary results for the water vole surveys are presented in Table 5.4 and 5.5.

	Year					
Water Vole Habitat Assessment	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Good (Green)	1, 2	1, 2	2, 3	1, 2, 3	1, 2	1, 2, 3
Moderate (Amber)	3, 4, 6, 7, 8	3, 4, 6, 7, 8	1, 4, 6, 7, 8	4, 6, 7, 8	3, 4, 6, 7, 8	4, 6, 7, 8
Poor (Red)	4, 5	4, 5	4, 5	4, 5	4, 5	4, 5
1-7 = Features surveyed on site. 8 = Features outside of site boundary						

Table 5.3 Summary of Water Vole Habitat Assessment at Netheridge

Year	**Water voles**
2008	1 ♂, 22 ♀
2012	5 ♂, 1 ♀
*2013	3 ♂, 2 ♀
♂ male, ♀ female, Juv Juvenile * cold temperatures so surveys stopped to ensure no harm to water voles.	

Table 5.4 Water Vole Trapping Survey Results for Netheridge

Year	**Number of Marker Latrines**	**Estimated Population of Water Voles**
2009	4	4
2010	12	10
2011	7	6
Bold: Year of habitat enhancement (February) 2010, water vole survey in 2010 undertaken in Summer 2010.		

Table 5.5 Water Vole Population Estimates from Netheridge Field Survey Results

5.3.2 Conclusions

Like Kirkby in Ashfield, the Netheridge site was believed to be a colony of a wider metapopulation. The observations from the Netheridge study support the conclusion drawn from the Kirby in Ashfield site (Sect 5.2.2), that small scale habitat manipulation can have a positive impact on colonies of water voles. However, Netheridge had good connectivity, with a network of diches within adjacent farmland and thus the surrounding and connecting habitat, and this will also be a strong factor in long term success of the colony.

From the initial surveys and habitat classification results a length of ditch was identified, that had no water vole present, which could be enhanced on a small scale. Five months after the habitat manipulation was completed, signs of water voles were recorded within this section of ditch. In addition, an adult water vole was captured during trapping for the first time within the enhanced ditch. These early results showed a positive response by the water voles to the habitat manipulation. However, it was noted that the shading and scrub control, which had once reduced habitat suitability required a long term management programme to maintain the optimal “green” status.

The methodology for monitoring on this site changed for the period 2009 to 2011 and therefore did not have the desirable continuity. Despite this a study of the field signs (Table 5.5) showed that the water vole colony had maintained a stable level on site.

The evidence from the study would suggest that the site and the adjacent habitats provide connectivity with a number of adjacent water vole colonies within a wider metapopulation, which has resulted in a stable population. The enhancement works undertaken provided additional good quality habitat on site for water voles to colonise with thus slightly increased numbers. However, due to the number of connecting ditches and other stochastic influences, such as flood risk, the water vole population is likely to experience fluctuations in accord with metapopulation dynamics as documented in the literature.

5.4 BRANDON MARSH

5.4.1 Post-release Monitoring

Table 5.6 identifies the pre-release water vole habitat classification for the various pools at Brandon Marsh Nature Centre. The most influential factors within this site that influenced where water voles should be released were the vegetation cover, presence of predator fish (i.e. pike) and flooding, consequently the water voles were only released into water bodies with predominantly "green" areas outside of the flood zone (see Sect 4.4.3).

The post-release monitoring results at Brandon Marsh were poor – see Figs A10.1 and A10.2 in Appendix 10. In 2012 only a few latrines were recorded around the Newlands area, together with couple of sightings of water voles swimming across East Marsh Pool. The survey method employed in 2012 was to use field signs (i.e latrines/grazing/burrows) which proved problematic, especially those due to the marshy wet conditions on site caused by an above average rainfall over winter 2011/2012 and spring 2012. Trapping was undertaken as an alternative method of surveying after the difficulties in 2011/2012, these were place in suitable areas around the pools where the water voles were released (See Fig A10.3, Appendix 10). The 2013 surveys captured no water voles on site.

However, loss of water voles from Brandon could not be completely confirmed due to the complex nature of the habitats, especially dense reedbeds and marshy areas containing dense sedges and grasses, and the associated safety issues with regard to access for survey purposes. Indeed if the River Avon was not connected to the site it is anticipated that the water vole colony would have established by dispersing within the ponds on site.

Water Vole Habitat Assessment	**Water Feature**
Good (Green)	The Newlands, Swallow Pool, Grebe Pool.
Moderate (Amber)	Grebe Pool, West Marsh Pool, River Pool, East Marsh Pool. Sections of Swallow Pool and Grebe Pool
Poor (Red)	Teal Pool, Central Marsh Pool. Small section of Swallow Pool

<u>Table 5.6</u> Summary of Water Vole Habitat Assessment at Brandon Marsh

5.4.2 Conclusions

The water vole release programme at Brandon Marsh was based on two factors.

1) Mink control being undertaken two years before the release, both upstream and downstream on the River Avon, and the constant control within Brandon Marsh. As a consequence, the numbers of mink recorded within the site and surrounding area had dropped considerably. Furthermore, due to the types of habitat on site and the continued control, it was considered that mink was a detrimental factor for the successful introduction of water voles.

2) Natural predators which have been recorded on site including otter (*Lutra lutra)* and grey heron (*Ardea cinerea).*

3) The complex mosaic habitat which would provide good quality burrowing and/or nest building opportunities for water voles.

However, even with these factors in place, the release was not a success. It is considered that the main factor, which differentiated the Brandon Marsh release from the other release programmes, was the delay in the introduction of the water voles from July to September. As discussed in Sect 4.4.3, this resulted in the release of predominantly juvenile water voles, none heavier than 120g. Although studies have shown that water voles become sexually mature at 112gm for female and 115gm for male (eg. Moorhouse et al., 2008), several of the voles released had only just achieved this weight, but most were below. In addition to the maturity factor, the time of the year of the release occurred when water voles naturally disperse - “The timing of release for juveniles should coincide with spring/early summer vegetation food and cover abundance” (Gow, no date).

As the River Avon runs adjacent to the site it is speculated that a number of the released vole dispersed into it and were lost to Brandon Marsh. Anecdotal evidence from a local gamekeeper contacted the wildlife Trust to inform them that he had captured a water vole in a mink trap approximately 3.5 km downstream of Brandon Marsh and released it back into the River Avon. However, without surveying all connecting watercourse/ditches it was not possible to establish whether or not any water vole colonies had established off site.

Although there were no observed signs of water voles during the 2013 survey, it cannot be concluded that there are no water voles left within Brandon Marsh, especially as the conventional monitoring methods turned out to be unrealistic. Searching for the field signs of water voles became unreliable due to the lack of bank side edges, since a majority of the habitat along the edges was marshy or submerged resulting in any evidence quickly perishing in the wet conditions. Furthermore, the presence of ground and reed nesting birds also resulted in limited access. As a result of the 2012 problems, trapping was introduced into the monitoring programme and was undertaken in the spring and autumn. This was again limited by the wet/marshy ground conditions and nesting birds.

As a result of the experiences at Brandon Marsh, it is recommended that for a release project involving a reedbed with shallow marshy margins, that to facilitate monitoring a combination of floating rafts, to encourage latrine sites, and radio/PIT tagging (upon the assumption that access is permitted upstream and downstream which was not the case on this site) are employed. As previously discussed in Sect 4.4.3, although radio tracking was planned and the equipment purchased, in practice it was not viable due to the age of the water voles and issues related to the collar size and their rate of growth.

5.5 KINGSNORTH

5.5.1 Post-release Monitoring

The Kingsnorth site, the survey programme, mitigation and water vole release programmes were extensively discussed in Sect 4.5. The site is large and contained, and thus was regarded as housing a metapopulation of water voles, with consequent potential for migration between the various pools.

The post-release monitoring programmes in 2013 2014 and 2015 were all conducted using field signs, and were thus compatible with the original surveys conducted in 2011 and 2012. The plans showing the survey results are presented in Appendices 11, 12, 13, 14 and 15

Table 5.6 shows the water vole habitat assessment results for Kingsnorth over the study period, and Table 5.7 the water vole population present on site as estimated from the number of latrines. The most influential factors within this site with regard to habitat assessment were the vegetation cover density/establishment and maintaining water levels.

The water voles were release into the "green" and "amber" habitat areas, with lower numbers of water voles into the amber ones to compensate for the lower quality habitat, hence increased food source area per water vole required to sustain the individuals.

	Pre Works	**Works and Mitigation**		**Post Works Monitoring**		
Habitat Assessment	**2007**	**2011**	**2012 water vole release in summer**	**2013**	**2014**	**2015**
Good (Green)	P2, P3, P4,	P1, P3, P7, #P4, #P3, X	+P1, +P3, +P7, +#P4, +#P3, +PH, X	P1, P3, P7, 2b, #P4, #P3, +X	P1, P3, P7, 2b, #P4, #P3, +X	P1, P3, P7, 2b, #P4, #P3, +X
Moderate (Amber)	+P1	2b, Y	+2b, +Y,	+Y, +PH	+Y	+Y, 2a
Poor (Red)		2a	2a	2a	PH, 2a	PH

* Features destroyed as part of proposed development

\# Existing features left post development.

~ Outside works boundary

All other features are newly created.

\+ Ponds water voles release into

<u>Table 5.7</u> Summary of Water Vole Habitat Classification at Kingsnorth

Regarding the overall population Table 5.7 shows that it continues to thrive, although numbers fell between the 2013 and the 2014 surveys by 30%. This can, largely be attributed to the loss of water voles from Pond H, although the habitat quality of the pool remained "green". The numbers again appeared to fall between 2014 and 2015. However, the field survey in 2015 was hindered due to limited access to the retained pond P3 due to increased dense scrub along the higher steep banks, and western side becoming inaccessible due to the new habitat creation works being undertaken preventing safe access. Therefore an accurate population assessment on this pond, which holds the largest colony of water vole on site, could not be undertaken.

Lining failures occurred in Ponds H and Pond 3 (created) had areas of failed lining which has caused it to rise to the surface and an artificial island to form. However, this did not impact on the water voles or the habitat quality, as a health colony is still present. Pond H a smaller pond was far more problematic, the entire lining of the pond rose up and caused the equivalent of drying-up the pond, with all the water sandwiched between the liner and underlying sand – the habitat quality thus fell from “green” in 2012 to “red” in 2014/2015. Consequently, only a couple of grazing sites were recorded within this pond after the lining had lifted, and in one season the water voles had emigrated from the pond.

5.5.2 Conclusion

The results of the mitigation demonstrated that the water voles translocated into an “amber” area (2b) could survive and breed successfully, with the number of water voles being higher directly after the first breeding year of release. The ongoing management resulted in improvements to the pond through additional seeding and increasing the water level, and as a consequence the habitat status moved from “amber” to “green”, the monitoring surveys show a current sustained level of a low number of water voles. All the habitats identified as “green” which water voles were released into have sustained a number of water voles, although the numbers have reduced. It is surmised that this is due to dispersal around and off site.

The study has shown that pond liners can be used successfully in water vole mitigation when employed in combination with suitable habitat creation, here soft banking using materials such as coir roles and appropriate soil. However, as described above in Sect 5.5.1 with regard to Pond H and Pond 3 (created), is not installed correctly and the lining lifts or is damaged the results can cause adverse problems for water voles.

Overall the water vole mitigation undertaken at Kingsnorth was a success as the created habitats have maintained a successful breeding colony of water voles. Although the population numbers within the different ponds has fluctuated the Kingsnorth colony continues to thrive. The loss of the small Pond (H) through lining failure will be rectified as part of the ongoing management of the site under the Natural England Licence.

The total vole numbers presented in Table 5.7 indicate a relatively stable population, suggesting that the assumption of a metapopulation contained within the site is correct. At the larger ponds (3, P3 and 2b) large enough colonies have been established for successful breeding. The consistent records at the smaller ponds and new ponds would suggest that water voles are successfully moving between ponds/ditched around the site. However, given the development works and landscaping being undertaken on site, with vole translocation and pools coming on and being taken off line, this conclusion can only be tentative, and further study over an extended period is required to confirm this theory.

	2011	2012	2013	2014	2015
	Pre works		**Post works monitoring**		
Pond Reference	**Population Estimate Based on Number of Latrines**				
Pond 1 (lost)	3				
Pond 2 (lost)	78				
Pond 1 (created)	-	-	8	2	2
Pond 3 (created)	-	17	14	18	32
Pond 7 (created)	-	-	19	3	3
Pond X (created)	-	3	2	3	3
Pond Y (created)	-	0	0	0	0
Pond P3 (retained)	24	50	35	36	(2)
Pond P4 (retained)	8	17	9	7	2
Pond H (created)	-	-	0	1	0
Pond 2B (created)	-	-	20	5	6
Total	**113**	**87**	**107**	**75**	**50**
The distinct drop in population (2) recorded for P3 in 2015 was due to health and safety issues with regard to accessing the pond not previously experienced.					

Table 5.8 **Water Vole Population Estimates from Kingsnorth Survey Results**

5.6 SUMMARY

The study of the four research sites revealed a variety of outcomes. The Kirby in Ashfield and Netheridge sites complemented each other, in that the different management practices present demonstrated the importance of ongoing long term management to enable a sustained water vole population once enhancement has been completed.

At Brandon Marsh the importance of release timing and advanced planning to ensure the success of the subsequent monitoring programme were emphasised. The water vole mitigation programme at Kingsnorth proved successful, and was due in no little part to careful habitat creation measures. However, this scheme also demonstrated that although artificial lining can be used for pond creation, care must be exercised in its installation.

The habitat assessments on at Kirkby in Ashfield and Netheridge identified water voles using predominantly those habitats assessed as green, but not necessarily as territory areas since the green habitat in Kirkby were used for food source only. The water voles did survive in amber habitats, but the numbers reduced as expected. Although water vole presence was not expected within the red habitat areas, evidence of grazing was still recorded even though the loss of a key element (i.e. water) would result in them being vulnerable to predators.

Although for the introduction program at Brandon Marsh, the water voles were released into habitat assessed as predominantly “green”, this was considered unsuccessful due to other factors but the inability to monitor the site effectively means that is conclusion could not be confirmed. The water vole reintroduction at Kingsnorth in habitats assessed as green or amber (water voles released in lower numbers to the latter) appear to have resulted in a healthy population being maintained across the site. However, management issues have caused the rapid degradation of some green areas to red, and the water voles have moved away from the red areas, only using them for food sources.

CHAPTER 6 DISCUSSION AND EVALUATION

6.1 Introduction

The analysis of the survey results post-site works and water vole introduction, as presented in Chapter 5, together with the observations made regarding experiences at the four study sites, lead to some general points and conclusions regarding the factors influencing the success of habitat enhancement and mitigation schemes for this UK BAP species.

The following sections discuss the key outcomes from this research, and suggest further research that should be undertaken to consolidate and build upon these findings.

6.2 Water Vole Habitat Assessment

The development and the application of Water Vole Habitat Assessment system has been described in Sect 3.3, and the results obtained during its use indicated that it was a successful too, both for assessing a site's potential for enhancement and for monitoring purposes once the works have been completed. However, given the limited data obtained from the sites studied, together with the additional variables in play (eg. enhancement works, management practices, vole releases and site location within a wider metapopulation), analysis to assess the systems effectiveness can only be tentative. Section 6.2.1 explores the observed relationship between habitat quality and the observed vole populations

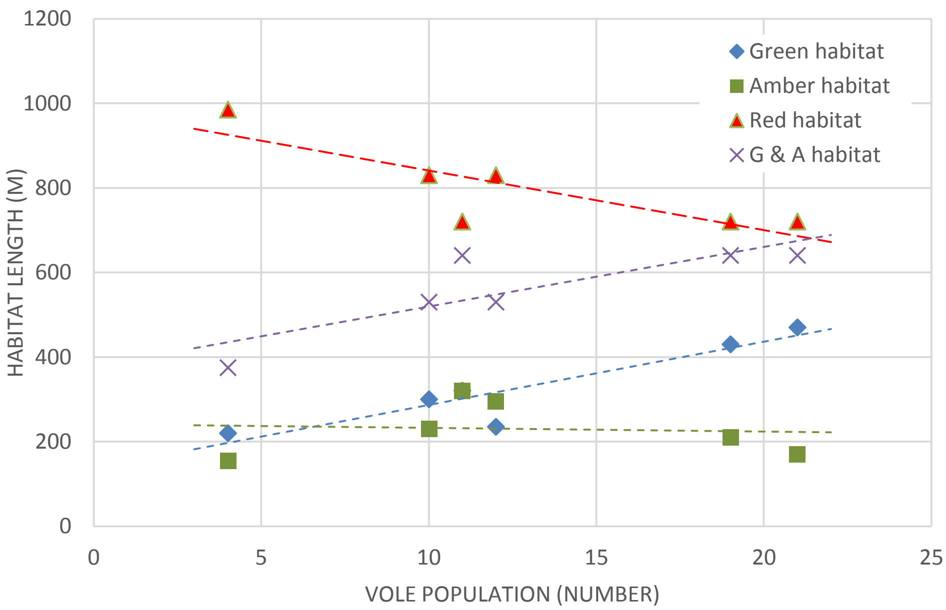
6.2.1 Evaluation of the Water Vole Assessment System.

Table 6.1 summarises for each of the sites studies, the habitat quality, using the traffic light system of the Water Vole Assessment system, in terms of the bank/perimeter length in metres, together with the observed water vole population. To simplify the analysis, the events which took place during the study period, such as enhancement works and vole releases have been ignored. Furthermore, adjustments have been made in the data for Kingsnorth to take account of ponds with exclusion fencing, ponds lost or becoming operational.

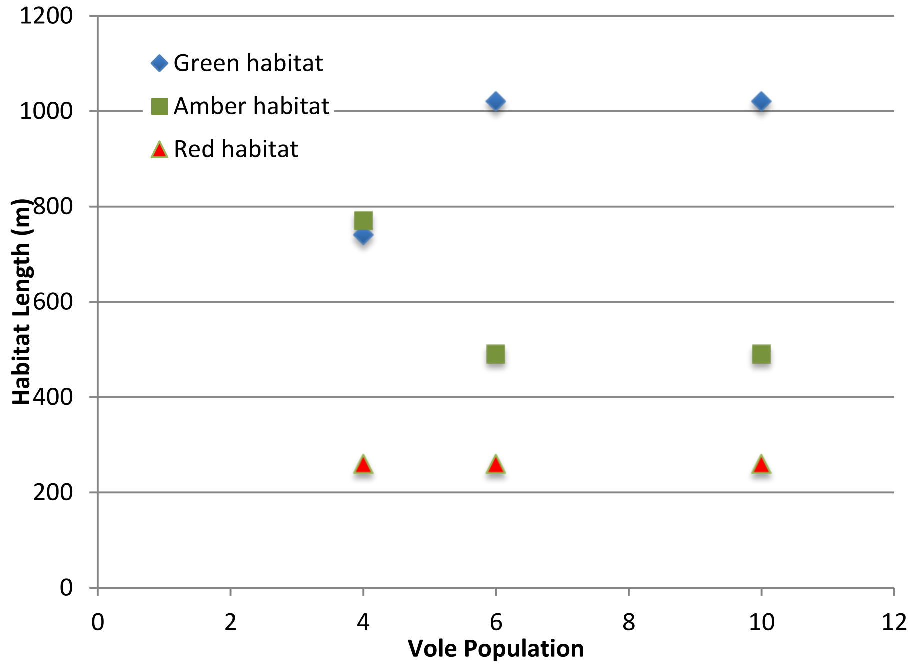
For each site a scatter graph was plotted for the green, amber and red habitat quality lengths against water vole population (Figs 6.1, 6.2 and 6.3). In addition, the data from all sites were combined to produce Fig 6.4. Linear trend lines have been included to facilitate interpretation.

Site	Year	Vole Population (number)	Habitat Length in m		
			Green	Amber	Red
Kirkby in Ashfield	2008	21	470	170	720
	2009	19	430	210	720
	2010	11	320	320	720
	2012	10	300	230	830
	2013	4	220	155	985
Netheridge from latrines	2009	4	740	770	260
	2010	10	1020	490	260
	2011	6	1020	490	260
from trapping	2008	23	740	770	260
	2012	6	930	580	260
	2013	5	1020	490	260
Kingsnorth	2011	84	1640	90	400
	2012	87	1640	90	400
	2013	107	2030	175	400
	2014	75	2030	490	85
	2015	48	1470	490	85

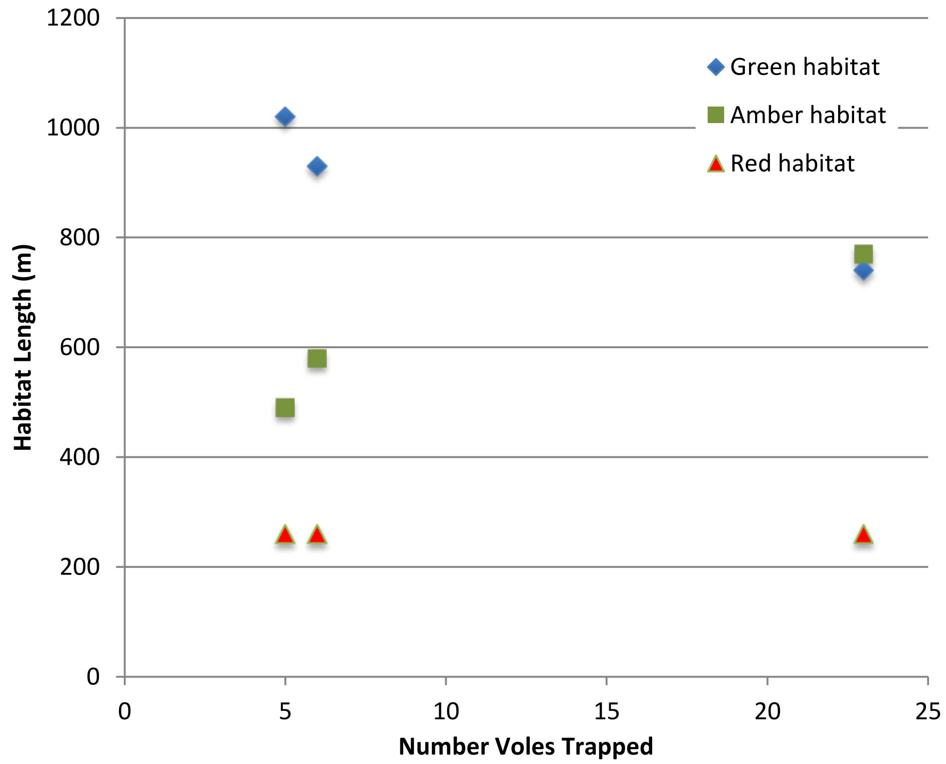
<u>Table 6.1</u> Observed Vole Populations and Habitat Quality Over the Study Duration



<u>Fig 6.1</u> Kirby in Ashfield – Relationship between Habitat Quality and Water Vole Population

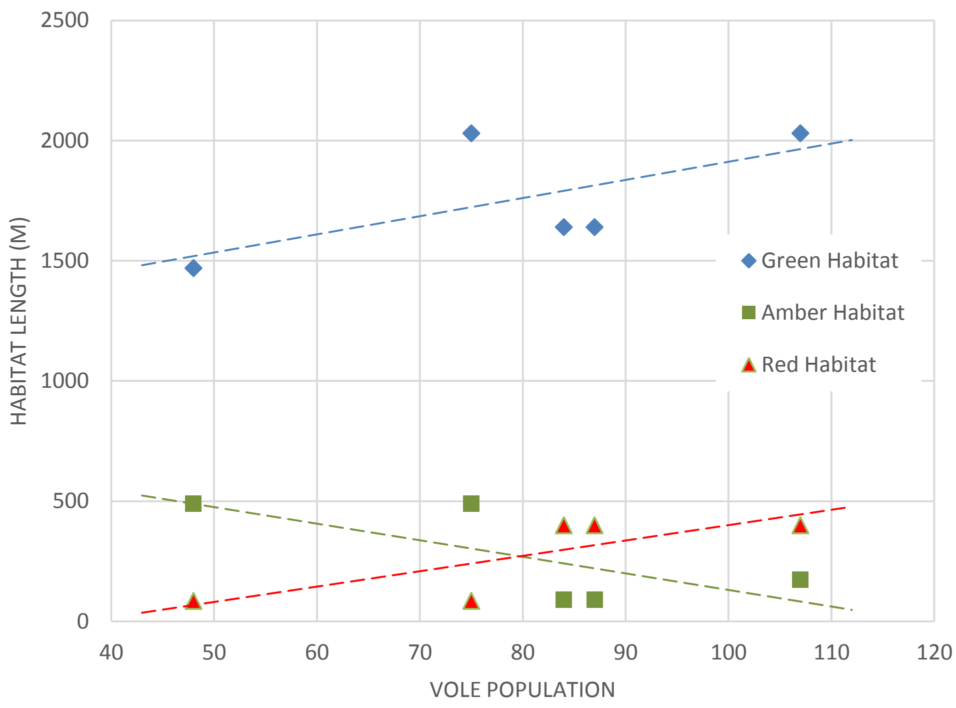


(a) Population Estimated from Number of Latrines

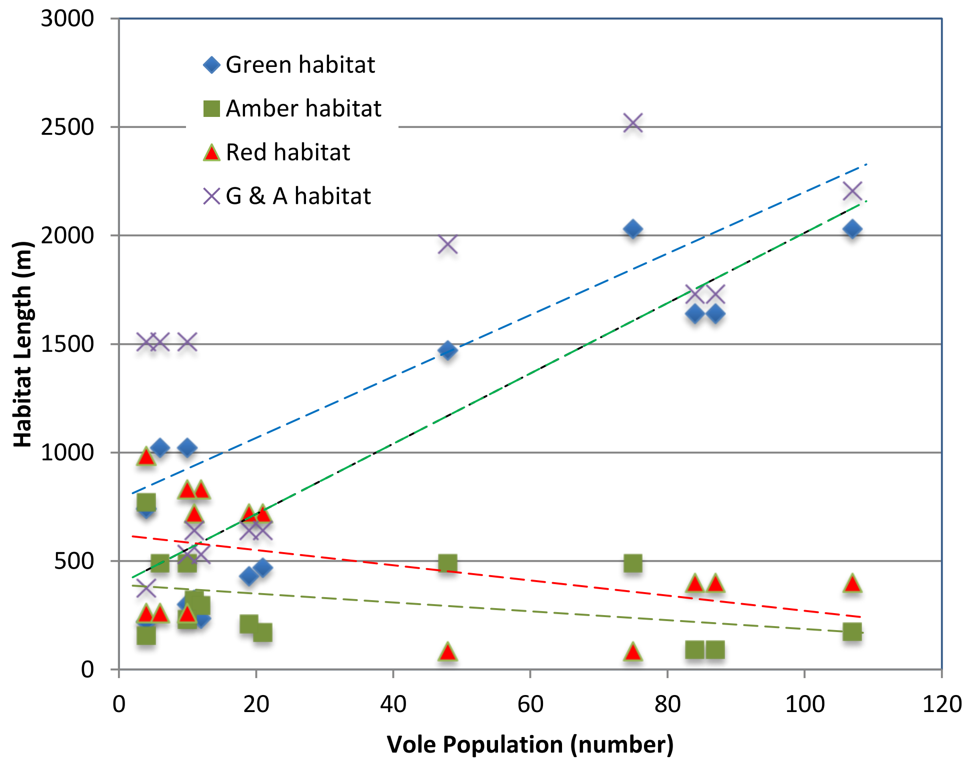


(b) Number of Voles Trapped

<u>Fig 6.2</u> Netheridge – Relationship between Habitat Quality and Water Vole Population



<u>Fig 6.3</u> **Kingsnorth – Relationship between Habitat Quality and Water Vole Population**



<u>Fig 6.4</u> **Combined Data from All Sites – Relationship between Habitat Quality and Water Vole Population**

The scatter plots all demonstrated an increasing trend for vole populations with the increasing length of optimal habitat. However, the relationship between vole population and sub-optimal (amber) and unsuitable (red), together with combined green and amber habitats was less clear. Kirby in Ashfield (Fig 6.1) demonstrated the expected increase in population with decreasing unsuitable (red) habitat length, as did Fig 6.4, where all the date were combined. However, at Kingsnorth (Fig 6.3) vole population appeared to increase marginally with increasing unsuitable habitat. This is probably an anomaly caused by the very small changes in the various habitat quality lengths throughout the duration of the study due to the ongoing pond creation and removal works and the associated habitat establishment. The trends at Netheridge (Fig 6.2a and b) must be regarded with caution giving the limited data due to the two different vole monitoring procedures employed.

Once it was established that there were observable trends relating vole populations with habitat quality, the non-parametric Spearman's Rank Correlation was employed to further explore these further, excluding Netheridge - see Table 6.2.

Evidence of a positive association between green habitat quality, and combined green and amber habitat quality with vole population were found for Kirkby in Ashfield and for all sites combined, with the former demonstrating a stronger relationship. A negative association for red habitat was shown at Kirkby in Ashfield.

Having identified that relationships existed between habitat quality and vole population, a simple linear correlation coefficient was determined to explore the strength of the relationships identified.

The results presented in Table 6.3 show that significant correlations existed for those relationships identified by the Spearman's Rank Correlation analysis (Table 6.2). Although positive relationships were shown between combined green and amber habitat lengths and vole population, the strongest relationships were for green habitat length and vole populations at Kirkby in Ashfield and for all the data combined at significance levels of 95% and 99% respectively.

This analysis has noticeable limitations, as referred to in the introduction to Section 6.3. However, despite this the analysis has demonstrated the value of the Water Vole Assessment system with regard to relating water vole populations and habitat quality. The relationship between Optimal habitat quality and population appears to be particularly strong.

Site	Habitat Class	Sample Size (n)	Spearman's Rank Correlation Coefficient (r)	Critical values of r	Outcome
Kirkby in Ashfield	Green Habitat	6	0.814	0.657 at p=0.2	Evidence of a positive association
	Amber Habitat	6	0.029	0.657 at p=0.2	No evidence of association
	Red Habitat	6	-0.772	0.657 at p=0.2	Evidence of a negative association
	Green+Amber Habitats	6	0.786	0.657 at p=0.2	Evidence of a positive association
Kingsnorth	Green Habitat	5	0.550	0.8 at p=0.2	No evidence of association
	Amber Habitat	5	-0.550	0.8 at p=0.2	No evidence of association
	Red Habitat	5	0.725	0.8 at p=0.2	No evidence of association
All Sites Combined	Green Habitat	14	0.703	0.679 at p=0.01	Evidence of a positive association
	Amber Habitat	14	-0.380	0.367 at p=0.2	No evidence of an association
	Red Habitat	14	-0.17	0.367 at p=0.2	No evidence of an association
	Green+Amber Habitat	14	0.665	0.626 at p=0.02	Evidence of a positive association

Table 6.2 **Spearman's Rank Correlation Analysis Results for Habitat Quality and Vole Population Data**

Site	Habitat Class	Sample Size (n)	Correlation Coefficient r	Critical value of r	Level of Significance
Kirby in Ashfield	Green Habitat	6	0.918	0.811	95%
	Amber Habitat	6	-0.082	0.729	Not significant
	Red Habitat	6	-0.837	0.811	95%
	Green and Amber Habitats	6	0.837	0.811	95%
Kingsnorth	Green Habitat	5	0.637	0.805	Not Significant
	Amber Habitat	5	-0.715	0.805	Not Significant
	Red Habitat	5	0.795	0.805	Not Significant
All Sites Combined	Green Habitat	14	0.880	0.661	99%
	Amber Habitat	14	-0.378	0.457	Not Significant
	Red Habitat	14	-0.434	0.457	Not Significant
	Green and Amber Habitat	14	0.732	0.661	99%

Table 6.3 **Linear Correlation Coefficients and Levels of Significance for Habitat Quality and Vole Population Data**

6.2.2 Utilising the Water Vole Assessment System.

Observations supported by the analysis of Sect 6.2.1 have shown the Water Vole Assessment system to be a successful and rapid way of assessing a site's potential for enhancement, and also for identifying those locations within a site where such works would be most beneficial. The system has also proved its worth in monitoring habitats once the enhancement and mitigation works have been implemented. It was observed from the survey results that evidence of water vole presence generally corresponded to the traffic light system of classification.

This method has also proven to be a suitable tool for habitat assessment with regard to conservation suitability, with the water voles tending to prefer the "green" (optimal) areas. By splitting habitat features (i.e. ditches, ponds, lagoons) into sections and assessing each using the system, a clear overview of the site's potential is obtained. Assessing the habitat at a given location simply involves identifying which elements in the check list are present (Table 3.1), with the classification of a water feature being either "green, amber or red" depending on the number of elements present/absent. The result can then be easily transferred onto drawings and site maps to provide an easy visual reference of water vole habitat quality.

Other factors that might prove constraints on a site's suitability, such a mink presence, soil contamination or flooding potential, are not included in this classification system – it just focuses on habitat quality. However, the system does provide a good baseline survey for the initial phase of site assessment, as was shown for site selection in this project. It has also proven useful in the monitoring the success of schemes post implementation, and thus should prove a useful aid in habitat management.

In applying the water vole habitat assessment, which has the advantage of being relatively simple and not requiring in depth training, the site's vegetation needs to have emerged and developed, thus its use should be restricted to the period from April to September.

Currently the habitat classification system is simple, which has the advantages mentioned above. However, the system also has the potential to be developed beyond a straightforward water vole habitat suitability assessment, to incorporate other factors, such as mink and flooding risk, for application in site selection. This could be then formulated into a system similar to the Habitat Suitability Index (HSI) used for great crested newts *Triturus cristatus* developed by Oldham *et al*. (2000). The HSI scoring systems is a "numerical index, where a score of between 0 and 1. 0 indicates unsuitable habitat, and 1 represent optimal habitat. The HSI for the great crested newt incorporates ten suitability indices, all of which are factors thought to affect great crested newts".

As observed in Sect 3.3, subsequent to the development of the habitat assessment method and its implementation, it was found that Harris *et al* (2009) had published their methodology designed for coastal and riparian grazing marsh dyke systems for identifying habitat suitability for water voles – termed the Water Vole Habitat Suitability system (WVHS). This uses a scoring system based on the number of features identified (Table 6.4 and 6.5).

The two methods were compared and Table 6.6 shows that, with the exception of two of the water features, the results are very similar with only a point difference in the results. The two irregularities were Ponds PH at Kingsnorth and water feature 5 at Netheridge (in bold) which were classed as red in the Water Vole Habitat Assessment system due to the loss of standing water - identified as the most important element. The WVHS scored them as optimal (Pond PH at Kingsnorth) and amber (water feature 5 at Netheridge), since this carried no weighting in the system.

Habitat Suitability Feature	**Score 1 if present**
Well developed (>60) bankside and emergent vegetation to provide cover	
Year round food sources	
Suitable refuge areas above extremes in winter levels	
Steep banks suitable for burrowing	
Permanent open water	
Presence of berm (ledge at water level)	
Lack of disturbance through poaching, grazing and/or recent management	
Nest building opportunities in vegetation above water level	
Habitat Suitability Assessment Score	

Table 6.4 Water Vole Habitat Suitability Assessment – Scoring System (after Harris *et al* (2009)

Score	Suitability	Comment
1	Unsuitable	This type of water body will contain very few features of benefit to water vole.
2	Unsuitable	Potentially containing little if any vegetation, poor or shallow bank, no berms and no suitable tussocks of vegetation near banks
3	Sub optimal	Does not contain enough vegetation, or sufficient bank side area.
4	Sub optimal	Does not contain enough vegetation, or sufficient bank side area.
5	Sub optimal	Does not contain enough vegetation, or sufficient bank side area.
6, 7 & 8	Optimal	Dense and varied vegetation, permanent open water, lack of disturbance, presence of berms, suitable refuge sites and/or nest building opportunities.

Table 6.5 Water Vole Habitat Suitability Assessment – Score Interpretation (after Harris *et al*, 2009)

6.3 Small Scale Habitat Enhancement

Most of the water vole conservation schemes reported in the literature (eg: Strachan, Moorehouse and Gelling, 2011) are undertaken on quite a large scale, and there is a paucity of information for small scale works. The study at Netheridge demonstrated that with appropriate ongoing site management, small scale habitat enhancement /manipulation can have a positive effect on water vole colonies. This was achieved through limited water body improvement, increasing the area of good quality water vole habitat within the site, thereby improving the available food sources and cover for runways, and through creating better connectivity within otherwise fragmented sites.

Initially, the Kirby in Ashfield showed promise following the enhancement works, but contrary to the observations at Netheridge, the subsequent two years saw the water vole population decline. Given the small sizes of both Netheridge and Kirby in Ashfield, it is highly likely that they are colonies in a metapopulation extending into the adjacent wetlands and ditches, and in both instances there is good connectivity. At Kirby in Ashfield this could have led to migration away from a site with declining habitat quality in favour of areas with better resources, or simply a severance of the vole colony from larger more stable sources, hence

Site	Water Feature Assessed	WVHS	Habitat Assessment
Kirkby	Ditch 1	5	Amber-red
	Ditch 2	4	Amber-red
	Lagoon 1	6	Amber
	Lagoon 2	6	Amber
	Lagoon 3	6	Green
	Lagoon 4	6	Amber
	Pond 1	5	Green
	Pond 2	2	Amber
	Pond 3	2	Red
Netheridge	1	4	Green
	2	6	Green
	3	8	Green
	4	7 - 2	Green-Amber
	5	**3**	**Red**
	6	5	Green
	7	5	Amber
	8	5	Amber
Brandon	Newlands	7	Green
	Swallow Pool	7 - 5	Green, Amber, Red
	Grebe Pool	7 - 5	Green, amber
Kingsnorth	P1	7	Green
	P3 (retained)	8	Green
	P4	6	Green
	P3 (created)	7	Green
	P7	7	Green
	PH	**5**	**Red**
	X	6	Green
	Y	4	Amber
Harris et al (2009) < 3 unsuitable; 3-5 sub-optimal, >5 Optimal Authors habitat assessment; Red = unsuitable, Amber = sub-optimal, Green = optimal.			

Table 6.6 **Comparison Undertaken for 2011 Habitat Assessments with the Harris *et al* (2009) WVHS.**

a gradual decline towards extinction. Conversely at Netheridge, the habitat enhancement works resulted in an improved habitat quality, with the ditches being able to support a healthy population with good connectivity to other colonies within the overall metapopulation.

This theory is given credence by the importance attached to habitat quality and connectivity in the metapopulation studies cited in Sect 2.2.

The enhancement works at Kirkby in Ashfield and Netheridge were both in the order of 200m in length, which is significantly shorter than the length of 1.5 to 2km suggested by MacPherson and Bright (2011) for viable colony establishment. However, the enhancement/renovation works they were considering were associated with large core sites and intended to expand the stable metapopulations already present, but also took into account potential mink predation. Care had been taken at Kirkby in Ashfield and Netheridge to eliminate the risk of mink predation, and thus these studies may be more closely aligned with those of Gibbs (1993) and Fedriani et al (2002), where the importance of small wetland sites to metapopulation sustainabilty was highlighted.

6.4 Site Management

Management of sites to ensure the sustainability of water vole populations is paramount. Without long term management any habitat enhancement/manipulation, whether it be large or small scale, will only result in a temporary solution to water vole survival and population decline.

The natural succession of colonising vegetation, such as hawthorn, blackthorn, bramble and bittersweet, can cause major shading which will rapidly reduce the suitability of water bodies and their banks for water voles. Shading is one of the easiest factors to manage with regard to habitat improvement for water voles.

The importance of ongoing management is demonstrated by three of the sites. Both Netheridge and Kingsnorth, which have long term management plans set in place and have been able to maintain the suitability of habitat for water voles over the years of monitoring since these schemes were implemented. Kirkby has had no management undertaken on it and even since the enhancement works in 2011, a substantial formally optimal (green) area has degraded into unsuitable/sub-optimal (red/amber) habitat.

Furthermore, with regard to the connectivity to suitable surrounding habitat, any short term habitat enhancement may end up as a temporary benefit but subsequent negative impact. Kirkby for example showed that although water voles did not use the enhancement undertaken on the ditch for colonisation, their response was to utilise it for connectivity into an area which although it had been identified as possessing optimal (green) for water vole habitat, had shown minimal evidence of their presence before the habitat manipulation.

If water voles are encouraged into an area which is not continuously managed there is a probability that natural succession will result in the deterioration of connecting paths and the gradual fragmentation between areas of previous habitat usage. This was not necessarily the case at Kirkby, since natural succession had already effectively severed a large section of habitat from the east of the site. The water vole population on site has gradually reduced over the years, and although the habitat manipulation/enhancement did not see a rise in number, this may have been due to the numbers being reduced by severance, and by emigrating voles not being replaced by a pool of immigration, making the recovery of the colonies slower or beyond help and hence moving towards extinction.

6.5 Water Vole Introduction Schemes

The success of introduction schemes, even on sites which possess suitable habitat, can be dependent on other factors, such as mink, ongoing management and timings of release. Furthermore, if the monitoring methodologies are inappropriate, then it may not even be possible to discover whether the introduction has been successful or has failed.

In the case of Brandon Marsh, mink is not considered to have had a detrimental impact on the water voles, due to the mink control measures which had been in place for a number of years. Recorded evidence of their reduced numbers, together with the high population of other species on site, such as moorhens and coots, which are heavily impacted when mink are present, demonstrate that they were not a problem.

It can therefore be concluded that by releasing a majority of juvenile water voles on site late in the year (September), even when good food sources were available has resulted in an unsuccessful introduction.

It can therefore be assumed that the timings of the water voles release resulted in their dispersal and that they did not establish breeding colonies. An addendum paper (Gow, 2012) to the 3rd Edition of the Water Vole Conservation Handbook (Strachan, Moorehouse and Gelling, 2011), states that recent studies have shown release timing to be critical, and for releases to be successful they should take place in June for over-wintering juveniles from the preceding year, and high summer (July/August) for juveniles weighing over 160 g. As the Brandon Marsh water voles were released outside this key period and a majority of those released were under 160gm and subsequent surveys could find no evidence of their presence, this suggests they either did not survive or dispersed beyond the boundary of the study area. Alternatively, water voles may be present, but in areas of the site outside the reach of normal field survey methods. However, to improve the chances of success of any future introduction programme, the releases should take place during the summer which would enable them to commence breeding locally and hence establish colonies.

The monitoring methodologies employed at Brandon Marsh proved to be unsuitable for the reedbed habitat which often possessed quite shallow graded margins which made access very difficult. A change of monitoring methodology would be required for future releases. This could involve the use of rafts scattered around the water edges to provide artificial latrine sites, which could easily be checked. Alternatively, or in addition, radio tracking surveys should be implemented. However, firstly this would require additional funding, and secondly an increased effort to convince surrounding land owners to give their permission for access. A decision would also have to be made whether to use either PIT tags or radio collars. The experiences to date, have left a question regarding the potential threat to the health of the water voles as those which are not fully grown are at risk of outgrowing the collars before they can be recaptured. Pit tags are inserted under the skin so have a reduced risk to the voles.

The release of water voles at Kingsnorth as part of the water vole mitigation strategy has to date been successful. The designs of the ponds that were created, showed that with the right bankside design, pond lining can be successfully used to create water vole habitat. However, when the lining failed in one of the ponds a rapid decline in habitat suitability was observed. As with the smaller scale projects of Kirkby and Netheridge, ongoing long term management is the most important factor in maintaining site suitability for water voles.

6.6 Mink Control

Extensive mink control measures were implemented at Brandon Marsh, both on site and on the adjacent River Avon. Monitoring data had shown that this to be successful, with the presence of mink declining significantly prior to the water vole release. Unfortunately, because of the late release and subsequent failure of the monitoring programme to locate any voles, it was not possible to judge whether or not the control measures had ensured that mink were not able to impact the introduction and the population of water voles, and were sustainable.

It would be valuable in understanding the relationship between water vole survival and mink control measures to achieve a successful release at Brandon Marsh and to continue the mink monitoring and control programme.

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

From the discussion and evaluation of Chapter 6, the conclusions that can be drawn from this water vole research project can be summarised as follows.

1. The water vole habitat assessment check list which was developed worked well for both initial baseline surveys and for post enhancement/release surveys, and in particular the relationship between vole numbers and optimal (green) habitat quality was confirmed. Regarding the initial baseline surveys, an understanding of the site's suitability for water voles is required, and subsequently if investment is deemed appropriate, the method also enables the designer to determine the most appropriate areas for enhancement. Post implementation, the method enables both habitat suitability and management practices to be monitored, thus ensuring the site's long term sustainability for water vole populations.

2. The enhancement works undertaken at both the Netheridge and Kirkby in Ashfield sites demonstrated that small scale enhancement works can be successfully employed to improve sites for the long term survival of water vole colonies. However, the post enhancement surveys demonstrated the importance of ongoing management for even small scale schemes.

3. As alluded to above, the long term success of enhancement works for a water vole population is likely to depend on the introduction and implementation of a management plan. This is of particular importance, as demonstrated at Netheridge and Kirkby, to control the natural succession of vegetation both to maintain good quality habitat, and to maintain connectivity, thereby ensuring continuity with a successful self-sustaining water vole metapopulation.

4. The success of water vole introduction programmes besides depending on the design of enhancement/creation works and site management programmes, will also depend on the timing of the releases. The problems encountered at Brandon Marsh were due to the releases being late in autumn instead of the recommended summer period. The releases at Kingsnorth proved much more successful since they were undertaken early enough to enable breeding colonies to establish, prior to overwintering.

5. The mitigation programme implemented in connection with the development of the Kingsnorth Commercial Park proved relatively successful, and it is believed that a potentially self-sustaining metapopulation was established. Despite the failure of the artificial liners in two of the created ponds, the works showed that with good design and installation practices, artificial liners can be used successfully for the establishment of water vole colonies.

7.2 The Project Aim and Objectives

The project objectives cited in Sect 1.5 were all designed to enable the overall aim to be achieved. From the background literature review, through site selection and post enhancement/introduction monitoring, these were all successfully achieved, with one exception. This was the water vole introduction and subsequent monitoring programme at Brandon Marsh.

However, overall the aim of the research:

> to determine the effectiveness of habitat creation and enhancement design methods for promoting the conservation and expansion of water vole populations

has been achieved. The four schemes studied demonstrated what can be achieved regarding water vole conservation with careful habitat creation and enhancement, providing an ongoing management plan is implemented and either good connectivity with a wider metapopulation maintained, or a self-sustaining one established.

The outcomes of the research will contribute to the development of best practice guidelines to enable the UK BAP targets of stemming and reversing the decline in UK water vole populations.

7.3 Recommendations

Broad recommendations that have emerged from the project are that:

1. the design guidelines given in the Water Vole Conservation Handbook (Strachan et al, 2011) provide a sound basis, and should be followed for both habitat creation and site

enhancement/creation works, and for small sites their place within their wider metapopulation taken into account;

2. the traffic light Water Vole Habitat Assessment system that was developed is recommended for water vole baseline and post-implementation monitoring when undertaken at the appropriate time of year when vegetation is sufficiently developed (May-September);

3. though less easy to apply, habitat assessment method (WVHS) of Harris *et al* (2009) is also recommended for water vole baseline and post-implementation monitoring providing its limitations are recognised;

4. the next step for assessing water vole habitat should be the creation of a methodology such as that developed by Oldham *et al* (2000) for great crested newts.

5. a site management plan should be drawn up and implemented to ensure the long term sustainability of water vole enhancement, creation and mitigation scheme.

With regard to continued water vole studies at the four research sites:

6. the monitoring programmes at Kirkby in Ashfield and Netheridge should be continued to establish the long term impact, success and cost effectiveness of the management at the latter, although this might lead to the loss of the water vole population at Kirkby; studies into the adjacent land should also be undertaken to establish the relationship between the colonies on these sites and their wider metapopulations;

7. funding should be sought for another attempt at water vole introduction at Brandon Marsh, with the lessons learnt from the 2011 introduction informing both the actual release and design of the subsequent monitoring programme;

8. with only three years of monitoring at Kingsnorth since the completion of the mitigation works in 2012, monitoring and management should continue to ensure the long term sustainability of the water vole population, and to continue to learn the consequences of such works.

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Appendix 1

Landfill Tax Credit Scheme Application

Proposal for a Landfill Tax Credit Scheme Funded Research Project Into

Water Vole Conservation

Background

Once common and widespread, water voles *Arvicola terrestris* have suffered a significant drop in numbers and distribution since the 1960's. This decline accelerated during the 1980's and 1990's due to changes in land use and riparian habitat management which has resulted in habitat loss, fragmentation and degradation. This habitat loss has increase water voles' vulnerability to predators, especially mink *Mustela vison*, whose population has increased.

The water vole was therefore chosen as a species for the UK Biodiversity Action Plan following the 1992 Rio de Janeiro Convention on Biodiversity. The action plan called to restore water voles to their former widespread distribution by 2010. Restoration and re-creation of extensive areas of riparian vegetation (with mink trapping if necessary) are suggested as the best mechanisms for increasing the water vole numbers and distribution.

The proposal

This proposal is for a Landfill Tax Credit Scheme (LTCS) funded part-time water vole conservation research officer. The research officer will work closely with water vole Species Action Plan (SAP) Lead Partner and others to deliver the action plan objectives by 2010.

The officer should be a graduate with some experience in hydrological and ecological surveys. The officer would be employed by the Environmental Body making the LTCS application, the Warwickshire Wildlife Trust. The officer's work-plan would be steered by the water vole Biodiversity Action Plan steering group under the Chairmanship of the Lead Partner the Environment Agency. The work programme is likely to include the following duties based at specific sites (in order to meet LTCS criteria):

1. Hydro-ecological surveys will be set up and conducted at selected test sites where water vole habitat creation works have been undertaken in order to provide baseline data. Existing plant species composition and vegetation structure will be assessed in order to provide data on riparian habitat. In addition, particular attention will be paid to gathering soil/ substrate data and information on water level fluctuations as the function of these variables determines the ability of water voles to burrow or create above ground predator proof nests.

2. Research will be conducted to identify opportunities to encourage riparian habitats such as planting schemes with water vole food plants (e.g. tussock forming species providing both food and cover), determining vegetation establishment mechanisms, and changing the hydrological characteristics of the sites in order to encourage water vole colonisation. The research will involve experimental design and tested habitat manipulation works in order to determine best practice. It is anticipated that some test sites will be adjacent to extant water vole populations in order to facilitate the assessment of experimental habitat manipulations (in replicated treatments) on water vole colonisation. Under the direction of the water vole Biodiversity Action Plan steering group, opportunities for the release of captive bred animals will be considered as part of the works to determine habitat suitability, within the framework of a wider species recovery programme. Mink management may need to be carried out ahead of experimental works in order for their potential impact to be negated.

3. Vegetation establishment techniques will be implemented at test sites and a monitoring programme will be developed for the sites to assess changes against the baseline hydro-ecological variables with water vole colonisation. This data can be used to determine the optimum hydro-ecological characteristics for vegetation establishment within created water vole habitat. The information obtained will be incorporated into a Handbook that will encourage best practice within water vole habitat creation projects. In addition, it is anticipated that the project data can be used to inform the selection of sites that are suitable for re-establishing vegetation suitable for populations of water voles and for restoration schemes that aim to increase water vole populations.

4. An education programme primarily in the form of leaflets and workshops will be developed using information obtained from the site hydro-ecology and water vole research and surveys and will be shared with organisations important to the conservation of the water vole (such as Local BAP Partnerships, Oxford University Wildlife Conservation Research Unit, riparian owners, managers and advisers etc) with a focus on promoting best practice. This will assist the UK SAP action points under 'Communications and Publicity' works, thus assisting the UK SAP targets to maintain and expand existing populations.

Draft Budget (3 year part-time programme)

Salary………………………………	£30,000
Overheads and costs	£5,000
Training / Equipment………………	£1,200
Car running costs…………………..	£4,000
Workshops…………………………	£4,000
Sundries, handbook leaflets etc……	£5,000
TOTAL	**£49,200**

James Calow, 29th October 2004
Middlemarch Environmental Ltd.

Appendix 2

Hartshill STW – Research Site Location and Habitat Survey

Appendix 3

Kirkby-in-Ashfield Phase 1 Habitat Survey Species Lists

Common Name	Scientific Name
Nettle	*Urtica dioica*
Great willowherb	*Epilobium hirsutum*
Rosebay willowherb	*Chamaenerion angustifolium*
White dead nettle	*Lamium album*
Creeping thistle	*Cirsium arvense*
Mugwort	*Artemisia vulgaris*
Spear thistle	*Cirsium vulgare*
Cow parsley	*Anthriscuc sylvestris*
Cleaver	*Galium aparine*
Hogweed	*Heracleum sphondylium*

Table A3.1 **Tall Ruderal Species**

Common Name	Scientific Name
Tufted hair grass	*Deschampsia cesputosa*
Sweet vernal grass	*Anthoxanthum odoratum*
Meadow grass	*Poa sp*
Cock's-foot	*Dactylis glomerata*
False oat grass	*Arrhenatherum elatius*
Timothy	*Phleum pratense*
Soft rush	*Juncus effuses*
Sedge	*Carex sp*
Dock	*Rumex obtrusifolius*
Meadow vetchling	*Lathyrus pratensis*
Common vetch	*Vicia sativa*
Hogweed	*Heracleum sphondylium*
Figwort	*Scrophularia nodosa*
Angelica	*Angelica sylvestis*
Crane's bill	*Geranium rotundifolium*
Perforated St John's wort	*Hypericum perforatum*
Ox-eye daisy	*Leucanthemum vulgare*
Creeping buttercup	*Ranunculus repens*
Meadow buttercup	*Ranunculus acris*
Broad leaved willowherb	*Epilobium montanum*
Silverweed	*Potentilla anserina*
Hedge woundwort	*Stachys sylvatica*
Mallow	*Malva sylvestris*
Common spotted orchid	*Dactylorhiza fuchsii*
Bird's-foot trefoil	*Lotus corniculatus*
Creeping thistle	*Cirsium arvense*
Nettle	*Urtica dioica*
Common knapweed	*Centaurea nigra*
Evening primrose	*Oenothera agg.*
Tufted vetch	*Vicia cracca*
Fairy flax	*Linum catharticum*
bramble	*Rubus fruticosus agg*

Table A3.2 **Grassland Species**

Appendix 4

Netheridge Phase 1 Habitat Survey Species Lists

Common Name	Scientific Name
Beech	*Fagus sylvatica*
Cherry	*Prunus sp*
Field maple	*Acer campestre*
Elder	*Sambusus nigra*
Hawthorn	*Crataegus monogyna*
Ash	*Fraxinus excelsior*
Dogwood	*Cornus sanguinea*
Willow	*Salix sp*
Hazel	*Corylus avellana*
Guilder rose	*Viburnum opulus*
Apple sp.	*Malus sp*
Blackthorn	*Prunus spinosa*
Bramble	*Rubus fruticosus agg.*
Creeping thistle	*Cirsium arvense*
Nettle	*Urtica dioica*
Spear thistle	*Cirsium vulgare*
Meadow buttercup	*Ranunculus acis*
Creeping buttercup	*Ranunculus repens*
Prickly sow thistle	*Sonchus asper*
Creeping cinqfoil	*Potentilla reptans*
Chickweed	*Stellaria media*
Clever	*Galium aperine*
Hogweed	*Heracleum sphondylium*
Ivy	*Hedra helix*
Cock's-foot	*Dactylis glomerata*

<u>Table A4.1</u> Broad Leaved Woodland Species

Common Name	Scientific Name
Sallow	
Goat willow	*Salix caprea*
Hawthorn	*Crataegus monogyna*
Blackthorn	*Sambucca nigra*
Dogwood	*Cornus sanguine*
Bramble	*Rubus fruticosus agg*
Guilder rose	*Viburnum opulus*
Rose	*Rosa sp*

<u>Table A4.2</u> Scrub Habitat Species

Common Species	Scientific Name
Nettle	*Urtica dioica*
Hogweed	*Heracleum sphondylium*
Creeping thistle	*Cirsium arvense*
Dock	*Rumex obtusifolius*
Great willowherb	*Epilobium hirsutum*

<u>Table A4.3</u> Tall Rederal Species

Common Name	Scientific Name
Timothy	
Meadow foxtail	
False oat grass	
Fescue	*Festuca sp*
Oxeye daisy	*Leucanthemum vulgare*
Meadow vetchling	*Lathyrus pratensis*
Bird's-foot trefoil	*Lotus corniculatus*
Yarrow	*Achillea millefolium*
Bittercress	*Cardamine flexuosa*
Silverweed	*Potentilla anserine*
Common knapweed	*Centaurea nigra*
Bristly ox-tongue	*Picris echioides*
Plantain	*Plantago lanceolata*
Common vetch	*Vicia sativa*

<u>Table A4.4</u> Grassland Species

Appendix 5

Mink Raft Locations on the River Avon

Aston University

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Aston University

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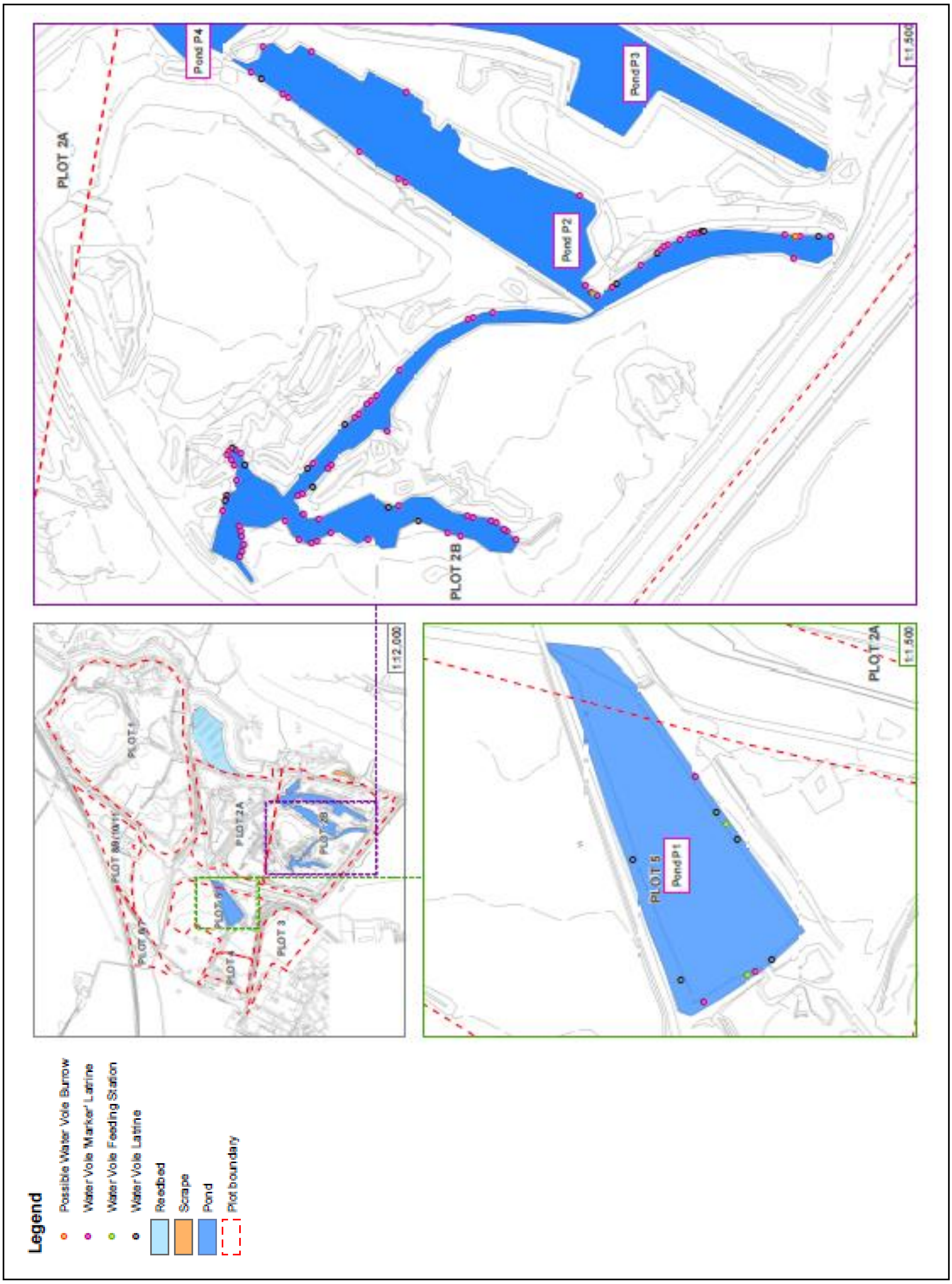
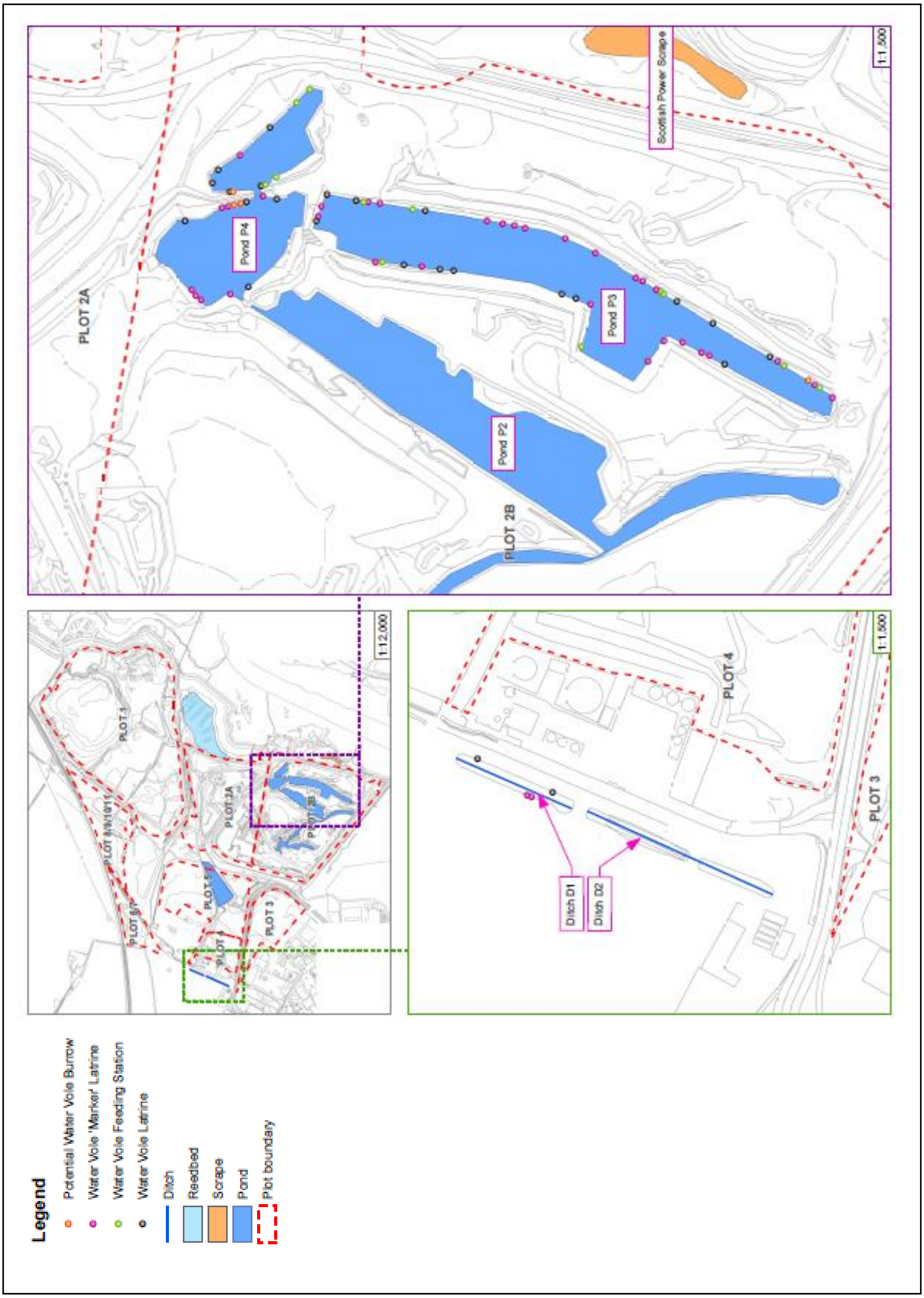
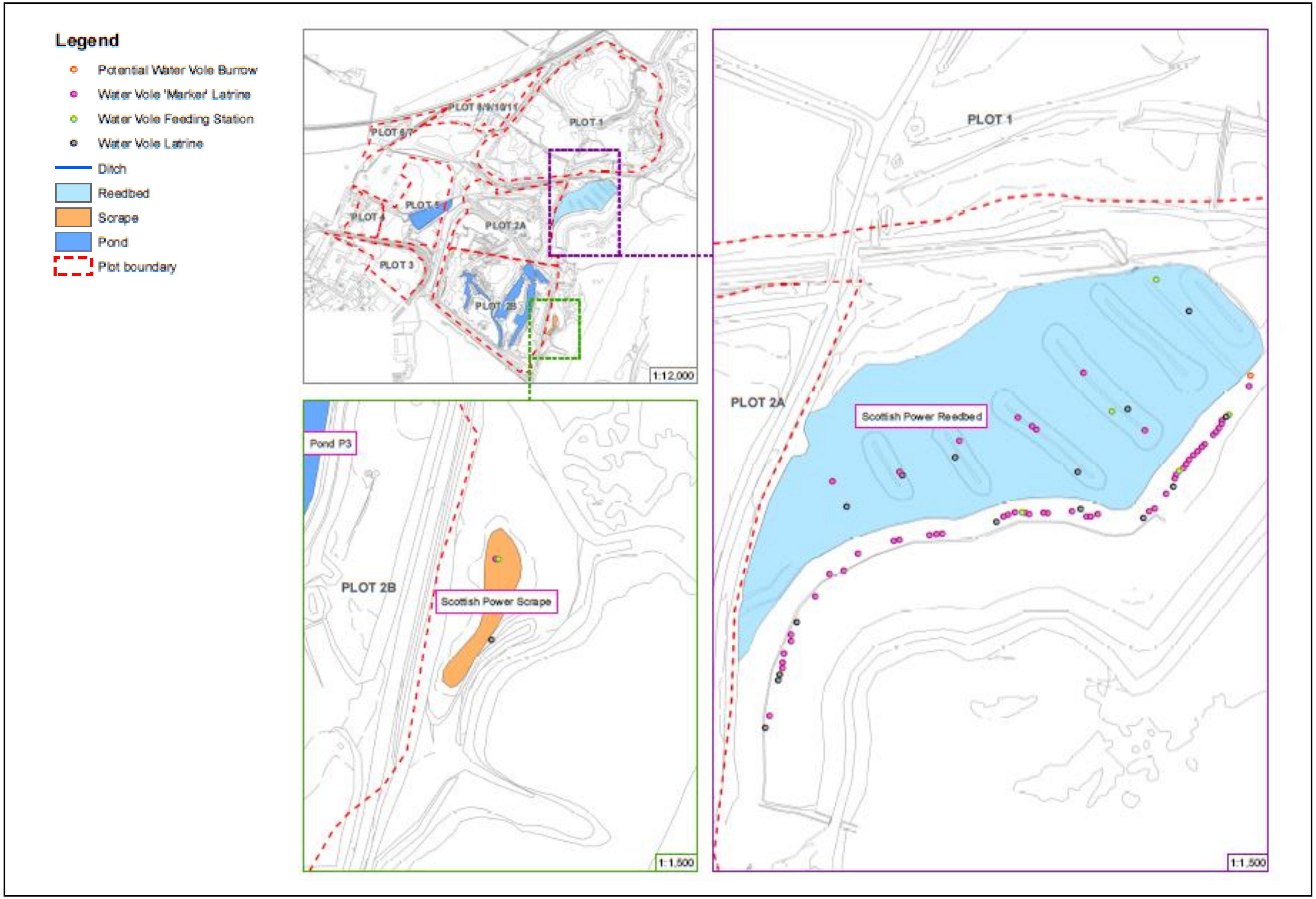
Appendix 6

Plans Detailing 2011 Kingsnorth Water Vole Survey
(from MEL, 2011)




Legend
Potential Water Vole Burrow
Water Vole 'Marker' Latrine
Water Vole Feeding Station
Water Vole Latrine
Ditch
Reedbed
Scrape
Pond
Plot boundary
PLOT 2A
Pond P4
Pond P3
Pond P2
PLOT 2B
Scottish Power Scrape
1:1,500
1:12,000
PLOT 1
PLOT 3
PLOT 4
Ditch D1
Ditch D2
1:1,500


Legend
Potential Water Vole Burrow
Water Vole 'Marker' Latrine
Water Vole Feeding Station
Water Vole Latrine
Ditch
Reedbed
Scrape
Pond
Plot boundary
PLOT 8/9/10/11
PLOT 6/7
PLOT 1
PLOT 5
PLOT 4
PLOT 2A
PLOT 3
PLOT 2B
1:12,000
Pond P3
PLOT 2B
Scottish Power Scrape
1:1,500
PLOT 1
PLOT 2A
Scottish Power Reedbed
1:1,500

Appendix 7

2012 Photographs of Kingsnorth Mitigation and Release Ponds

Fig A7.1   Pond 1

Fig A7.2   Pond 2A

Fig A7.3 Pond 2B

Fig A7.4 Pond 3

Fig A7.5 Pond P3 (foreground) and Pond P4 (background)

Fig A7.6 Pond 7

Fig A7.7 Pond H

Fig A7.8 Pond X

Fig A7.9 Pond Y

Appendix 8

Water Vole Survey Results for Kirby in Ashfield 2009 to 2013

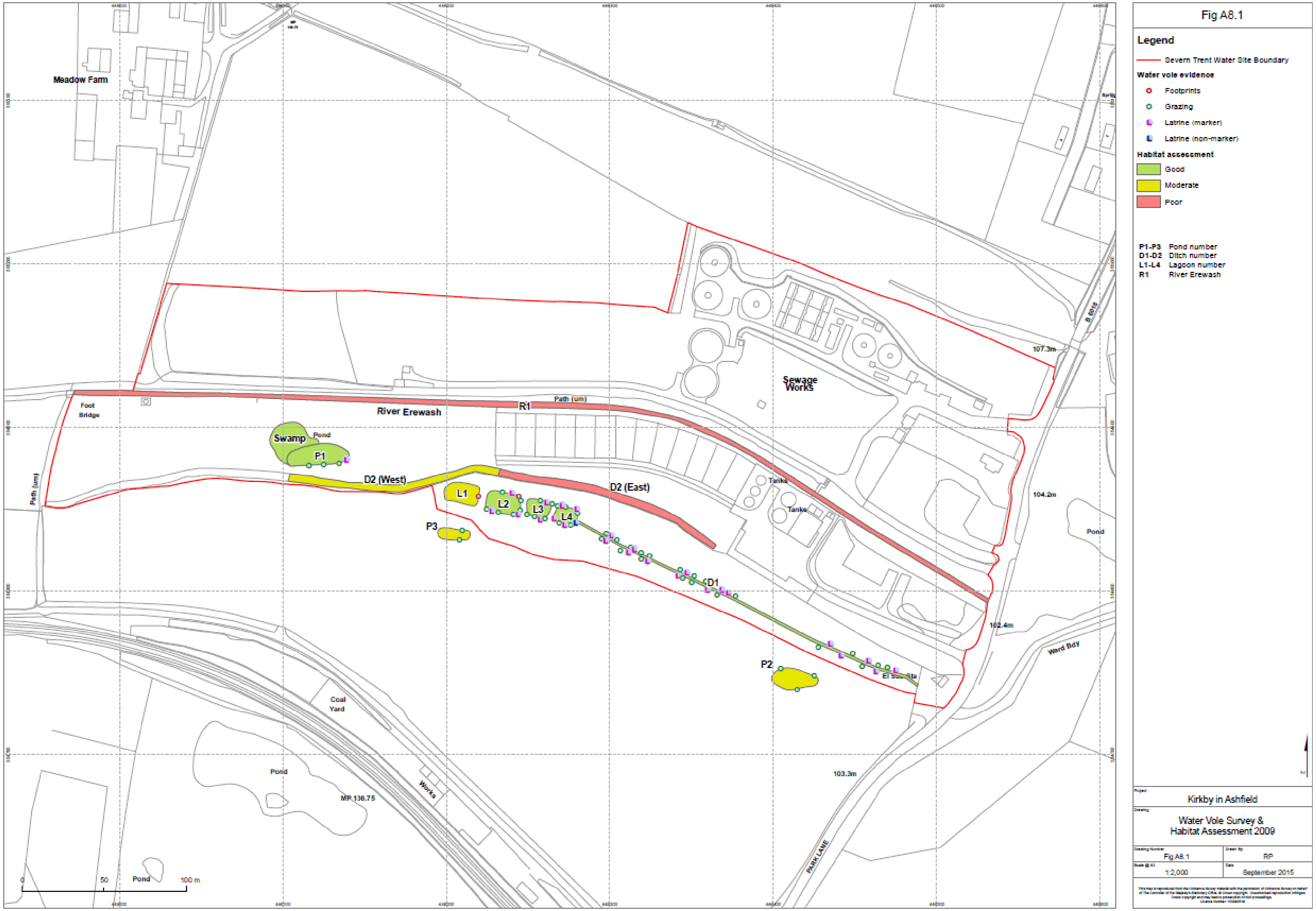


Fig A8.1 Kirkby in Ashfield Water Vole Survey 2009

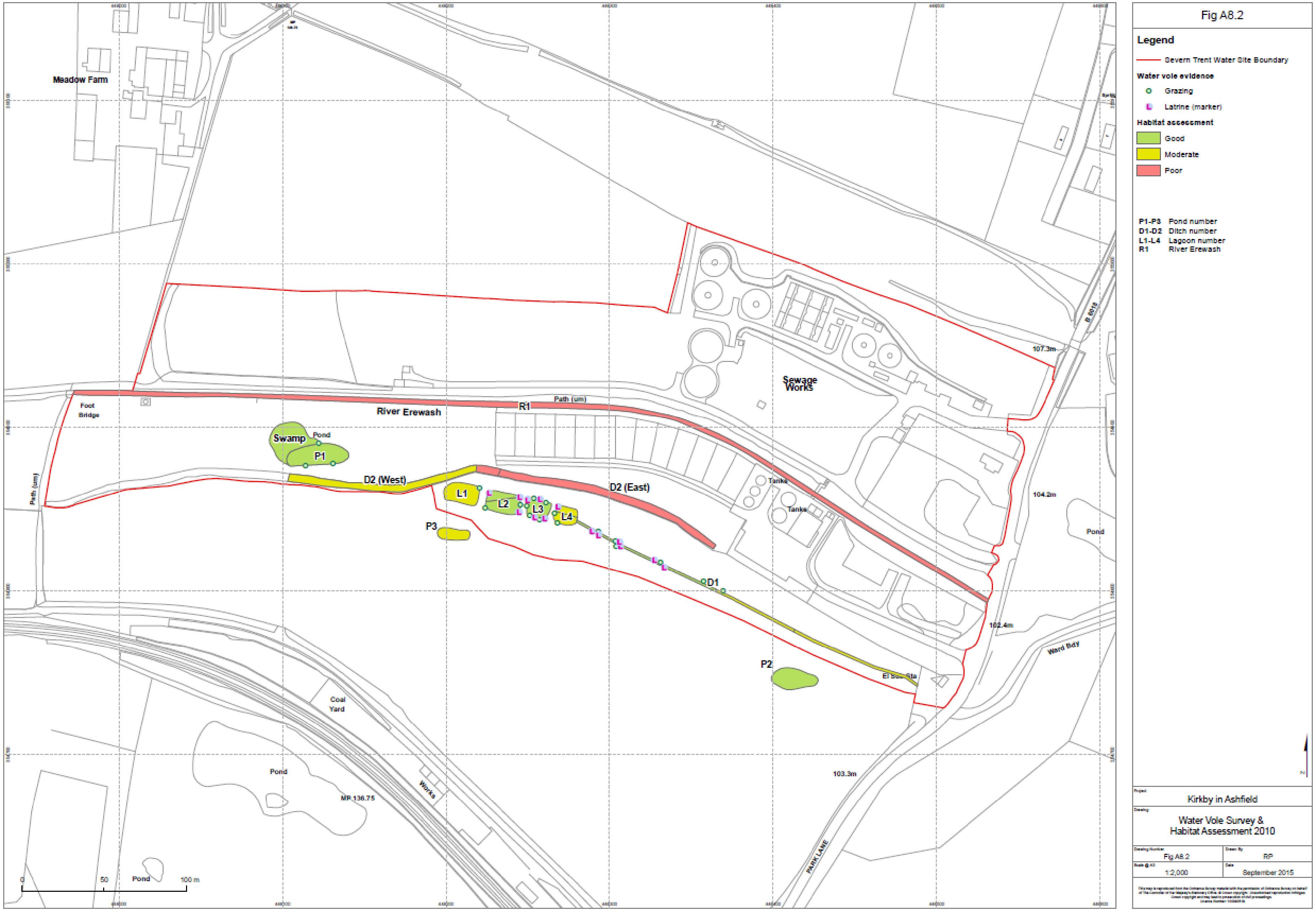


Fig A8.2 Kirkby in Ashfield Water Vole Survey 2010

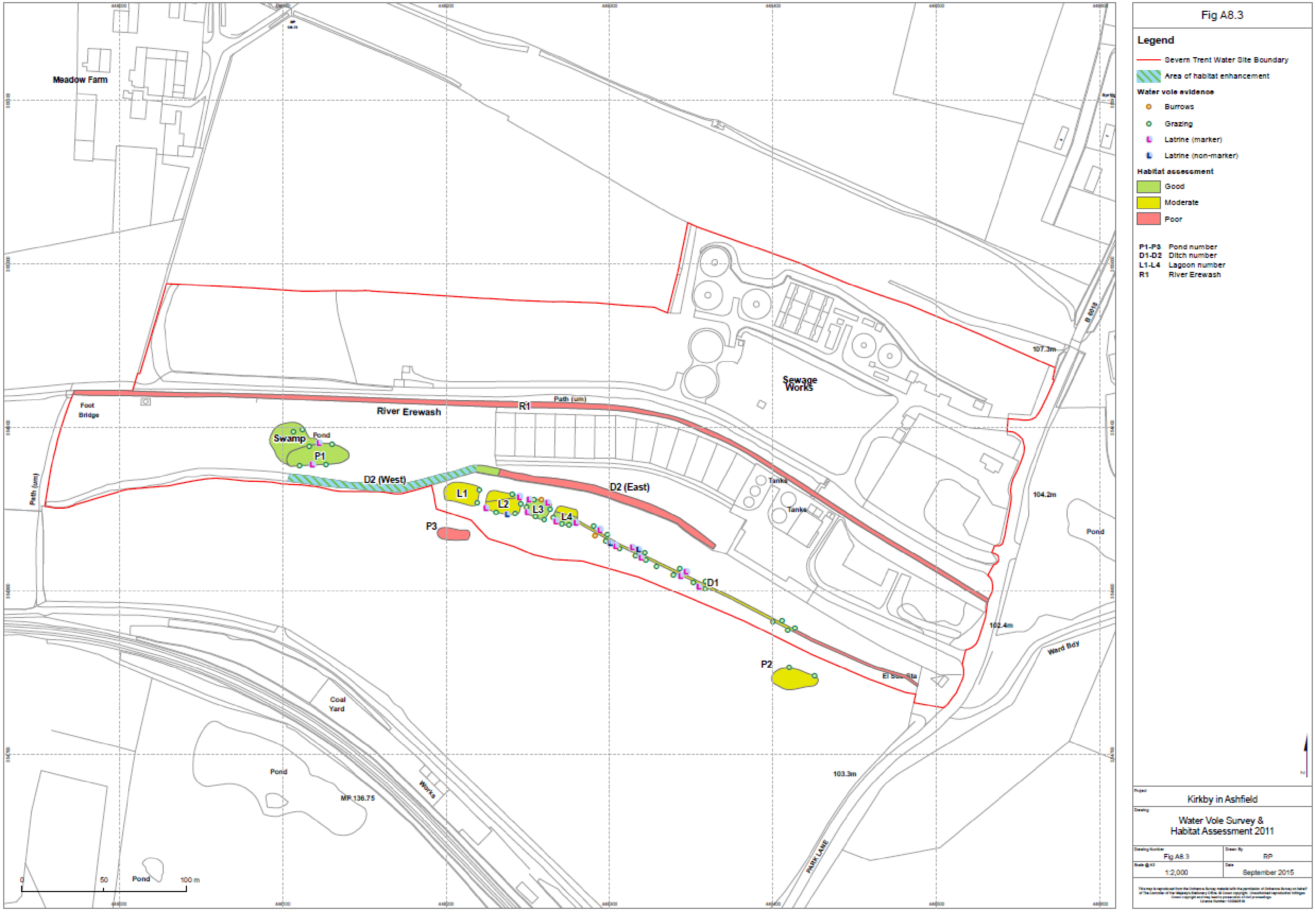


Fig A8.3 Kirkby in Ashfield Water Vole Survey 2011

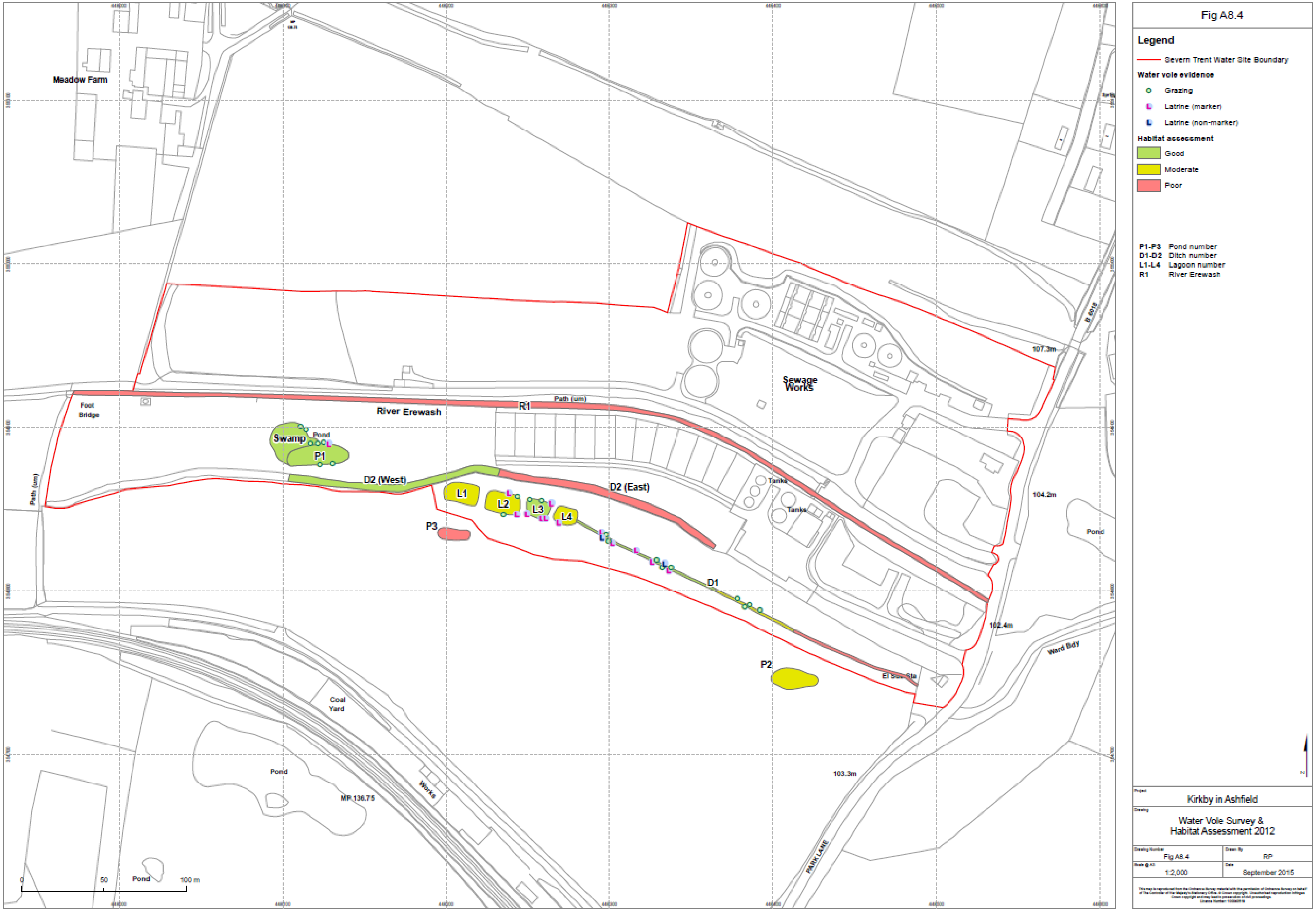


Fig A8.4 Kirkby in Ashfield Water Vole Survey 2012

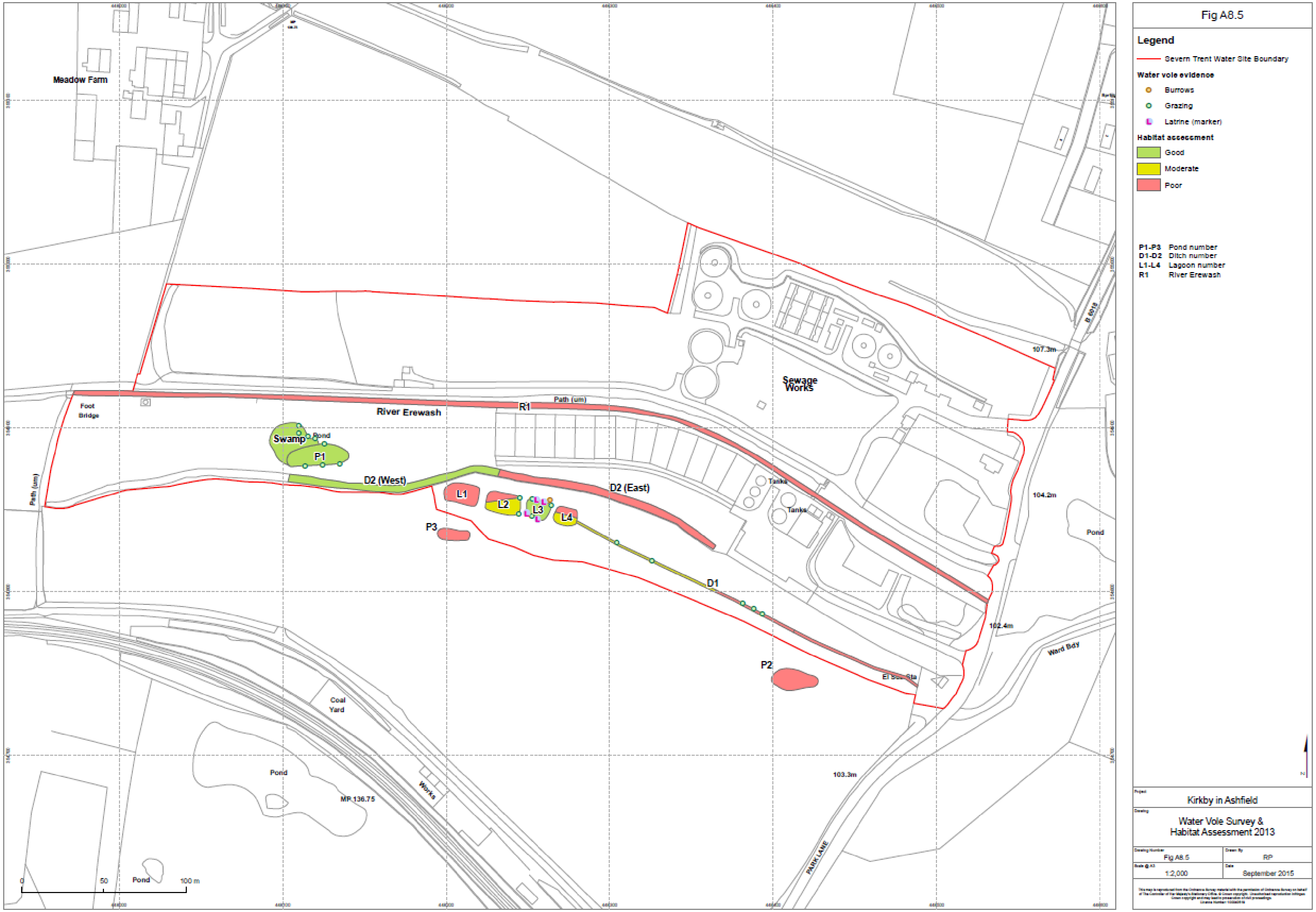


Fig A8.5 Kirkby in Ashfield Water Vole Survey 2013

Appendix 9

Water Vole Survey Results for Netheridge 2009 to 2013

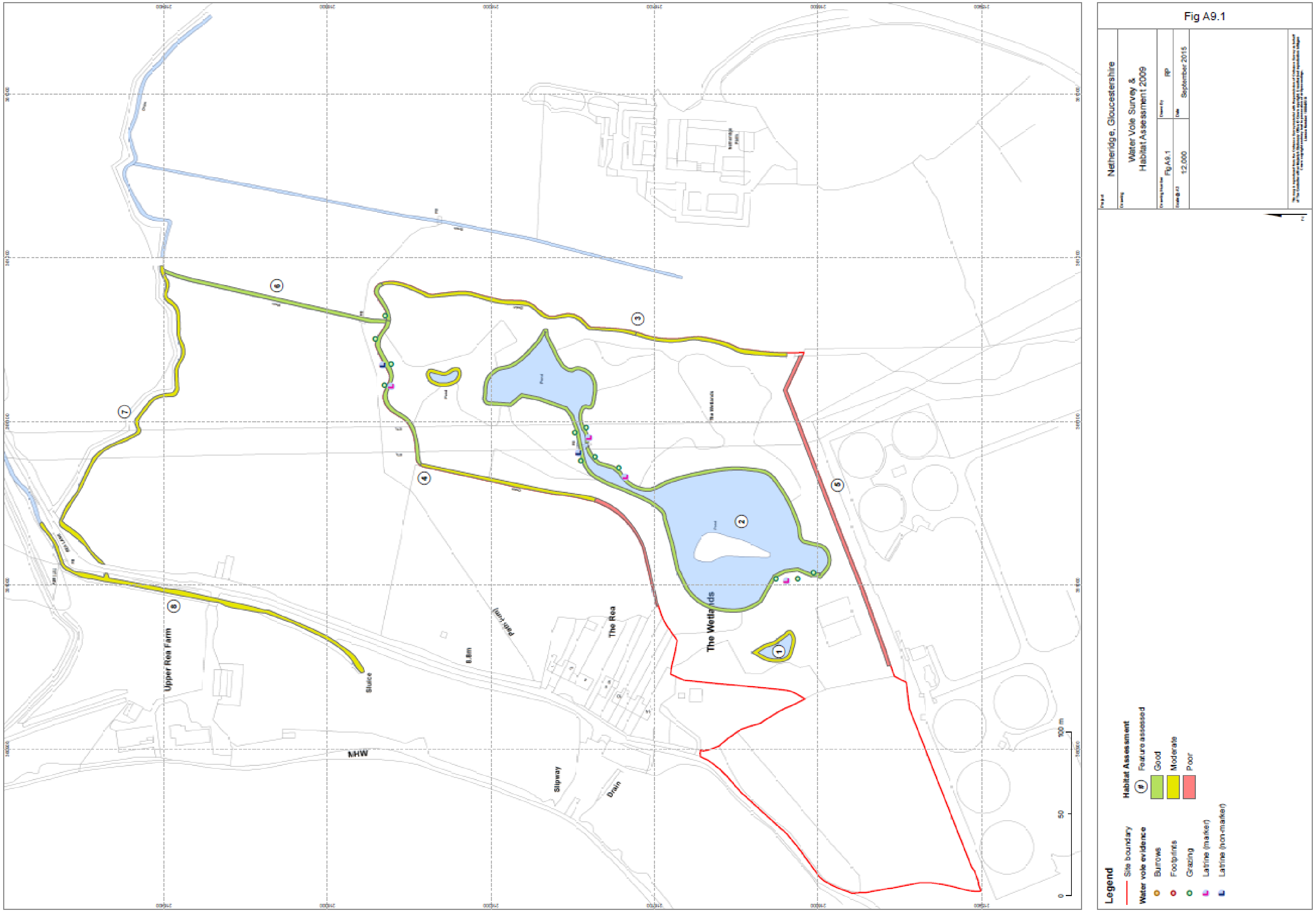


Fig A9.1 Netheridge Water Vole Survey 2009

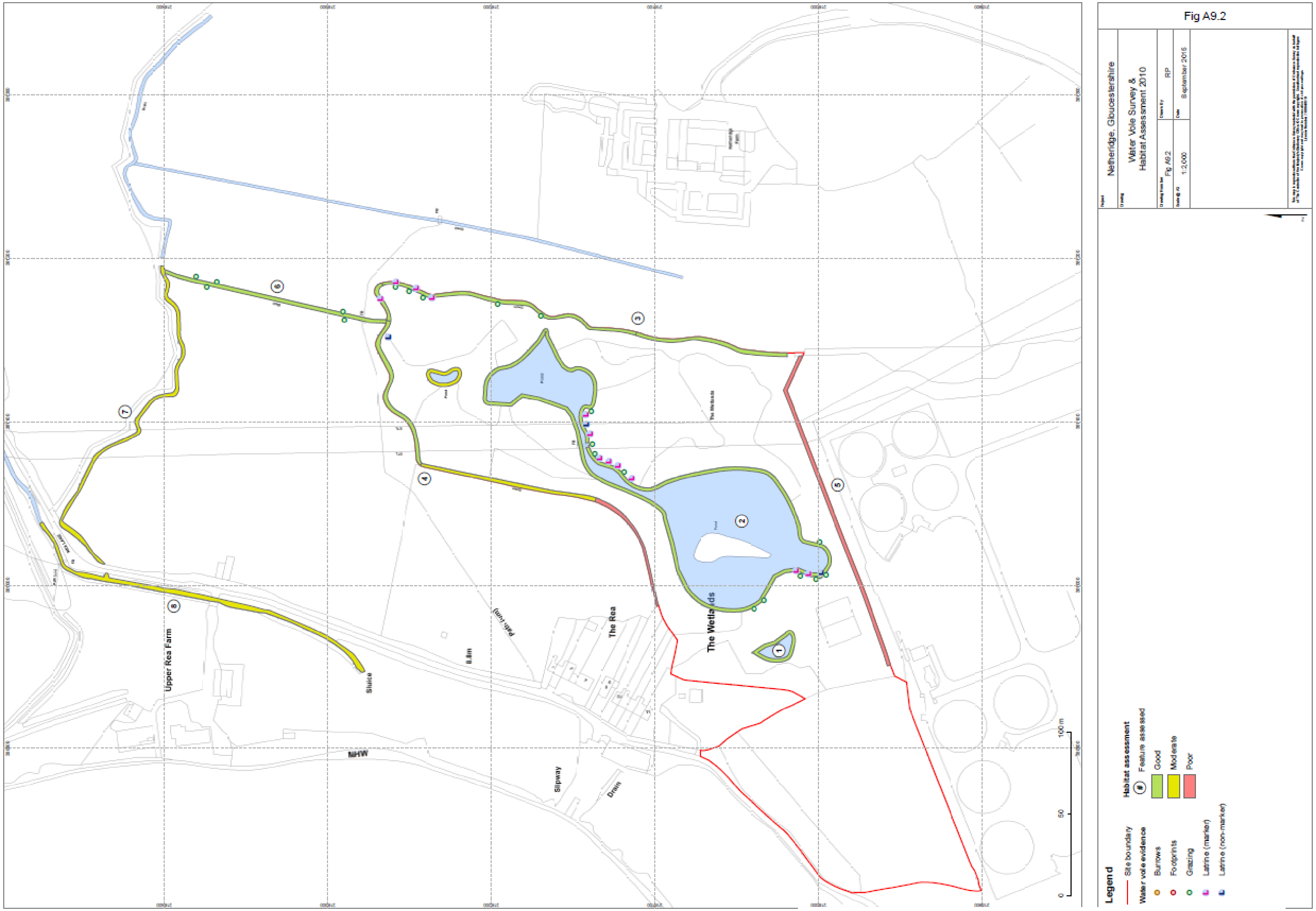


Fig A9.2 Netheridge Water Vole Survey 2010

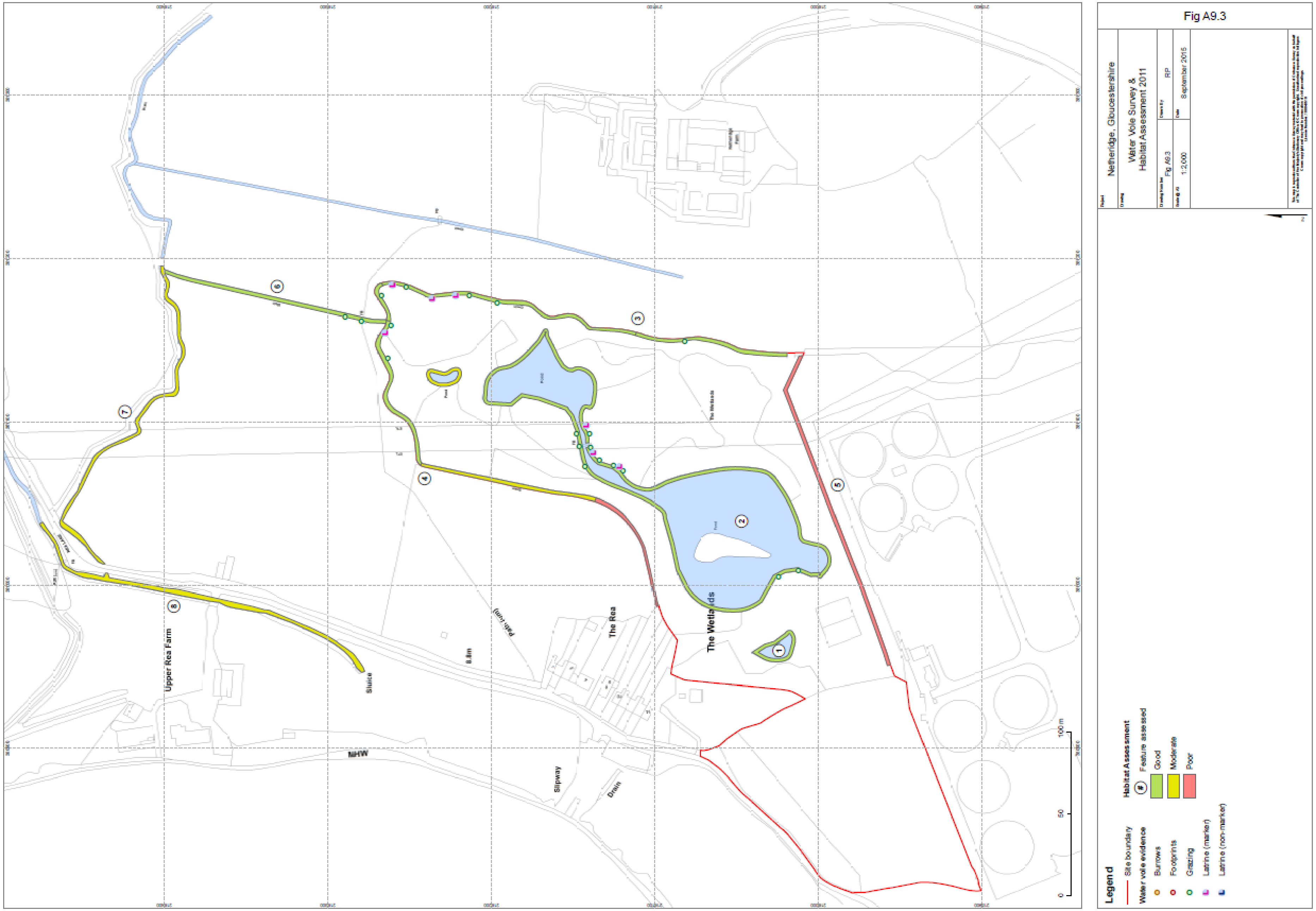


Fig A9.3 Netheridge Water Vole Survey 2011

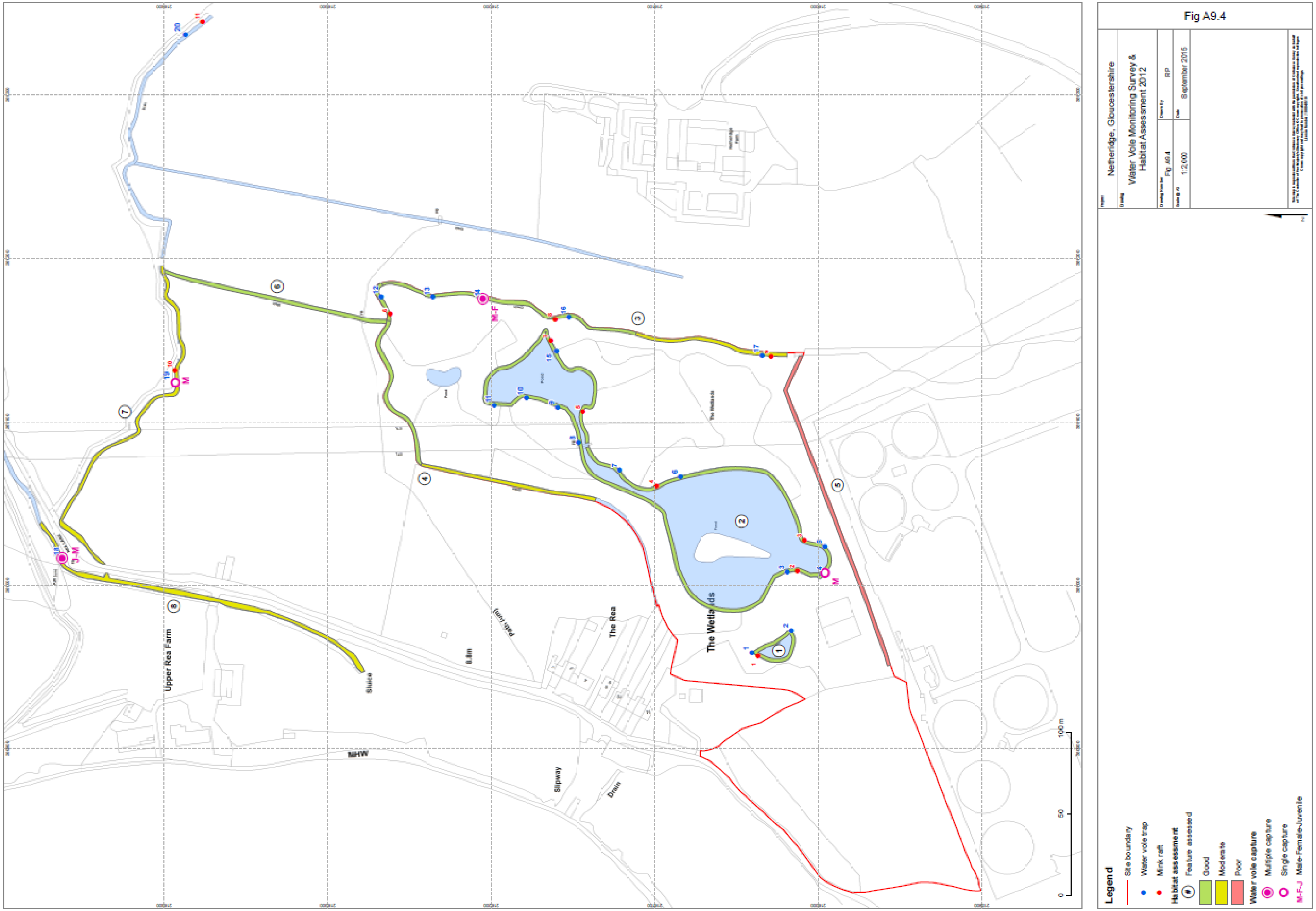


Fig A9.4 Netheridge Water Vole Survey 2012

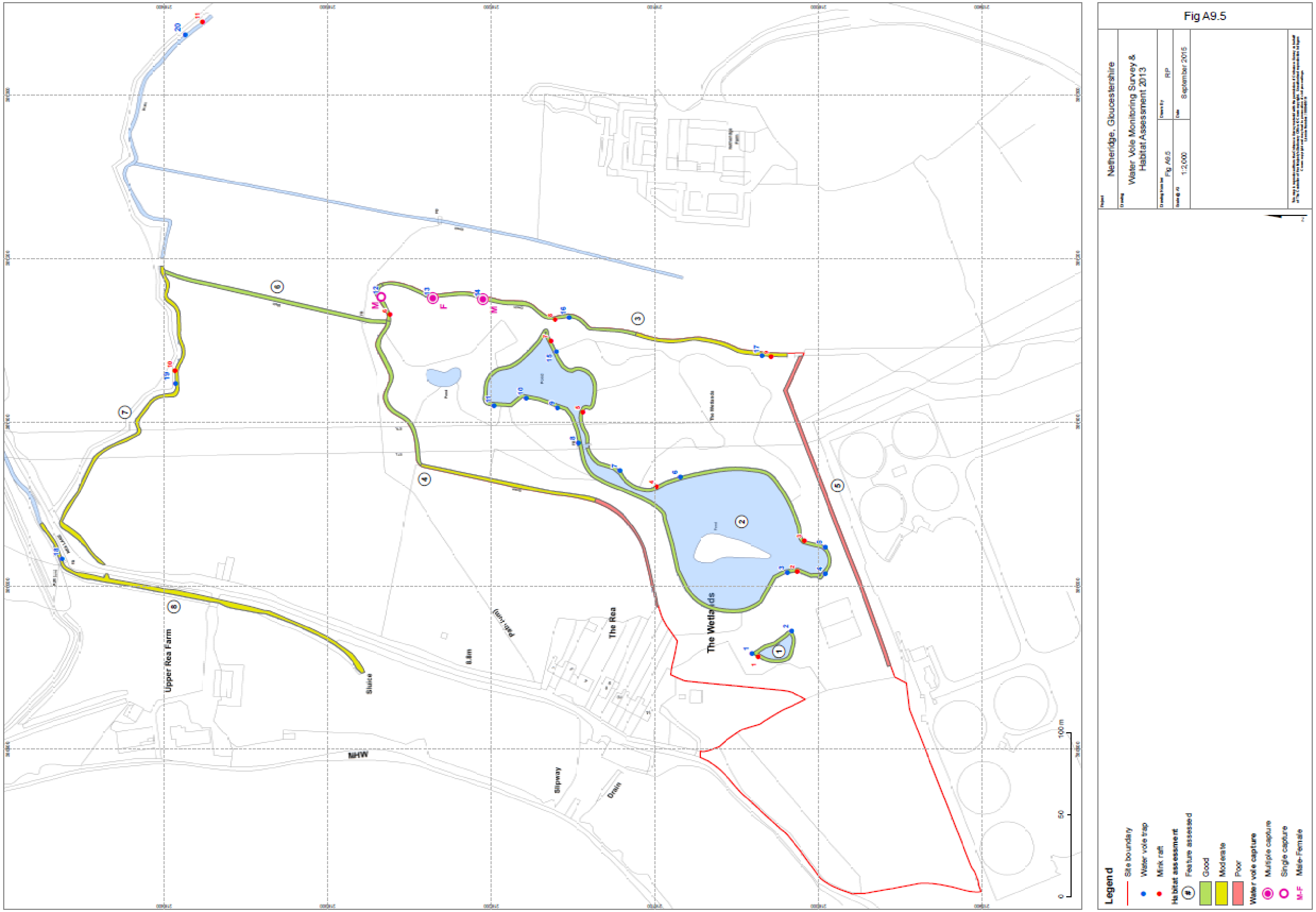


Fig A9.5 Netheridge Water Vole Survey 2013

Appendix 10

Water Vole Survey Results for Brandon Marsh 2012 and 2013

Fig A10.1 Brandon Marsh Water Vole Survey 2012

Fig A10.2 Brandon Marsh Water Vole Survey 2013

Appendix 11

2011 Water Vole Survey Results for Kingsnorth

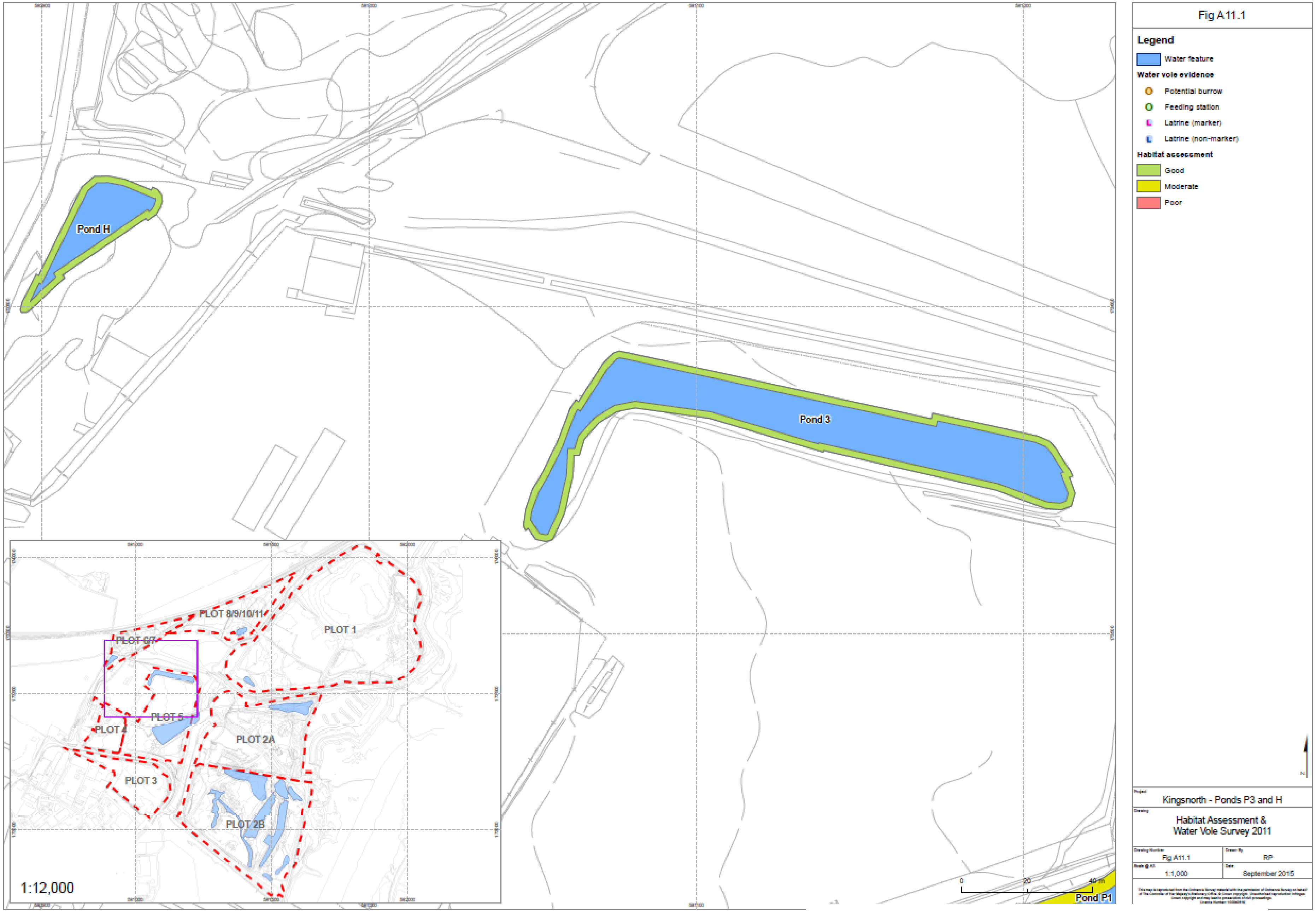


Fig A11.1 2011 Water Vole Survey Results for Kingsnorth – Ponds P3 & H

Fig A11.2 2011 Water Vole Survey Results for Kingsnorth – Ponds P1 and 7

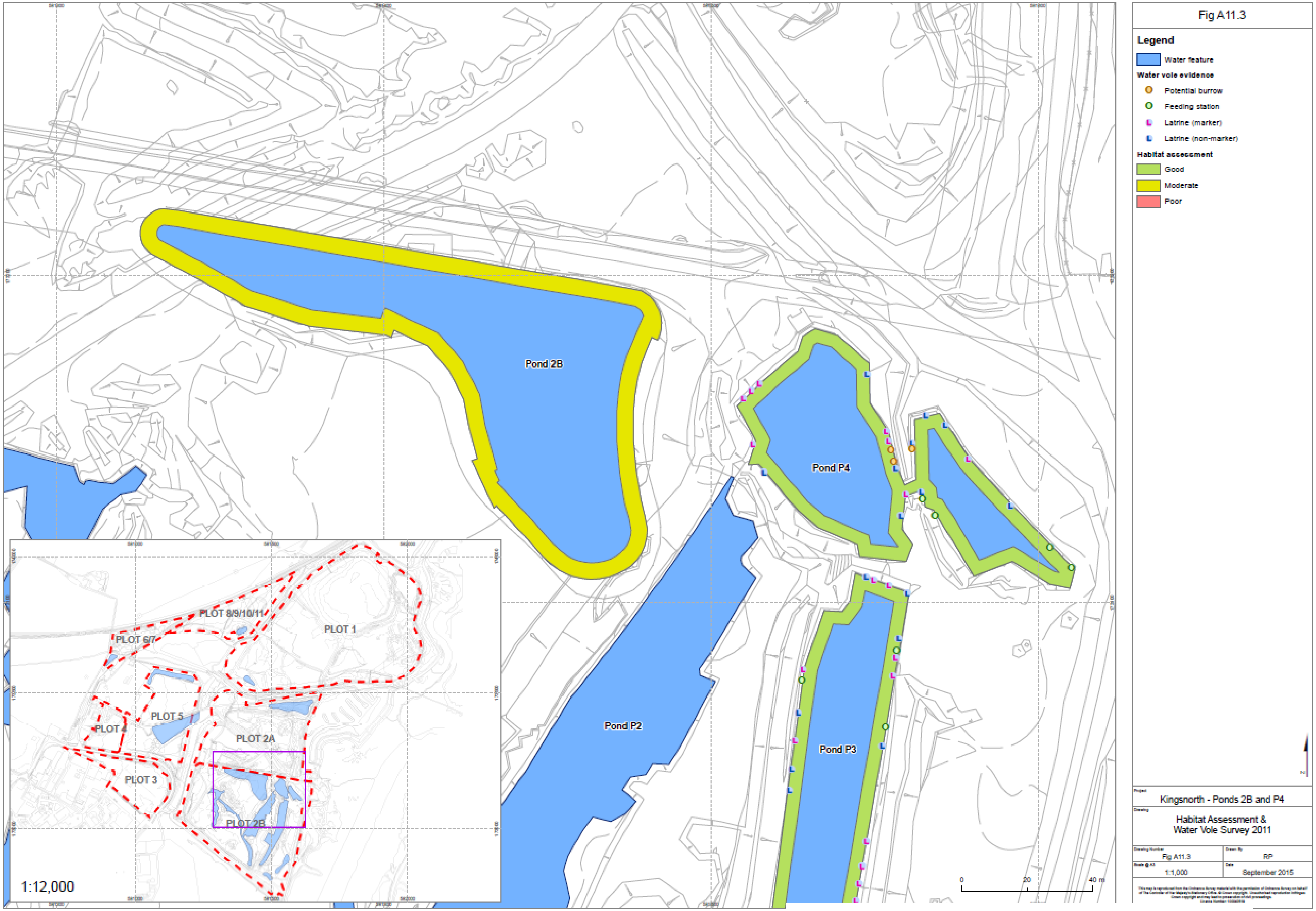


Fig A11.3 2011 Water Vole Survey Results for Kingsnorth – Ponds 2B and P4

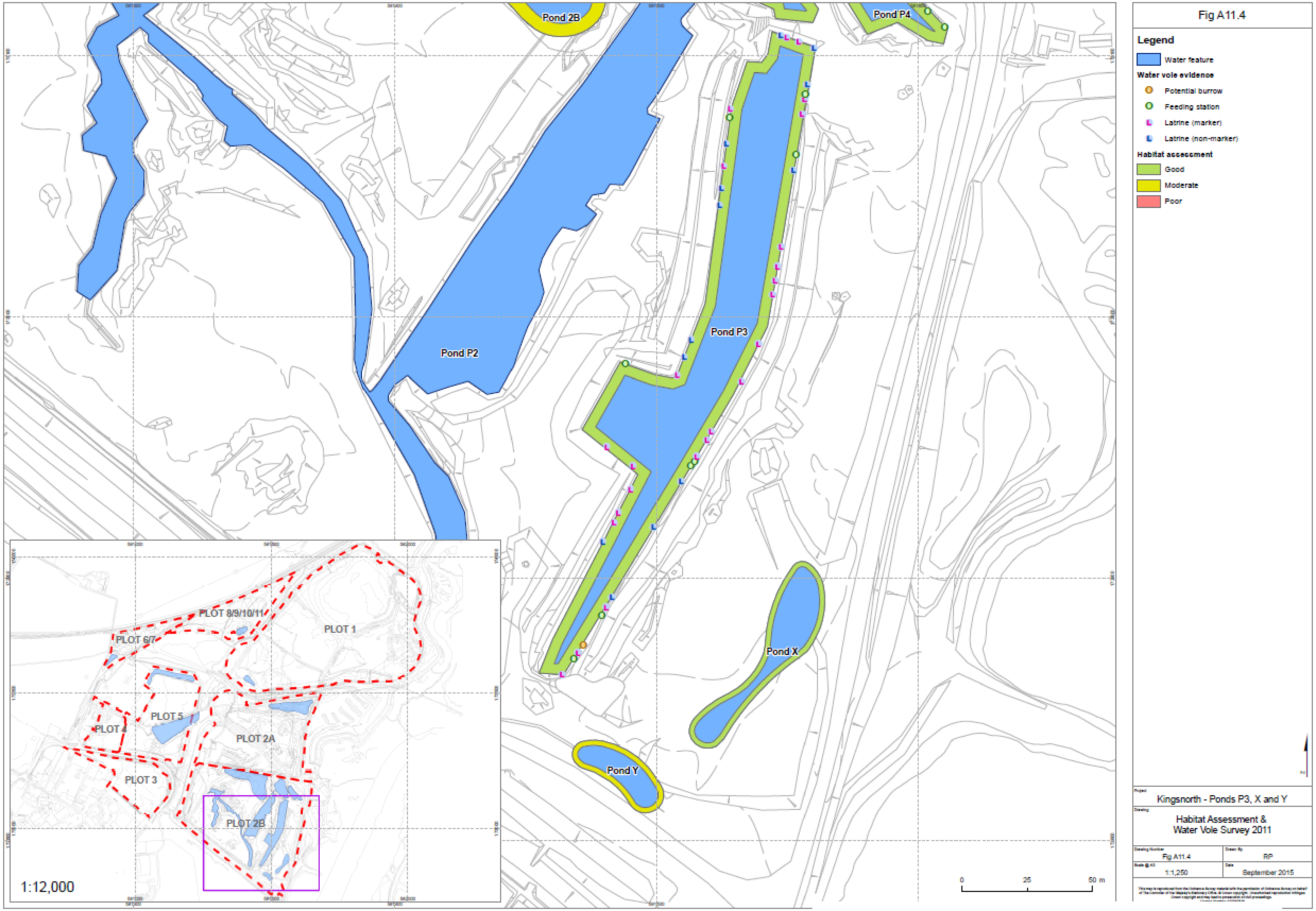


Fig A11.4 2011 Water Vole Survey Results for Kingsnorth – Ponds P3, X and Y

Appendix 12

2012 Water Vole Survey Results for Kingsnorth

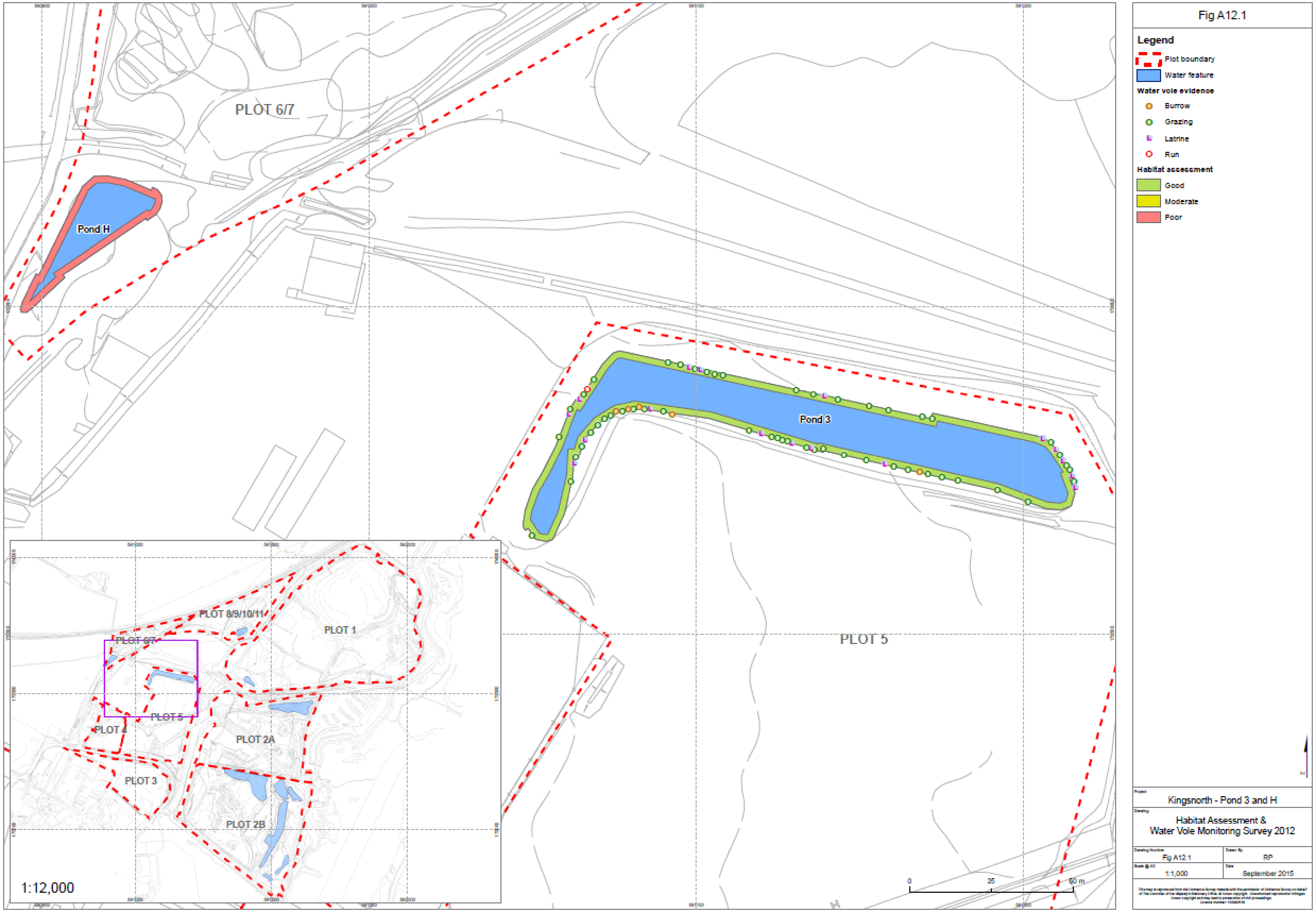


Fig A12.1 2012 Water Vole Survey Results for Kingsnorth – Ponds P3 & H

Fig A12.2 2012 Water Vole Survey Results for Kingsnorth – Ponds P1 and 7

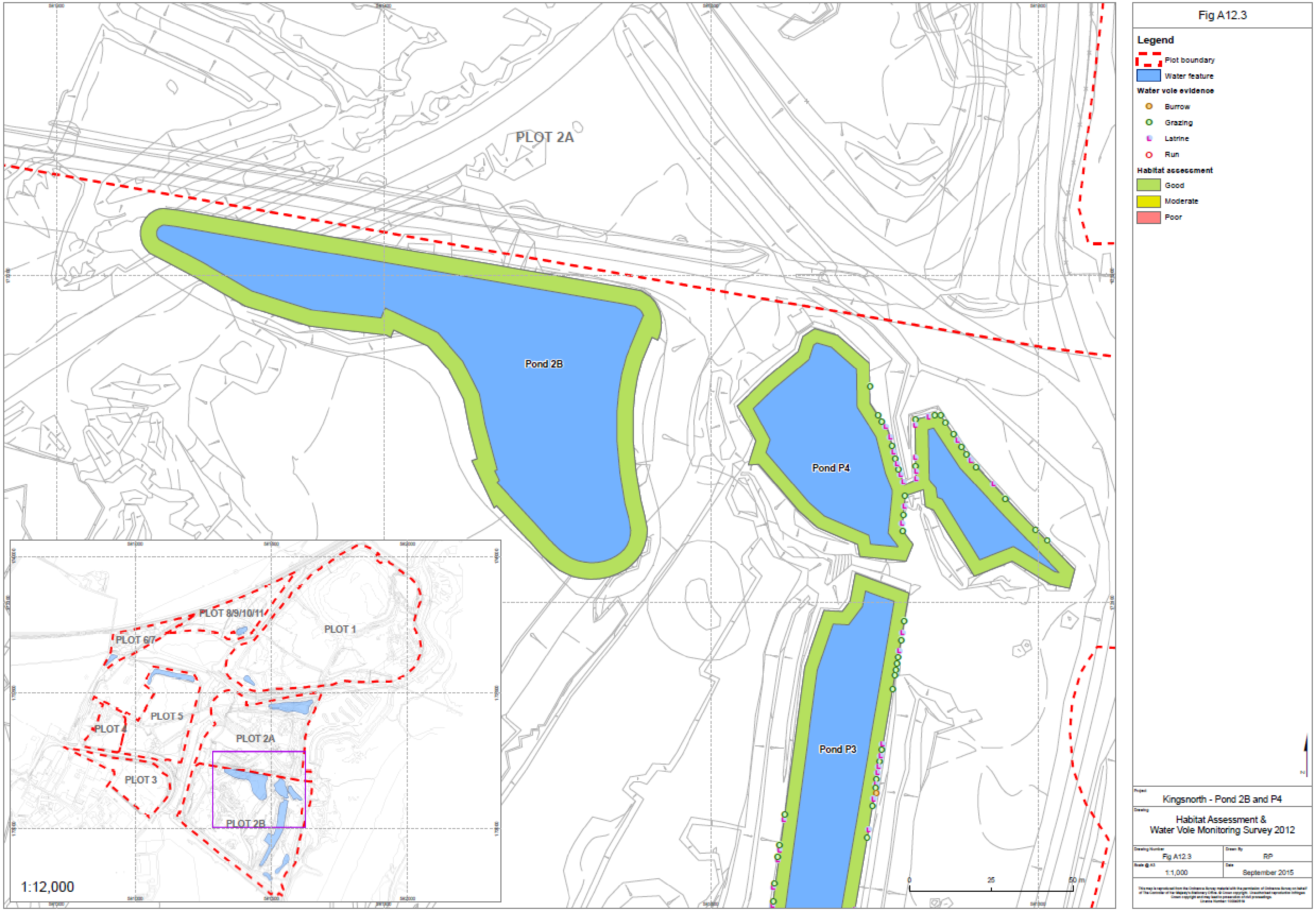


Fig A12.3 2012 Water Vole Survey Results for Kingsnorth – Ponds 2B and P4

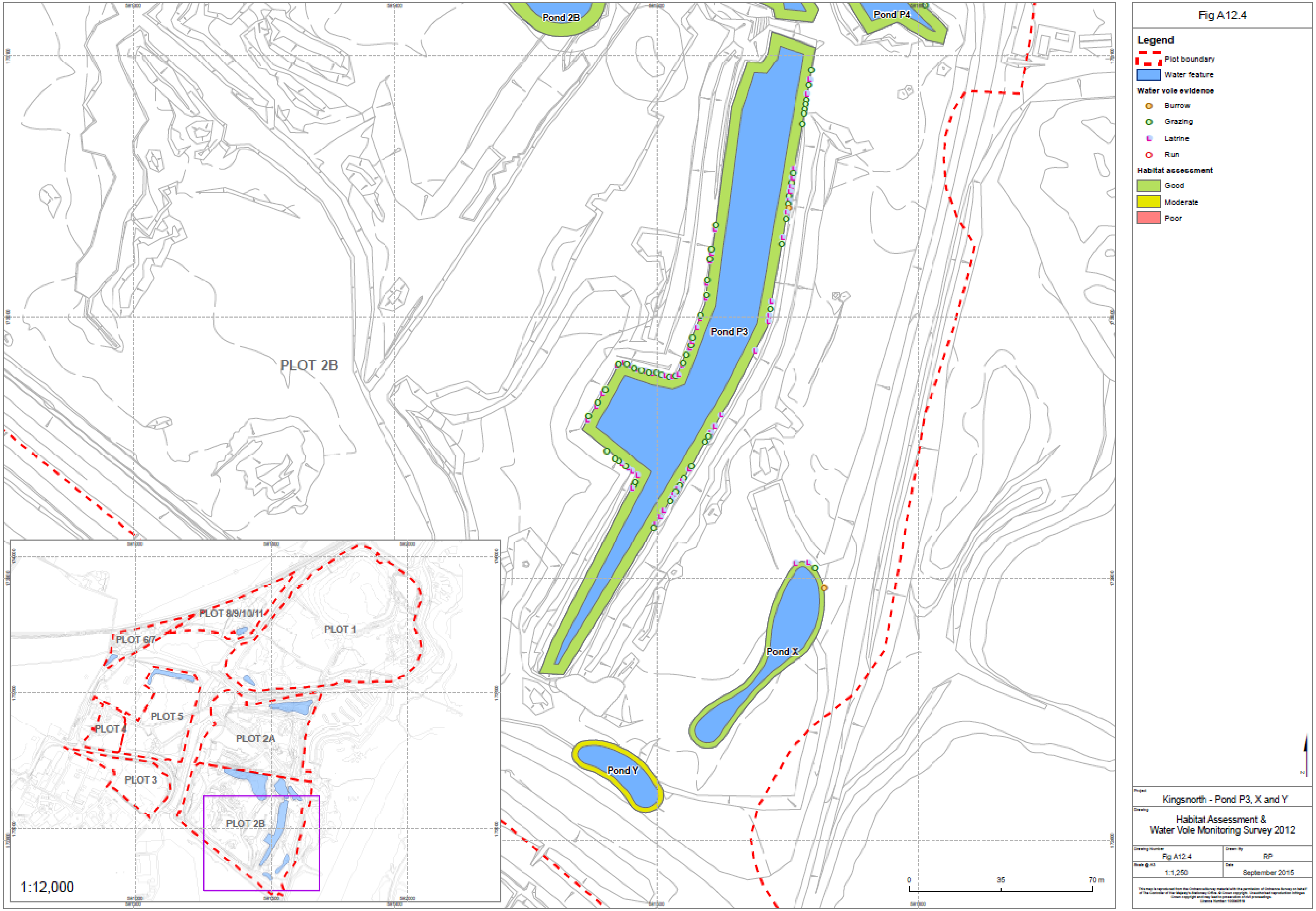


Fig A12.4 2012 Water Vole Survey Results for Kingsnorth – Ponds P3, X and Y

Appendix 13

2013 Water Vole Survey Results for Kingsnorth

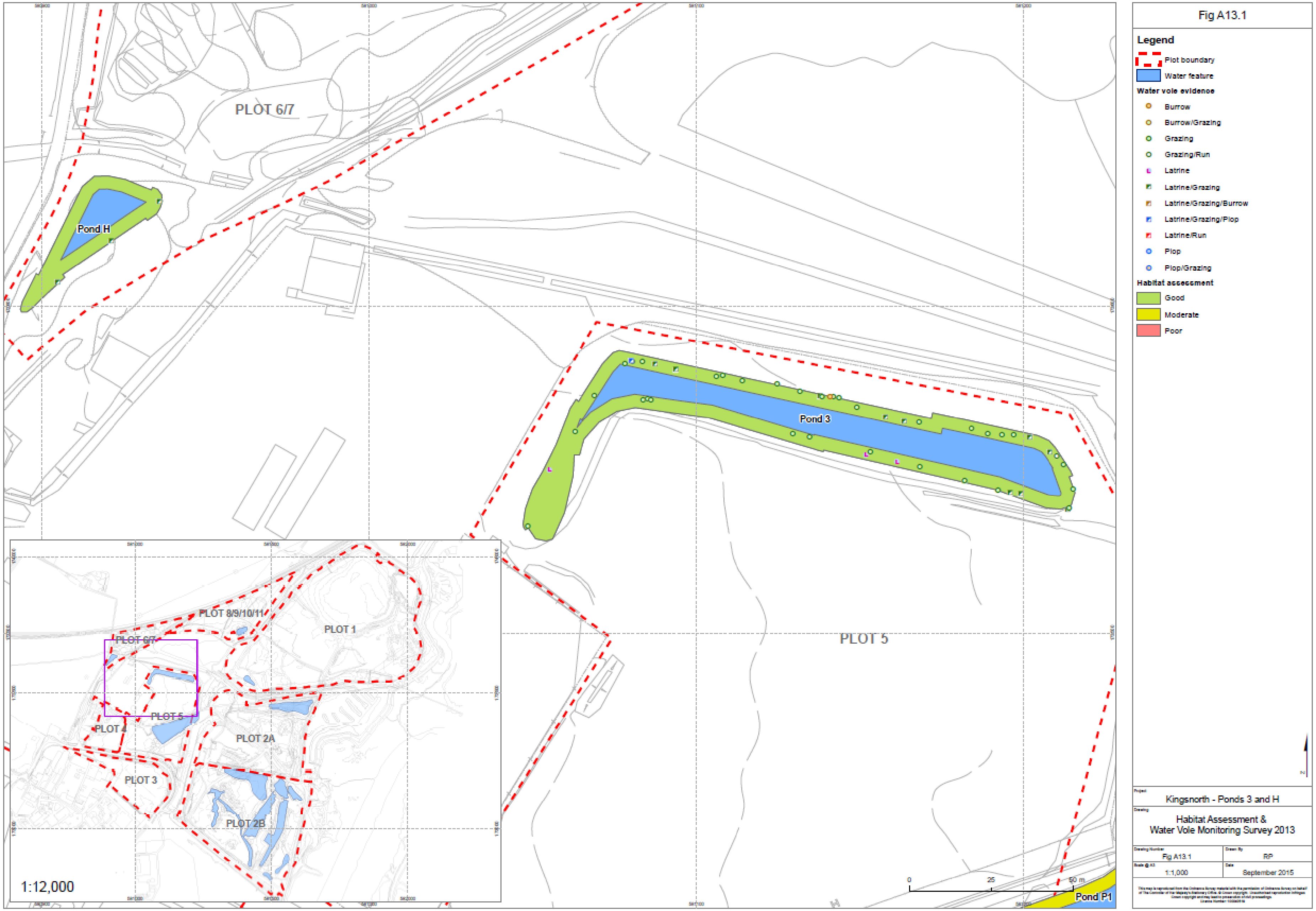


Fig A13.1 2013 Water Vole Survey Results for Kingsnorth – Ponds P3 & H

Fig A13.2 2013 Water Vole Survey Results for Kingsnorth – Ponds P1 and 7

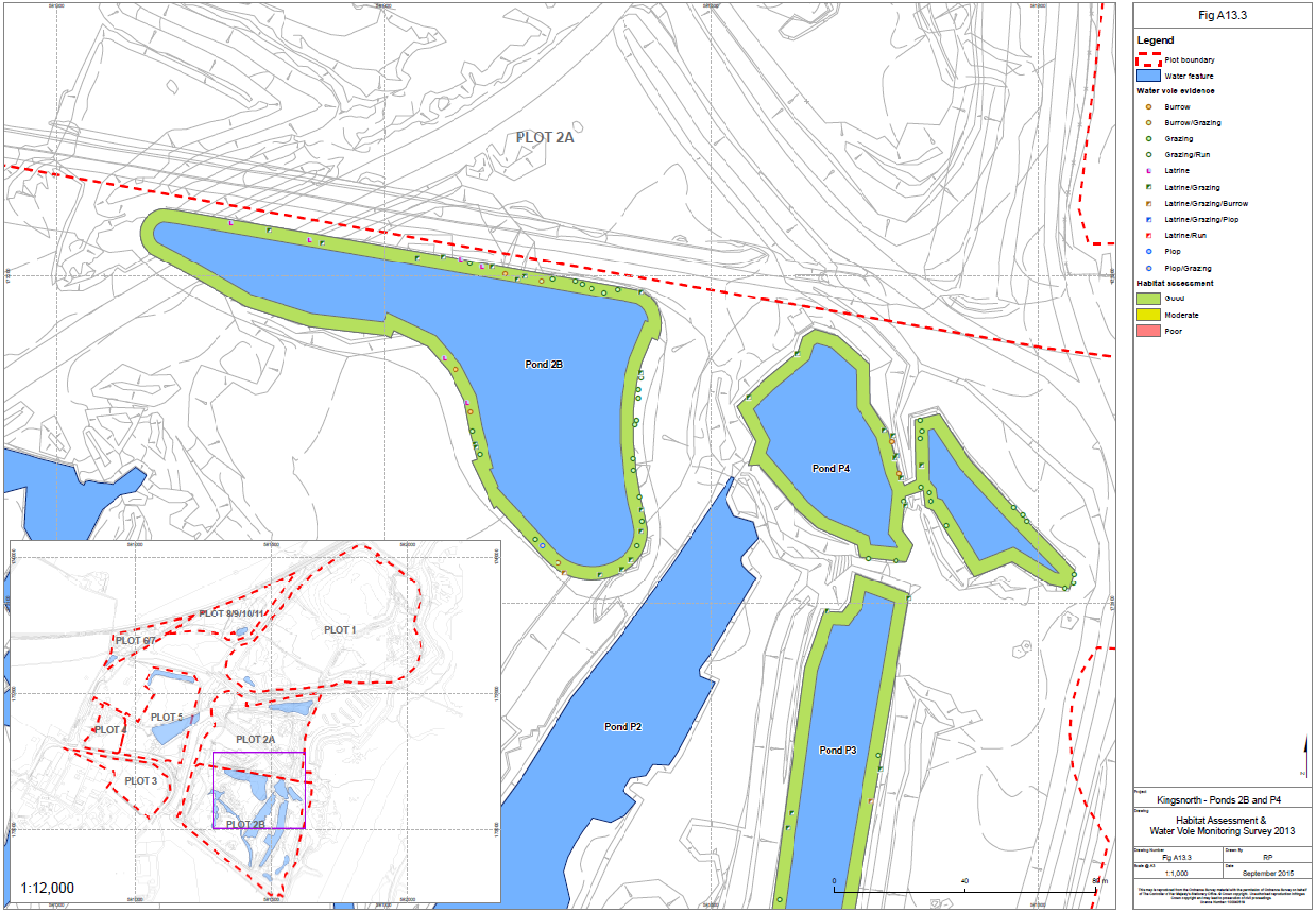


Fig A13.3 2013 Water Vole Survey Results for Kingsnorth – Ponds 2B and P4

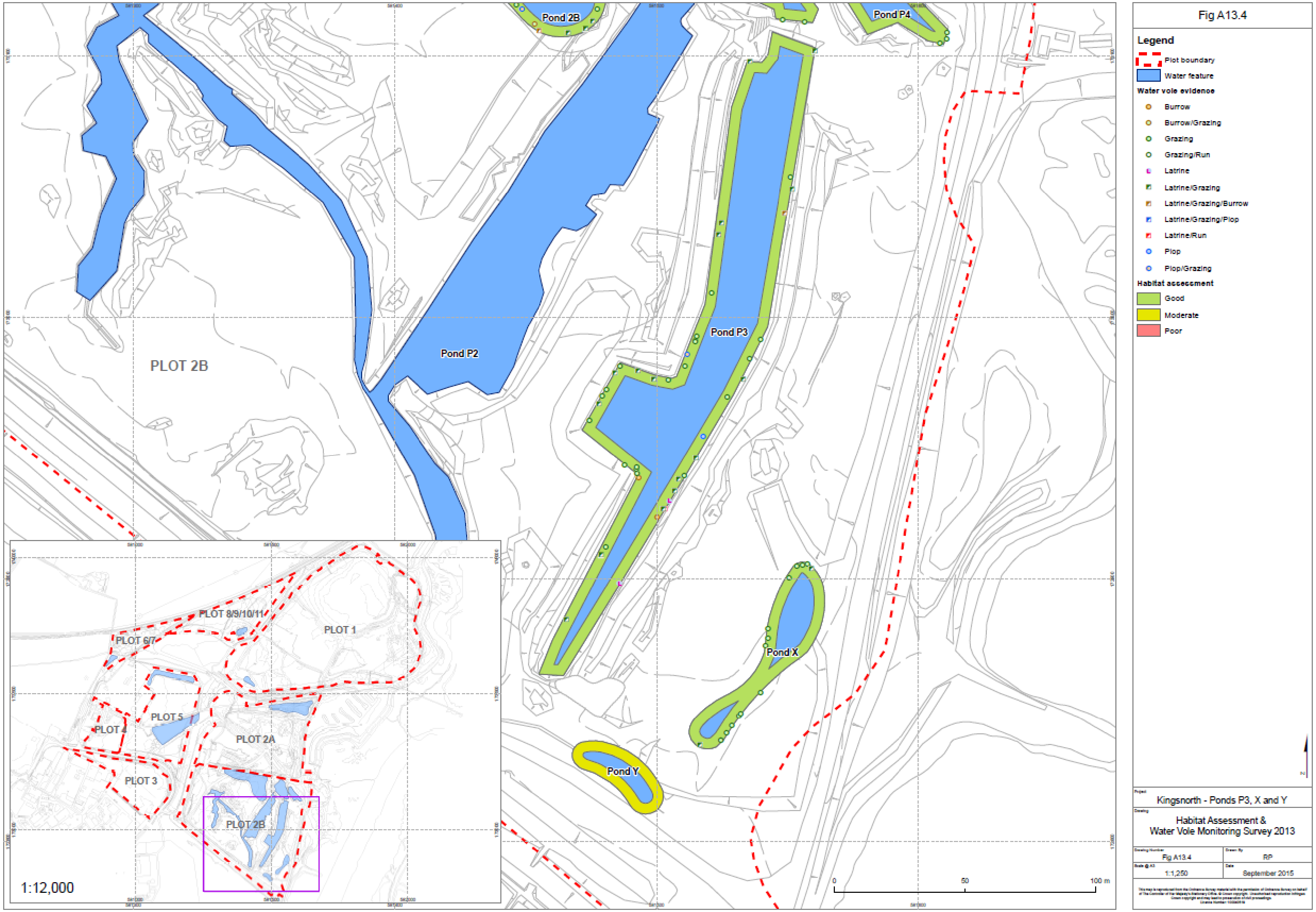


Fig A13.4 2013 Water Vole Survey Results for Kingsnorth – Ponds P3, X and Y

Appendix 14

2014 Water Vole Survey Results for Kingsnorth

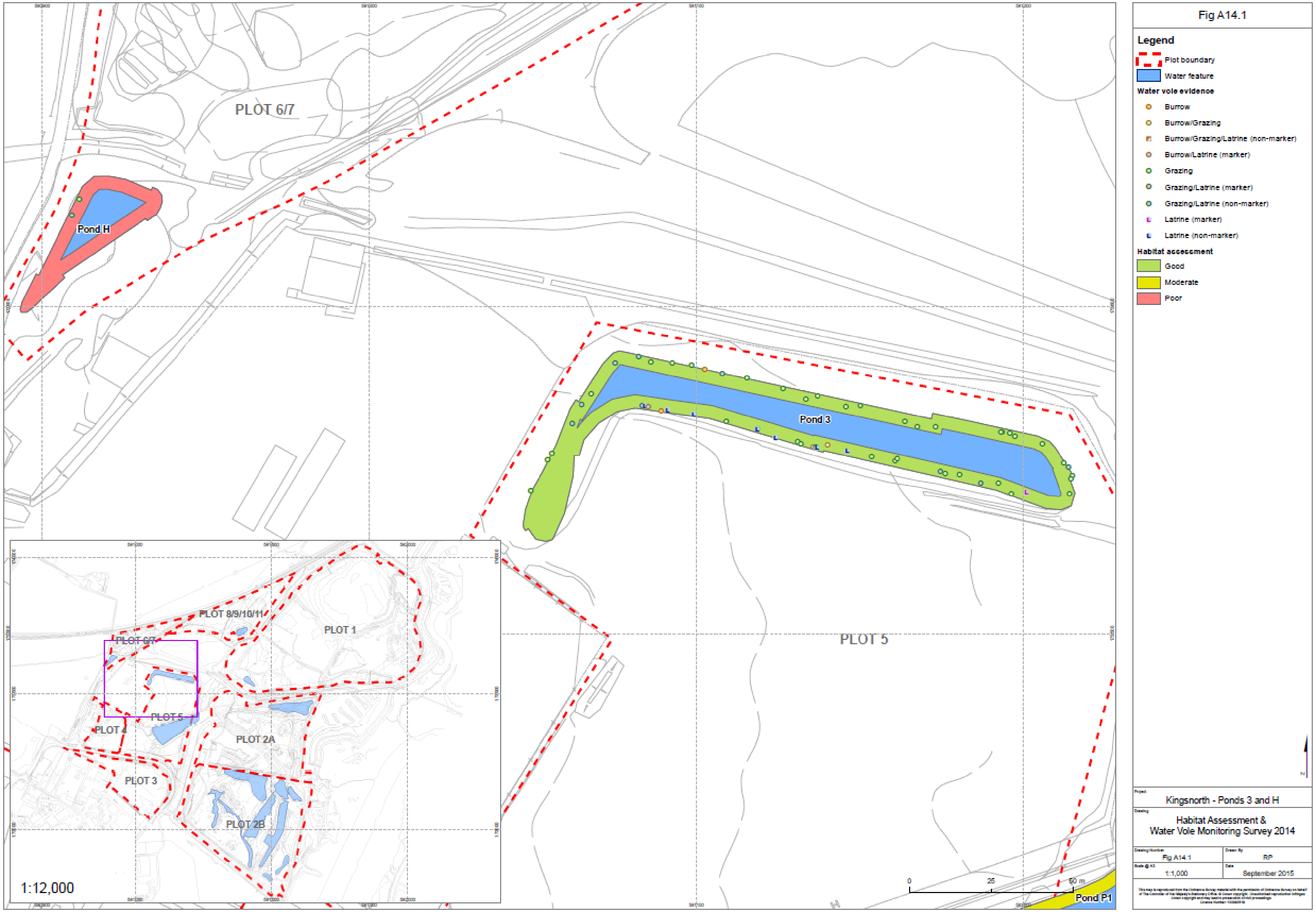


Fig A14.1 2014 Water Vole Survey Results for Kingsnorth – Ponds P3 & H

Fig A14.2 2014 Water Vole Survey Results for Kingsnorth – Ponds P1 and 7

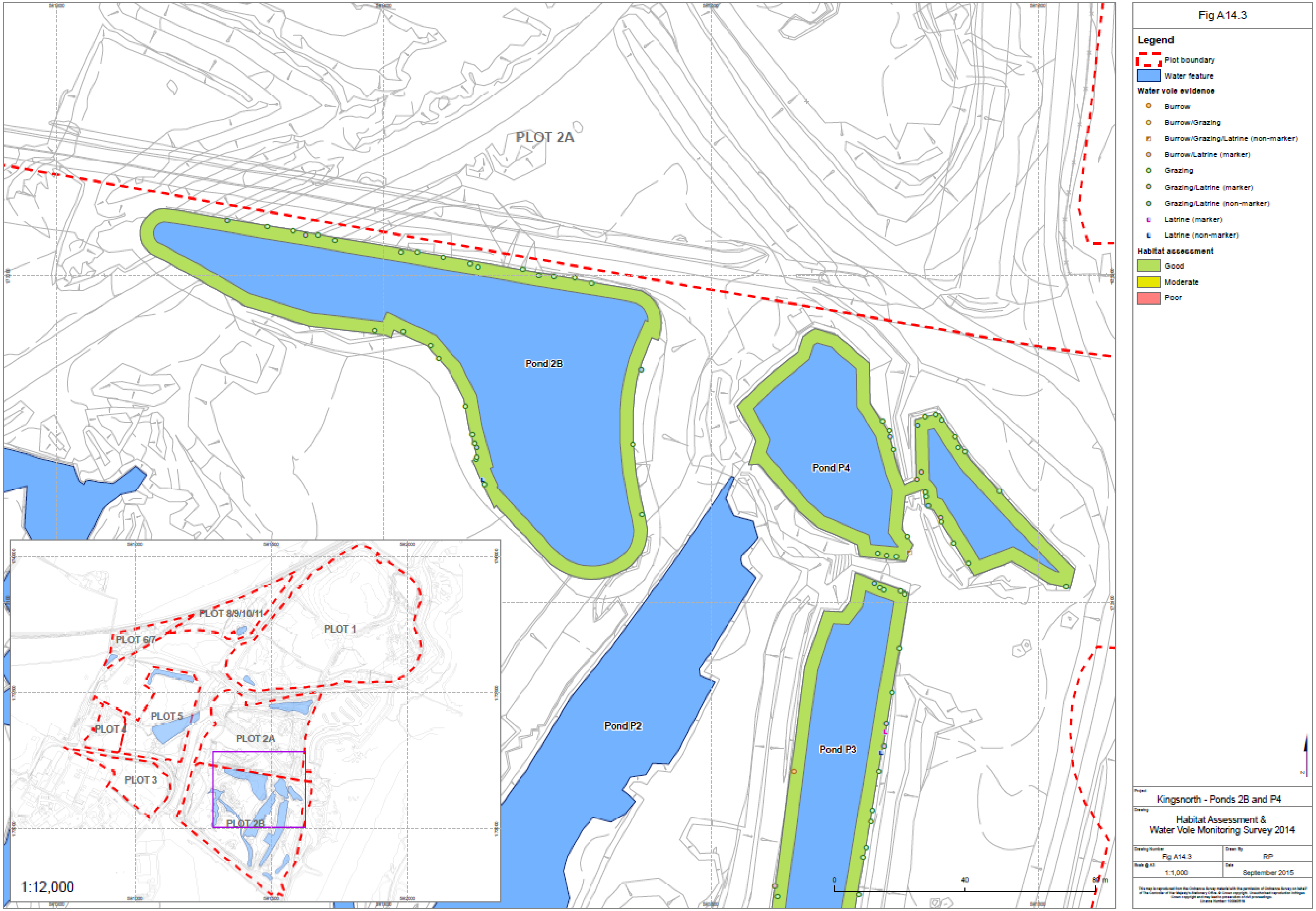


Fig A14.3 2014 Water Vole Survey Results for Kingsnorth – Ponds 2B and P4

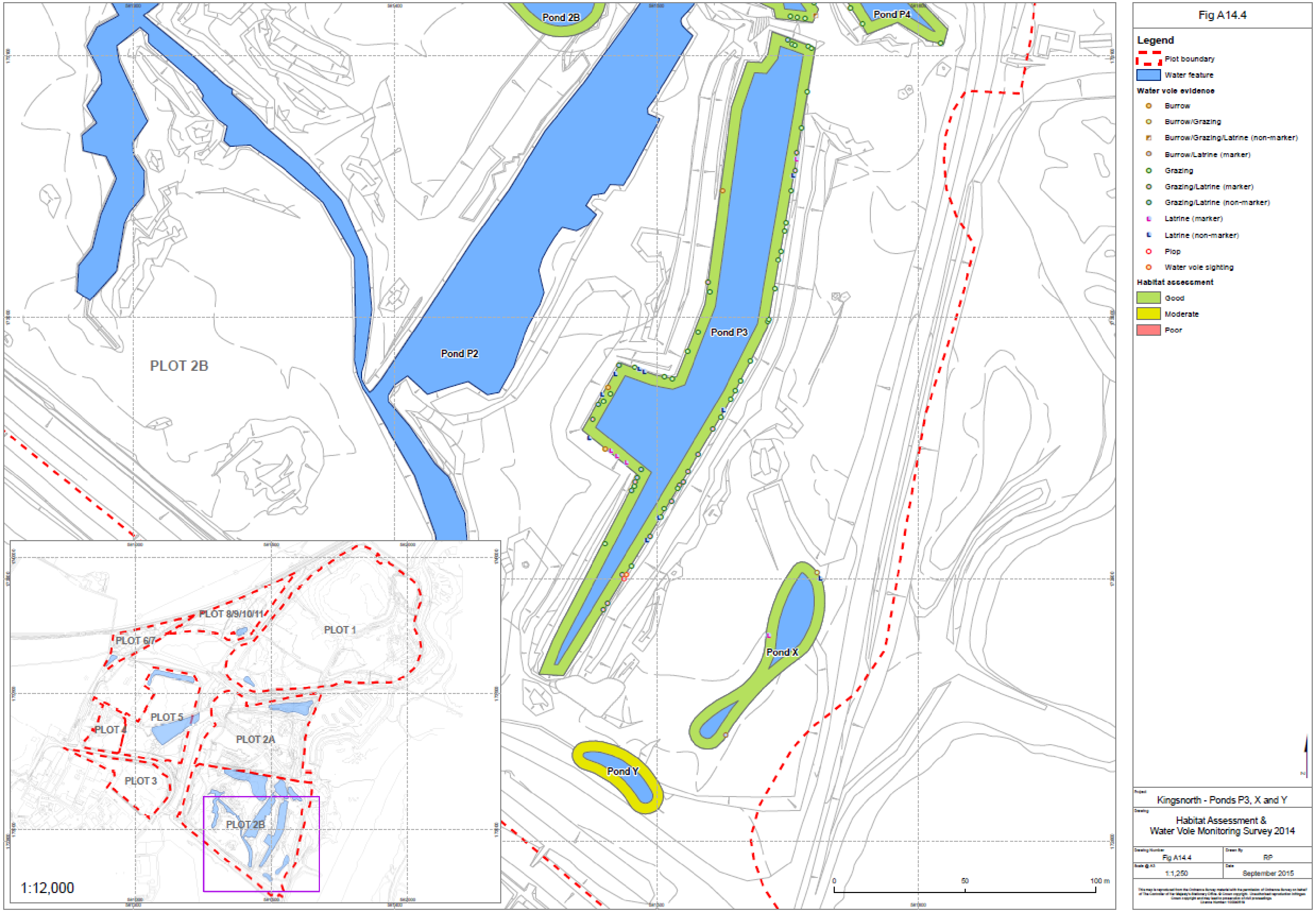


Fig A14.4 2014 Water Vole Survey Results for Kingsnorth – Ponds P3, X and Y

Appendix 15

2015 Water Vole Survey Results for Kingsnorth

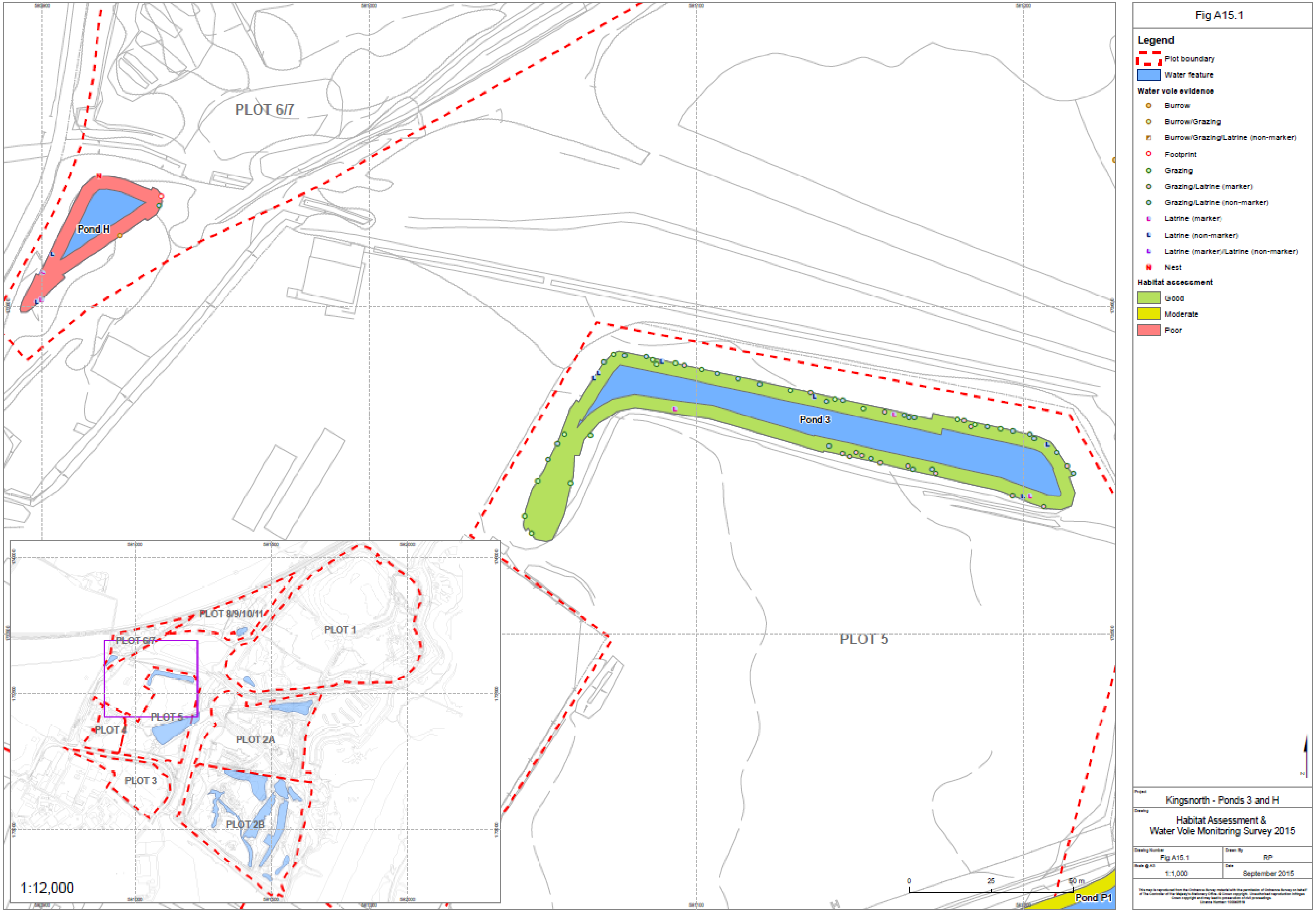


Fig A15.1 2015 Water Vole Survey Results for Kingsnorth – Ponds P3 & H

Fig A15.2 2015 Water Vole Survey Results for Kingsnorth – Ponds P1 and 7

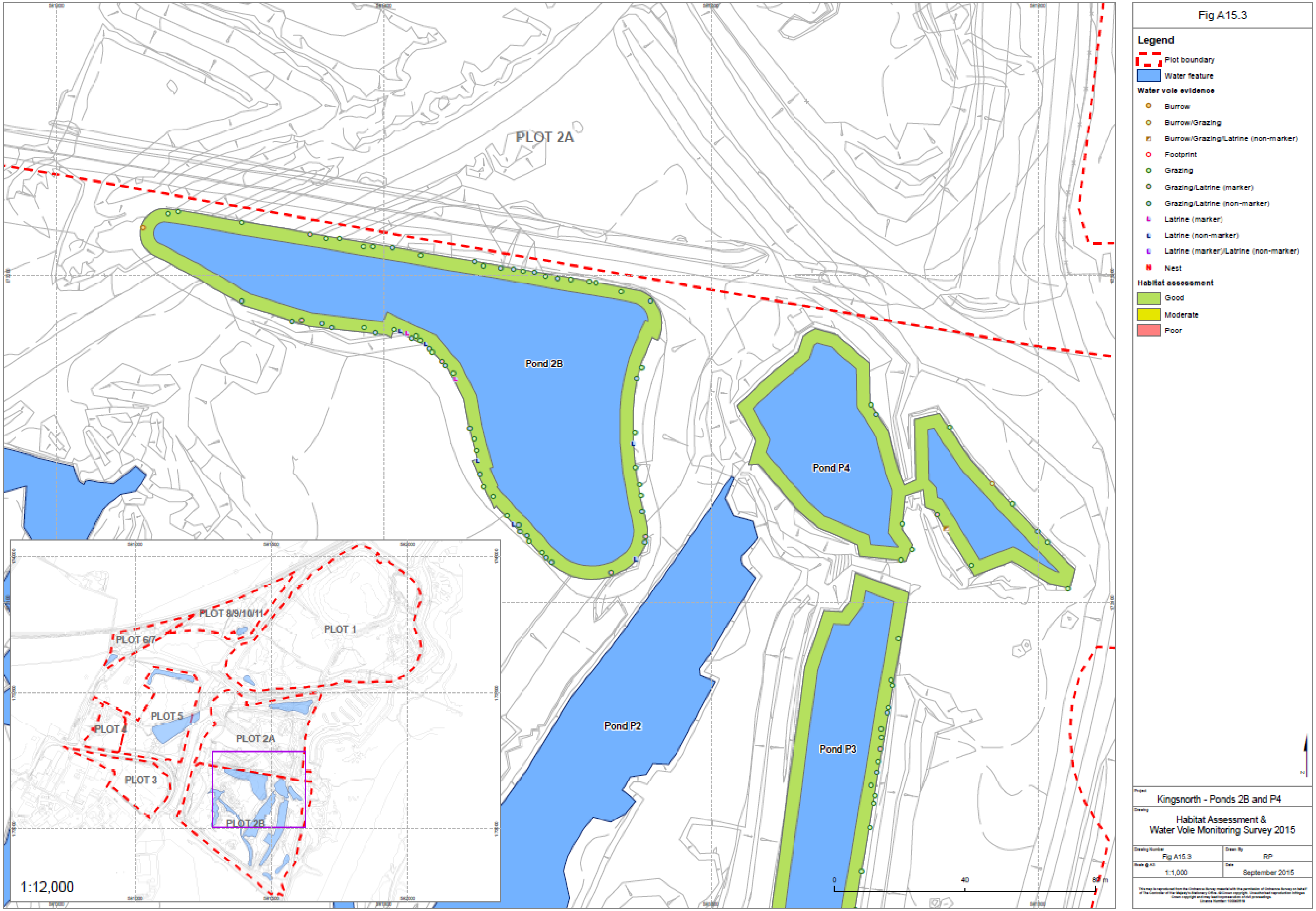


Fig A15.3 2015 Water Vole Survey Results for Kingsnorth – Ponds 2B and P4

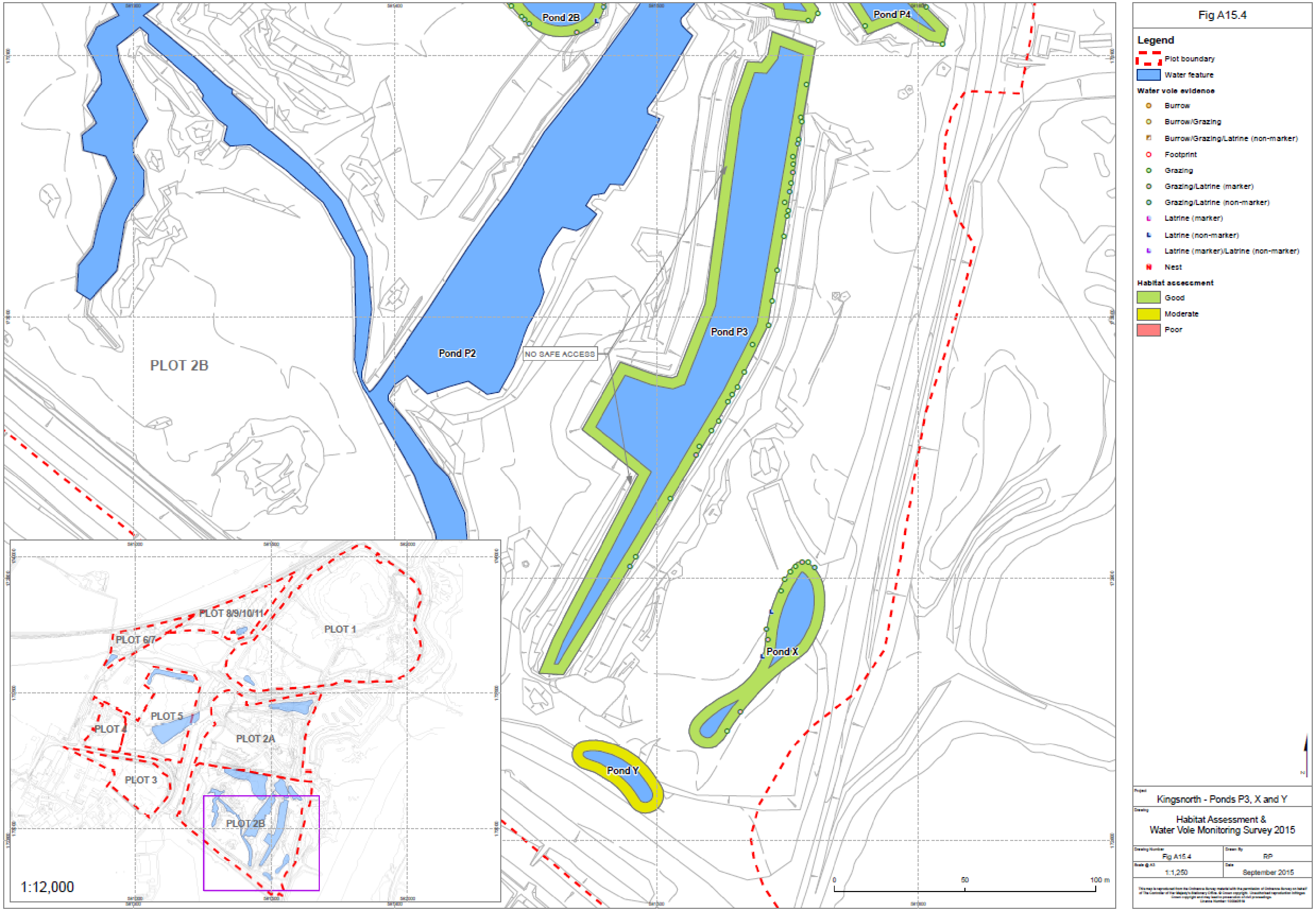


Fig A15.4 2015 Water Vole Survey Results for Kingsnorth – Ponds P3, X and Y