THE NORFOLK RIVERS TRUST

RESTORING NORFOLK'S RIVERS

THE RIVER MUN (OR MUNDESLEY BECK)

A WATER FRAMEWORK DIRECTIVE LOCAL CATCHMENT PLAN

DEVELOPED IN PARTNERSHIP WITH

Environment Agency

CONTENTS

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INTRODUCTION

This plan has been produced by Norfolk Rivers Trust in consultation with relevant agencies, landowners, farmers and residents in the Mun Catchment. The aim of the plan is to provide a framework for improvement of the ecological status of the Mun River (or Mundesley Beck as it is known by some locals), guided by the Water Framework Directive. Delivery of the actions outlined in the plan will lead to improvements in water quality throughout the catchment, providing benefits for a variety of species and habitats as well as for agricultural and drinking water abstraction.

The plan begins by providing an audit of the current state of the catchment. Then information gathered is used to identify ecological pressures in the catchment. In the final stages of the plan, solutions to these pressures are identified, costed and prioritised. Several projects have elements which could be pushed forward soon with the help of local support and volunteers.

THE WATER FRAMEWORK DIRECTIVE

The Water Framework Directive (WFD) was introduced in 2000 and commits European Union member states to improving the physical and ecological quality of their streams, rivers and lakes. The quality of these waters is measured using a range of indicators outlined below which combine to give a picture of a river's health. Using this combination of indicators a river (or groundwater unit, or lake) is then graded on its overall "ecological status", and designated as either bad, poor, moderate, good or high. Each member state is required to bring its water bodies to good status by 2015. Where this is not possible, good status must be achieved by 2021 or 2027, depending on the severity of the barrier to good status. The majority of Britain's rivers fail to attain good status due to a wide variety of pressures. In England, the Environment Agency is responsible for WFD delivery.

Water Framework Directive Status	Current river Status (2009)	Predicted by 2015
Bad		
Poor	**Overall ecological status Fish**	**Overall ecological status Fish**
Moderate		
Good	**Invertebrates Good Phosphate Flow dynamics supports good**	**Invertebrates Good Phosphate Flow dynamics supports good**
High	**Dissolved oxygen Ammonia pH Zinc**	**Dissolved oxygen Ammonia pH Zinc**
	Heavily Modified Water Body for wider environment	**Heavily Modified Water Body for wider environment**

Table 1. Results of detailed water body investigations undertaken by the Environment Agency to determine the status of the River Mun. A prediction about the status at the next "waypoint" in the WFD schedule (2015) is also shown.

A CHOICE FOR THE FUT URE OF OUR RIVERS…

RIVER MUN STATISTICS

Approximate river length:	7.94 km (Source and STW – Sea)
Catchment area:	22 km2
Legal designations:	Bathing Water Directive, Nitrates Directive
Protected area designations:	Parts of Templewood are a Country Wildlife site

WHY RESTORE RIVERS?

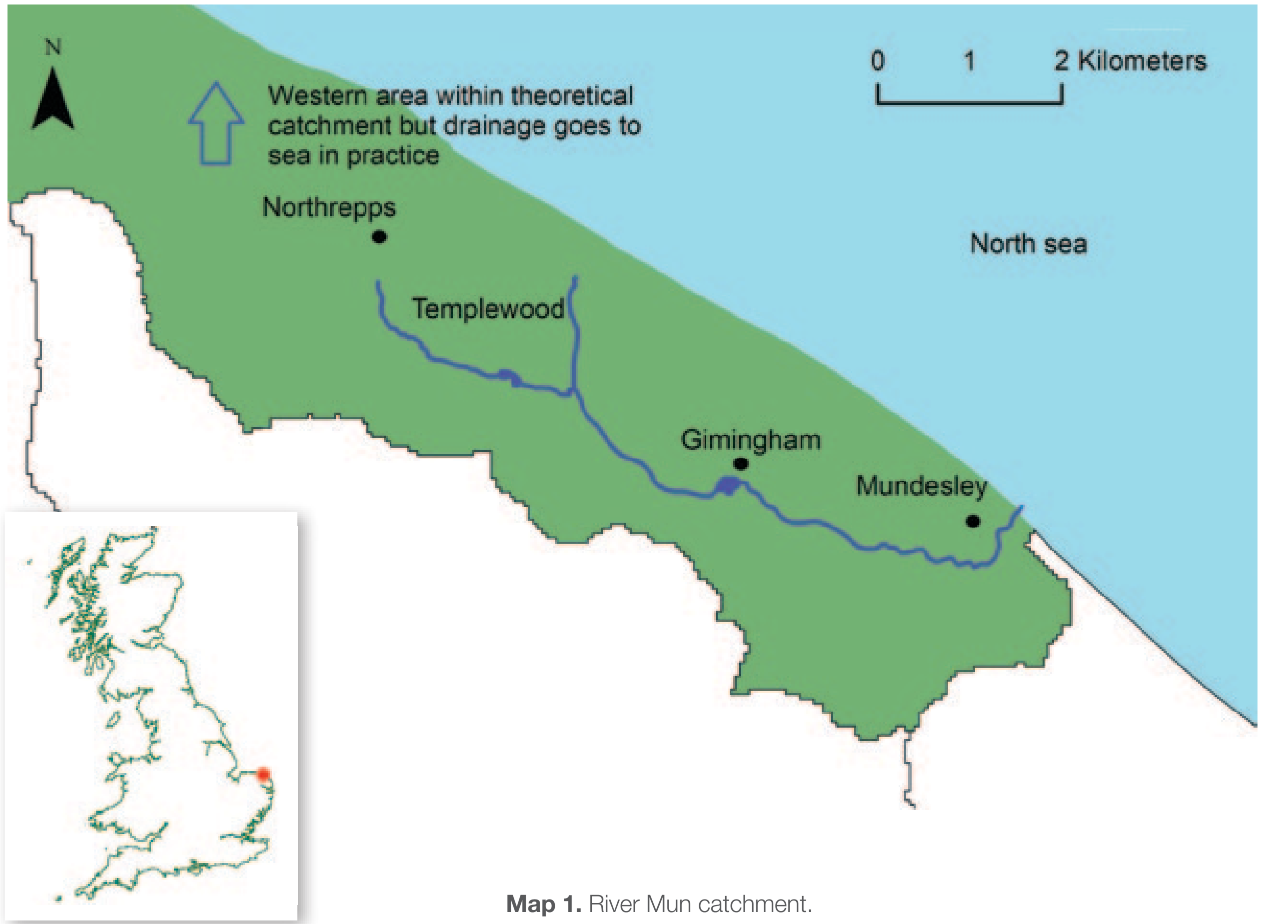
Britain's rivers generally fail to reach "good" ecological quality. This is both a problem in itself and a sentinel of trouble.

A well-functioning river system is an inseparable combination of good water quality, distinctive physical processes and diverse wildlife. These factors interact to provide benefits. A naturally functioning river has a floodplain with sufficient capacity to absorb inundation and to act as a store for silt carried by high flows. The river channel is also self-scouring. This reduces flood risk and the need for expensive management. Headwater forests reduce surges of water into the system by increasing drainage and removal of water. Moreover, the vegetation, microbes and invertebrates in the river corridor also absorb and process pollutants. This enhances water quality within limits, however, very polluted rivers have less wildlife and in turn a reduced capacity to provide such benefits. This leads to a downward spiral. Wildlife itself also has an intrinsic value and is enjoyed by groups such as fishermen, ramblers and bird watchers.

If any of the three pillars of the river system are damaged (water quality, physical processes, ecosystem), then the value of the entire interconnected system is reduced. Arguably, we also have a responsibility to repair our damaged natural heritage for future generations. Thus, ecological restoration aims to enhance the functioning, as well as the intrinsic value of our beautiful rivers.

SECTION 1 THE CATCHMENT

The Mun is a small river which draws its waters from a superficial aquifer comprised predominantly of sands and gravels. It flows parallel to the Norfolk coast from Northrepps through Gimingham and discharges into the sea at Mundesley. The river sometimes flows from a ditch which originates close to Northrepps, but the initial source of its water is usually the treated effluent from Northrepps Sewage Treatment Works. The flow is then augmented by multiple seepages throughout Templewood. The amount of water derived from the catchment is less than would normally be expected due to the proximity to the coast which means that groundwater is lost towards the sea, instead of draining into the river exclusively. In general, the stream has been modified extensively by multiple impoundments and channel straightening. There are no sections of naturally meandering river channel. The catchment itself is predominantly comprised of arable agriculture, with some forest immediately surrounding the river in its upper reaches.



Map 1. River Mun catchment.

THE COMMUNITY

It is part of the Norfolk Rivers Trust's mission to gain the active participation of the community to restore their river. Stakeholders help us to set objectives, keep us informed about issues on the ground such as pollution, and actively volunteer to make many more worthwhile projects possible.

Norfolk Rivers Trust have recently started to work in the Mun catchment, and we were very pleased to receive around 170 people at our latest event. So far, we have also been grateful for the enthusiasm and participation of several locals in the process of planning future conservation work, and would be very happy to hear from anyone who has an interest in conservation around the River Mun.

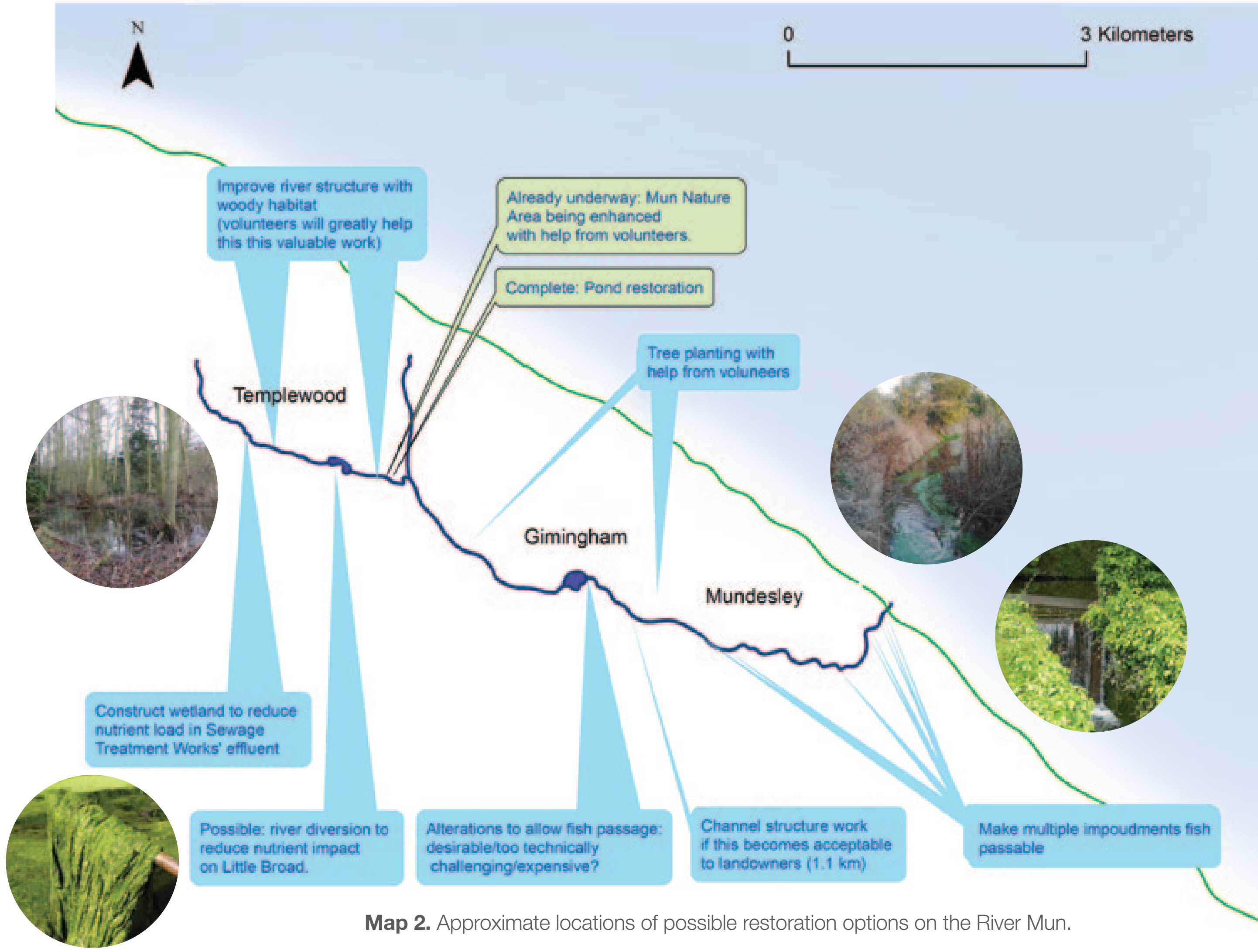
Cooperation from landowners and support from volunteers have been vital in the first projects which we have undertaken surrounding the Mun, such as pond restoration and public access work at The Grove which was underway in March 2014.

Rhododendron clearance at The Grove.

A pre-works briefing.

OVERVIEW OF RESTORATIONS OPTIONS

Summary of possible restoration options on the River Mun. These proposals will greatly enhance the water quality and wildlife value of the river. It is stressed that these are subject to landowner consent and are only outline ideas at this stage, with the exception of projects which are underway which are being undertaken in partnership with landowners.



Map 2. Approximate locations of possible restoration options on the River Mun.

GEOLOGY AND GEODIVERSITY

Introduction

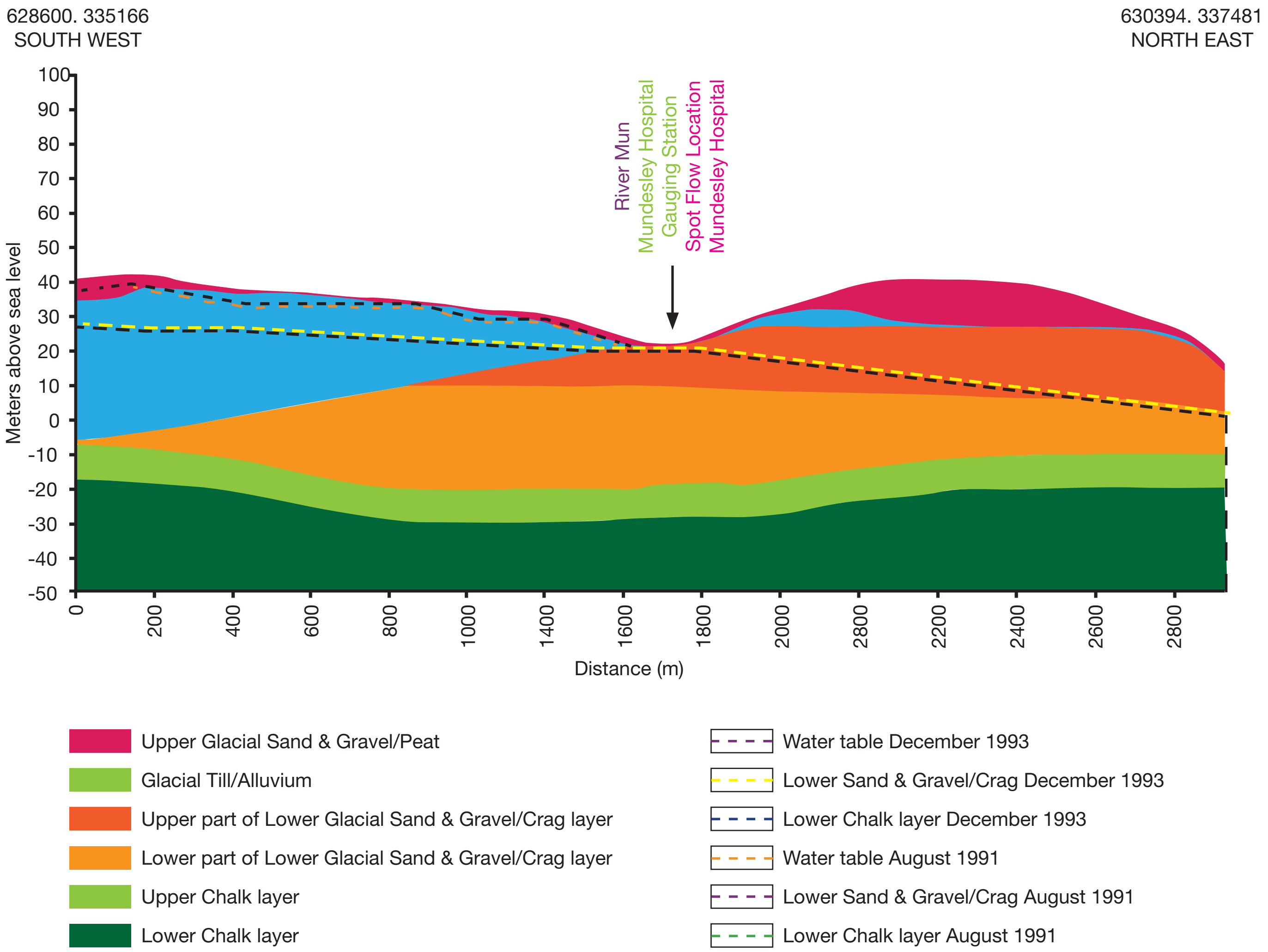
The River Mun is a small river in north-east Norfolk. It is only about 8 km (5 miles) in length. It has its headwaters at Northrepps, at the eastern end of the uplands of the Cromer Ridge. It skirts the southern margin of the Ridge, flowing in a south-easterly direction parallel to the coastline, before turning abruptly north-eastwards to meet the sea at Mundesley. This drainage pattern suggests that the river may once have been a stream feeding into the headwaters of the River Bure, perhaps 200,000 years ago, but marine erosion has since removed the eastern end of the Ridge and hence the rivers's connection with this river system.

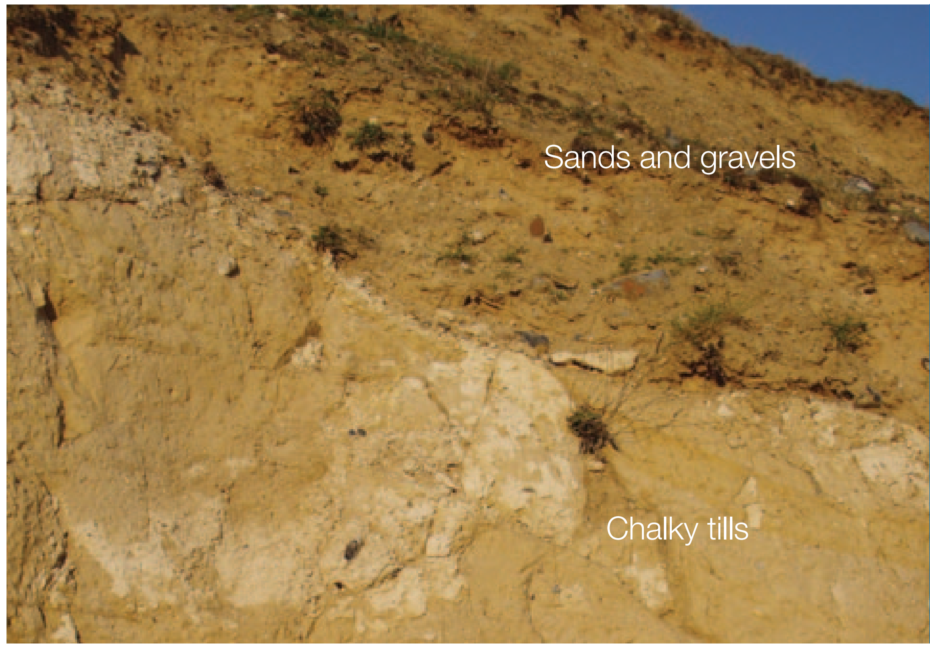
Like chalk rivers in Norfolk, the River Mun is fed from aquifer-held groundwater rather than surface water, and its flow is gradually released through springs or directly up through the river bed. Unlike chalk rivers, the aquifer here is not chalk bedrock but a mixture of permeable Ice Age sands, gravels and chalky clays which underlie the Cromer Ridge and neighbouring uplands to the south.

The Ridge was formed from deposits left behind by a succession of ice sheets during the Anglian glaciation, about 450,000 years ago. In this area it rests on a layer of marine sands, gravels and clays of the Norwich Crag, about 2 million years old. This complex geology can readily be seen where the Ridge meets the sea in the cliffs between Overstrand and Trimingham. Chalk is present underground, but at considerable depth so it has little influence on local groundwater; a borehole at Craft Lane, Northrepps, penetrated no less than 67 m (220 ft) of sands and clays before reaching it. Rain falling on the Ridge percolates down through the permeable, sandy soils and thick glacial deposits to recharge the aquifer. The groundwater is slightly alkaline, due to the presence of chalky clays, and has a higher content of dissolved iron than many other rivers in Norfolk. It emerges where the ground surface intercepts the water-table, for example along the floor and sides of the valley floor, or in the cliffs along the coast where it causes some spectacular landslips.

Wildlife in rivers such as the River Mun is vulnerable to changes in river structure, processes and water chemistry. In particular, flood defence and drainage work may lead to an alteration of the channel shape by deepening and straightening, with knock-on effects on river flow and biodiversity.

Cross Section of geological layers at Mundesley Hospital.
Image courtesy of the Environment Agency.





Gimingham Quarry provides window into the sediments of the Cromer Ridge. Seen here, chalky tills at the base of the pit are overlain by sands and gravels of the Briton's Lane Formation.

The headwaters

The headwaters of the Mun are located near the Rectory at Northrepps. A pond and springs here are fed by waters emerging where the valley floor intercepts the aquifer. The river is little more than a ditch between here and Frogshall. It receives water from a sewage treatment works, and the high content of dissolved phosphates adversely affects water chemistry. There is much carr (damp woodland) at Frogshall and the Templewood Estate where the valley is floored with poorly draining alluvium and peat; the river here is fed by baseflow and a series of springs and wet flushes. Its waters were diverted into a straightened channel in the early 19th century to facilitate drainage of this soggy land. Water management on the Estate in the early 20th century included ditching associated with the creation of plantation woodland, and damming the river to create duck flighting ponds, the largest of which is known as Little Broad. The river's former course is discontinuously present as a ditch on the valley floor. The waters of a small tributary enter the stream just upstream of the Cromer Road bridge; these rise from springs in a valley above Clapham Dams Farm.

A boiling spring in the river bed near Frogshall Bridge, March 2014.

The River Mun at Gimingham Hall Farm. It is now a drainage canal and has lost a formative relationship with its floodplain.

Middle reaches

The middle reaches of the River Mun have been extensively straightened and canalised since the early 19th century, as part of land reclamation and flood control work. There are no stretches which exemplify its former meandering channel form, as visible on Faden's map of Norfolk (1797). Where the river flows rapidly its bed is sand and gravel, otherwise organic-rich silts predominate in quiescent stretches, as in the floodplain meadows of Gimingham Hall Farm. The network of cross-dykes and soke-dykes here is evidence of a systematic drainage programme, and the river itself is embanked above the valley floor on the northern margin of the floodplain. The impoundment of the river at Gimingham Mill is likely to have had knock-on effects on water levels in this part of the valley. The present mill dam was constructed across the valley in the early 19th century, and there is now a relative height difference of some 4 m (13 ft) above and below it, so the dam and nearby fishing lakes are now perched above original floodplain level.

Lower reaches

Downstream of Gimingham, the river follows an embanked, canalised course on the northern side of the floodplain. This stretch is prone to low flows and drying out, but this has been mitigated in recent years by strict controls on the amount of water that can be taken for local irrigation. The river flows over a bed of sands and coarse gravels in many places. It has a gradient of approximately 2.1 m (6.9 ft) per km between the Hospital and High Street Bridge at Mundesley; thereafter it steepens, reaching some 16 m (52.5 ft) per km as it flows to sea level through a natural ravine in the cliffs. This ravine would originally have been incised by the river in dynamic response to variations in river flow and in base level caused by coastal retreat. The river's course is artificially modified in various ways as it passes through the village. Its waters are firstly diverted from the ravine into a former mill pond before being directed back into the ravine through a steep sluice. They pass through a concrete channel before eventually flowing into the sea through a piped culvert on the beach. These obstructions alter the river's ability to shape its own channel; they also impede the migration of migratory fish.

The waters of the River Mun are channelled through a steeply inclined concrete spillway as they pass under Paston Road.

Tim Holt-Wilson
Norfolk Geodiversity Partnership

WILDLIFE

Despite the many challenges which the wildlife in the Mun valley faces, the catchment supports a diversity of organisms which benefit from the river.

Photograph: © Jonathan Lewis

Photo 3. Kingfisher

Photograph: © Jonathan Lewis.

Species profile: River Kingfisher, *Alcedo atthis*

When walking down a gurgling river, one is sometimes lucky enough to be graced by the teal blue flash of a kingfisher speeding busily past. This incredible little bird feeds on small fish and invertebrates at a voracious rate, consuming its entire body weight each day. During the mating season, the kingfisher will catch 5,000 small fish to sustain itself and its young. Kingfishers do not have a beautiful song to match their striking colours, but they do have a variety of calls with different meanings. In fact, one call signifies to their mate and young: "I'm home!"

In the winter, when some of the kingfishers' feeding spots freeze over, the birds migrates towards coastal estuaries where the warming effect of the sea, and the salt water prevent freezing. Most of the time, however, kingfishers stick to a particular territory and will be seen in the same spot routinely.

Species profile: The Eurasian Otter, *Lutra lutra*

The otter is a predatory mammal which uses its excellent swimming ability and specialised teeth to feed on a variety of prey such as fish but also amphibians and occasionally birds. They have even been shown to be capable of eating toads despite their poisoned skins. They corral the amphibians into groups before proceeding to skin them and eat the nutritious innards. Otters hold territories against the same sex, and this stops their numbers building up into high densities, especially when food is scarce. This beautiful and reclusive animal is wide ranging and can be seen around ponds, lakes, rivers and marine habitats.

Photo 2. Otter

Photograph: © Jack Perks

Wildlife profile:
River plants

The benefits of aquatic plants for lowland river systems are threefold: they reduce pollution, they improve river structure and they are a vital habitat for other wildlife.

Scientific studies have shown that plants remove excess nutrients caused by sewage effluent or agriculture. Their sinuous fronds create a large surface area for colonisation by algae, bacteria and invertebrates which process nutrients and organic matter within the river. Their roots directly remove nutrients. They also stabilise sediment and thus prevent movement of toxins which may be bound to sediment particles. Water plants' physical role is also vital. They narrow the channel in places and cause water to accelerate, as well as holding water up in other places. This allows differential scour and deposition of sediment, which helps river channels to remove and store sediment. Together with trees, they are nature's architects of channel structure, helping rivers which have been artificially straightened to recover to a more meandering form. Water plants are also a rich habitat for invertebrates which feed the larger animals in the river system. Last, but not least, their delicate greens and subtle white flowers are also one of the wonders of the British countryside.

Ten years ago this section of stream was absolutely straight and featureless. Growth of plants and sediment deposition around dead plants has caused a return to a more natural meandering form, which in turn has started to cause pools and riffles to develop. (Photo: Olly van Biervliet, Fox's Beck, Norfolk. With thanks to John Dowland)

Water crowfoot in flower.

Water plants cause flow variation which also encourages sediment storage and scour.

Varied water plants represent shelter and food for a diversity of other wildlife.

A HISTORY OF HUMAN MANAGEMENT AND THE CATCHMENT

Geologically, the River Mun is about 450,000 years old, created when the Anglian glaciation threw up the eastern end of the Cromer ridge, and a river valley was formed to the south by fast flowing glacial melt waters, depositing vast amounts of gravels and clay. As the flow reduced over thousands of years, the valley bottom was eventually covered with a deep layer of sedge peat.

The earliest human occupation in the valley is shown by the large number of flint tools dating back, at least, to the Neolithic re-inhabitation sometime after the last glacial ice retreat some 15,000 years ago. Sheltered from the worst northerly winds, this fertile valley would always have been a pleasant place to live.

The first written references to the river appear in 1082 when William the Conqueror drew up his Doomsday Book to record the value of his newly conquered lands. Although the Mun itself is not named, four mills are recorded in Northrepps, Gimingham and Mundesley.

Since then, an ever-increasing number of medieval legal records relate mainly to disputes over the use of the water. For instance, in July 1305 the Manorial Roll records that John Spriggy, the feudal tenant in Mundesley, complained bitterly that *"Walter le Hunte with many other neighbours, broke my mill and carried away parts of its timber construction"*. The mob went on to break into his pond *"consuming the fish therein"*. This case was not resolved in court, though Spriggy and friends exacted revenge later with an armed attack upon his neighbour's property, for which he was duly fined.

River water from the Mun was valued differently at different times. The parish boundaries of Northrepps, Sidestrand, Southrepps, Trimingham, Gimingham, Trunch and Mundesley are partially determined by the need for access to the Mun. Undoubtedly it has always been a vital source of clean drinking water for people and their livestock: cattle, draught oxen and horses and for dipping sheep. It was also a source of fresh fish, particularly when contained in a *"stank"*, a riverside aquarium constructed of wood and caulked with clay to protect the edible fish from predators like hungry herons, otters or angry peasants. Fish *"stanks"* were seen as bastions of wealthy privilege and were often the target of furious resentment, especially during the Peasants Revolt in 1381.

Flowing water was an essential source of power for corn grinding mills. The exact location of the two mentioned by Doomsday in Northrepps is lost, though likely to have been in the south eastern corner of the parish where the flow would have been strongest. Those in Gimingham and Mundesley were probably exactly where the remains of their later replacements still stand. By the 18th century both Gimingham and Mundesley mills were replaced with larger brick and steel constructions.

The first mile of the river (one fifth of its length) flows through Templewood estate, a large broadleaf woodland mostly planted in the early 20th century. In 1899 the owner, Sir Samuel Hoare built a dam across a low point of the Mun where Northrepps, Southrepps and Sidestrand all meet to make a lake he named Little Broad as a private amenity and for duck shooting. While under construction,

Sir Samuel's daughter Christobel unearthed a worn-out quern stone of a type issued to Roman occupation troops for grinding their own flour. Archaeologists speculate that it may have been deliberately thrown into a natural pool at that point, according to the ancient superstitious tradition for broken tools.

The many archaeological finds from the Mun valley tell of continuous human occupation since the Neolithic to the Bronze age, through the Roman, Saxon and Medieval to the present day. At first, livestock grazed adjacent meadows and any ploughing was relatively shallow. Therefore, it was not until the 20th century that human activity began to seriously impact the purity of this watercourse. Over time the river's natural meander was straightened to its present course and the water levels were lowered gradually down to the gravel bed below the ancient peat, most of which has eroded or incorporated into the arable fields.

When artificial fertilisers were developed after the First World War, agricultural crop production rates increased dramatically, but the resulting run-off from the fields was enriched with nitrogen and phosphates, causing chemical pollution.

Since the 1930's three sewage treatment plants have been constructed along the Mun to cope with the increasing demands of modern living and resultant effluent from the various villages. Over time the polluting effect has increased in the river, especially since the introduction of powerful chemical detergents for washing laundry and dishes. Despite improved systems, the enriched water has caused periodic massive growth of filamentous algae, which depletes the water of oxygen when it decomposes, killing most aquatic life. This effect has been particularly acute in the pools of the upper reaches and almost total eradication of fish in Little Broad.

The Mun valley seldom appears in art, but a charming poem composed by a local shepherd survives from the late 19th century (back cover). Access to the Mun in reality is as limited as the representation in the arts, with almost no official public access to the river. Perhaps the saddest moment of the River Mun's life is where it joins the sea, forced into a pipe to cross the beach: an ignominious end to a small but nonetheless vital river.

Eddie Anderson

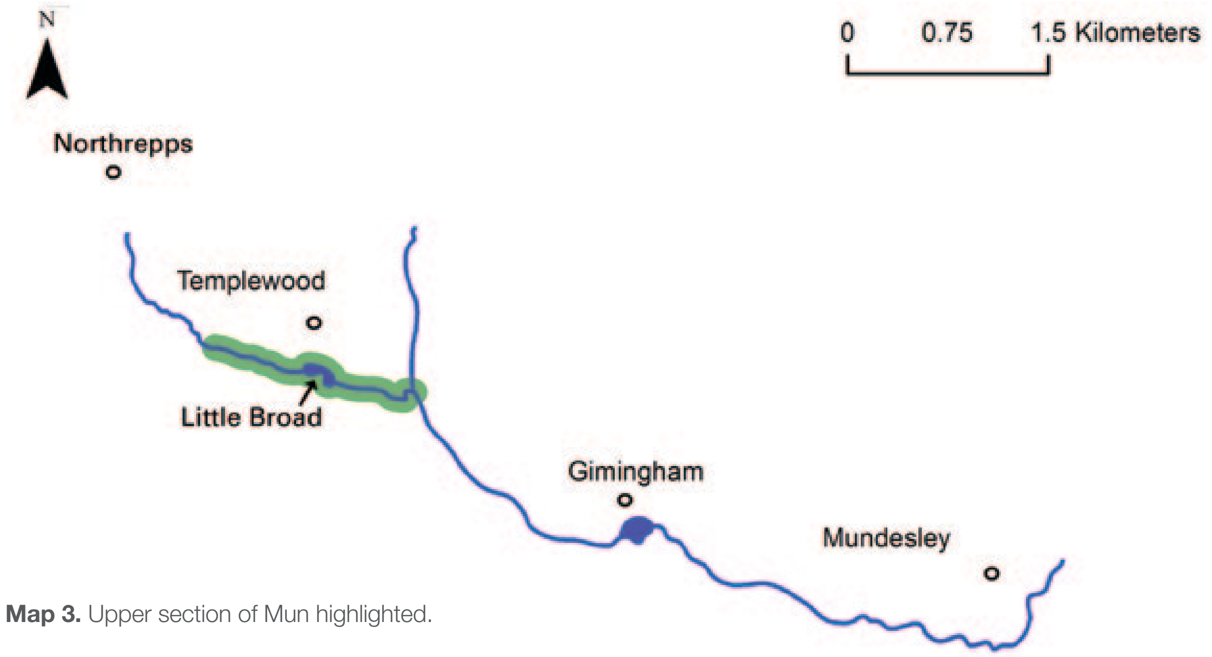
With information from Norfolk Historic Environment Record, Norfolk County Council.

THE MUN FROM SOURCE TO MOUTH

Section 1 – Templewood

From the outfall of the sewage treatments works the river flows through a small copse and then a meadow where the nutrient rich waters nourish abundant water plant growth which obscures the river channel (Photos 1 and 2). The stream then flows through Templewood, which is an area of wet woodland. The woodland acts as a buffer from agricultural land, and initial water quality monitoring shows that the water which filters through the wood is lower in nutrients than the river itself. The stream flows through Little Broad, an artificial lake built in the nineteenth century. Little Broad is surrounded by common reeds, but has suffered from repeated eutrophication events in the past and initial water quality monitoring results show that it has a very high load of nutrients, especially phosphate, which cause repeated fish-kill events. Drawing on knowledge from scientific studies it is very likely that nutrient enrichment also explains the apparent lack of plant diversity in the lake. Despite this nutrient enrichment, large freshwater mussels and stone loaches are found in the Mun in Templewood.

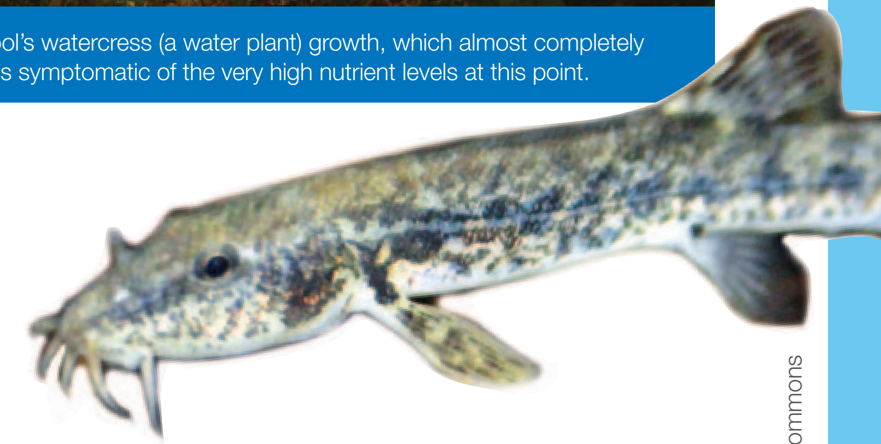
The stream exits the lake through a high sluice and flows out of the wood, past a series of historic ponds which have recently been cleared and restored with the help of Norfolk Rivers Trust. Wildlife such as insects and otters use wetland environments interchangeably, so the proximity of ponds and wet woodland to the river creates a valuable mosaic of habitats which increase the value of the freshwater landscape. The stream is bordered on its western edge by arable agriculture in this lowest part of the section, and would greatly benefit from an increased buffer strip size comprised of rough grassland to reduce diffuse pollution from agriculture and to enhance the habitat.



Map 3. Upper section of Mun highlighted.

Photo 1. Wet woodland immediately below sewage treatment works.

Photo 2. River Mun flowing through abundant fool's watercress (a water plant) growth, which almost completely obscures the channel. The vigour of this growth is symptomatic of the very high nutrient levels at this point.



Fish-kills due to eutrophication are common place in Little Broad.

Photograph: © Karelj/Wikkipediacommons

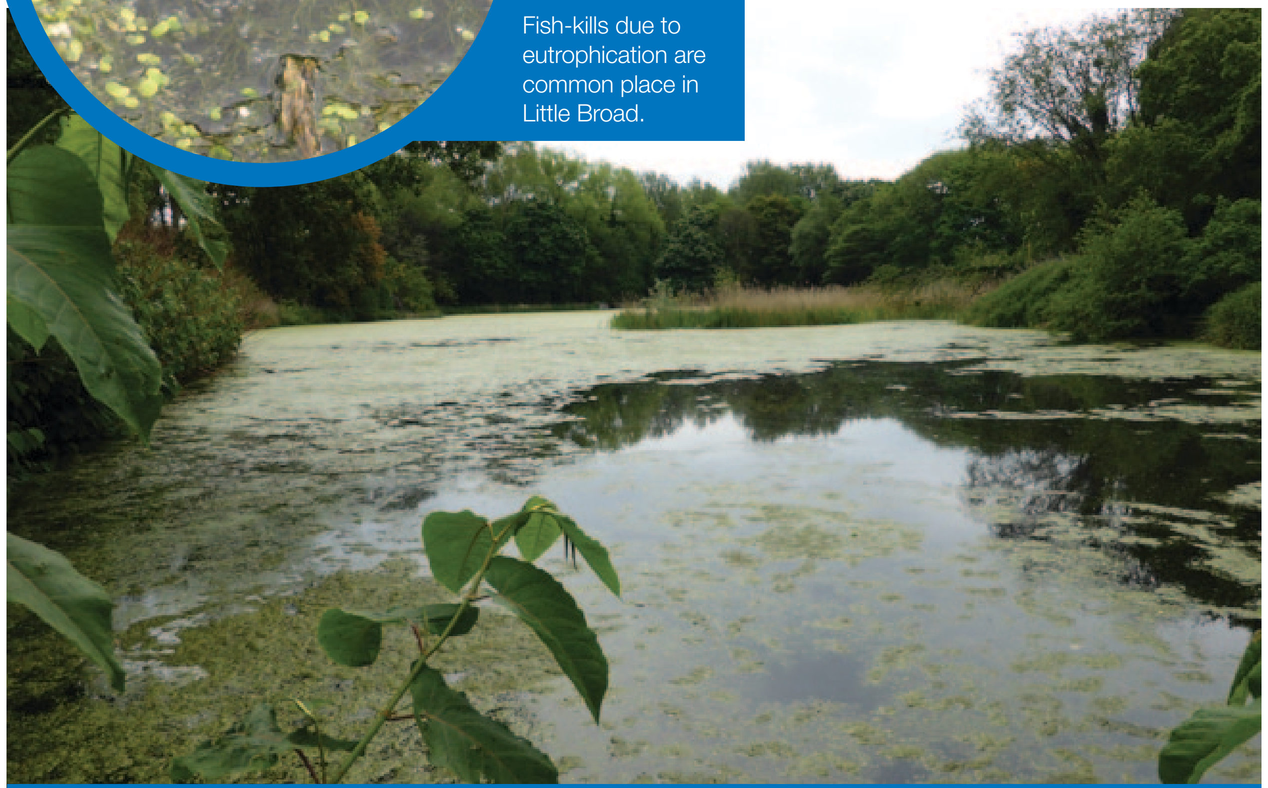
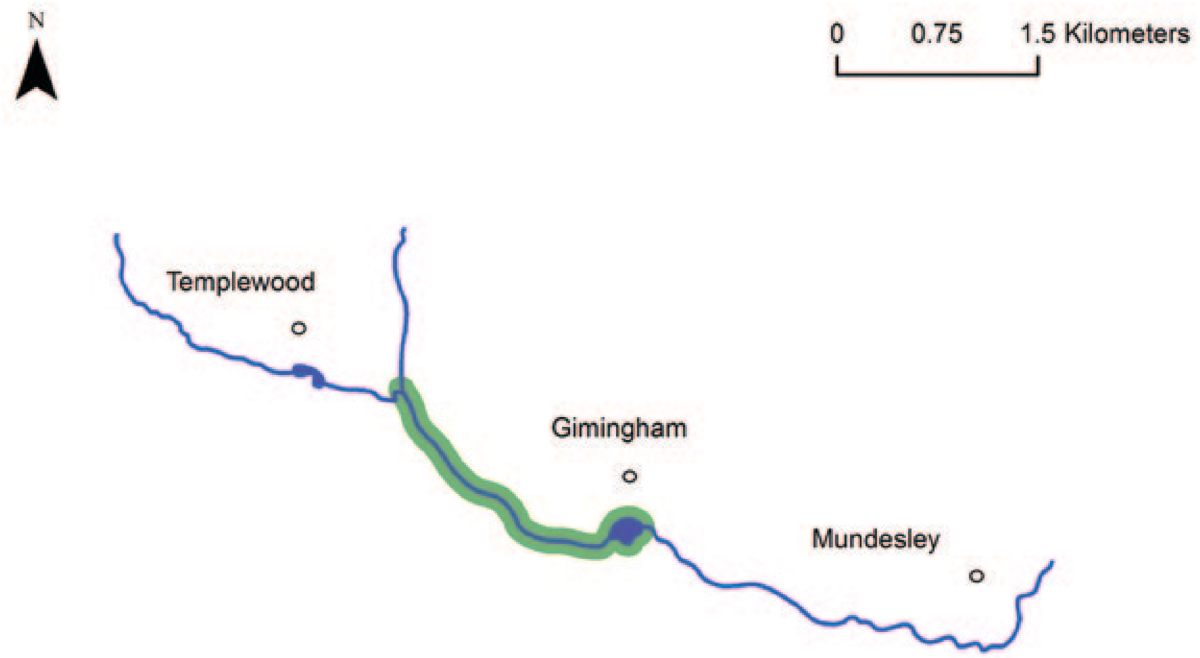


Photo 3. Little Broad in Templewood. Giant knotweed (an invasive plant species) can be seen in the foreground.

Section 2 – Templewood – Gimingham

Below the Cromer road, the Mun flows in a very straight course through farmland (Photo 4). It is buffered by a few metres of scrub or reeds throughout much of this section. As the stream approaches Gimingham it becomes increasingly deepened and ponded due to the impounding effect of the mill (Photo 6). At Gimingham itself the river enters several fishing ponds and backs up behind the mill.



Map 4. Middle section of Mun.

Photo 4. Straightened section of Mun below the Cromer Road.

Photo 6. Sluggish section of River Mun upstream of Gimingham.

Photo 5. Scrub vegetation and reeds provide a buffer around the river from arable land throughout much of this section.

Photo 7. Gimingham fishing lakes.

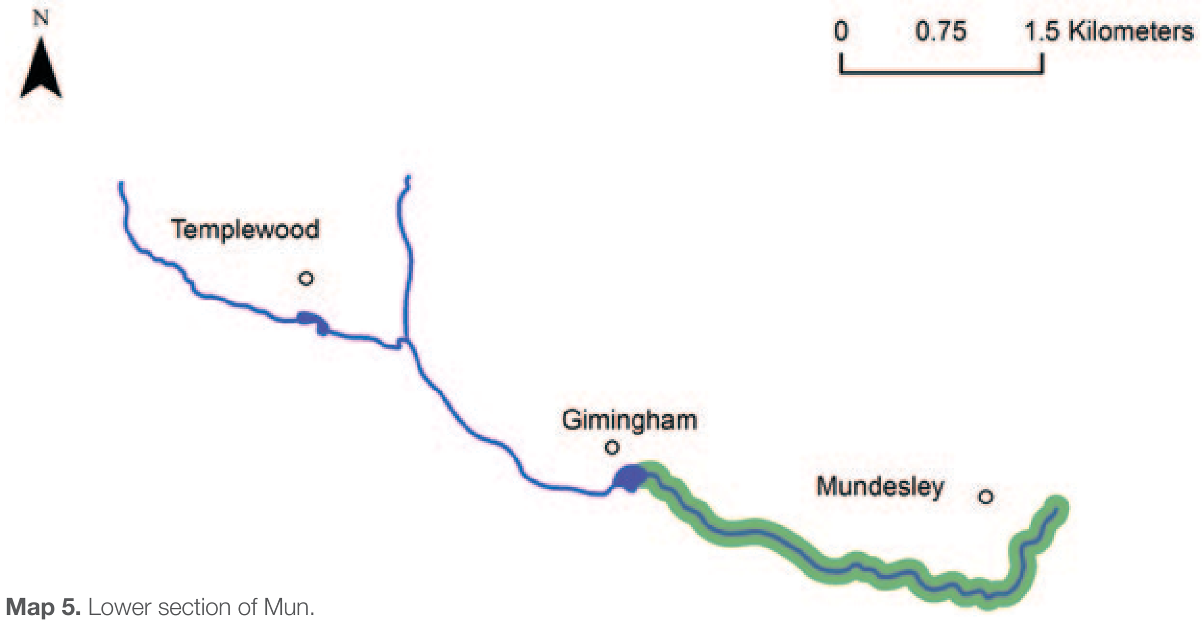
Photo 8. Mill pond at Gimingham.

Section 3 – Gimingham – tidal outfall

Below Gimingham, the stream continues to run through agricultural fields with a very straight course. One section of the river is absolutely straight for over 600m. There is little tree cover to provide variation in shading and woody debris to improve aquatic habitat in this section. At first, the water runs with satisfactory velocity, but it again becomes ponded and sluggish as it approaches the gauging weir at Mundesley Hospital. Emergent macrophytes (water plants) also increasingly grow across the channel in this section (Photo 10). The high level of nutrients will increase plant growth. The slow flows result in sedimentation in the channel and may lead to a greater need for de-silting of the channel which is costly. De-silting has also been shown to be damaging to aquatic organisms such as plants and invertebrates.

Fisheries surveys have revealed the presence of invasive signal crayfish downstream of Gimingham Mill.

As the stream approaches Mundesley and its tidal outfall, the gradient becomes increasingly steep, and consequently the water velocity increases. By the golf course there are well-scoured gravels and a good population of water starwort *(Callitriche sp)*. In Mundesley itself, the stream's connectivity is reduced by seven impoundments within 250m of the sea. These are believed to cause a fragmentation of the stream's fish community and impair the movement of migratory fish.



Map 5. Lower section of Mun.

Photo 9. Mun just below Gimingham.

Photo 10. Sluggish channel with insufficient velocity to prevent emergent water plants from establishing themselves across the channel.

Photo 11. Gauging Weir at Mundesley Hospital.

Photo 12. Gauging Weir at Mundesley Hospital.

Photo 13. River Mun by golf course. Note appreciable increase in flow velocity and healthy amounts of the water plant starwort (Callitriche sp).

Photo 14. Tidal outfall of River Mun.

Photo 15. Tidal outfall of River Mun.

SECTION 2 THE PROBLEMS AND SOLUTIONS

The River Mun would naturally have been a stream which would have meandered from its source through woodland towards a steeper section at its tidal outfall at Mundesley. There would have been a varied population of fish throughout the river, most likely including migratory trout and certainly eels.

RIVER STRUCTURE

The Mun has been straightened throughout its course, with no natural sections remaining. The reduction in sinuosity will have greatly reduced the length of river and so the amount of habitat. A lack off meandering channel, and few trees to provide woody material also means that there is very little habitat variation.

In general terms, an increase in the sinuosity of the channel, combined with tree planting would greatly improve the stream habitat. Patches of rough grassland are also valuable, and a patchwork of trees and grassland would be the ideal outcome. Removal of key impoundments will be necessary to restore the necessary gradient to make re-meandering worthwhile. This is because rivers need a certain gradient to meander under natural conditions.

CONNECTIONS BETWEEN THE RIVER AND ITS FLOODPLAIN AND ALONG-RIVER BARRIERS

In a natural, highly productive stream, there is seasonal connectivity between the river and its floodplain and unimpaired movement of fish species along the river. A stream like the Mun might have had a fairly modest floodplain size, but nonetheless this would have been valuable to wildlife.

It appears that the Mun does not connect to its floodplain, even during periods of high flow. This greatly reduces the river's marginal habitat, and prevents the rich ecological interchange between the stream and its river corridor which would occur during inundation.

There are multiple impoundments along the river which isolate different fish populations in the river, and are one cause of the generally impoverished fish community which has been assessed to be "poor" by the Environment Agency. Perhaps of equal importance, these barriers also cause water to pond upstream of them, thus preventing an establishment of natural flow velocities and river form. Sedimentation and emergent plant growth is encouraged by the impoundments, resulting in an inefficient situation where the channel would have reduced capacity and could require periodic clearing. A natural channel would not require maintenance of this type.

Overall, the stream ecosystem would benefit from increased re-connection to the floodplain where possible, and a removal of impoundments. These steps would have the twin benefits of reducing the amount of stream maintenance required and of enhancing the impoverished fish community.

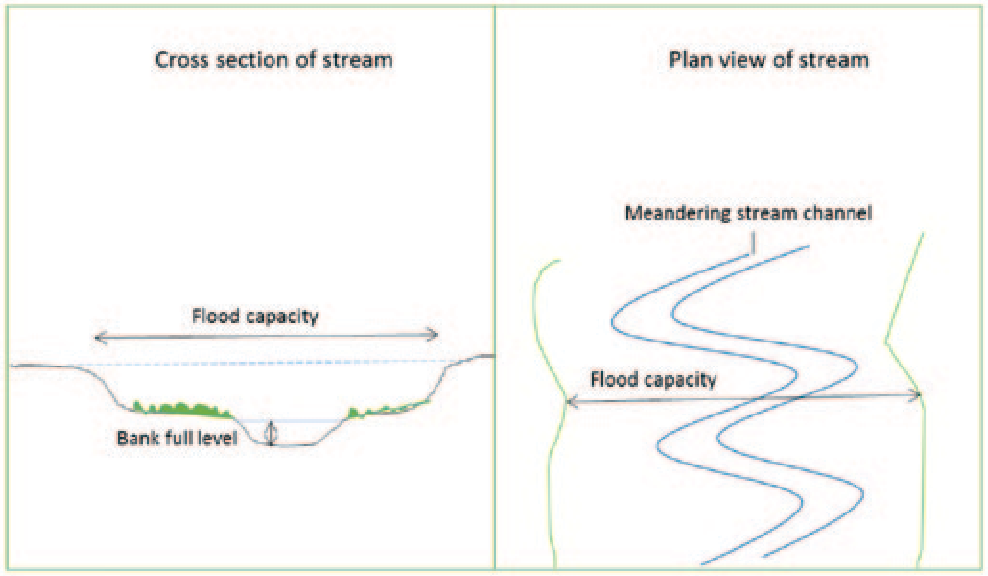


Figure 1. Morphological modifications to streams should be based on bank full capacity (the height of common higher flows) and should have sufficient flood capacity (maximal levels). If bank full capacity and sinuosity are properly incorporated, then sediment regime will also be modulated by alternate sediment storage and scour. This will reduce/negate need for sediment clearance.

FISH PASSAGE

From a Water Framework Directive perspective, the poor fish community is of central concern. Analysis of monitoring work by the Environment Agency suggests that multiple impoundments along the river mean that the fish community is fragmented and not able to migrate along the river as it naturally would. Ten barriers to fish passage have been identified, with 7 within 250 metres of the tidal outfall.

WATER QUALITY

In general, the water quality of the Mun is considered to be good, according to Environment Agency monitoring which takes place in the lower sections of the stream.

However, Little Broad, which is an on-stream lake at the top of the Mun, has been shown to have been contaminated by a very high nutrient loading. Water quality monitoring indicates that this is likely to be due to treated but nutrient rich effluent from the Northrepps Sewage Treatment Works. In particular, the concentration of the nutrient phosphate are very high. This results in algal mats and duckweed growing vigorously and choking the lake's wildlife. This has been shown to cause oxygen 'supersaturation' which has coincided with a fish kill in the lake. Moreover, this will deprive the lake of oxygen as algae dies and rots, killing submerged aquatic animals (a process called eutrophication). Phosphate is derived directly from human sewage and from cleaning products. Norfolk Rivers Trust are interested in helping to reduce the phosphate input by finding a way to provide alternative cleaning products which do not contain phosphate, thus reducing this component of the problem. Moreover, a wetland upstream of the lake could remove phosphorus by biological and chemical processes.

Phosphorus

River ecosystems have evolved to function with relatively low levels of the nutrient phosphorus. In low nutrient conditions, lowland streams will adopt their characteristically beautiful vegetative form with clear water running over abundant submerged plants such as *Ranunculus sp*. growing within the channel and a gradient of emergent vegetation such as the yellow flag iris appearing at the edge of the channel.

Algal mats and duckweed start to grow in March and will build throughout the season until they smother the lake, removing oxygen as they rot.

Diverse water plant growth on the upper River Leach facilitated by good water quality.

ECOSYSTEM

The ecosystem of the River Mun and its river corridor may be described as lacking in connectivity and "patchy" in terms of quality. The river corridor, benefits from the protective buffering effect of Templewood in its head-waters but otherwise there are few native trees surrounding the Mun. Isolated populations of invasive species are present and these are discussed more fully later.

The in-stream component of the ecosystem appears to have a good invertebrate community, apart from the presence of invasive signal crayfish *(Pacifastacus leniusculus)*. Some of the fish species which would be expected are present, but in low numbers and isolated from each other making individual populations vulnerable to chance destructive events. Trout and bullhead, which would be expected to be found in the Mun, are entirely absent. Data on water plants is not available, but observation has suggested that regular impoundments of the stream have caused a shift towards a plant community associated with siltation and still water environments.

ABSTRACTION

The River Mun is a small river with seven significant licenced abstractions along its length. It is important to remember that this water is used for purposes such as irrigating crops and public water supply which we all benefit from. Water is removed to a degree which results in the Mun containing less water than it would naturally. Nevertheless, the water flow in the river is considered to be sufficient to support a good quality aquatic ecosystem. This is shown by analysis of invertebrate life in the river.

STATUS OF INVASIVE NON-NATIVE SPECIES ON THE RIVER MUN

The Norfolk Non-native Species Initiative have analysed data covering the Mun catchment to identify current invasive non-native species (INS), management options and future risks. Invasive species spread rapidly and can cause both economic and environmental problems.

Distribution maps

In addition to the records of INS found by the Norfolk Rivers Trust during their walkover survey of the River Mun we have interrogated the NBIS database, which contains almost 3 million individual records of species sightings in Norfolk, to identify any other reports of INS from the catchment in the last 5 years. Within the catchment we have received reports of:

Canada goose

Egyptian goose

Muntjac deer

Giant knotweed

Himalayan balsam

Giant hogweed

Floating pennywort

Rose-ringed parakeet (reported from a Garden Centre – so this is probably an individual escapee)

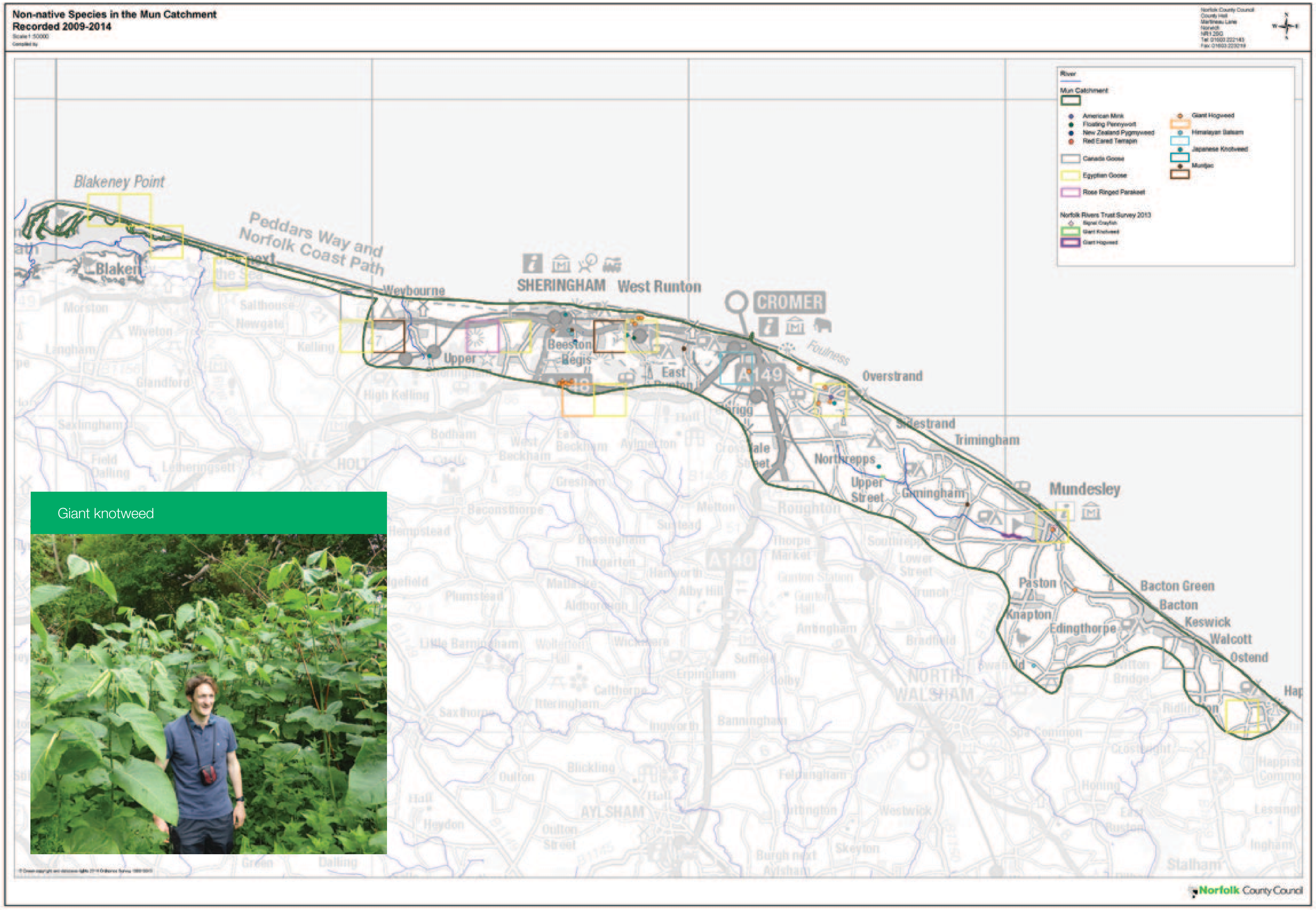
Signal crayfish

Most of the records of INS are clustered around the main centres of population within the catchment (Cromer and Sheringham). The only species recorded adjacent to the river itself are giant knotweed, giant hogweed and signal crayfish, which corresponds to the results of the Norfolk Rivers Trust's survey.

The rest of this report focuses on invasive species close to the river itself.

Photograph: © The Scottish Deer Centre

Muntjac deer graze on your trees, preventing regeneration of the woodland that is so important for river systems.



Giant knotweed

Map 6. Positions of invasive species in the Mun catchment.

WHAT CAN YOU DO?

You can help us by reporting any sightings of INS to the Norfolk Non-native Species Initiative. This can be done using RINSE's new smartphone App (**http://www.rinse-europe.eu/smartphone-apps**), the NBIS website (**http://www.nbis.org.uk/**) or by e-mail (**nnnsi@norfolk.gov.uk**).'

KEY INVASIVE SPECIES CLOSE TO THE RIVER MUN

Signal crayfish - The American signal crayfish was originally introduced to Great Britain in the 1970's to farm for food, but quickly escaped in to the wild and adapted well to our environment. Not only does the signal crayfish reach a larger size than our native white-clawed crayfish but it is also more aggressive, meaning that it can easily out-compete the crayfish for refuges and resources. In addition, the signal crayfish is also a vector of spread for the crayfish plague, a fungal disease which is fatal for the white-clawed crayfish but not the signal crayfish. The signal crayfish can also cause declines in invertebrate and fish populations through competition and predation. Many Norfolk rivers now contain populations of signal crayfish, while only a handful of white-clawed crayfish populations remain.

Management – Once established in a waterbody, this species is almost impossible to eradicate. The only option for eradication involves the use of a biocide – with a pyrethrum called Pyblast being the most commonly used chemical for this purpose. The area being treated needs to be hydrologically isolated to ensure that none of the biocide escapes in to the wider environment, and to ensure that it maintains a sufficient concentration for long enough to ensure complete mortality of the signal crayfish. The costs and practicalities of this approach mean that it is only a realistic option at a small number of sites. Intensive trapping of signal crayfish can reduce their numbers, and correspondingly reduce their impact on the wider ecosystem, but cannot deliver complete eradication. Indeed, trapping can sometimes lead to the spread of signal crayfish (by trappers "seeding" new areas), crayfish plague and bycatch such as otters.

Japanese knotweed - Japanese knotweed is native to Eastern Asia and was introduced to Britain as an ornamental garden plant in the mid-19th century. The plant has creamy white flowers that appear at the tips of the stems between August and September. It has rhizomes (underground stems) that can spread up to seven metres from the parent plant and to a depth of up to three metres; this makes the plant extremely difficult to eradicate. A new plant can grow from only 0.7g of rhizome.

Japanese knotweed is able to out-compete native vegetation, reducing the overall diversity of vegetation in an area. It can also contribute to river bank erosion, increase the risk of flooding and cause significant damage to infrastructure (the rhizomes of Japanese knotweed are able to push through many hard surfaces, including asphalt, building foundations and drains).

Note: At a late stage, the alleged Japanese knotweed in the catchment was identified as giant knotweed. This is still invasive but less vigourous and less common. We have kept the Japanese knotweed description as it is likely to be a greater risk in the future.

Management – Japanese knotweed is notoriously difficult to eradicate, but it can be achieved providing an appropriate management programme is pursued over the required period of time. The most cost effective way to eradicate this plant is using a glyphosate based herbicide, such as Roundup. This can either be applied by a foliar spray or by injecting the herbicide directly in to the stem of the plant. Experience in Norfolk has shown that the stem injection method is capable of eradicating the plant in a much shorter period of time. After 1 year of stem injection we typically see only 10-20% re-growth the following year. A second year of stem injection delivers almost total eradication. Herbicide application has the biggest impact in September when the plant is investing more resources in growing it's rhizome network than it's above ground vegetation.

American signal crayfish

Giant hogweed - Giant hogweed is a terrestrial perennial plant originating from the Caucasus mountains in south-west Russia and Georgia. It was first recorded in the wild in the UK during the late 19th century. The plant can grow up to five metres in height with the lower leaves reaching up to 1.5 metres in length. The plant spreads solely by seed, with a single flower head producing up to 50,000 seeds.

Giant hogweed presents a significant health risk as even small amounts of the plant's sap can cause severe blistering of the skin following exposure to sunlight. Problems can persist for up to six years after exposure to the sap. The plant is also able to outcompete many native plant species and can cause increased bank erosion in riparian environments.

Management – Unlike Japanese knotweed, which spreads through vegetative means, giant hogweed reproduces by seed. This means that different eradication methods are available.

Whenever any control of giant hogweed is undertaken great care must be taken not to brush against the plant with bare skin, or allow any of the plant's sap to get on you as the plant's sap causes severe blistering.
The plant can be eradicated using a glyphosate based herbicide which should be applied in late-April or May, when the leaves of the plant are large enough to absorb a sufficient dose of the herbicide's active ingredient to kill the plant. It is also possible to kill the plant by cutting its taproot. This can be done using a spade, and should be carried out earlier in the year, as soon as the plants are visible (late-March to early-April).

Giant hogweed

BIOSECURITY CONSIDERATIONS

It is widely accepted that it is far better to prevent invasive species from becoming established in the first place than to have to eradicate them or control them in the longer term. New INS can be prevented from entering a catchment if key pathways of introduction are restricted by certain user groups undertaking simple biosecurity measures (eg anglers, boaters, contractors).

The wider catchment of the River Mun contains relatively few invasive non-native species when compared with many other catchments in Norfolk. This is probably at least partly due to its isolated nature. Fishing, which increases the likelihood of INS introductions, is restricted to a small number of locations. However, the close proximity of killer shrimp *Dikerogammarus villosus*, which is continuing to spread throughout the Broads catchment, is cause for concern and means that efforts to increase awareness of basic biosecurity should be given a high priority. In the Mun catchment I believe that the key potential pathways of introduction are associated anglers, conservation workers, tourists, landowners and land managers.

SUMMARY AND RECOMMENDATIONS

The relative scarcity of invasive species is encouraging, and if those that are already found in the area are managed appropriately then I anticipate invasive species having a negligible impact on the health of the wider catchment.

The small populations of invasive plants found near the river should be eradicated as a matter of priority, to prevent further spread. The population of signal crayfish at the lower end of the catchment is a cause for concern and could impact on fish populations in the river. Before any impoundments are removed it should be considered as to whether these are preventing the movement of signal crayfish further upstream.

The presence of floating pennywort in the catchment is worrying, as this is one of the most damaging invasive aquatic plants found in the UK. It is currently found in what looks to be an isolated location, a long way from the River Mun itself. I advise that the eradication of this species should still be carried out in the near future, to prevent it's further spread within the catchment or to other areas.

Note: NRT have commenced the process of removal of this species following this recomendation.

Good biosecurity will play an important part in ensuring that the Mun catchment remains relatively free from invasive species. As the catchment is quite isolated, and there are few users of its freshwater habitats, it seems likely that most introductions will be carried out by those who own or manage stretches of the waterways in the catchment. This includes contractors who may be brought in to do work in or near the river. Before any machinery is brought on to the site the contract manager should check where the machinery was last (if it was in an area that killer shrimp or crayfish plague is known to be present then particular care should be taken) and the machinery must be cleaned. Groups such as gardeners and landowners could be made more aware of INS of concern, how they can prevent their introduction and what to do if they find them through targeted campaigns such as those that have recently been run in the Broads (eg the 'Go native for Norfolk!' garden centre accreditation scheme and the Workshops and training materials generated through the RINSE project for farmers and landowners). Signage should be erected at areas used by anglers advising them of the biosecurity measures that they should undertake.

Mike Sutton Croft
Norfolk Non-native Species Initiative (NNSI)

TREES AND WOODY HABITAT

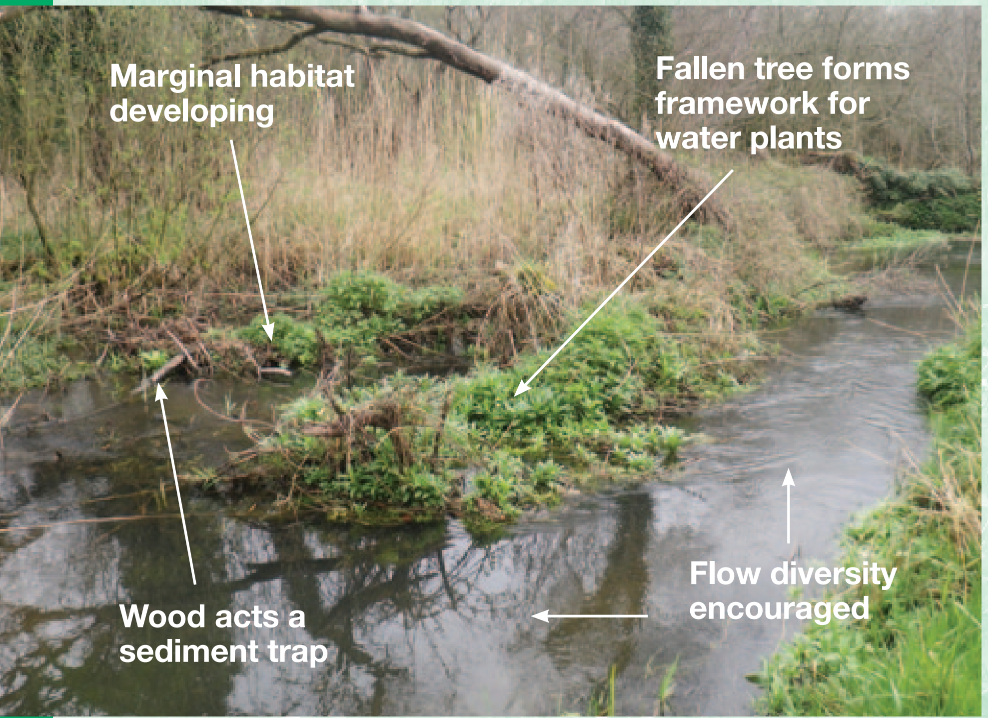
Over the past two decades the importance of trees bordering rivers has become increasingly apparent.

Recent research has highlighted the threat that climate change poses to aquatic ecosystems through changing water temperatures. As water warms the oxygen levels decrease in water and this can cause death of aquatic organisms. Small streams such as the Mun are especially vulnerable. The recent Environment Agency project "Keeping Rivers Cool" highlights the importance preventing dangerous temperature increases in the water by shading.

Trees also intercept and modulate agricultural nutrients and sediment. They can increase infiltration, thus reducing flooding.

Trees are vital as "architects" of river structure. Live trees act as hard points, stabilizing banks and helping meanders to develop. Tree roots in banks provide vital habitats for a multitude of species, notably native crayfish, otters and eels. Dead trees in the river are equally important. They are a key habitat. Moreover, large dead wood (especially entire trees) initiate the natural recovery of rivers from straightening and cause flow diversity. In fact, tree planting and addition of large woody material are the most cost effective and among the most beneficial measures which Norfolk Rivers Trust undertake.

Overall, the Mun has tree cover in Templewood, but lacks the desirable mixture of tree cover which would result in the benefits described above. More dead woody habitat would also be desirable throughout the river.



Natural tree fall has several benefits for habitat creation, channel structure and sediment modulation.

Growing trees have changed this former straightened drainage channel into a river with a more natural structure and in-stream islands (*anastonising* channel).

Tree acts as a hard point and has caused a meander to develop.

Tree acts as a hard point and has caused the development of a pool. Submerged tree roots are also excellent habitat for brown trout.

Natural tree fall has caused a great range of microhabitats and greatly increased in-stream surface area for a diversity of river invertebrates.

SECTION 3 AN ACTION PLAN

In the future, the Mun could be a stream where a diverse and connected ecosystem thrives within the river corridor. The need for river maintenance could also be reduced. There would be benefits to such enhancement for the local community, who can already access the stream at a few points. Increased access will form part of an ongoing ecological restoration projects.

In general, improvements to this river consist of: removal of impoundments, re-meandering sections, increase floodplain connectivity, tree planting, and improvements in the ecological state of Little Broad by improving water quality.

SECTION 1 – TEMPLEWOOD

The wet woodland surrounding this section of river gives the area the potential for a high quality ecosystem. The primary concern is that Little Broad has a high nutrient load resulting in eutrophic (algal growth and decomposition) events which have killed fish in the past. Of secondary importance is the straightened form of the stream.

As part of the planning procedure, a project to monitor the water quality in Little Broad is ongoing. Details are shown in (Figure 1 - 3). The monitoring has two purposes:

1. To allow future restoration works to be well informed in order to undertake the most effective action for the river and lake ecosystems.
2. To provide baseline data to determine how effective works which may take place in the future have been.

The initial results have shown that damagingly high levels of the nutrient phosphorus flow into Little Broad, and that the lake has been contaminated with a high phosphorus loading. Over the initial 4 months of data, concentrations are commonly ten times higher than the levels that would be expected in a near-pristine lake (current average = 401 µg/l, pristine = about 40 µg/l).

The high concentrations of nutrients in the stream could be reduced by constructing a wetland and re-meandering the stream below the sewage treatment works. This would cause phosphate removal by chemical binding to substrate particles, and biological removal during the growing season. A pioneering new wetland design is being investigated by NRT which could reduce nutrient levels even more, and might represent an ideal solution.

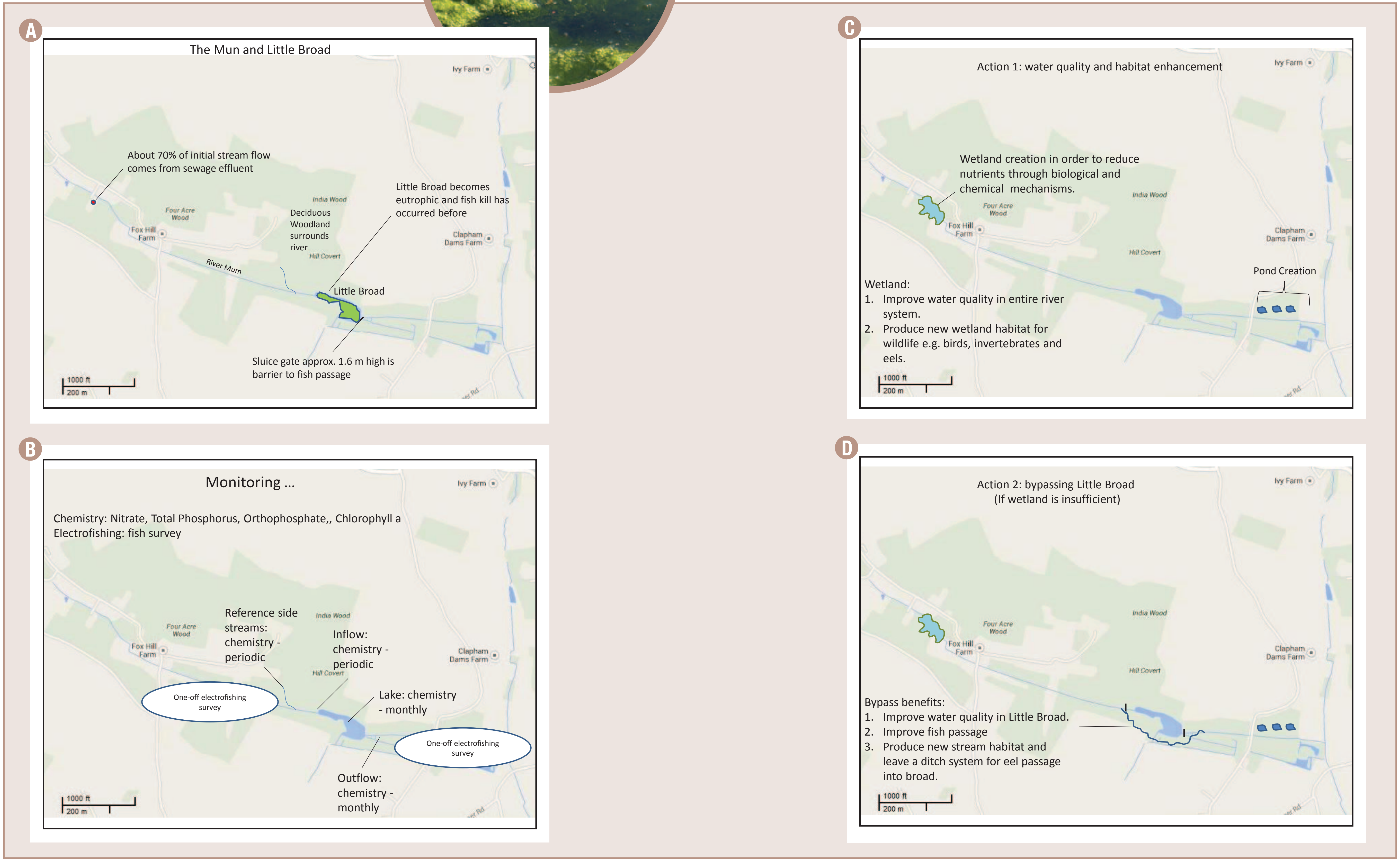
Moreover, a community initiative has been suggested by locals in which low-phosphate (perhaps subsidised) cleaning products could be used in the locality of Northrepps to reduce the supply of phosphate to the sewage treatment works.

If these measures prove insufficient to allow biological recovery of Little Broad, diverting the Mun around the lake would reduce the nutrient levels entering the lake. With the stream diverted, the lake would fill from groundwater seepages which have been shown to have lower concentrations of nutrients, thus rehabilitating the lake ecosystem. Importantly, the groundwater seepages within and just upstream of the lake contribute an addition 50% of water flow to the lake (an increase of 9 litres per second). As a result there would be enough flow to sustain the lake, although there could be a reduction in water levels. River ecosystems are more robust in the face of nutrient enrichment so protecting the lake is especially important.

Additional ecological benefits would accrue from construction of backwaters, restoration of off-stream ponds and addition of woody debris to sections of the Mun through Templewood.

Templewood monitoring and possible actions

Figure 2. Schematics showing: **A.** The current situation at Little Broad. **B.** Monitoring program. **C.** Lower cost actions which will improve water quality and enhance habitat. **D.** River bypass possibility to improve ecosystem of Little Broad if the wetland solution is insufficient.



Templewood monitoring and possible actions

Figure 3. Water quality data from the main River Mun and exemplar groundwater seepages which enter the stream.

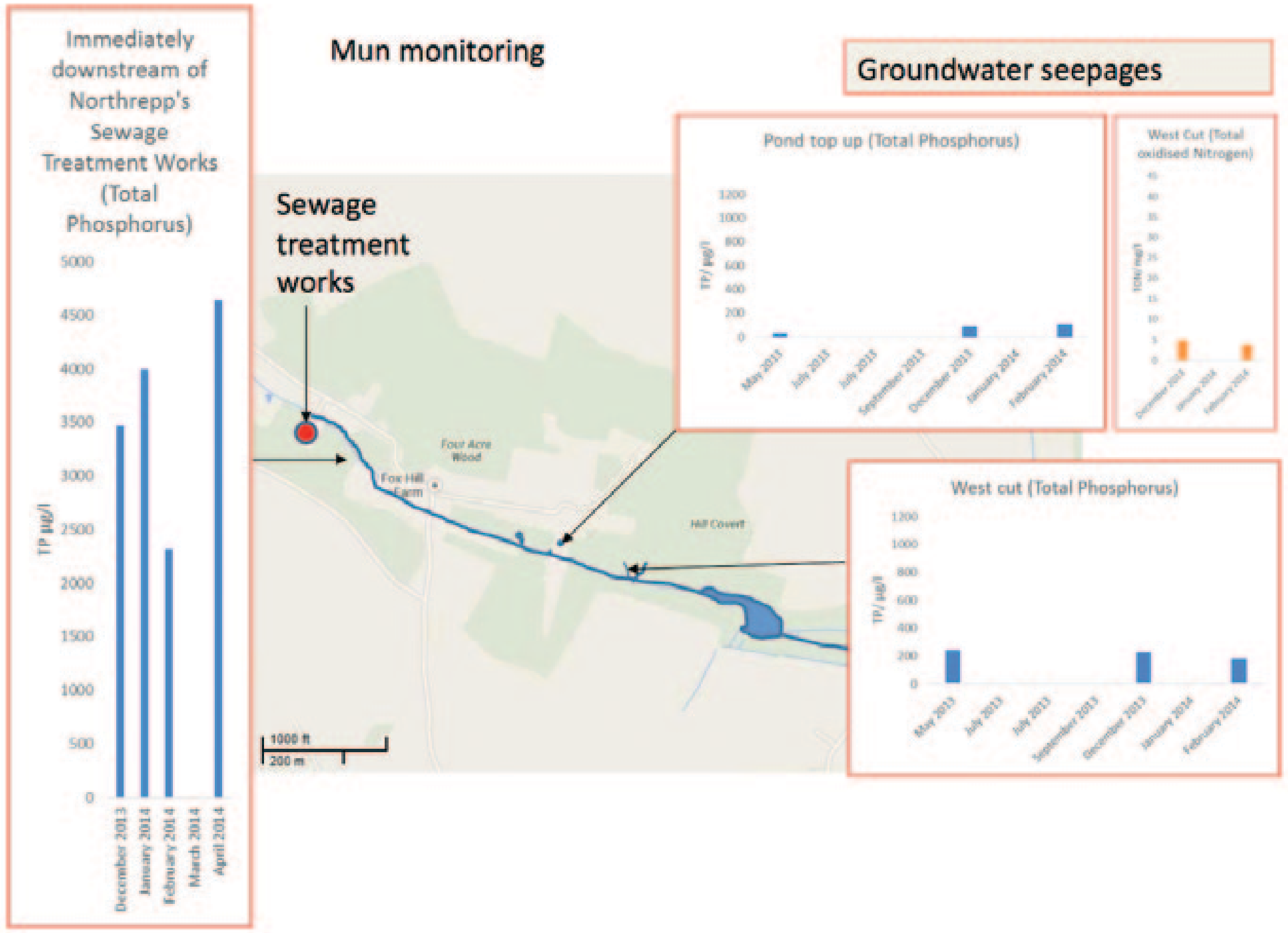


Figure 4. Water quality data showing results from the stream inflows and outflows as well as the lake itself.

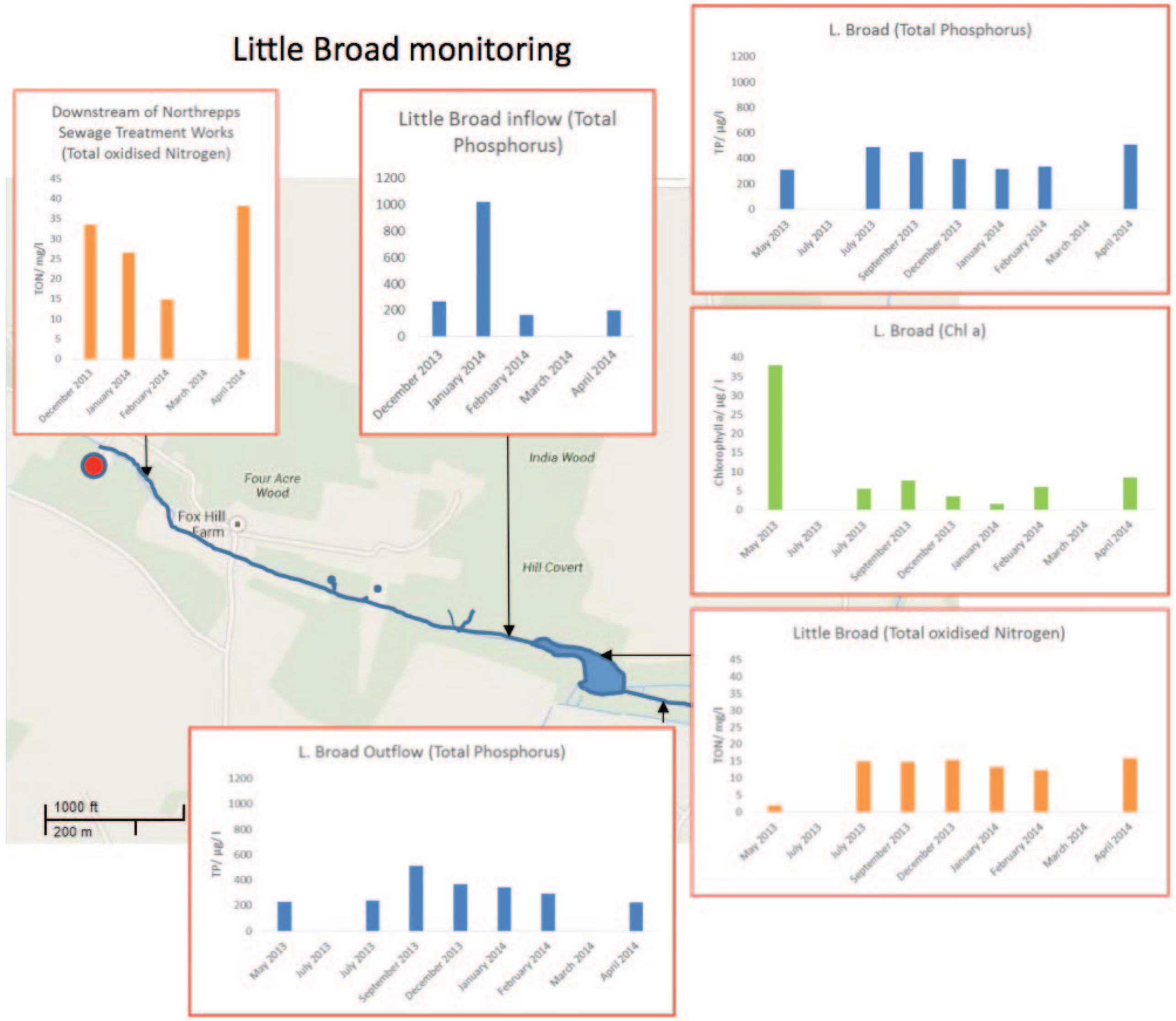
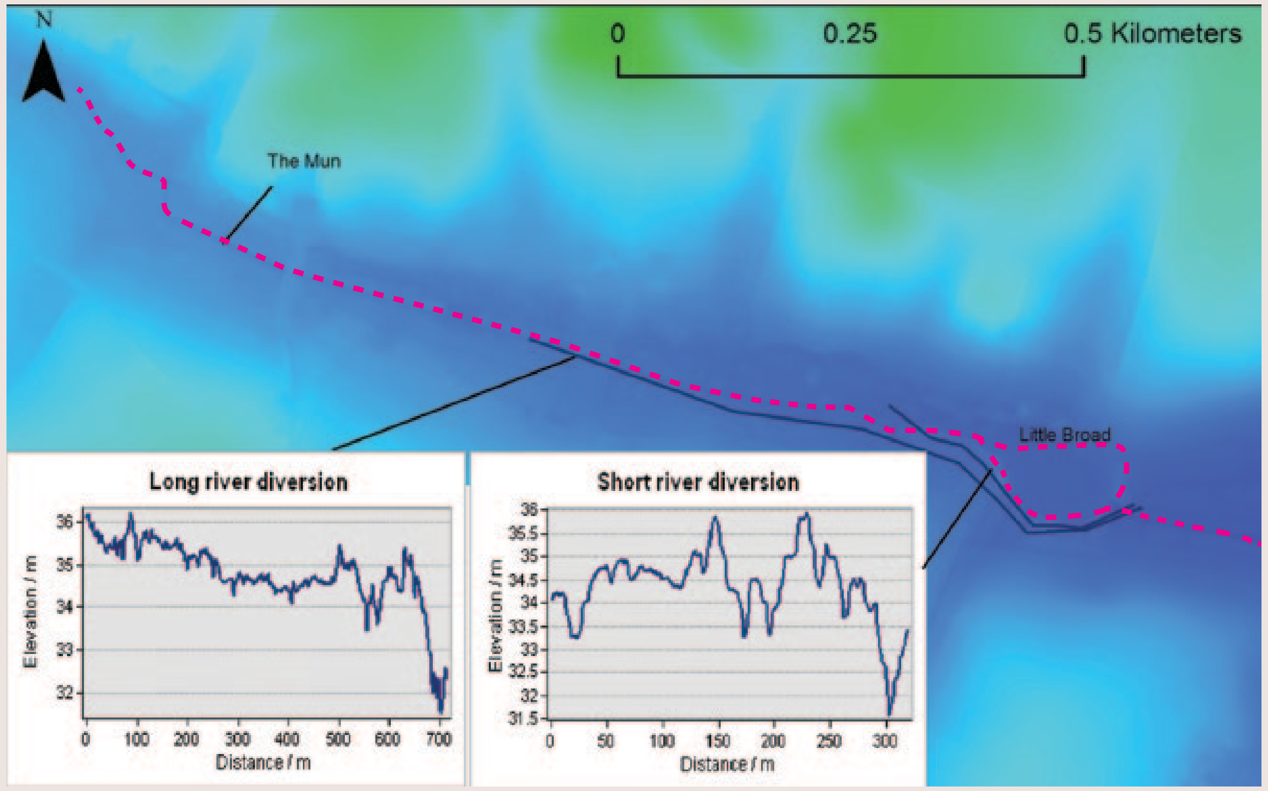


Figure 5. Elevation long profiles showing change in topography along approximate routes of river diversions past Little Broad. The profiles show that there is ample gradient for a river diversion to be possible. However, the key technical difficulty is that the upstream river channel (in the far left of both graphs) must always be above the downstream channel. This means that the river bed would need to be dug about 3 metres deep in places. Moreover, the stream would be likely to incise (Cut downwards) due to the overall height difference. This would leave a river channel cut deep into the ground. This would therefore be a job which is intensive in terms of effort and would result in a channel deep in the landscape which is not always ecologically ideal.



SECTION 2 – TEMPLEWOOD – GIMINGHAM

Most immediately, this section of the river would benefit from slightly increased cover by native trees. Tree planting should be planned to produce a mosaic of habitats which would include the existing rough grassland is also valuable to species such as ground nesting birds. The main in-channel restoration measure would be an increase in river gradient to prevent the river velocities from becoming so low that natural river processes are impaired. This would enhance the ecosystem, and if combined with some channel modifications would greatly reduce or negate the need for silt management. However, such a modification would require expensive and complex work where the river crosses Mill Street, and may not be cost-effective or desirable to residents.

SECTION 3 – GIMINGHAM – TIDAL OUTFALL

Again work on channel structure, tree planting and removal of impoundments would convert the stream from what is now effectively a siltation-prone drain into a healthily functioning and self-scouring river. Works may be more technically feasible in this section, because impoundments are small.

In Mundesley itself, fish passage could be encouraged by modification or removal of impoundments. Eel mats are a simple measure which allow young eels (elves) to crawl past key impoundments such as the Mundesley Mill weir in the Chalet Park. It should be borne in mind that full scale improvements to fish passage would prove relatively technically difficult and very expensive work in some cases. The benefits of this work in isolation might be limited be to allowing fish passage into sections of river upstream that are currently degraded and lack habitat anyway. Care should also be taken not to facilitate the spread of invasive crayfish along the river when considering impoundment removal. Therefore, it is suggested that impoundment modifications would be most appropriate as a second step once upstream sections of the river have themselves been restored to a reasonable degree. In general, the prioritisation of impoundment removal should be on a few “keystone” impoundments which represent not only a barrier to fish passage, but also result in the siltation and degradation of large proportions of the stream as well.

FURTHER INFORMATION

Environment Agency - Keeping Rivers Cool report
Rivers by Design - rethinking development and river restoration
World Wildlife Fund - Why are chalk streams special?
River Restoration Centre manual of river restoration techniques
Norfolk Wildlife Trust
River Rehabilitation for Eastern England Rivers
Environment Agency homepage
Introduction to the Water Framework Directive

COSTS AND TIMELINE

The Water Framework Directive objective for the Mun Catchment is to reach Good Ecological Status by 2027, and each of the actions set out in this report will assist in achieving that goal.

The river, is approximately 8 km long and is connected to several still water ponds and lakes. Due to centuries of modification, all sections of the river could benefit from ecological restoration to return it to a productive and natural state.

Overall, the order of priorities for the river are as follows:

1. Improve water quality in uppermost part of river and Little Broad. This would confer downstream benefits.
2. Improve river structure and habitat, by tree planting/ addition of large woody debris, channel morphology work, and floodplain re-connection.
3. Modify impoundments to make them fish passable where this is possible and does not facilitate movement of signal crayfish.

Measures to improve of water quality in upper part of the catchment can start immediately. Tree planting and addition of large woody debris can commence where and when community support and funding permits. Volunteer groups could have an important role in making such work possible in the near future.

In the longer term, modifying impoundments to make them fish-passable will need to be undertaken. This work should be prioritised carefully to target areas where maximal benefits to both fish passage and river structure will accrue. Channel morphology work on sections of the middle Mun is only likely to be beneficial where impoundments can be removed first to enable sufficient gradients to facilitate increased flow velocities for the stream channel to become self-scouring.

Action	Number of kilometres / sites	Predicted cost	Achievable timeline	Responsibility / capability
Option 1 to improve water quality in headwaters	1 Wetland	£25,000	2015	Volunteers /NRT
If option 1 is insufficient: Mitigation of poor water quality in Upper Mun. River diversion past Little Broad.	0.85 km 1.3 km including sinuosity	£40,425	2021	NRT/ EA / IDB
Option 2 to improve water quality in headwaters	1 Phosphate stripping	£ 1,000,000 Thereafter: £500,000 pa	2027	Anglian Water
Reduction in phosphate use by community	Northrepps area	Currently unknown, sub-sidy for cost of cleaning products desirable.	2015	Good will from local residents/ NRT/ Anglian Water
Removal of invasive species 1: Rhodendrons	1 large site	£0 (Cost of community engagement events + NRT time excluded)	Already complete	Volunteers /NRT
Removal of invasives 2: Floating pennywort, Giant knotweed	2 sites	£400	2015 (pennywort removal commenced)	Volunteers /NRT
Pond restoration	3 ponds, and parking space	£864	Already complete	NRT
Tree planting downstream of Gimingham	2.7 km of bank planting	£900	2021	Volunteers/ NRT
Fish passage 1 (in order of priority)	2: EA gauging weir and impoundment close to the golf course	£6,600 + good will agreements	2021	Volunteers/ NRT / EA
Fish passage 2	7 sites within 250 m of sea	£ 99,000	Ongoing to 2027	EA/NRT
Fish passage 3: Gimmingham mill	1	£ 396,000	Ongoing to 2027	EA/NRT
Fish Translocation past Giminham mill	1	£1,000	2021	EA/NRT
Channel structure: below Gimingham	1 km	£63,525	On going to 2027	NRT / EA / IDB
Non-native species management	Whole catchment	£1,000	On-going	Volunteers/ NCC / EA / NRT

* Note: costs include another 10% for monitoring where appropriate and always include VAT.

It's many years ago, they say,
Since I began ot run this way
And as no water can be found
By digging deep into the ground,
To Mundesley I'm a gift divine.
Though in the eyes of few I shine.
Yet quietly I run along,
And do not mind the noisy throng
Of boys and girls who me frequent
And never ask why I was sent.
And men and women, too, are found,
Who take supplies the year all round.
And never on the bended knee
Do thank the Lord for sending me.
And some complain too when they come
That I'm not nearer to their home;
And others say I'm not so clear
As water they have seen elsewhere.
But still to duty I attend.
Whether I please them or offend;
I'm free to all, whoever will,
May all their empty vessels fill.
And still I run along the way,
And serve the people day by day,
And all the cattle I supply
That come and drink as I pass by.
And if I only stop one day,
The people are in such a way,
No water they can get for tea.
To wash their clothes they must have me.
But now no longer I must stay
And talk the precious time away;
For I've a duty to fulfil.
And so must hasten to the mill,
For there, I turn a ponderous wheel,
And grind the precious grain to meal;
I run along a darksome cell,
And lose the light I love so well.
But soon my liberty I find
And leave the horrid place behind;
I run with one triumphant boast
Into the sea, and there I'm lost.
And mixing with the briny spray,
I'm tossed about from day to day;
And so, as far as some can see,
I never more shall be set free.
But lo!! I'm drawn again on high.
And float in clouds along the sky.
And soon descend in drops of rain
To refresh the thirsty plain.
And thus a witness I would be
Of Him, who still sustaineth me.
And with a soft sweet murmur tell
The Lord has ordered all things well.

Tom Thurlow, Shepherd
19th Century poem about the Lower Mun

THE NORFOLK RIVERS TRUST
RESTORING NORFOLK'S RIVERS

The Norfolk Rivers Trust
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