Catchment Based Approach

Chalk Stream Restoration Strategy 2021
Main Report

This CaBA Chalk Stream Restoration Strategy was written and collated by Charles Rangeley-Wilson, chair of the CaBA Chalk Stream Restoration Group, (CSRG) in consultation with:

The CaBA CSRG Panel

Sarah Powell, Environment Agency, Chalk Stream Manager
Sophie Broadfield and Affie Panayiotou, Defra
Anne Dacey, Environment Agency
Rose O'Neill & Charlotte Rose, Natural England
Fayza Benlamkadem & Magda Styles, Ofwat
Dave Tickner, WWF
Stuart Singleton-White, Angling Trust
Ali Morse, The Wildlife Trusts
Barry Bendall, Rivers Trust
Janina Gray, Salmon & Trout Conservation
Andy Thomas, Wild Trout Trust
Richard Aylard & Yvette de Garis, Thames Water
Jake Rigg, Affinity Water
Ian Colley, Wessex Water
James Wallace, Beaver Trust
Jake Fiennes, NFU

The CaBA CSRG Expert Panel

Chris Mainstone, Natural England
David Sear, Southampton University
Kate Heppell, Queen Mary University
Geraldine Wharton, Queen Mary University
Steve Brooks, Natural History Museum
John Lawson, independent water-engineering consultant
Vaughan Lewis, independent river restoration consultant
Tim Sykes, Southampton University
Carl Sayer, University College London
Jonathan Fisher, independent environmental economist
Alan Woods, Cam Valley Forum
Owen Turpin, Environment Agency

In addition, a wider stakeholder group (see acknowledgements page 137) comprising individuals, academics, river keepers, fishery managers, farmers and landowners, chalk-stream associations, angling clubs and staff from numerous regulatory, independent and third-sector organisations have made contributions at the draft consultation stage and during river walks in June and August 2021 and in direct correspondence with the CaBA CSRG.

Numerous Environment Agency and Natural England staff have contributed their expertise with passion and enthusiasm, as have representatives from the water companies covering chalk catchments.

CaBA CSRG is grateful for all their valuable, expert and passionate contributions.

Foreword

This CaBA Chalk Stream Restoration Strategy represents the collective passion and ambition of all sorts of people and organisations who care about chalk streams and who wish to see them restored to full ecological health.

In terms of our stewardship of the environment, chalk streams are a considerable challenge, because they flow through the busiest part of the country; and a weighty responsibility, because they are such rare and special rivers. Chalk-stream ecological health is under pressure everywhere and failing in many places. This CaBA plan identifies what we need to do to relieve that pressure and address those failings. We will only succeed by working together and by acknowledging and living up to our individual responsibilities and roles.

The CaBA Chalk Stream Restoration Group

One big wish – enhanced status for all chalk streams

As will be shown in this report, people who are passionate about chalk streams have asked for one big thing again and again over the last twenty years: that is for the government to give chalk streams a status which reflects the fact that these rivers are not just locally precious, but globally unique, by providing a statutory driver for the investment needed to restore their ecological status.

Seven chalk stream catchments are currently designated as sites of special scientific interest (SSSI) and four as special areas of conservation (SAC)*, the latter our highest designation. These streams are designated for particular reasons which mark them out even amongst chalk streams, but the results of their enhanced protection are obvious when you look at the investment afforded to their protection in comparison with the rest.

All chalk streams are classified as priority habitat, but once they were THE river priority habitat, with their own investment driver: the Biodiversity Action Plan (BAP) priority habitat driver. Now, chalk rivers are one of a subset of criteria of priority habitat, and the designation itself has not always been that powerful.

Over and over, while preparing this report, it has been made clear that when it comes to the investment decisions which determine the health of our chalk streams – in reducing abstraction, or pollution or paying for habitat work – a powerful *statutory* driver makes all the difference. A statutory driver allows the regulators, industry and NGOs to do what they need to do to bring our chalk streams back to ecological health, not just in a few privileged places, but right across the map.

Rivers are found all over the world, but chalk streams are very largely English. They should be our pride and joy. Enhanced status which drives investment – whatever form that needs to take – will allow them to become so. Statutory protection is this group's primary recommendation.

*SSSI catchments: lower Frome / Bere Stream / Test / Kennet / Nar / Hull h'waters / River Crane (h'waters of Moors River) SAC catchments: Avon / Itchen / Wensum / Lambourn

Consultation feedback and next steps

Thank you to everyone who took part in the consultation process, via the CaBA hub, in direct correspondence or by attending one of our river-walk days in August. All of the insights, information, ideas and factual corrections were immensely useful.

As a result of the feedback we have added some additional sections with associated recommendations covering:

• planning and development rules for chalk streams (to match the farming rules for chalk streams)

• the impacts and regulation of aquaculture

• nature-based solutions and aquifer recharge

• the potential impacts of climate change and scenario planning

• the role of fishery management

In addition we have completed the survey of abstraction as a % of recharge (A%R) which was an action in the first draft and have incorporated some of its useful findings into the recommendations in the *Water quantity* section.

We are a long way down the road of building the CaBA chalk stream information hub.

We are a long way down the road of initiating the national network of flagship catchment restoration projects. The Minister has written to the water companies and they have responded positively.

The first iteration of the agreed chalk-stream map is almost ready for publishing and some of you have very helpfully added information to that database, picking up 'lost' streams like the Westbrook in Kent, the fascinating scarp-face streams of the Sussex Downs, a few tributaries of the Driffield Beck, some streams in Lincolnshire and others.

We have done some additional work on the structure and ordering of the recommendations and have added an extra section called *Integrated policies*, where we have set out in more detail the case and options for statutory designation.

One of the most common themes in the consultation feedback was a feeling, sometimes very strongly expressed, that the strategy needed more information on the who, how and when on the big questions such as abstraction reductions, rolling out tertiary treatment to sewage-treatment works on chalk streams, addressing storm overflows, establishing farming and development rules for chalk catchments, designating all chalk regions as 'water-stressed' to enable compulsory metering and so on. As we have shown in this strategy there have been reports before, several of them, and they have all articulated the same frustrations with the failing condition of our chalk streams. We all know the river flows are too low in some chalk streams and that water quality needs to improve. The questions are: who is going to fix these things and when?

At least we can say that the last of that list has now happened: chalk regions are now all classed as 'water-stressed', which will enable the roll out of metering. And those initiatives which are in the CaBA group's power to set in motion right now, have been set in motion: the information hub, the map, the flagship projects, the A%R survey which will be very useful to stakeholders. The case for a flagship flow-recovery project in the Chilterns is being investigated by the water companies, RAPID and WRSE.

As can be seen in the strategy, however, we have gone back to the basics in trying to address why these issues of flow and water quality have been so challenging over the past thirty years or more and how we can shift the road-blocks. That process is not easy: it requires that all parties get into an uncomfortable, but collaborative space, are honest about the existence and scale and causes of the problems on the one hand and on the other are honest about the need for pragmatism and expediency in addressing them.

The difficulty in setting out right now a time-table for all the recommendations is that much of what is called for is currently in the field of play and under review. In that sense this strategy, as well as setting some things in motion, is also about articulating clearly and compellingly and with broad agreement across all sectors, the need for changes in legislation and government guidance and in what is considered the art of the possible.

The national framework for water resources is our best chance in decades to win some ground back for these ecologically essential chalk streams that are under such pressure. It is a process in motion and we hope this strategy will influence its workings.

The Environment Bill and changes to the way we support and govern farming is a great chance to build into farming rules and incentives ways of farming that will make a big difference to river health. These are also processes in motion and we hope this strategy will influence their workings.

We believe that *the* key is a form of statutory designation for chalk streams. That alone would unlock the capacity for investment and prioritisation which is clearly needed. To cover those places where we cannot right now define the commitment and the timescale, we have added a commitment in Integrated Policies to develop and publish within 12 months of the publication of this strategy an **implementation plan** (where these things are set out and time-bound).

We have also undertaken to maintain the CaBA CSRG to help drive the actions and to review this strategy every five years, as this will synchronise with price reviews and will allow us to take stock of what has been done and what is yet to do.

1. Introduction

Chalk streams are a special type of spring-fed river unique to England and north-west Europe. Like other spring-fed streams, chalk streams derive most of their flow from underground aquifers, but the chalk aquifer and the chalk landscape are distinctive and give to these rivers a blowsy and gentle quality which marks them out historically, aesthetically and ecologically: chalk streams flow through a busy, modern landscape which is nevertheless steeped in history; they have been shaped extensively by man over the centuries and yet they also possess – because of their alkalinity, minerality and their cool, stable and gentle flows – a rich ecology and biodiversity.

Chalk is a form of limestone (made of the remains of countless billions of tiny marine fossils) which is distinct from the harder, more heavily fissured limestones of the Cotswolds, northern England, or Ireland. Chalk is a softer and younger form of limestone and the chalk landscape and the chalk-stream flow regimes and characters reflect this. They are exceptionally equable rivers. Crucially, the geology, water chemistry and flow regimes of chalk streams define their distinctive physical characteristics and these define their ecologies.

Also distinguishing chalk from the more globally widespread forms of limestone is the fact that the chalk beds laid down across Europe in the Cretaceous geological epoch have either been extensively worn away (because chalk is so soft) by glaciers or buried deep beneath younger deposits. It is an accident of geological history that only in England (from Dorset to the eastern wolds of Yorkshire) and France (an area known as the Anglo-Parisian basin) and also near Aalborg in Denmark, do we find a relatively tiny global total of chalk streams. In England we have identified 283 named chalk streams listed in the index (Appendix H), as well as chalk spring-line zones draining the scarp-faces.

There are a few dozen very famous chalk streams: Hampshire's Test and Itchen are the most obvious, arguably the jewels in the chalk-stream crown. But the Frome, Piddle, Allen, Wylye, Avon and Kennet, and in Yorkshire the Driffield Beck are all comparable. Amongst and between these, however, are dozens of less well-known streams that are every bit as precious, given that together these amount to most of the chalk streams in the world: the Meon, Ebble, Pang, Wye, Chess, Mimram, Beane, Ivel, Cam, Nar, Babingley, Burn, Great Eau, Foston Beck and Gypsey Race, to name just a few. In addition and almost innumerable are the scarp-face springs that rise along the north-eastern-facing ridge of the chalk, especially from the Sussex Downs, through the Chilterns and north through Lincolnshire and Yorkshire: a spring-line assemblage of chalk rills which is also a distinctive and precious resource.

It is no coincidence that the confluence of geological history which created such globally rare and ecologically rich rivers also shaped a part of the world which has

The world's first geological map, drawn by William Smith (who also built water meadows) picks out the English chalk in a serpentine band of green.

been a crucible of human activity for thousands of years and is now the busiest, most intensely inhabited part of the United Kingdom. The conflict between the ecological integrity of spring-fed streams and busy human activity is a global phenomenon because spring-fed streams by their natures flow through habitable and malleable landscapes. If the pressure on spring-fed streams from agriculture, population and industry is intense almost everywhere, it is probably at its most intense in southern and eastern England and even there it is pushed to a peak of intensity on the chalk streams which surround London.

There are multiple pressures on chalk streams: we extract water from them, we pollute them with treated and not-so-treated sewage, and we have re-shaped them again and again over the centuries, through deforestation, milling, canalisation, dredging. All this has combined to create what has been called the 'chalk-stream crisis': a collapse in ecological condition which in the worst places means that rivers are hardly rivers (the headwaters of the Beane, the Misbourne and other rivers near London either do not flow at all or flow rarely) and which elsewhere leads to low flows, eutrophication, excessive siltation and denuded, de-natured physical habitat.

Over the last three decades the ecological state of England's chalk streams has become a subject of growing concern. In some respects and in some places, the condition of these rivers has improved as a result of intense lobbying, passionate and proactive restoration and because of the enhanced protection afforded to designated chalk streams: protection which drives investment in sewage-treatment works, for example. Elsewhere the widespread perception is of a general decline under increasing pressures, whether from water abstraction, agriculture, population growth, the impact of invasive species or a multiplicity of other causes.

But the extraordinary characteristics of these rivers and the fact we are stewards of a globally scarce ecosystem has also strengthened a resolve which is now felt in all quarters of society, from grass-roots stakeholders all the way to government, to restore to good ecological health these unique rivers and the landscapes that support them.

This **restoration strategy** is designed as a road-map to guide us on that journey. It will take some time to get to the destination – to think otherwise would be to underestimate the scale of the undertaking or the ambition in our vision: 283 ecologically vibrant chalk streams, all flowing with a healthy flush of clean water through meandering channels over bright gravel; streams full of wildlife, streams which are a pleasure to spend time beside and which could and should be a credit to the stewardship of our generation.

The north-facing chalk cliffs of Hunstanton, where – unusually – the lower band of chalk is stained red.

2. The chalk stream: origins and ecology

2.1 A brief history of chalk

All our chalk streams share a special and rich ecology which derives from their geological origins.

The story of chalk began in a warmer world 100 million years ago. Carbon dioxide levels were four times what they are today – and sea levels were much higher. The supercontinent of Pangea (when all the continents on earth were crammed into one landmass) had fragmented into Laurasia and Gondwanaland and the Atlantic Ocean was in the early stages of formation.

As tectonic plates rifted and shifted, undersea mountain chains rose along the mid-ocean divides. This tectonic / volcanic activity enriched the oceans with calcium and pushed the sea levels higher still, to create shallow inland seaways across large tracts of the Eurasian plate which later became the British Isles, Europe and Russia.

There were few mammals then. On land mostly dinosaurs, and insects. In the sea, rays, sharks and reptiles. But also and especially in the sunlit and shallow seas covering Europe, there were vast clouds of a phytoplankton called a coccolithophore, each microscopic organism wrapped in an interlocking exoskeleton of calcareous plates called coccoliths.

For millions of years these coccolithophores swarmed in infinite abundance, and at death their tiny exoskeleton plates rained down to the bed of the sea, accreting into deep layers. With sea levels so high and all the land flooded, there were no rivers and therefore no sources of sediment which might otherwise have muddied the fossil graveyard. Europe lay at the floor of a perfect kind of tropical infinity pool, and those dead skeletons were left to accumulate uncorrupted by any other substance into the most amazingly pure, deep beds of what became the bright, white calcium carbonate known as chalk.

Stand at the white cliffs of Dover, Hunstanton or Flanborough Head and consider that this sea-bed deepened by about 1cm every 1000 years and you will get some idea of the length of time the chalk sea lasted: 30 million years or so. Hence chalk lent its name to an entire geological epoch – the Cretaceous (from the Latin *creta* meaning chalk).

The Cretaceous period – and the accumulation of chalk on the floor of this pre-historic sea – ended when a giant meteorite struck the earth near the Yucatan peninsula in Mexico. The collision caused giant tsunamis, which radiated in all directions, and threw enough dust into the atmosphere to cause global cooling on a vast scale: most animals including the dinosaurs were wiped out, as was that eustatic engine of chalk creation, the pure chalk sea.

Chalk was laid down across a much larger area than where we now find chalk streams. A map of the globe in the Cretaceous era shows shallow, inland seas stretching in a belt across Europe as far as the Urals. Not to mention across parts of America, Australia and Arabia too. So, why do we find chalk-streams only in England and small parts of north-eastern Europe?

The process that created the chalk landscape of south-east England began in the early Cenozoic period, as the continents of Europe and Africa slowly collided, lifting and rippling the Anglo-Parisian basin – which was once the sea floor – into a gently rumpled surface. Across subsequent epochs of glacial advance and retreat this was progressively worn down, until the remains left behind after the final glacial retreat were sculpted by glacial meltwater into a distinct arc of rolling chalk downs, wrapped around basins of younger deposits and in one place – the Sussex Weald – broken open to expose a dome of older ground with the two ridgeways of chalk either side.

England was once joined to France by that same ridge of chalk hills, which curled south into Normandy, showing how all the chalk streams of the Anglo-Parisian basin are essentially part of the same super catchment. That link was severed when a vast amount of glacial meltwater from the southern North Sea spilled over the ridge of downs into the English Channel and wore the chalk hills away, leaving behind the iconic white cliffs of Dover.

You can almost run a ruler along the north-western scarp of the English chalk downs, from Dorset all the way to Yorkshire. While to the south-east and east the chalk dips progressively under younger rocks and post-glacial sedimentary deposits, to the north-west of that line the chalk has been worn away, exposing Jurassic, Triassic and Devonian layers. Hundreds of miles away, the plains of chalk which lie across parts of Europe, through Lithuania, Estonia, Belarus, the Ukraine and Russia, even as far as Kazakstan, are hidden under such deep layers of peri-glacial drift that the rivers in those regions are deeply incised and do not resemble chalk streams as we know them.

The explanation then, as to why chalk streams are globally so rare and why so many are English, points to a serendipitous collision of geology, weathering and climate which has created a rolling massif of chalk downs, polished clean by glaciers, but crucially not worn away, nor covered with glacial deposits, coinciding with a temperate, maritime climate: all this giving birth to the 283 pellucid, calcareous, spring-fed rivers we call chalk streams.

2.1.1 The chalk aquifer and equable flows

In a natural chalk catchment the chalk aquifer acts like a vast sponge, soaking up rainfall over the winter months, releasing it slowly through the summer. Only a small proportion of flow reaches a chalk stream by surface run-off. This creates a stable flow-regime with the stream comparatively buffered against the extremes of wet weather and drought compared to ‘freestone’ (run-off dominated) rivers.

This stability can be seen in the ratio between high and low flows, generally less than 10:1 in a chalk stream (as low as 3:1), contrasting with ratios of more like 100:1 in clay-dominated catchments. Conversely, although the peak flows in chalk streams are lower than in run-off rivers, they last longer. Naturally, an unmodified chalk stream may flow at the bank-full stage (when the water is at the limit of the holding capacity of the channel) for 30% of the year, compared to only 5% in a freestone river.

The chalk aquifer, water chemistry and temperature

As with flow, the aquifer bestows stability upon the chemical and physical properties of the groundwater. A slow journey through the chalk makes the chalk stream’s flow calcareous and cool, its pH generally around 7.4 to 8 and the water temperature at the springs, a steady 11ºC, winter or summer.

The filtering effect of the chalk and the stable, gentle flows also make the natural chalk stream famously bright and clear-watered. Even in the downstream reaches, an unmodified chalk stream should run clear after rain, with a high degree of connectivity between the river and the floodplain allowing the surrounding land to act as a secondary filter, in addition to the aquifer.

Nutrient levels would naturally have been very low in the unmodified chalk catchment, with total phosphorus around 0.01 - 0.03 mg/l and nitrogen 0.2 mg/l allowing for a degree of natural increase in the downstream reaches as a result of nutrient spiralling and the likelihood of the impact of mixed geologies further down the catchment.

2.2 Types of chalk stream

No two chalk-streams are exactly alike, however. Chalk varies in its hardness, stratification, fracturing, and permeability. The layers of superficial deposits which lie on top of the chalk also vary from one valley to the next. There is quite a difference, therefore, between the River Frome and the River Itchen, although both are considered chalk streams. Similarly, many chalk streams flow from or through deep deposits of glacial drift, and these chalk streams (rivers like the Nar in Norfolk as compared to its purer chalk neighbour the Babingley) are also relatively more responsive to rain.

Even so, all chalk streams are *relatively* equable, low-energy rivers and this underpins their character as rivers and their rich biodiversity.

In reality, we have a spectrum of pure chalk rivers and chalk-influenced rivers. A river is the product of its landscape, especially its geology. The geological map shows our landscape as a marbled swirl of bedrocks and superficial layers and the precise mix of these in any given valley will shape the characteristics of the river that flows through it.

A ‘pure’ chalk stream, like the upper Itchen, flows from an uninterrupted sweep of chalk hills, overlain by the thinnest layer of limey top-soil. But on the upper Frome in west Dorset, you will find in the headwaters a much more complex mix of chalk, greensand, mudstone and clay, and in places impermeable, clayey top-soils, with the river increasingly flowing over a purer chalk bedrock as it moves downstream. The Itchen is a more equable and gentle river as a result, very rarely coloured by rain (never in its natural state). The Frome is more incised, flashy and powerful.

It can be helpful to broadly group chalk streams into four types.

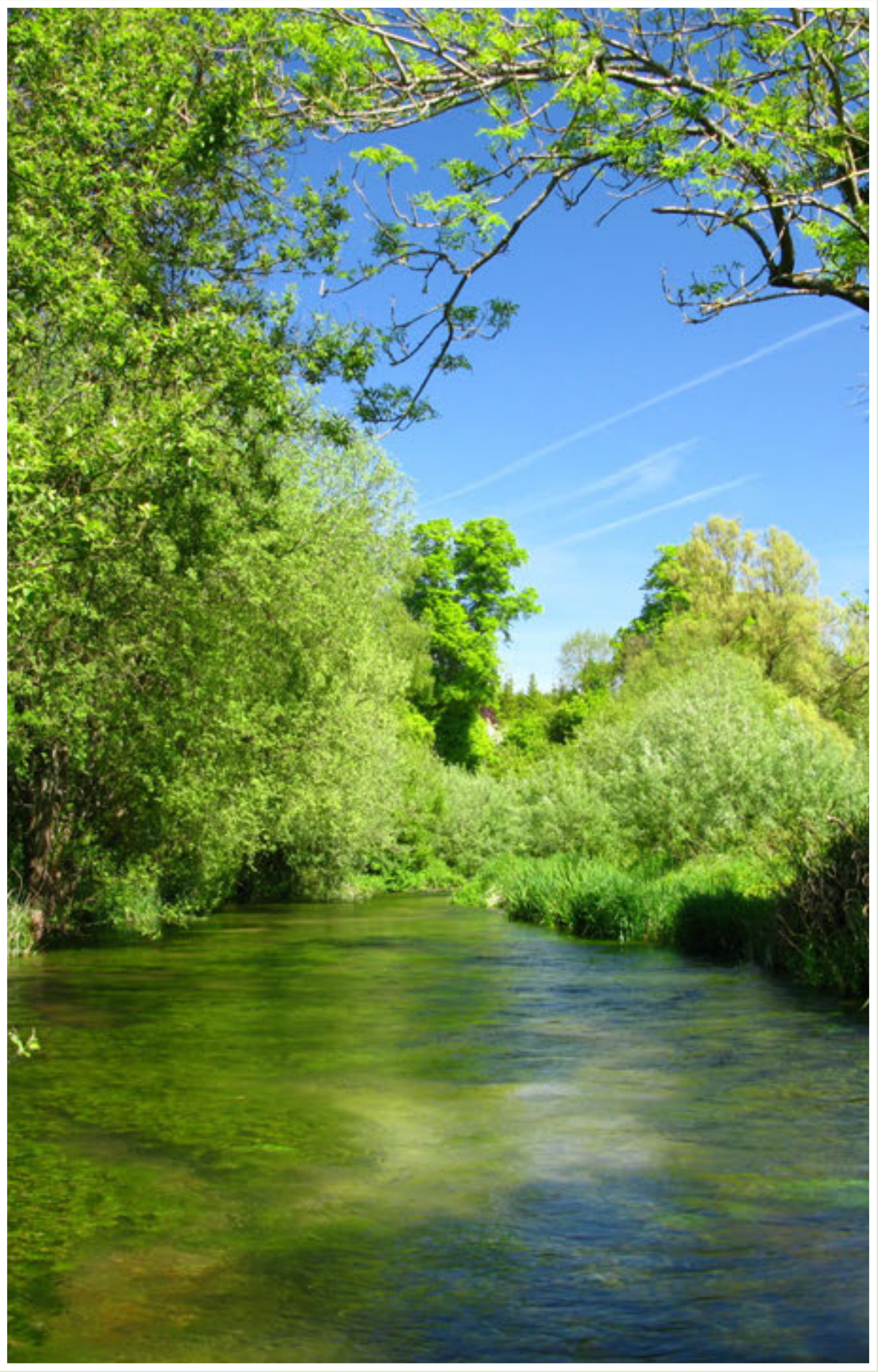
Group A: classic slope-face chalk streams. These are streams that rise directly from the chalk, flow over chalk and then in some cases – usually in their lower reaches – over younger tertiary (sand and clay) deposits. This group would include the majority of the Hampshire-basin streams and the majority of those that flow into the Thames basin. Most of the iconic chalk-streams like the Itchen or Test or Kennet are in this group. Group A can be sub-divided into slope-face streams that flow from and largely across chalk (eg Chess) and those that rise from chalk but mostly flow over tertiary outcrops (eg Wandle).

Group B: mixed-geology chalk streams. These are streams which tend to rise beyond (ie to the north and west) of the chalk but then flow over / through the chalk – this is a minority of chalk streams but the Great Stour in Kent is a good example, rising on gault clay / greensand and then flowing through the chalk. The Nadder is another example, as is the Hampshire / Wiltshire Avon and the Dorset Frome. These streams will have ‘flashier’ flow regimes, will tend to colour after heavy rain and take longer to clear too, because of the influence of the headwater geology.

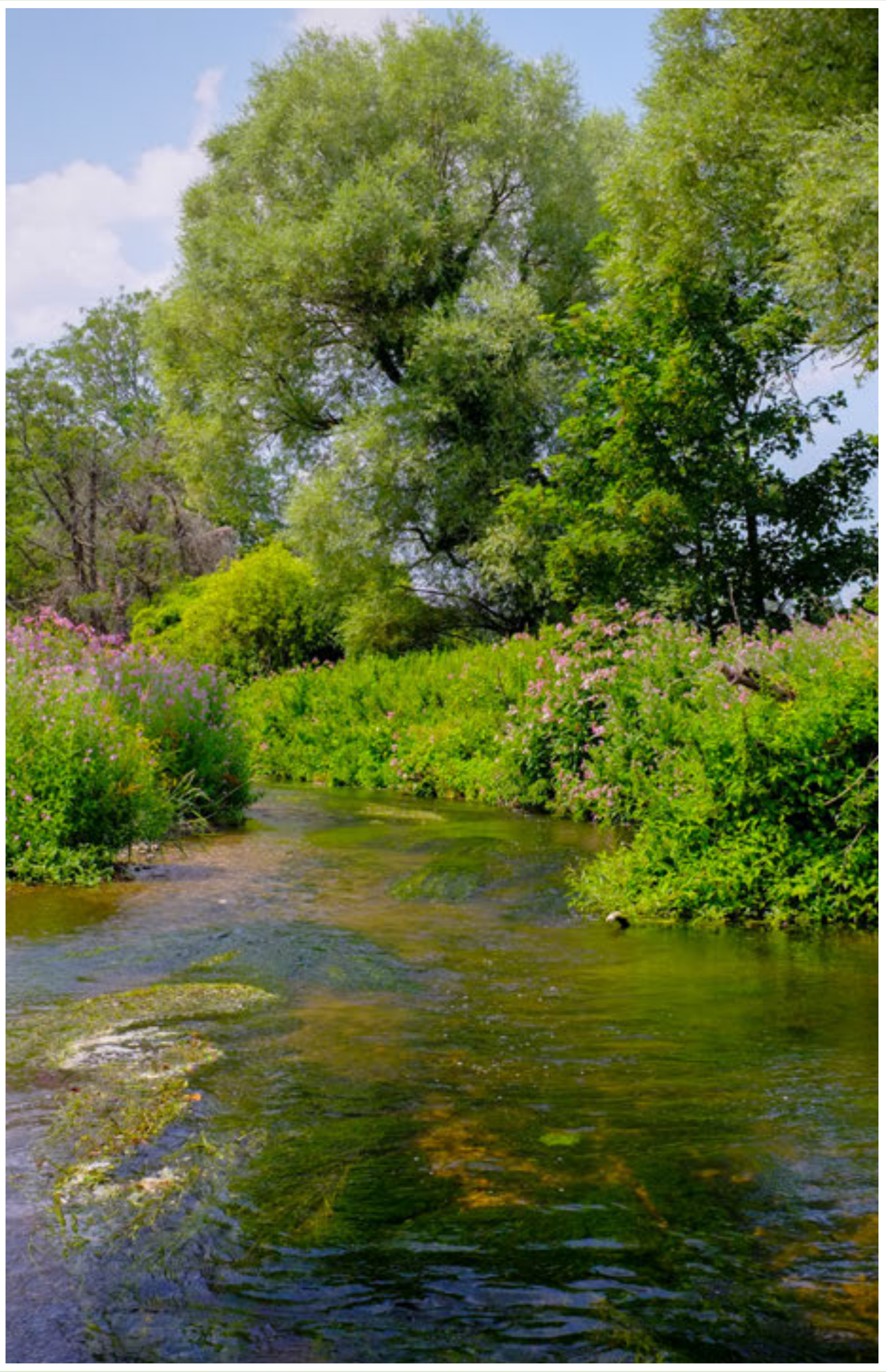
Group C: scarp-face chalk streams. These are the scarp-slope streams which rise at the base of the chalk and tend to run for a short distance over older (clay rich) chalk and then flow out onto the underlying gault clay and greensand beds. The Fontmell Brook in Dorset is a scarp-slope stream, as are the Lewknor and Chalgrove west of the Chilterns, likewise the streams rising along the spring-line of the Sussex Downs, or the north-flowing streams of the Gog Magog Hills, the westward flowing streams in north-west Norfolk and all the streams west of the Yorkshire Wolds.

Group D: Pleistocene ice-impacted chalk streams can fall into any one of the above categories but these streams rise from chalk that was directly impacted by major glacial action during the Pleistocene. This group would include the northern Chiltern streams and the East Anglian, Lincolnshire and Yorkshire streams. Group D could be further subdivided into streams that flow from chalk over glacial outwash deposits (the Wensum) and those that flow from chalk onto older (pre-glacial) river deposits, such as the pre-glacial Bytham River which flowed eastwards from the Midlands across Norfolk and emptied into the North Sea north of Lowestoft: the streams that lie between the Chilterns and Norfolk.

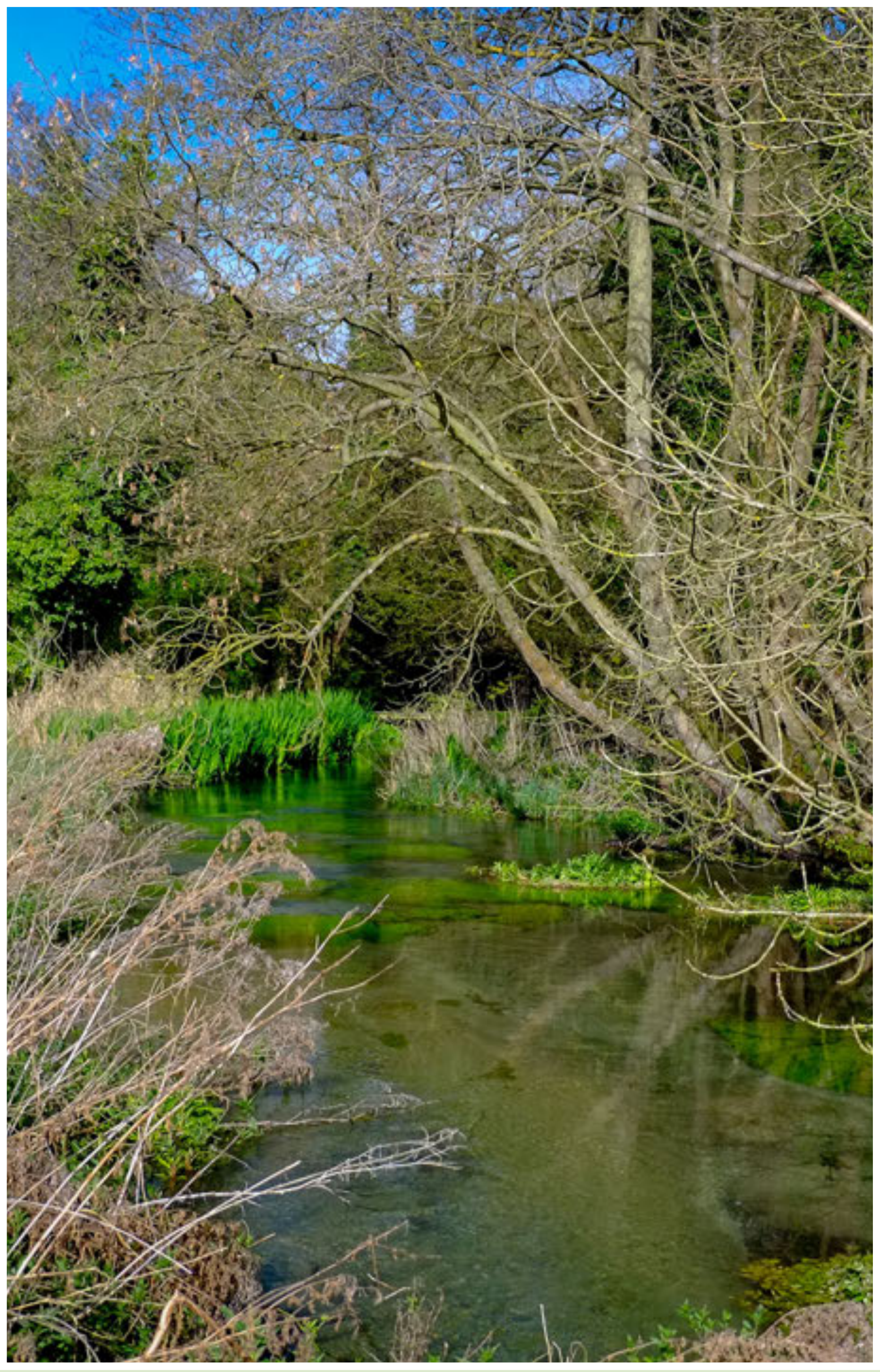
For a list of all English chalk streams and their types, see Appendix H.



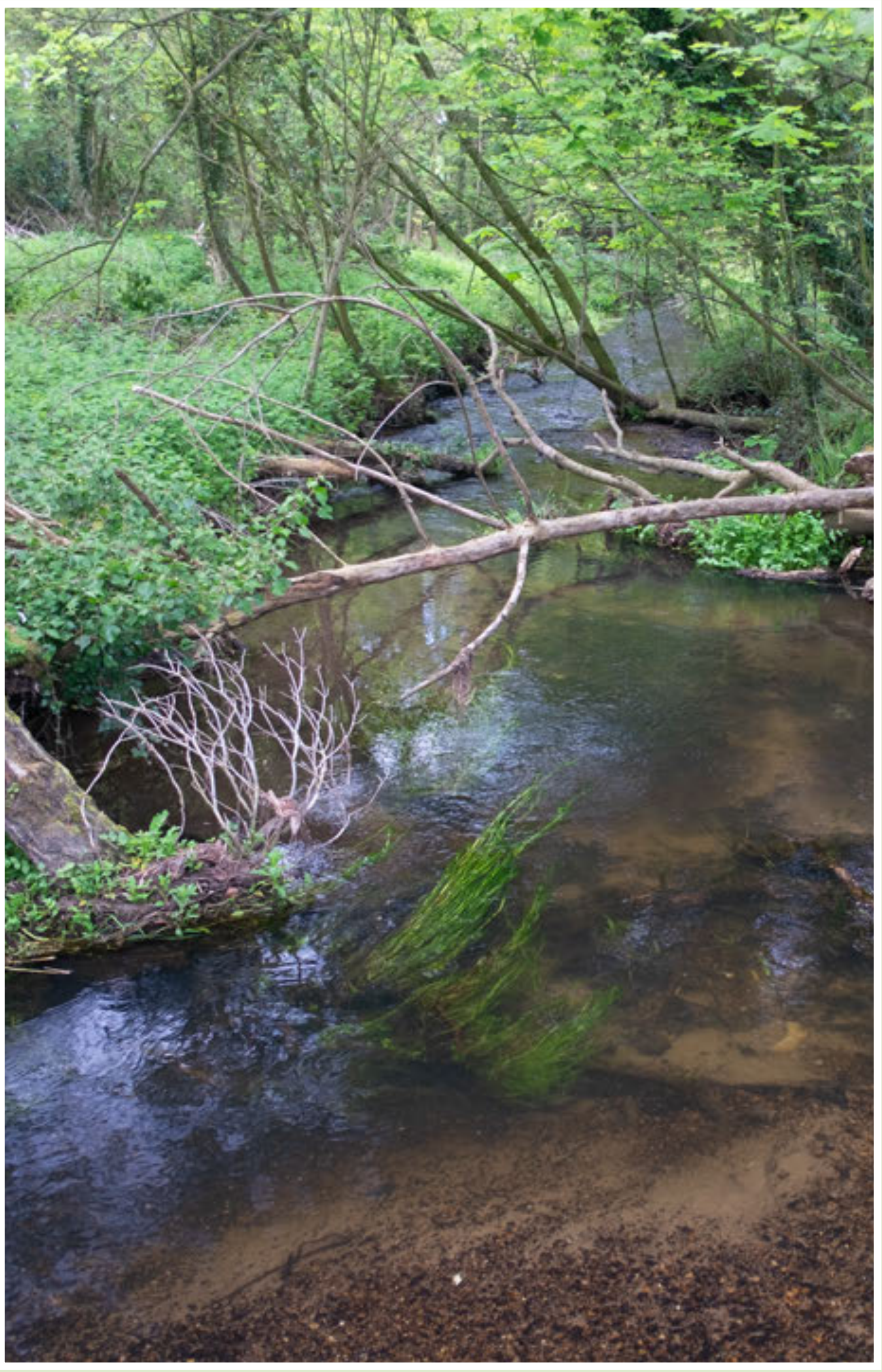
The River Alre in Hampshire: a slope-face 'classical' Group A chalk stream.



The River Frome in Dorset: a typical mixed-geology Group B chalk stream.



The River Babingley in Norfolk: a scarp-face Group C (and D) chalk stream.

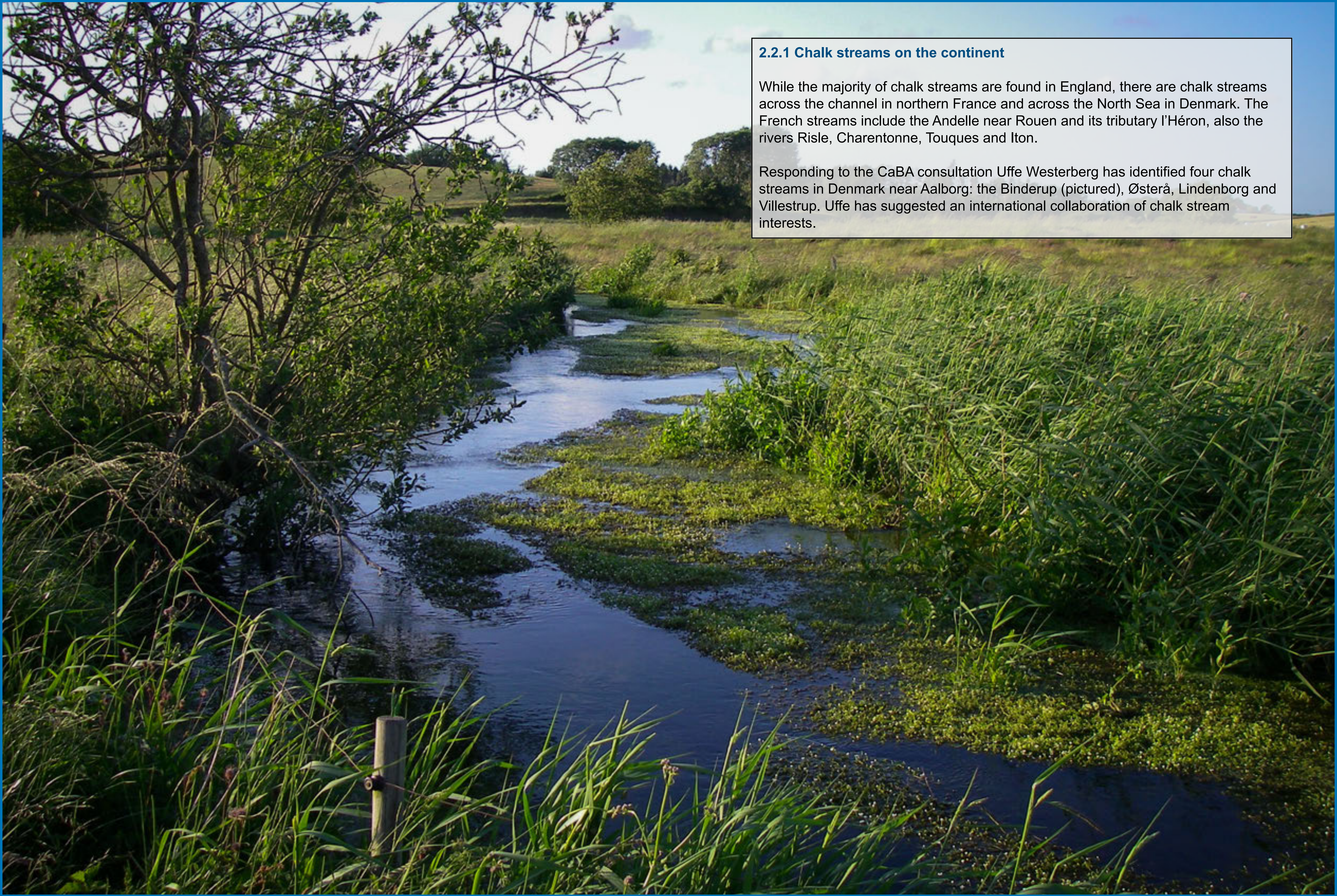


The River Glaven in Norfolk: a Group D chalk stream.

2.2.1 Chalk streams on the continent

While the majority of chalk streams are found in England, there are chalk streams across the channel in northern France and across the North Sea in Denmark. The French streams include the Andelle near Rouen and its tributary l'Héron, also the rivers Risle, Charentonne, Touques and Iton.

Responding to the CaBA consultation Uffe Westerberg has identified four chalk streams in Denmark near Aalborg: the Binderup (pictured), Østerå, Lindenborg and Villestrup. Uffe has suggested an international collaboration of chalk stream interests.



2.3 Chalk-stream ecology

The geological foundations of any chalk-stream catchment shape the hydrology and physical form and therefore the ecology of the stream. But the ecology shapes the stream too.

The shaping forces of glaciation

Chalk streams are low-energy, equable rivers. The distinctive, rolling valleys they flow through, however, were carved by much more energetic forces during multiple phases of glaciation which ended with the Devensian, 70,000 to 9,000 BC. Protracted freeze and thaw at the edge of the ice fields generated massive meltwater flows which rushed south over semi-frozen chalk hills, carving our distinctive chalk downland. Much of the chalk – being porous, soft and soluble – was worn away, but the insoluble and harder flint buried within it (flint also derives from the remains of sea animals: it is a precipitate of the silica-based exoskeletons of diatoms, radiolarians and sponges) was crushed by glacial action into sand and gravel and debouched onto the valley floors.

The shaping forces of ecology

When the glaciers finally retreated about 10,000 years ago, the chalk thawed and the more gentle engine of spring-fed flow kicked into life, as did the ecological forces of landscape engineering: the vegetation and animals which shaped the evolving chalk stream.

The role of wood and vegetation

Higher-altitude spring-fed streams in New Zealand or Patagonia give some indication of the shape of the early Holocene chalk stream, with their multiple primary and secondary interconnected and ultra-stable channels meandering through tussocky, steppic grassland. On the English chalk stream, however, trees and beavers would have come to play a more decisive role as the climate warmed. Progressively the open grassland of a frigid and chilly post-glacial climate will have made way for the early colonisers of pine, dogwood, juniper, successive invasions of birch, then finally the oak, alder and willow of a deciduous and temperate wet woodland.

The succession onto the chalk-stream floodplain of trees like alder, willow and oak, growing and dying, blown over by wind or felled by beavers, would have had a significant shaping impact on the evolution of the pre-human chalk stream. Fallen trees and beaver dams will have energised and subtly destabilised the formerly ultra stable grassland channels, compelling the streams to break out of their banks and find new pathways across the floodplain.

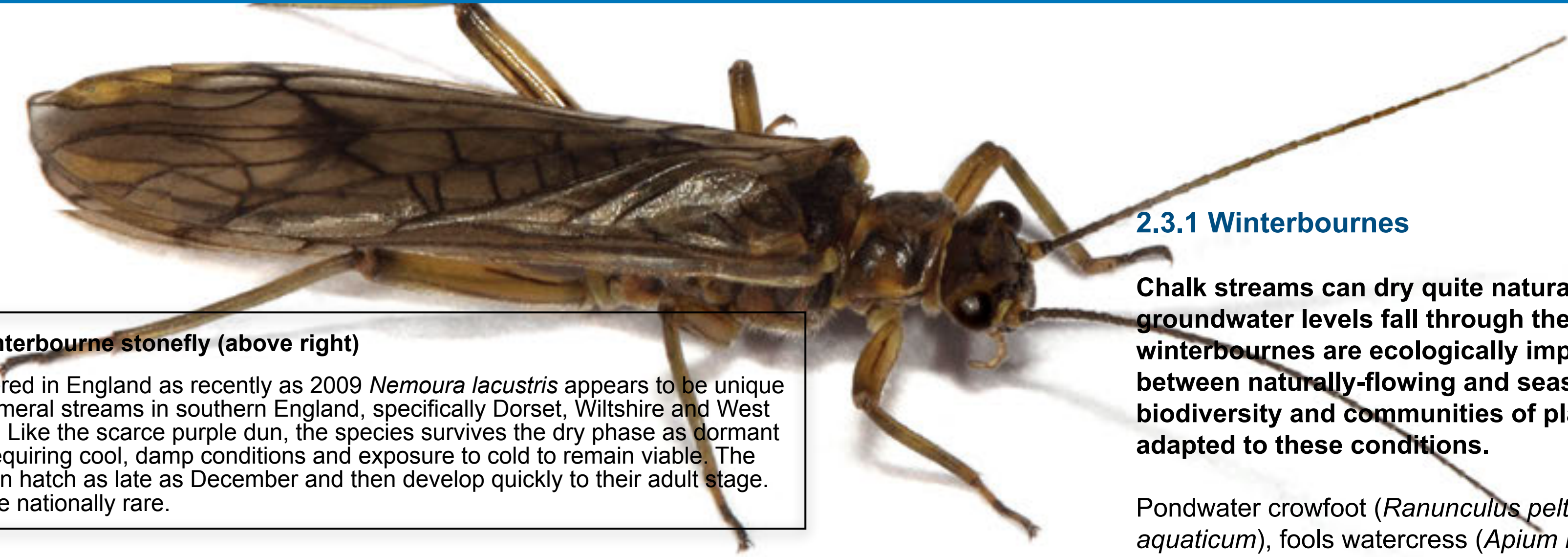
Then there was the more subtle but just as vital role of riparian and in-stream plants, as well animals, fish, invertebrates all adding not only to the variety of habitat in a chalk stream, but the morphological processes too: ranunculus, for example, fractures the flow into a series of mini channels within channels, packing out the water level, causing localised scour or deposition and the sustained saturation of riparian soils. Vast numbers of spawning salmonids would have mobilised the gravel. Large herbivores would have grazed the banks and the mosaic of woodland and meadow.

The ‘natural’ chalk stream

We could probably call this post-glacial, pre-human phase of the chalk stream’s existence, the ‘natural’ chalk stream: meandering, broad and shallow, gravelly channels, oozing under and around fallen trees, breaking out into ponds, nuzzling the tussock-lined banks in semi-drowned meadows.

Suffice to say, it is difficult to find a chalk stream today in anything like what we might call this ‘natural’ (pre-human) physical and ecological state. There are wild sections of headwater scarp-streams in the Sussex Downs, parts of the Wraxall Brook and Bere Stream in Dorset, or the Nar in Norfolk, where the river flows in multiple channels through woodland and fen. Similarly, there are few examples of the natural fen habitat which would have surrounded the streams, and the springs: most of the spring-line fens have by now been drained into a fretwork of ditches. It is a key message in this plan that chalk-stream restoration should include landscape-scale restoration of these fen landscapes along the spring line: the benefits would roll on down through the whole system.

While it is not impossible to think that we might be able to restore a larger proportion of our chalk-stream habitats to something much closer to this state than we have today – by taking agriculture away from the river’s edge and off the floodplain, by restoring natural flow regimes, groundwater levels, floodplain saturation and channel forms – for much of the resource, we have greatly modified rivers which are nevertheless home to a diverse, sometimes rare and endangered range of plants and animals, from the winterbourne reaches, all the way through the chalk stream system and across the wider riparian and surrounding landscape.



The winterbourne stonefly (above right)

Discovered in England as recently as 2009 *Nemoura lacustris* appears to be unique to ephemeral streams in southern England, specifically Dorset, Wiltshire and West Sussex. Like the scarce purple dun, the species survives the dry phase as dormant eggs, requiring cool, damp conditions and exposure to cold to remain viable. The eggs can hatch as late as December and then develop quickly to their adult stage. They are nationally rare.

Winterbourne black flies

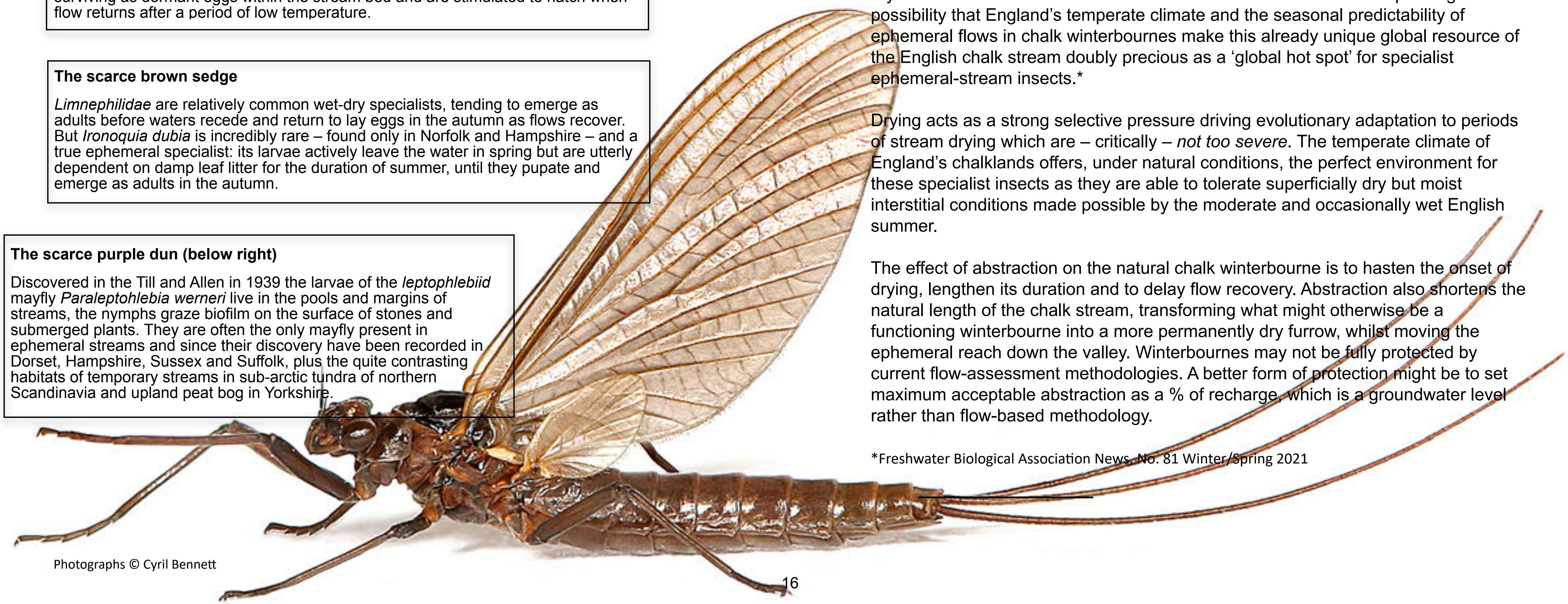
First discovered by Mike Ladle and Jonn Bass in Dorset's South Winterborne in 1975, *Metacnephia amphora* is restricted to winterbournes in southern England. The filter-feeding larvae of *Metacnephia amphora* and also *Simulium latipes* are adapted to the specific conditions provided by streams that naturally dry seasonally, by surviving as dormant eggs within the stream bed and are stimulated to hatch when flow returns after a period of low temperature.

The scarce brown sedge

Limnephilidae are relatively common wet-dry specialists, tending to emerge as adults before waters recede and return to lay eggs in the autumn as flows recover. But *Ironoquia dubia* is incredibly rare – found only in Norfolk and Hampshire – and a true ephemeral specialist: its larvae actively leave the water in spring but are utterly dependent on damp leaf litter for the duration of summer, until they pupate and emerge as adults in the autumn.

The scarce purple dun (below right)

Discovered in the Till and Allen in 1939 the larvae of the *leptophlebiid* mayfly *Paraleptohlebia werneri* live in the pools and margins of streams, the nymphs graze biofilm on the surface of stones and submerged plants. They are often the only mayfly present in ephemeral streams and since their discovery have been recorded in Dorset, Hampshire, Sussex and Suffolk, plus the quite contrasting habitats of temporary streams in sub-arctic tundra of northern Scandinavia and upland peat bog in Yorkshire.



Photographs © Cyril Bennett

2.3.1 Winterbournes

Chalk streams can dry quite naturally in their upper reaches when groundwater levels fall through the summer and into early autumn. Natural winterbournes are ecologically important, dynamic habitats in which the shifts between naturally-flowing and seasonal, occasionally-dry states supports high biodiversity and communities of plants and insects which are uniquely adapted to these conditions.

Pondwater crowfoot (*Ranunculus peltatus*), watercress (*Rorippa nasturtium-aquaticum*), fools watercress (*Apium nodiflorum*) sweetgrass (*Glyceria spp.*) and brooklime (*Veronica beccabunga*) are typical of chalk-stream winterbourne plant communities.

Some rare species of insect are specially adapted too, with life-cycles which enable them to survive dry stages – see opposite. Notably, these insects rely on the wet and dry shifts that characterise chalk winterbournes. Recent research is pointing to the possibility that England's temperate climate and the seasonal predictability of ephemeral flows in chalk winterbournes make this already unique global resource of the English chalk stream doubly precious as a 'global hot spot' for specialist ephemeral-stream insects.*

Drying acts as a strong selective pressure driving evolutionary adaptation to periods of stream drying which are – critically – *not too severe*. The temperate climate of England's chalklands offers, under natural conditions, the perfect environment for these specialist insects as they are able to tolerate superficially dry but moist interstitial conditions made possible by the moderate and occasionally wet English summer.

The effect of abstraction on the natural chalk winterbourne is to hasten the onset of drying, lengthen its duration and to delay flow recovery. Abstraction also shortens the natural length of the chalk stream, transforming what might otherwise be a functioning winterbourne into a more permanently dry furrow, whilst moving the ephemeral reach down the valley. Winterbournes may not be fully protected by current flow-assessment methodologies. A better form of protection might be to set maximum acceptable abstraction as a % of recharge, which is a groundwater level rather than flow-based methodology.

*Freshwater Biological Association News, No. 81 Winter/Spring 2021

2.3.2 Chalk-stream plants

Chalk streams feature a higher species richness of in-stream and riparian plants than any other type of river in the country. Most distinctive of all plants in the perennial reaches is the chalk-stream 'classic' brook water crowfoot, (*Ranunculus penicillatus subsp. pseudofluitans)* whose constellations of white flowers rise above the waterline in spring and early summer. Ranunculus needs swift-flowing water to grow, and its dense clumps are home to millions of simuliidae larvae which filter diatoms from the water: the perfect example of ecological engineering.

Other distinctive perennial chalk-stream species include: river water dropwort (*Oenanthe fluviatilis*); water starwort (*Callitriche*) which grows in neat clumps, and can tolerate slower, shadier and siltier water than ranunculus, and is often the dominant plant in wooded and slower reaches, or in low-flow years; lesser water parsnip (*Berula erecta*) with its dense, creeping clumps of broad and bright green leafage; water speedwell (*Veronica anagallis-aquatica*); fool's watercress and watercress; water forget-me-not and the distinctive unbranched bur reed, aka eelgrass (*Sparganium emersum*). In slower reaches in addition to starwort you can expect to find the handsome, and eponymous mare's tail (*Hippuris vulgaris*) sashaying from side to side in the flow, water milfoil (*Myriophyllum spicatum*), various species of pondweed (horned and fennel-leaved), and common club-rush, with its tall, rod-like leaves rising above the surface.

The channel margins feature reed canary grass (*Phalaris arundinacea*), reed sweetgrass (*Glyceria maxima*), drifts of common reed (*Phragmites australis*) and tall, vibrant stands of the spear-leaved bur reed (*Sparganium erectum*). Then there are the architectural stands of hemlock water dropwort (*Oenanthe crocata*), and greater tussock sedge (*Carex paniculata*).

Flag iris (*Iris pseudacorus)* with its distinctive yellow flowers, is the almost quintessential marginal flower, decking out the channel margins in early summer like celebration-day bunting. But purple loosestrife (*Lythrum salicaria*) is another plant which brings colour to the river's edge, along with white and purple comfrey (*Symphytum officinale*), water mint (*Mentha aquatica*), hairy willowherb, (*Epilobium hirsutum*), water forget-me-not (*Myosotis scorpioides*) and marsh marigold (*Caltha palustris*).

If the land around the stream is uncultivated the banks will merge seamlessly to fen, swamp and carr wet woodland, dominated by reed grass and common reed, as well as greater tussock sedge and tree species that thrive on base-rich moist or saturated soils: willow, alder, ash (threatened now, sadly) and oak. These carr woodlands are vital to the morphological function of the stream: the patchily shady and sunlit river is more biodiverse; dead or wind-blown trees in the stream provide vital refugia for fish and invertebrates; and vitally, they give energy to the benign and ultra-stable flows of the chalk stream, leading to a more varied and dynamic channel form.

Healthy chalk streams feature incredible biodiversity and to describe every characteristic plant, fish and insect would take up dozens of pages. A comprehensive listing can be found in Chalk Rivers: Nature, Conservation and Management (details in Appendix A).

2.3.3 Chalk-stream invertebrates

Chalk streams feature abundant and diverse invertebrate communities, with such a large number of distinct species that a comprehensive list would take up half this report. To keep things simple, the chalk stream invertebrates can be grouped as a) insects including ephemeroptera (the upwinged mayflies), plecoptera (stoneflies), trichoptera (caddis flies) and coleoptera (beetles); b) crustaceans, including freshwater shrimps, hoglice and crayfish; c) molluscs (Gastropoda) including snails, mussels and slugs and d) hirudinea, including leeches, plus flatworms and round-worms.

The population balance in terms of presence and abundance changes according to subtleties of habitat and to location on the river system: for example there are specialist winterbourne species as described in section 2.3.1; many of the ephemeroptera species thrive in the gravelly, well-oxygenated reaches of the perennial upper river, while the hoglouse *Assellus aquatics,* for example, and certain species of pea mussel are much more common in the downstream, slower-flowing reaches of the larger chalk streams.

The famous *Ephemera danica* mayfly, so prominent because of the the size of the insect (it is the largest upwinged mayfly) and the abundance of its hatches (legend has it they were once used to fertilise allotments in the Kennet valley), is actually rare or absent from the very upper reaches of the swiftest, clearest chalk streams, because in its larval, underwater phase it lives in sandy silt.

It is worth underlining the historical and natural abundance of many of the chalk stream's invertebrate species, an abundance that is rare to find nowadays. The mineral-rich, pure, equable, cool and oxygenated waters and sheer volume of habitat in the gravel substrates and dense macrophyte growth marked chalk streams out for their stunning abundance of fly-life and this is a large part of why these rivers gained such a reputation in the 19th century as streams on which dry-fly anglers could practise their craft to a highly refined degree.

The reliable presence of upwinged mayflies on the stream surface is one easy way to mark out the *relative* ecological health of the stream: you will see good numbers of upwinged flies almost every day of the year on the Alre in Hampshire. You will rarely see them on the Cam. This is down to the *relative* degradation of the habitat and water quality: many of the classic chalk-stream invertebrate species, and those that are most visible during the final stages of their life-cycle when they hatch and float in flotillas down the stream, are profoundly sensitive to pollution (see section 5.2.2), reduced flows and siltation.

The native white-clawed crayfish (*Austropotamobius pallipes*) deserves special mention: although not confined to chalk streams, it requires hard, alkaline water, and chalk streams should be a natural stronghold for this greatly endangered indigenous crustacean. Sadly, the chalk rivers in which one can find white-clawed crayfish are now few and diminishing rapidly as the invasive signal crayfish continues to spread (see section 6.3.6).

Ephemera danica is our largest upwinged mayfly, and is common in chalk streams. In larval phase it lives for two years in sandy silt beds, before hatching in profusion in May and June. Its rising and falling mating flight is performed in the lea of riverside trees and on warm evenings, the female 'spinner' will return to the river to lay her eggs, before collapsing spent and exhausted on the surface of the stream where she becomes easy food for trout, chub, ducklings and dippers.

Group	Family	Species (angler's name)	Score
Mayfly	Heptageniidae	Heptagenia sulphuria (yellow May) Rithrogena semicolorata (olive upright)	10
Mayfly	Leptophlebiidae	Paraleptophlebia submarginata (turkey brown)	10
Mayfly	Ephemerellidae	Ephemerella notata (yellow evening hawk) Serratella ignita (blue-winged olive)	10
Mayfly	Ephemeridae	Ephemera danica (mayfly or green drake)	10
Stonefly	Perlidae	Isoperla grammatica (yellow Sally)	10
Caddis	Goeridae	Silo nigricornis (black sedge)	10
Caddis	Brachycentridae	Brachycentrus subnubilus (grannom)	10
Caddis	Sericostomatidae	Sericostoma personatum (Welshman's button)	10
Caddis	Leptoceridae	Athripsodes cinereus (brown silverhorn) Mystacides azurea (black silverhorn)	10
Caddis	Rhyacophilidae	Rhycophila dorsalis (sandfly)	7
Caddis	Polycentropodidae	Polycentropus flavomaculatus (dark sedge)	7
Caddis	Limnephilidae	Halesus radiatus (caperer) Limnephilus binotatus Limnephilus lunatus (cinnamon sedge) Potamophylax latipennis (large cinnamon)	7
Mayfly	Caenidae	Caenis luctuosa (angler's curse) Caenis macrura (angler's curse) Caenis rivulorum (angler's curse) Caenis pusilla (angler's curse)	5
Caddis	Hydropsychidae	Hydropsyche instabilis (grey flag) Hydropsyche pellucida (grey flag)	5
Mayfly	Baetidae	Alainites muticus (iron-blue) Baetis fuscatus (pale watery) Baetis rhodani (large dark olive) Baetis scambus (small dark olive) Baetis vernus (medium olive) Centroptilum luteolum (small spurwing) Cloeon dipterum (pond olive) Nigrobaetis niger (iron-blue) Procloeon bifidum (pale evening) Procloeon pennulatum (large spurwing)	4

The table above lists well-known chalk-stream species of mayfly, caddis fly and stonefly according to their pollution sensitivity. Monitoring the invertebrate populations in chalk streams is a vital component of tracking the ecological health of these streams (see fba.org.uk and riverflies.org).

10 = highest sensitivity. Ref: DoE / NWC Biological Monitoring Working Party.

2.3.4 Chalk-stream fish

The salmonids indigenous to all English chalk streams include the brown trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*). The grayling (*Thymallus thymallus*) is considered a native in chalk streams, but is only indigenous to the Avon and Thames chalk stream catchments*. It has been introduced to many other chalk streams but the distribution is still patchy.

The distribution of the threatened Atlantic salmon is also patchy, for a different reason: barriers to migration. It is now very much limited to the southern chalk streams of Wessex, and a few in the Thames. Once in a blue moon salmon will show up in other catchments, the Kentish Stour, or the Ouse, for example. These are likely strays, as are some of the salmon in the Thames, but straying is an evolutionary adaptation which enables salmon to repopulate streams from which they have been lost.

The brown trout is closely related to the salmon: they can even hybridise and often do in the Dorset Frome. But brown trout do not depend on a marine phase in their life cycles (though a proportion of any trout population does go to sea) and so they remain in at least the headwaters of almost every English chalk stream and are a hallmark of these rivers. Salmon, trout and grayling are all highly sensitive to pollution, and will be rare or absent in severely abstracted, eutrophic reaches.

If the faster-flowing, cooler upper reaches of most chalk streams are apparently dominated by brown trout, they are also heavily populated, though less visibly, by bullheads (*Cottus gobio*), minnows (*Phoxinus phoxinus*) and stickleback (*Gasterosteus aculeatus*) which thrive in the upper reaches and though diminutive can make up nearly a third of the fish biomass in chalk streams. Eels (*Anguilla anguilla*) will also thread their way to the headwaters of chalk streams, though the eel population builds in a downstream direction. The sea and river lamprey (*Petromyzon marinus and Lampetra fluviatilis*) are also migratory, feeding in coastal / estuarial waters but they swim up the river at spawning time.

Grayling, if present, will build in number through the lower-upper to middle reaches: they spawn on slightly finer substrates than trout and salmon and tend to prefer medium-paced glides. Rheophilic cyprinids, especially dace (*Leuciscus leuciscus)*, but also roach (*Rutilus rutilus*) and chub (*Leuiscus cephalus*) are common in the middle-to-lower reaches of most chalk streams, along with perch (*Perca fluviatalis*) and pike (*Esox lucius*) and the brook lamprey (*Lampetra planeri*).

While salmon, sea trout and lamprey migrate to sea to feed and eels migrate to sea to spawn, all of the rheophillic cyprinids and brown trout also are at least partially migratory within the river system itself, underlining the importance of removing barriers to migration (of which there are many) in any good catchment-scale restoration programme; bearing in mind that barriers can also be chemical-, flow- and temperature-based.

* The grayling is also native to the Ribble, Trent, Severn, Wye, Welsh Dee and Yorkshire Ouse.

While the brown trout (above) is a widespread and defining chalk stream fish, the protected species present in chalk streams include its close and threatened cousin the Atlantic salmon, as well as the bullhead, brook, river and sea lamprey, spined loach and grayling.

2.3.5 Chalk-stream birds and mammals

The richly biodiverse, fecund chalk stream, with its sustained spring flows, saturated floodplain, and abundance of food is also home to a great variety of birds and some key mammals. Marshy areas in the riparian zone, the valley sides and springheads attract snipe (*Gallinago gallinago*), which may stay to breed in the right habitat, redshank (*Tringa totanus*) and lapwing (*Vanellus vanellus*). Scrub and reed-beds support sedge warbler (*Acrocephalus schoenobaenus*) and reed bunting (*Emberiza schoeniclus*). On and around the river itself the kingfisher (*Alcedo atthis*) is a common sight (and sound), as is the dipper (*Cinclus cinclus*) on the riffles, the little grebe (*Tachybaptus ruficollis*), moorhen (*Gallinula chloropus*) and even the rare water rail (*Rallus aquaticus*).

The occasionally-inundated floodplains of the larger chalk streams are important areas of flooded meadow and provide habitat for white-fronted geese (*Anser albifrons*), Bewick's swan (*Cygnus columbianus*) and mute swan (*Cygnus olor*), golden plover (*Pluvialis apricaria*) and yellow wagtail (*Motacilla flava*). Dense beds of phragmites are home to the reed-warbler (*Acrocephalus scirpaceus*), while chalk streams are a nationally important habitat for the rare Cetti's warbler (*Cettia cetti*), grasshopper warbler (*Locustella naevia*) and pochard (*Aythya ferina*).

Swifts (Apus apus), swallows (Hirundo rustica), house and sand martins (Delichon urbicum and Ripiria riparia) all use the excellent feeding opportunities provided by dense hatches of insects. Like the hirundines, Daubenton's bat (*Myotis daubentonii*) feeds low over water, and is a common sight for anglers making the most of the evening rise in summer. The less-cultivated chalk streams, with broad riparian corridors of woodland provide the best habitat, with roosting sites in old decaying trees, fractured bark and branches.

Chalk streams provide good habitat for the otter (Lutra lutra), water vole (*Arvicola terrestris*) and water shrew (*Neomys fodiens*). The otter is making a comeback and is now a relatively common site on healthy reaches. The water vole has suffered extreme decline nationally, mostly because of the spread of American mink. Chalk streams where the mink are absent or regularly trapped provide excellent habitat where the endearing vole can reach very high densities: it is partial to dredged river-banks, making restoration projects aimed at addressing this particular problem more challenging where vole numbers are high. Like the vole, the water shrew is also threatened by the American mink, but where mink are absent the water shrew finds favourable habitat in and around a healthy chalk stream. Mink are most usually controlled by fishermen and river keepers.

Below: the otter, kingfisher and water vole are distinctive sights on chalk streams.

© Tim Filce / Wikimedia

© Andeas Trepte www.avifauna.info / Wikimedia

© Peter Trimming / Wikimedia

2.4 The trinity of ecological health

Chalk-stream ecological health depends on three things. This plan addresses each in turn and all three in combination:

• water quantity (the naturalness of the flow regime)

• water quality (how clean the water is)

• physical habitat quality (the physical shape of the river, but incorporating biological factors like invasive species which can degrade habitat directly and indirectly)

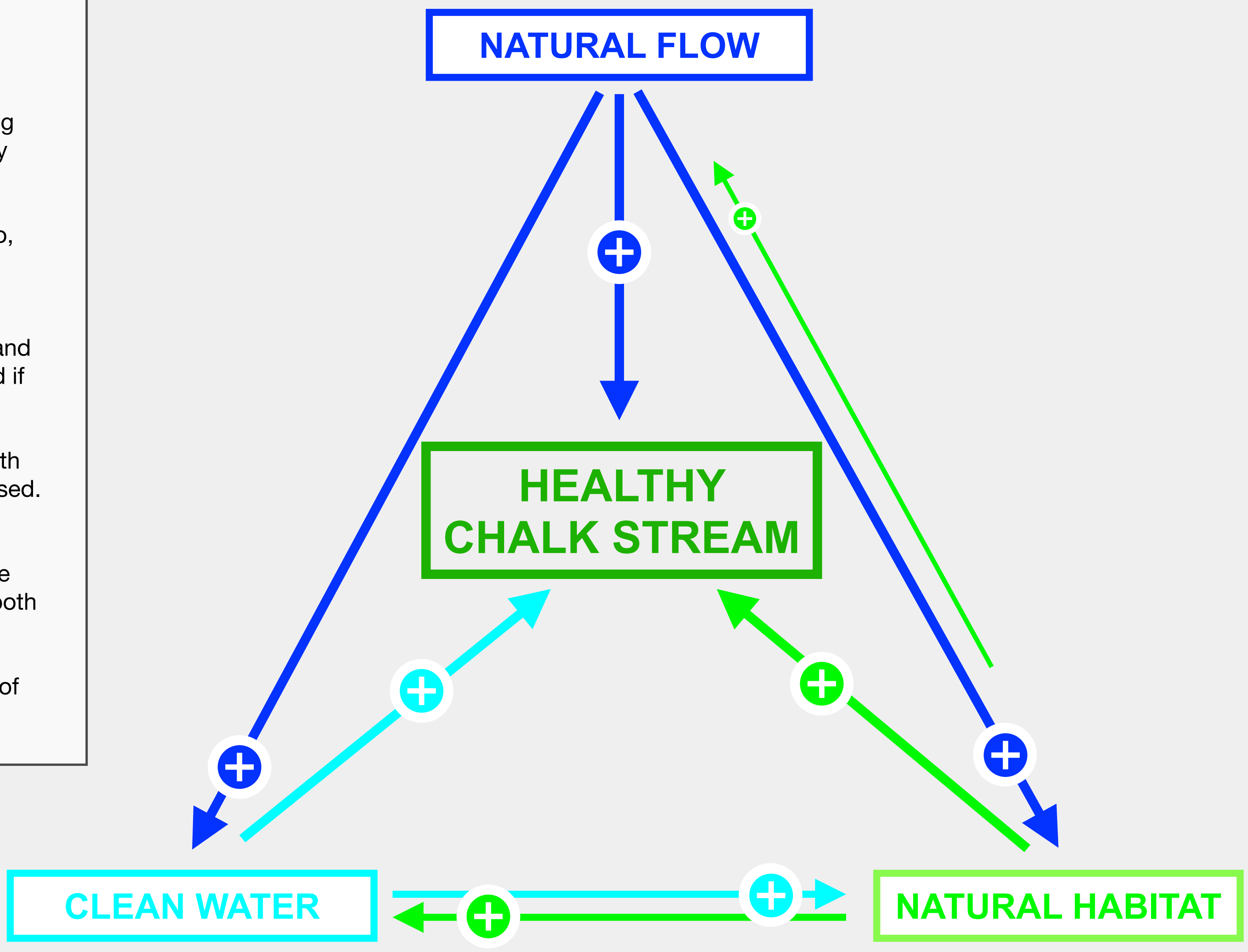
We look at these issues singly because it helps to focus, but together too, because it is important to remember how each one either positively or negatively affects the others.

Re-naturalising flow will improve river health by improving water quality and physical habitat. But the benefit of renaturalising flow is greatly increased if water quality and physical habitat are improved too.

Improving water quality or physical habitat will likewise enhance the health of the chalk stream although not as much as when flow is also renaturalised.

Therefore the best restoration strategy will address all three together: re-naturalising flow and improving water quality while using landscape-scale physical-habitat improvements to consolidate the beneficial impacts of both and thus deliver maximum ecological improvement.

Combining all three will achieve this outcome more effectively by orders of magnitude than when the elements are each improved in isolation.



A simple diagram illustrating the positive correlations between flow, water quality and physical habitat, to show how positive gains in ecological health are maximised by making improvements to all three components.
The arrows may be reversed for negative correlations, showing how water quality and habitat diminish as flow is lost to abstraction, for example.

4. Water quantity: restoring flow

4. Water quantity

4.1 The ecological impacts of low flows

Equable flows are a notable feature of the natural chalk stream to which the ecology is adapted. Occasional low flows resulting from dry periods are also a natural phenomenon. Many chalk streams feature winterbourne reaches which dry naturally for at least a few weeks in most summers and some of the plants and insects in these reaches are winterbourne specialists, with life cycles specially adapted to brief periods of drying. There is a significant difference between this seasonal and climatic but natural phenomenon and the unnaturally suppressed flows caused by groundwater abstraction.

In terms of the impact on ecology, the chronic and unnaturally low flows caused by excessive groundwater abstraction, adversely impact the ecology of a chalk stream by:

- reducing velocity of the current
- reducing water depth and the spatial volume of in-channel habitat
- increasing the residence time of water in the river channel
- increasing the temperature of water in the channel
- increasing the concentration of pollutants
- reducing oxygen levels
- increasing sediment deposition
- reducing or interrupting the lateral connectivity between the river and its marginal, riparian habitats and floodplain
- disrupting the passage of migratory fish

It is important to understand the *interaction between* and the *spiralling effects* of these pressures. For example, reduced water velocity will limit the growth of the rheophilic (current-loving) plants like ranunculus and increase the deposition of sediment in the channel. The sediment in turn also limits the growth of ranunculus. The lack of ranunculus reduces the inter-crown scour that flushes sediment. Depleted summer flow velocities are reduced yet further because the channel is effectively bigger relative to the volume of water – because of the lack of ranunculus (which naturally has the effect of packing out the summer flows). The reduced flow and the lack of ranunculus drive up water temperature, decrease oxygen levels, limit habitat for fish and insects. And so on. The chalk stream becomes locked in a vicious circle of decline and the negative impact of every other stress exerted on the system is magnified.

Many of the plants and animals native to chalk streams are adapted to and depend upon adequate flow velocity, including the designated / protected ranunculus and the Atlantic salmon as well as other rheophilic plants (starwort, berula etc), salmonid and cyprinid fish species, and numerous species of riffle-dwelling invertebrates. The presence and abundance of these animals and plants are fundamental features of a healthy chalk stream. All of them suffer under unnaturally suppressed flows and the range of concomitant impacts.

The spiralling impact of low flows on ranunculus will reduce the depth of water, but low flows definitively reduce water depth anyway: the combined impact is a reduction in the volume and value of available habitat for fish and insects.

Low flows will increase the temperature of the water, but the chalk-stream ecology is adapted to cool water: for the salmonid fish community, for example, temperatures over 22ºC can be fatal. Increasing water temperature will impact metabolic rates in animals and raise biochemical reaction rates in plants, causing significant diurnal fluctuations in oxygen levels, stressing fish and insects.

Low flows increase the concentration of pollution because as flows diminish there is less water as a dilutant. Nutrient levels that might otherwise be tolerable can become damaging, even with the nutrient source at a constant. Low flows also increase pollutant levels by increasing the deposition of sediment on the bed of the river: deep beds of sediment hold chemical and biological pollutants, but sediment also fills in and smothers the interstitial spaces in the stones and pebbles on the river bed in which many chalk stream insect species live. Sediment also smothers and kills salmonid eggs through effective suffocation, physical and biological.

Naturally a chalk stream flows at bank-full stage for a very high proportion of the year (30%). Saturated riparian margins and floodplains and a fluency of connection between the river and those wetted marginal areas are hallmarks of a healthy chalk stream. Although other factors, especially dredging, and the creation of perched channels to drive mills and water-meadows, have caused rivers to sag back inside unnaturally disconnected channels, reduced flows is another very significant cause of this disconnection between the river and its surrounding landscape. It is also important to note the ways in which these channel modifications render the chalk streams less resilient to the ecological impacts of low flows, whether natural or unnatural in origin.

The value of re-establishing the hydrological connectivity between the chalk stream and its supporting riparian, fen and floodplain habitats is a key tenet of this strategy: re-naturalising flows is essential to this process.

4.2. A history of groundwater abstraction

While chalk streams, springs and wells have for centuries been used as a source of water, groundwater abstraction for public water supply accelerated markedly through the second part of the 20th century particularly following the 1945 Water Act.

The 1945 act marked the beginning of a national water-supply policy, making it a requirement by law to obtain a licence from the Minister to dig boreholes and abstract water. A key point is that ecological protection was built into the Act: where the rights would, in the opinion of the Minister, substantially reduce the flow of water in a stream, the Minister could insist on gauges and minimum flows below which no abstraction should take place. However, with groundwater abstraction the water is taken from the chalk aquifer, not ‘from the stream’. Unlike surface-water abstraction, whose immediate impact on flow can be measured with a gauge, groundwater abstraction reduces flows by lowering the groundwater level which drives flows: nothing in the wording of the Act allowed for this basic difference.

The new Ministerial power combined in the post-war years with burgeoning demand for water across the south east and thus drove a surge in the growth of groundwater abstraction. Groundwater abstraction on chalk streams reached a peak in the mid-1980s.

On the River Misbourne for example, groundwater abstraction which had slowly increased from zero to about 4 Ml/d (millions of litres per day) between 1900 and the late 1930s then doubled in the six years or so to 1945, then trebled again to a peak of 35 Ml/d in the mid 1980s, almost half the annual recharge of the catchment.

Similarly, on the River Ver there was a steady increase from zero to approximately 7 Ml/d between 1865 and 1945 when abstraction surged, climbing to a mid-1980s peak of 45 Ml/d, almost half the annual recharge of the river and almost all in the drier years of 1964/5, 1972/3 and 1975/6.

Left: The River Ver – once the pride of Hertfordshire’s chalk streams – barely flowing in May 2017.

The River Wey in Dorset
The River Piddle
The River Allen
The Wallop Brook
The Bourne Rivulet
The River Meon
The River Wey in Surrey
The River Pang
The Letcombe Brook
The River Ver
The River Misbourne
The River Darent
The Little Stour
The River Hiz
The Hoffer Brook

Above: the fifteen chalk streams identified by the National Rivers Authority in 1991 as suffering from acute low flows caused by abstraction.

The flows of those in green support good ecological status in 2021, those in red do not. The Hiz and Hoffer Brook are not assessed.

4.2.1 Community & government responses to low flows

In the late 1980s and early 90s a series of dry years brought the scale of abstraction and its impact on chalk streams into focus, with numerous chalk streams like the Darent in Kent, the Misbourne in the Chilterns and the Piddle in Dorset drying up completely.

This provoked an outcry from anglers, locals and conservationists. Numerous associations were formed: the River Piddle Protection Association, Action for the River Kennet, the Ver Valley Society, the River Beane Restoration Association, the Darent River Preservation Society and others.

The National River's Authority's (NRA) Alleviation of Low Flows (ALF) scheme was catalysed by these complaints. The NRA identified 40 rivers nationally – including 15 chalk streams – that were suffering acutely from low flows caused by abstraction and directed urgent investigations and remedial actions.

For example, on the River Pang where groundwater abstraction had accounted for 35% of the water available to the river, the NRA agreed a reduction at Compton Pumping Station from 13.5 to 5 Ml/d. On the River Piddle where abstraction amounted to 42 Ml/d, Wessex Water agreed to halve its pumping from Briantspuddle.

ALF evolved into the EA's Restoring Sustainable Abstraction (RSA) programme which has thus far delivered alterations to 124 abstraction licences on chalk streams, returning 105 Ml/d of water to the environment, and removing 284 Ml/d of licence headroom.

As a result of the RSA programme, abstraction on the River Ver, for example, has been reduced from 45 Ml/d to 28 Ml/d today (28% of the catchment recharge of 99 Ml/d). On the River Misbourne abstraction has been reduced from 32 Ml/d to 17 Ml/d today (23% of the catchment recharge of 71.5 Mld).

ALF and RSA have undoubtedly been moves in the right direction, but in the drought of spring 2017 many of the chalk streams in the Chilterns and Hertfordshire were dry or drying along much of their lengths.

The River Darent in June 2005. Identified by the NRA in 1990 as suffering from acute low flows, in 2021 over half of the average annual recharge is lost to abstraction.

4.2.2 Action plans and charters

Consequently, a number of reports, charters and action plans have been published over the past 20 years both by government and NGOs, all addressed at a range of issues affecting chalk streams, including groundwater abstraction. These have included:

• 1999 English Nature – Chalk rivers: nature, conservation and management

• 2004 UK Biodiversity Action Plan steering group for rivers – The state of England's chalk streams

• 2009 WWF – Rivers on the Edge

• 2013 Angling Trust & partners – A Chalk Stream Charter

• 2014 WWF – The State of England's Chalk Streams

• 2017 WWF – Water for wildlife: tackling drought and unsustainable abstraction

• 2019 The Angling Trust – Chalk Streams in Crisis

• 2020 NGO coalition – Chalk Streams First

It is worth examining the headline information, complaints and called-for remedial actions of these various publications. They can all be found by following links listed in **Appendix A** at the end of this report.

Requested actions over 20 years

The reports and charters cited above and in Appendix A have articulated the points in section 4.1 – with a growing body of evidence and case studies – regarding the ecological impact of low flows caused by consumptive groundwater abstraction, especially on the chalk streams around London.

Various actions to mitigate this impact have been repeatedly called for over the years – some have been addressed, or partially addressed, while others have not. These actions fall into four groups:

Modelling and flow targets

• modelling of natural and impacted flows, flow targets, and the correlation of flow targets to ecological stress

Modifying the abstraction regime

• re-aligning abstraction via pricing mechanisms / replacing groundwater abstraction with surface-water and moving the point of abstraction to less sensitive areas

Reducing the demand for water

• management of water demand through metering, the targeting of inefficiencies and through building regulations

Legislation

• calls for Ofwat to be charged with a duty of care for the environment
• abstraction licence reform
• powers to revoke licences without compensation
• protected designation for ALL chalk streams

4.2.3 Key government actions & responses

In response to the actions identified by NGOs and government agencies, various schemes, acts and environmental targets have been delivered, including:

• NRA / EA schemes Alleviation of Low Flows and Restoring Sustainable Abstraction

• environmental flow targets / indicators in 2008 and & 2013

• Catchment Abstraction Management Strategies

• enhanced powers for the Environment Agency to revoke or vary abstraction licences without paying compensation

• Abstraction Incentive Mechanism

• the transposition of the Water Framework Directive into UK Law

• reform of abstraction licensing

The table on the following page summarises the various actions identified by government agencies, NGOs and stakeholders showing whether or not they have been delivered, either wholly or partially. There are some accompanying notes of explanation in the second table.

Further details and analysis of these actions can be found in Appendix B.

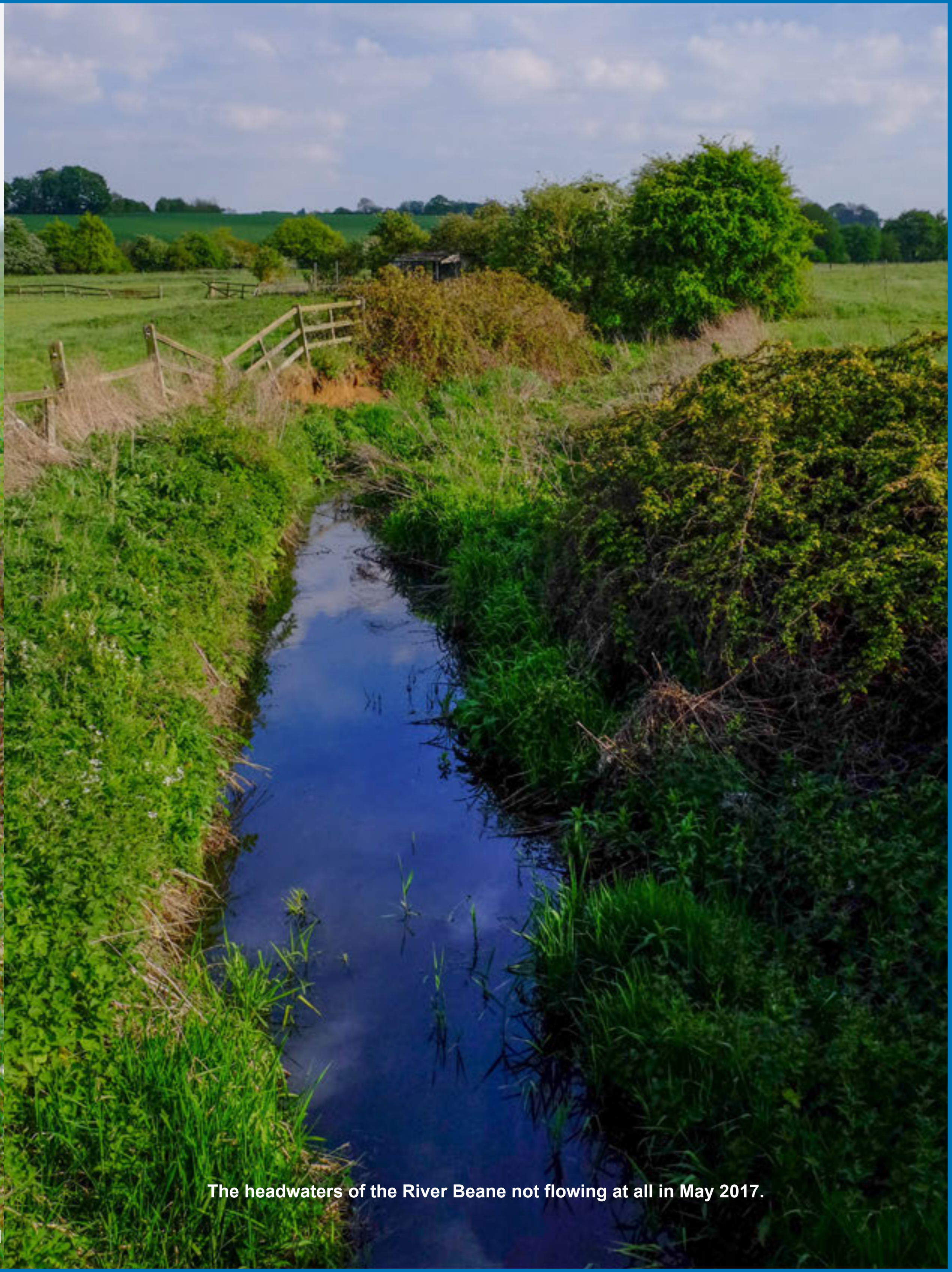
Identified need / demand	1999 Natural England	2004 UK BAP	2009 WWF	2013 Angling Trust	2014 WWF	2017 WWF	2019 Angling Trust	2020 Chalk Streams First
Detailed modelling of natural flows	✓							✓
Flow targets	✓	✓				✓		✓
Definition of 'serious damage'						✓		
Abstraction Incentive Mechanism – inception or reform			✓	✓	✓	✓		
Replacing groundwater abstraction with surface-water and storage				✓				✓
Moving abstraction to areas of surplus	✓			✓				✓
Demand reduction via public awareness and targeting inefficiencies	✓	✓	✓	✓				
Water-efficient housing			✓					
Compulsory metering			✓	✓	✓		✓	
Ofwat duty of care for environment				✓			✓	
Abstraction-licence reform			✓		✓	✓		
Powers to revoke all licences without compensation						✓	✓	
Protected designation of all chalk streams				✓	✓		✓	

The called-for actions from reports and charters 1999 to 2020

Identified need / demand	Delivered ?	Comment
Detailed modelling of natural flows	✓	There are now groundwater models for many chalk-stream catchments but these are not easily available or comprehensible to the public.
Flow targets	✓	We have flow targets, but the EFI could be better adapted to protecting natural flows in headwater and ephemeral reaches of chalk streams.
Definition of 'serious damage'		There is still no firm definition of 'serious damage'.
Abstraction Incentive Mechanism– inception or reform	✓	We have AIM, although the degree to which AIM schemes yield meaningful amounts of additional flow at times when it is most needed in chalk streams is questionable.
Replace chalk groundwater abstraction with surface-water abstraction and storage		This is a key part of the Chalk Streams First proposal – an idea held back for three decades by the cost of infrastructure, but now potentially realisable in the Chilterns and Hertfordshire.
Moving abstraction to areas of surplus		Some chalk groundwater abstraction points have been relocated, but in some cases that has created pressure on other chalk streams: for example the reduction of pumping on the Ver and Misbourne and commensurate increase on the Chess in 2003 / 2004
Demand reduction via public awareness and targeting inefficiencies		Water companies are addressing per-capita consumption in their current water-resources plans but there is the potential to do far more
Water-efficient housing		Defra may soon recommend adoption in all chalk catchments of a currently-optional enhanced requirement of a water consumption standard of 110 litres per day
Compulsory metering		Still no compulsory metering in areas dependent on chalk aquifers in spite of requests in 2009, 2013, 2014 and 2019
Ofwat duty of care for environment	✓	From Defra's guidance to Ofwat, March 2013: 'The government expects Ofwat to support abstraction reform through its regulatory functions'
Abstraction-licence reform	✓	Reform is in progress.
Powers to revoke all licences without compensation	✓	The EA now has this power but it has rarely been used (for non-water companies the licence can only be changed without compensation if the abstraction is causing serious damage)
Protected designation of all chalk streams		There is still no overarching designation that adequately reflects the international rarity of chalk streams.

What has and has not been delivered from the list of called-for actions from reports and charters 1999 to 2020


The headwaters of the River Beane barely flowing in April 2009.


The headwaters of the River Beane not flowing at all in May 2017.

4.3 Existing programmes

4.3.1. Water abstraction plan

Following the 'Making the most of every drop' consultation in 2013 -2016 (see Appendix A and B.6) Defra published in December 2017 (now updated in September 2020) their Water abstraction plan (WAP) (see Appendix A) setting out how government intends to reform the abstraction regime and protect the environment by:

• making full use of existing regulatory powers to move 77% of groundwater bodies to the required status by 2021

• developing a stronger catchment focus bringing together the EA abstractors and catchment groups to develop local solutions

These local solutions will include:

• changing abstraction licences to reflect water availability and reduce the environmental impact of abstraction

• creating flexible licence conditions that encourage water-storage, trading and efficiency

The policy paper states 'having the right flow in our rivers and protecting groundwater levels is essential to supporting healthy ecology, enhancing natural resilience to drought, and ensuring that rivers continue to support wellbeing and recreation. Sustainable water abstraction is therefore essential to ensure that river flows and groundwater levels support ecology and natural resilience'. Chalk streams are specifically cited as iconic, globally rare and important habitats that are 'diminished' by unsustainable abstraction.

The Environment Agency will review and update the status of chalk streams and groundwater body status when it updates the river-basin management plans in 2021.

4.3.2. Environment Agency actions

The plan states that where 'where the environment cannot cope' government 'will take action'. In priority water bodies such as Natura 2000 sites, that will be all actions required, regardless of cost. In other sites action will *depend on cost-benefit analysis* (see section 7.2).

To meet this goal the Environment Agency will:

• use the water industry national environment programme (WINEP), to ensure water companies take a continuing and leading role in addressing unsustainable abstraction

• review time-limited licences. Approx 25% of all 20,000 abstraction licences are time-limited: 2,300 of these will expire before 2021. The Agency will renew these licences only if: the abstraction is sustainable / the abstractor has a reasonable need of the water / the abstractor will use the water efficiently

• complete its RSA programme*

• the EA will continue to prioritise changes to the most 'seriously damaging' licences

• the EA has already made changes to protect Natura 2000 and SSSI's

• investigate all licences not used in the last ten years and revoke (January 2017 - January 2019) an estimated 600 unused licences that are no longer needed

• bring into regulation all significant abstractions that have been exempt historically (approximately 5,000 in addition to the 20,000 licensed abstractions)

* The 1990s ALF project evolved into the EA's Restoring Sustainable Abstraction (RSA) programme, which has thus far delivered alterations to 124 abstraction licences on chalk streams, returning 105 Ml/d of water to the environment. Further sustainability reductions amounting to 100 Ml/d will be delivered by 2025 through the water industry environment programme (WINEP).

4.4 Next steps - national framework

Through the new initiative the national framework for water resources, regional planning groups have been set up to identify the best strategic-resource solutions to deliver more sustainable abstraction and a better environment. Each regional group must produce a regional water-resources plan (WRMP), considering answers to a range of scenarios, including an enhanced scenario which looks to give greater protection to chalk streams.

These groups are tasked with identifying options that provide the best value to customers, society and the environment, rather than simply focusing on the lowest cost. The water-company components of the regional plans will be included in water company water resource management plans (WRMPs) in 2024.

The plans need to address the following:

• increasing resilience to drought

• greater environmental improvement, in order to achieve a sustainable abstraction regime across all sectors

• reducing water usage – with a target of 110 litres of water use per person per day by 2050, while also reducing demand in business, industry and agriculture

• reducing leakage by 50% by 2050

• reducing the use of drought permits and orders

• increasing supplies by exploring options to develop new supplies such as:

- reservoirs
- water re-use schemes and desalination plants
- shared supplies with other sectors
- catchment-based work to improve water management

This regional planning is supported by the water-Regulators' Alliance for Progressing Infrastructure Development (RAPID). Ofwat has made an allowance of £469m to progress 17 potential strategic regional solutions in the current water-company business plans, which may then be included in plans for the next price review. If the schemes are approved through the water company WRMPs and the price review in 2024, they will still take several years to plan, build and commission. For example, if chosen, the South-east strategic resource option (reservoir) is expected to be completed in 2037/38.

Government has launched a consultation on the draft revised WRMP guidelines for water companies to use in drawing up their water resource management plans in 2024. The most significant changes are that water companies:

• should use natural capital in decision-making and provide environmental net gain through their WRMPs, and

• should plan to reduce abstraction where it is causing the most environmental damage

Specific to chalk streams, the enhanced scenario would see nearly all chalk streams treated as if they were in Abstraction Sensitivity Band 3, greatly increasing the reductions in abstraction needed to meet the desired environmental destination.

Examples:

For example the EA has identified that:

• the River Ver is currently 77% below natural at Q95 (recent actual 9.1 Ml/d versus 39.7 Ml/d modelled natural at Q95) and 73% below the EFI with a deficit of 24.7 Ml/d

• the River Chess is currently on average 41% below natural at Q95 (recent actual 11.5 Ml/d versus 19.6 Ml/d modelled natural at Q95) and 31% below the EFI with a deficit of 5.2 Ml/d

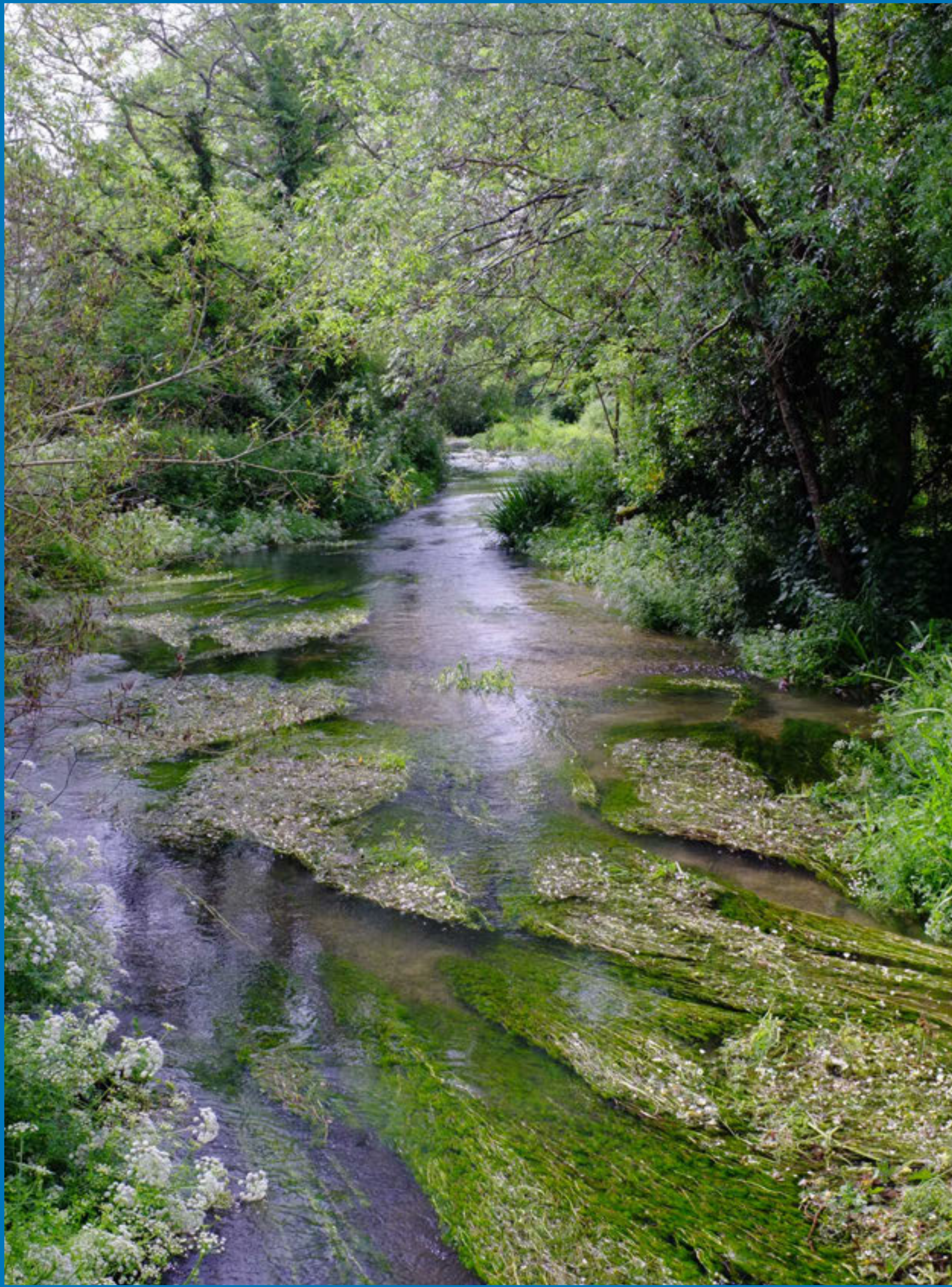
These calculations are made using the EFI RAM methodology (see following section 4.6.1) and therefore take into account upstream discharges and are made at the waterbody boundary.

The need to prioritise where flows are recovered.

It is worth noting, by contrast, the flow deficits identified on the Lower Colne – 246 Ml/d and the Lower Lea 273 Ml/d, many times the size of those on the tributary chalk streams.

Thus far there is no explicit distinction between the ecologically-essential flow recoveries of the tributary chalk streams and those that are arguably less ecologically beneficial on the lower, highly-modified urban main rivers. In addition, any flow recovery realised on the tributaries will, by definition, benefit the main river.

Healthy flows for all chalk streams? The regional planning process and resulting strategic resource options could mark the step-change needed to bring about better protection of flows in our chalk streams.



4.5 Next Steps - joint NGO perspective

As of the latest WFD assessment cycle flows in 91 chalk-stream waterbodies and 75 separate chalk streams (see Appendix H) have been assessed as DNSG (does not support good). The majority these waterbodies are on chalk-stream tributaries of the Thames and Ouse around London and north into Cambridgeshire, catchments with the highest population densities and where the public are most frustrated at the condition of their failing chalk streams.

If what we are already doing for chalk streams were working well, we would not be seeing the heightened levels of frustration among chalk-stream advocacy groups, the media and public. Whilst actions and schemes delivered thus far may have brought progress, so that chalk streams like the Allen, Piddle and Bourne which were once at crisis point, now support good ecological status, nevertheless, ALF and RSA and schemes like AIM, and incremental abstraction reform under the EFI assessment criteria will only ever deliver so much.

On the rivers most stressed by groundwater abstraction the deficits between present flows and flows within 10% of natural (an acceptable level of reduction) are vast (see section 4.6.5). The national framework recognises this. But how can we move from talking about the issue to doing something about it?

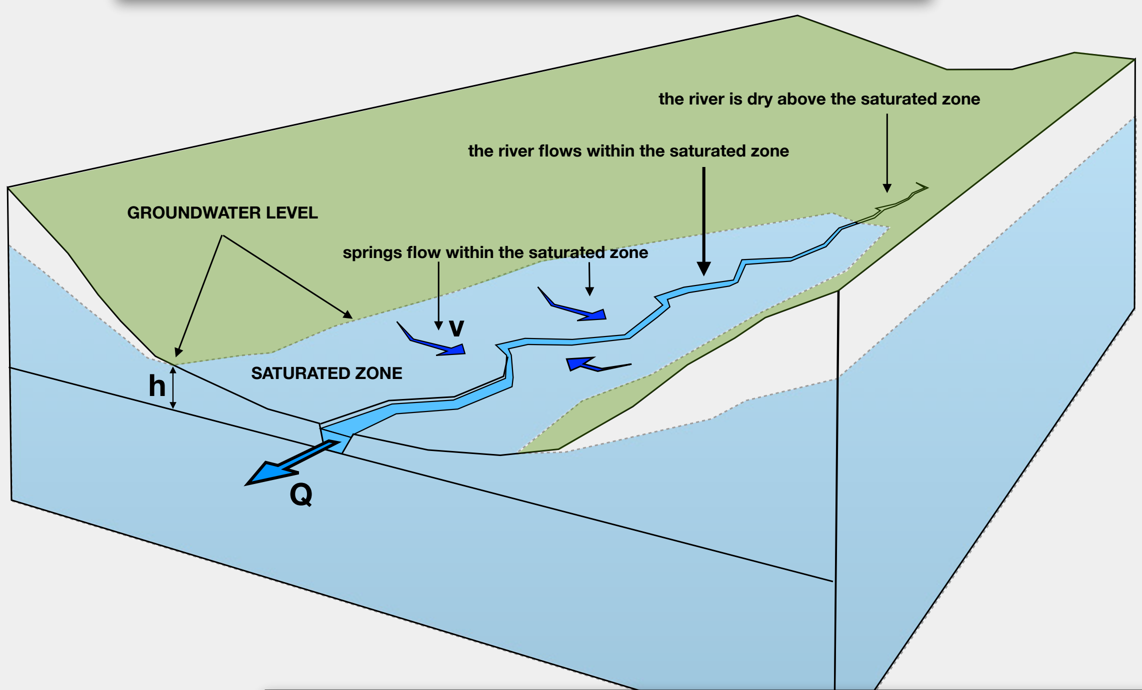
To save the most flow-stressed chalk streams – to leave their environment in a better state than we found it – and to protect public water supply, we need to develop a different system of abstraction, one which re-naturalises the chalk stream's flow and shifts the point of abstraction to less environmentally sensitive points in the catchment. In some cases we will also need to bring water into a catchment, because in places demand is greater than natural supply, no matter where the abstraction point.

This approach was identified in the very first 1999 NE report into the state of our chalk streams and indeed in the 1993 NRA report into the Alleviation of Low Flows. It was also identified in the 2013 Defra paper *Making the most of every drop*. We need to listen to these oft-repeated ideas and design a system of abstraction better fitted to the hydro-ecological properties of the chalk aquifer and chalk streams.

Each and every water-resources option for increasing resilience and supply and for improving the environment, from strategic reservoirs to inter-regional transfers of water, to desalination and demand management, will depend on the principle of flow recovery if chalk stream flows are also to recover sufficiently to support good ecological status. The principle of flow recovery, therefore, should be addressed as an integral part of regional planning. It is explained in the following section '4.6 How a chalk stream works'.

Left: The River Piddle was once threatened by acute abstraction but is now in good ecological condition with healthy flows.

A SIMPLIFIED DIAGRAM OF A CHALK-STREAM VALLEY SHOWING HOW THE GROUNDWATER LEVEL – WHICH RISES AND FALLS – DETERMINES THE EXTENT OF THE SATURATED ZONE IN THE VALLEY FLOOR FROM WHICH SPRINGS RISE AND THROUGH WHICH THE CHALK STREAM FLOWS.



In theory the chalk stream flow (Q) is broadly proportional to the height (h) of the groundwater level above the river bed, so that $Q = ah^{2.5}$

where (a) is a constant determined by the shape of the valley and properties of the chalk and will vary from one valley to the next.

If (h) is the average height of the groundwater level above the valley bottom, elementary hydraulics shows the velocity flow (v) from the spring sources in the valley upstream is proportional to $h^{0.5}$. Assuming a V-shaped valley, the area of the exposed fissures is proportional to h^2. Therefore, the baseflow (Q) in the river from the springs upstream is proportional to $h^{0.5} \times h^2 = h^{2.5}$

In simple and general terms, this means that a 10% increase in the height of the groundwater above the valley bottom effects a 25% increase in flows.

4.6 How a chalk stream works – groundwater drives flow

A chalk stream's flow is dominated by groundwater from the chalk aquifer. Chalk is permeable and a large proportion of the rain that falls on chalk hills, especially in winter, sinks into the ground and percolates through the rock to form the saturated zone of the chalk aquifer. It can take some time for groundwater levels to respond to rainfall and this varies from valley to valley, depending on the localised aquifer permeability, which is strongly influenced by the fracturing of the chalk.

The groundwater level rises and falls through the year as the underground body of water fills and slowly empties. Typically, the groundwater level rises from November through to April, when the growing season is over and the air is colder and a larger proportion of the rain sinks into the ground. It then falls through the summer when the air is warmer, and evapotranspiration soaks up much of the rain instead, while the groundwater continues to discharge to the river. Generally, chalk-stream flows are at their lowest in the early autumn.

The total amount of winter rainfall and how much of it sinks into the ground (known as 'effective rainfall') largely determines the level of flows through the following summer. If groundwater levels are high in the spring after a good winter recharge, then (natural) flows will hold up well through the summer. If groundwater levels are low in the spring after a dry winter, then generally the chalk stream will be very low by the end of summer.

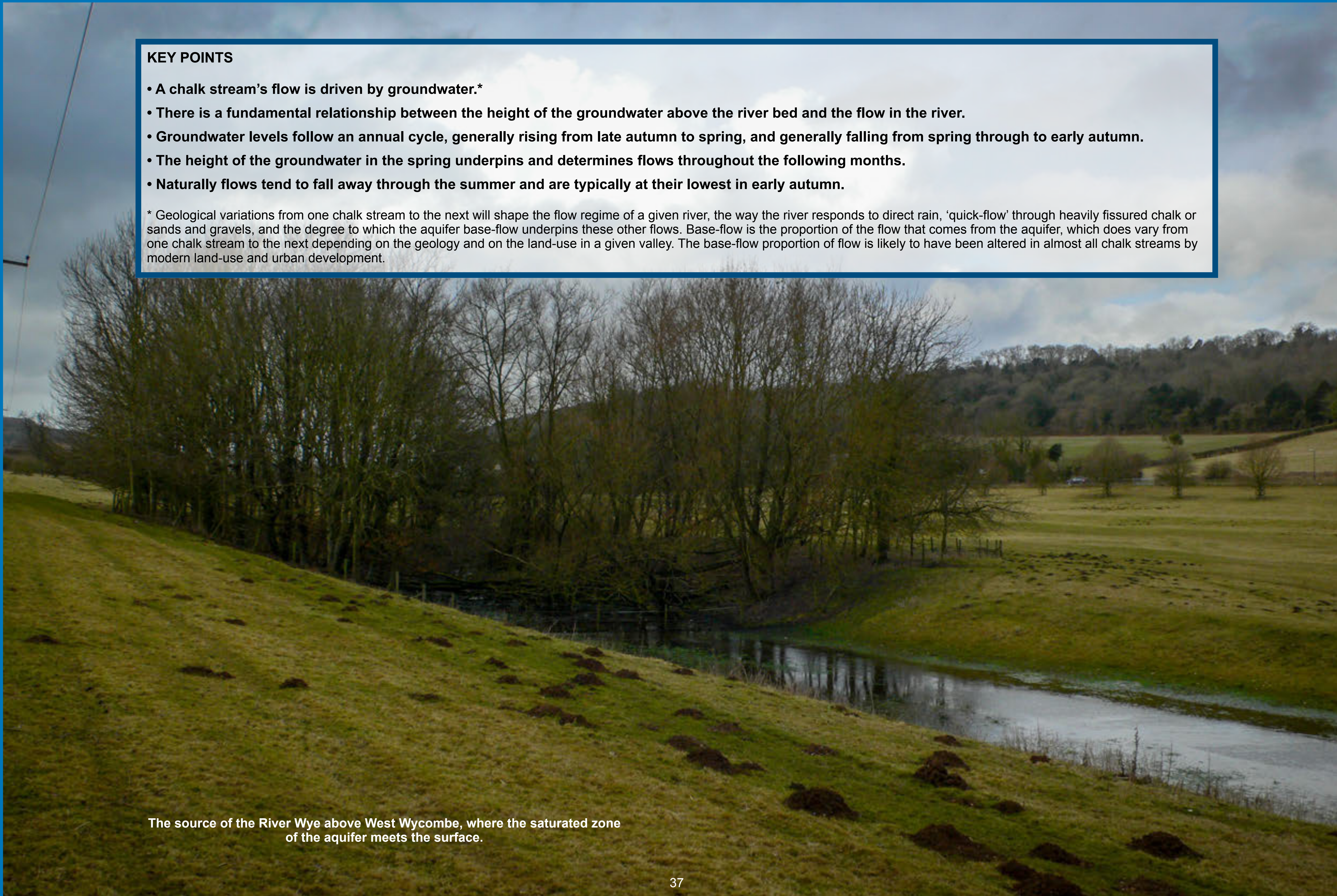
The diagram on the opposite page represents a simplified chalk-stream valley. It shows how a chalk stream flows within the saturated zone of the valley floor, where the aquifer intersects with the surface topography. In the upper reaches of a typical chalk-stream valley, the upper boundary of that saturated zone moves up and down the valley with the rising and falling groundwater level. These ephemeral reaches are known as winterbournes.

From the point at which the chalk stream starts to flow (the upper boundary of the saturated zone) groundwater levels determine the intensity of the flow in the channel – because the amount of water flowing down a chalk stream is dependent on the height of the groundwater above the river bed. In very broad terms a 10% increase in the height of the groundwater above the river bed equates to a 25% increase in flow.

KEY POINTS

- **A chalk stream's flow is driven by groundwater.***
- **There is a fundamental relationship between the height of the groundwater above the river bed and the flow in the river.**
- **Groundwater levels follow an annual cycle, generally rising from late autumn to spring, and generally falling from spring through to early autumn.**
- **The height of the groundwater in the spring underpins and determines flows throughout the following months.**
- **Naturally flows tend to fall away through the summer and are typically at their lowest in early autumn.**

* Geological variations from one chalk stream to the next will shape the flow regime of a given river, the way the river responds to direct rain, 'quick-flow' through heavily fissured chalk or sands and gravels, and the degree to which the aquifer base-flow underpins these other flows. Base-flow is the proportion of the flow that comes from the aquifer, which does vary from one chalk stream to the next depending on the geology and on the land-use in a given valley. The base-flow proportion of flow is likely to have been altered in almost all chalk streams by modern land-use and urban development.



The source of the River Wye above West Wycombe, where the saturated zone of the aquifer meets the surface.

4.6.1 How chalk stream flows are currently assessed / location of assessment points.

Appendix B.2 gives details of the existing Environment Agency methodology of flow assessment, the Environmental Flow Indicator (EFI).

The EFI defines ecologically acceptable deviation from natural flow at various points in the flow curve, grouped according the deemed sensitivity of the river: there are three Abstraction Sensitivity Bands (ASB). It says that a greater reduction is acceptable when flows are high than when they are low. For example, the percentage of allowable deviation from natural flows of an ASB3 (the most sensitive) river is 24% at Q30 and 10% at Q95.

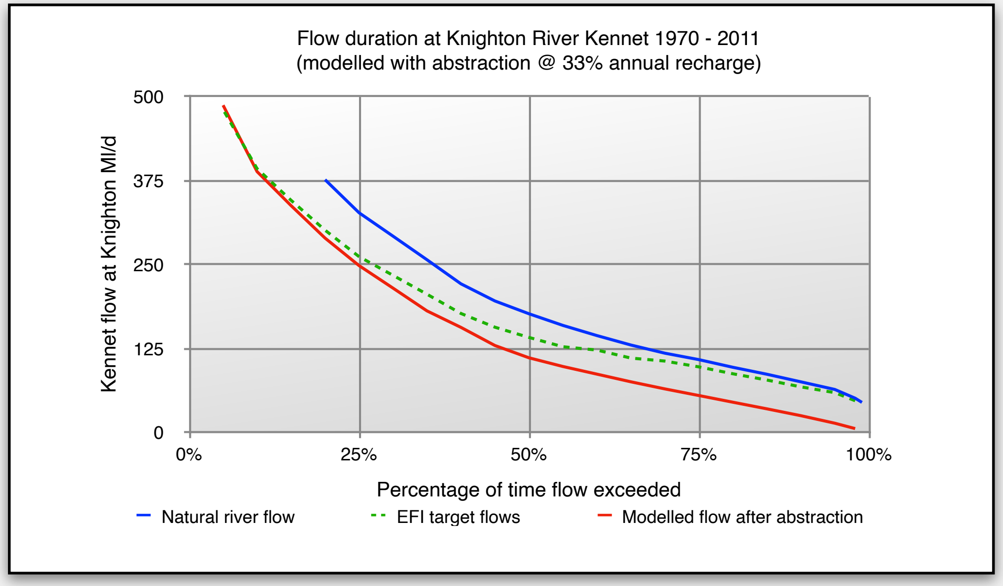
This is based on the concept of flow protection enshrined in the 1945 Water Act, that abstraction should cease (or reduce) when flows fall below certain targets: it is a well-adapted system of protection for flows impacted by surface-water abstraction (because when you stop abstracting the effect is immediate), but is limited as a way of protecting flows in a groundwater system, because the water taken out of the ground in, say, February, will have an impact on flows in September.

For example the EFI does not protect flows in a winterbourne, because 90% of 0 Ml/d is 0. From an ecological point of view, the degree to which a winterbourne is unnaturally dried by abstraction relates not to whether it dries at all but to the number of days it dries for, how quickly it dries and how far down the river the drying extends.

A secondary aspect of the EFI methodology (in terms of protecting flows in chalk streams) is the potential distance between the reaches of the chalk stream impacted by groundwater abstraction and the position where the flows are assessed. As shown in appendix B2 the EFI formula depends on modelling the 'natural' flow in the river, then adding the discharges from sewage works, then subtracting from that total the recent actual abstractions, to arrive at a figure for recent actual (RA) flow. If the RA is below the Environmental Flow Indicator (EFI), then the river is deemed 'non-compliant' (ie. the flows potentially do not support 'good ecological status').

However, the assessment points tend to be at waterbody boundaries. Flows in the River Chess, for example, are assessed at the downstream boundary. This is a long way from the source and is downstream of sewage discharges. Even if the flow at that point is compliant (on the River Chess it is not) this does not mean that the flow in the headwaters is also compliant.

A third issue relates to whether or not it is possible to conform groundwater abstraction to the staged % allowable reductions from natural flow. The graph above right shows a flow-duration curve for the Upper Kennet modelled as if the



abstraction were running at 33% of aquifer recharge. This is a high % of abstraction but it makes the point clearly and is not atypical for chalk stream near London. The graph shows three flow-duration curves: the modelled natural flow of the River Kennet (blue) / the modelled flow assuming abstraction at 33% catchment recharge (red) / the Environmental Flow Indicator flow curve (green).

The EFI flow curve moves across the space between the modelled abstracted and the modelled natural flow because – according to the EFI – abstraction should account for a smaller and smaller volume of natural flow as flows in the river diminish through Q50, Q70 and Q95, towards the end of summer.

It is not straightforward to manage groundwater abstraction in such a way as to get chalk stream flows to conform to this EFI line. Reducing groundwater abstraction does not have the immediate impact on flow that reducing surface water abstraction does. By the time you get to the given trigger point, the flow-duration curve is already on another, lower trajectory and flow cannot therefore recover to the natural level until the aquifer is recharged again, which tends to occur in the winter.

Appendix C.3. and C.4. give further information on two types of flow protection – hands-off flow and the Abstraction Incentive Mechanism – that use this idea of managing flows through reducing groundwater abstraction in the summer.

Appendix D is a summary of NGO recommendations ref existing flow- and abstraction-management methodologies.

4.6.2 Abstraction as % of recharge (A%R)

Assessing groundwater abstraction as a % of the average annual recharge (A%R) of the aquifer – ie. groundwater abstraction as a % of the amount of 'effective' rainfall that sinks down into the ground to drive base-flows in the river – is a simple and easily comprehensible way to assess the level of groundwater abstraction in a given catchment.

As such A%R is a potentially useful tool for assessing and comparing the likely scale of abstraction impacts on flows, the extent and geographical distribution of groundwater abstraction pressure, and as a way of enabling stakeholders to contribute to and understand the process of strategising how to address those pressures over time.

Until now accessible information, such as it is, has confined stakeholder knowledge to a limited binary assessment of whether flows do or do not support good ecological status. The degree to which flows do not support good status is not readily available. The methodology for making the assessment, the EFI, is relatively complex, and relies on flow data, including sewer discharges, combined with computer modelling.

A%R may not capture the subtle nuances and complexities of groundwater behaviour or the fact that subterranean catchments are not always or at all times the same size as surface catchments, or that aquifers can be layered, but these points notwithstanding it does give a basic idea of the level of abstraction as a % of the water balance in a given catchment or even across a set of neighbouring catchments.

Moreover, because A%R simply quantifies the % of the water balance taken by groundwater abstraction and is not based on flow data at a fixed assessment point, it inherently assesses the level of impact of groundwater abstraction on the whole catchment including the ecologically valuable headwater and ephemeral reaches of chalk streams, reaches that might not be assessed by a fixed assessment point some way down the valley or d'stream of a sewer discharge.

A%R simply assesses the proportion of water taken by groundwater abstraction and as such it gives an indication of the likely degree of impact of that abstraction on flows.

4.6.3 The impact of varying A%R on flows.

The two charts on the following page show modelled flow at two assessment points on the River Ver, Redbourn and Hansteads. The River Ver is about 18 miles long. Redbourne is 8 miles from the source, while Hansteads is close to the downstream confluence of the Ver with the Colne.

The modelled natural flow in the Ver is shown in dark blue: the Ver has been impacted by groundwater abstraction for fifty years and so assessment of natural flow depends on modelling. The Environment Agency's EFI flow (shown as if for an ASB3 river – although in fact the Ver is ASB2) is shown in dotted green: as stated this is the allowable deviation from natural flow deemed to be capable of supporting good ecological status (see section 4.6.1 above).

Modelled flow under four levels of abstraction as a % of annual catchment recharge is shown by the coloured lines: light blue = A10%R (ie. with 10% of the effective rainfall / recharge of the aquifer taken by groundwater abstraction) orange = A20%R, magenta = A30%R and red = A40%R.

The existing abstraction of the River Ver is A33%R: therefore close to the magenta line. Historically it has been much higher, but abstraction reductions have been made on the River Ver in recent years.

As can be seen, this level of abstraction still yields flows that are a long way short of the EFI:

At Redbourn A30%R indicates that the river dries for 25% of the year when otherwise it might not dry at all.

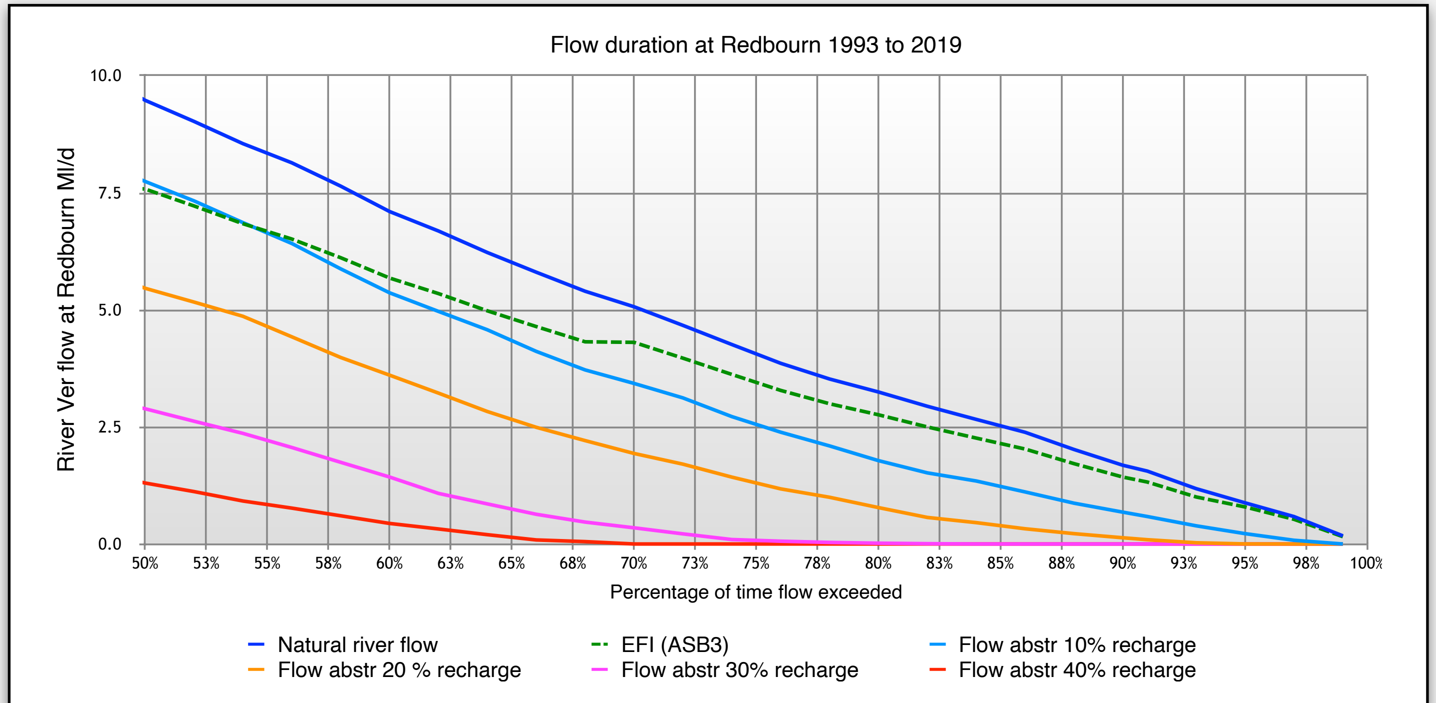
Note also that this far upstream an A%R which meets the EFI as far as Q60 – roughly 10% – is below the EFI at Q95.

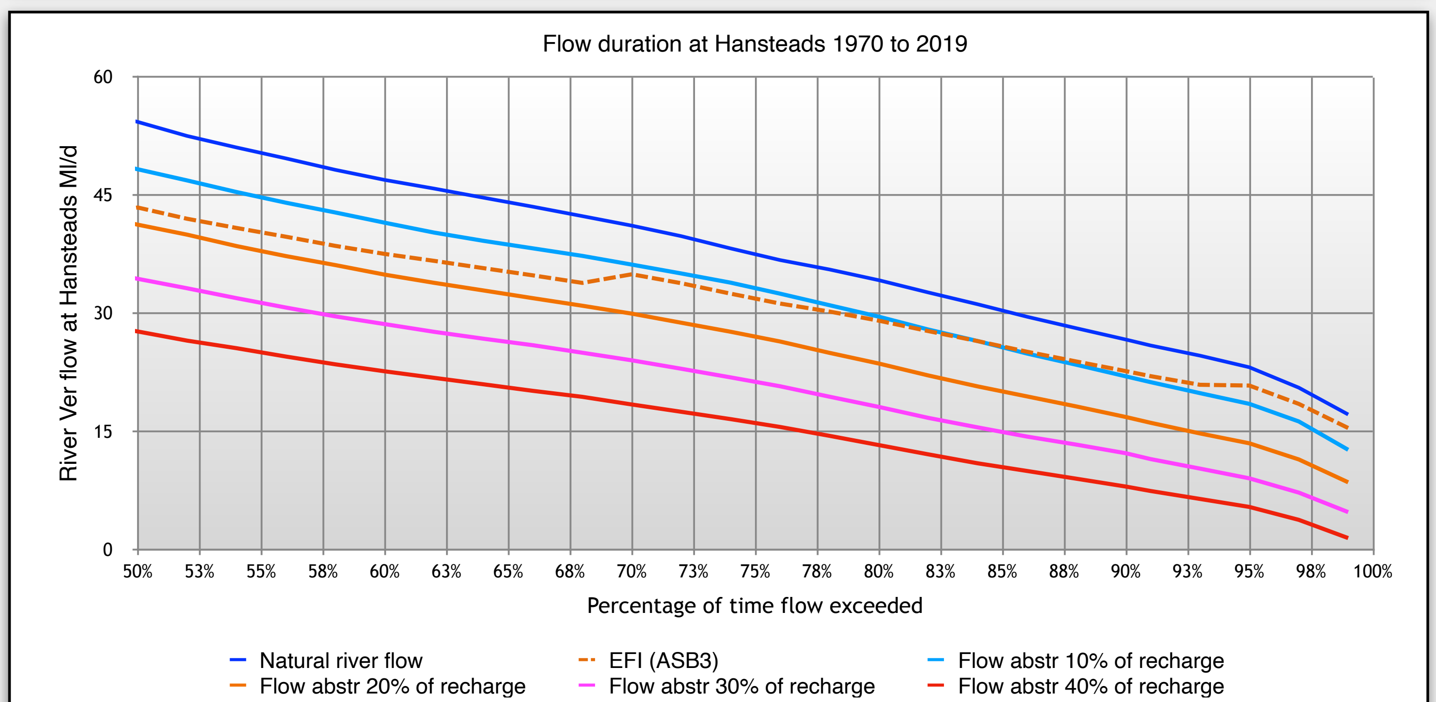
At Hansteads A30%R yields flows at Q95 of 10 Ml/d when naturally they would be about 23 Ml/d.

Again note that an A%R which meets the EFI at Q50 – about 20% – needs to be closer to 5% to meet the EFI at Q95.

Results from this simple form of assessment of the Ver and of other chalk streams suggest that groundwater abstraction should account for no more than between 5% to 10% of catchment recharge if the stream's flows are to meet (or get close to meeting) the EFI at Q95.

Note that although the EFI for ASB3 rivers at Q95 is 10%, for SSSI and SAC rivers the recommendation is a reduction in flow of no more than 5%, which would suggest a total groundwater abstraction of less than 5% of recharge.





Left: flows in the River Ver as natural and under four levels of abstraction: 10%, 20%, 30% and 40% of recharge.

These graphs are based on John Lawson's lumped parameter model of the Ver catchment: for further details see Abstraction impacts on the River Ver catchment – comparison of Environment Agency and Chalk Streams First modelling (link provided in appendix A)

4.6.4 A Survey of A%R

Item 10 under 4.9: 'water quantity recommendations for action' proposes a national survey of abstraction as % of recharge in order to:

a) understand the scale of groundwater abstraction in chalk stream catchments and

b) investigate A%R as a simple and accessible method for independent assessment of abstraction impact and prioritising action.

At the request of the CSRG group Defra commissioned a survey of a select number of chalk catchments between Dorset and Yorkshire. John Lawson FREng, FICE, FCIWEM, undertook the survey. The catchments were selected as representative of a broad range of chalk stream types and across a geographical spread from the Frome in Dorset to the Gypsey Race in Yorkshire.

Full results of this survey are presented in a table in Appendix C.4. A summary of the results is represented in the map on the following page below.

If, based on the assessment for the Ver in 4.6.3, we take A10%R as the threshold for 'sustainable' groundwater abstraction – a level that would get close to meeting the EFI target for ASB3 chalk streams: ie. a maximum reduction from natural flows of 10% at Q95 – we can see from the the third column that a fair number of rivers already meet this target or are comfortably within it (blue).

These chalk streams tend to be in the south west in Wessex or north east in East Anglia, Lincolnshire and Yorkshire where population densities and therefore water resources pressures are lower. It is important not to take from this that flows in these streams will in all cases meet EFI or CSMG targets. A%R deficits are not the same as EFI deficits and A10%R may not guarantee flows within 10% of natural at Q95, let alone the 5% of natural expected of designated rivers like the Test, Itchen, Lambourn and Avon. For example there is an EFI deficit on the Itchen not identified by A%R process.

On the other hand, the scale of the abstraction pressure on chalk streams around London and in Cambridgeshire and Kent is clearly orders of magnitude higher. These are also the chalk streams that are causing the greatest concern amongst campaigners where flows are felt to be failing: the Misbourne, Chess, Ver, Gade, Lea, Darent, Cray, Hiz, Cam, Granta and others.

The fourth column in the chart shows the approximate deficit to A10%R, ie. the amount of water that would need to be left in the ground, not abstracted, for the given catchment to meet a figure of A10%R – and therefore regain flows likely to be close to those deemed in the EFI to support a good ecology.

4.6.5 Prioritising abstraction reduction

Because it is easy to understand and accessible to non-specialist stakeholders A%R helps to facilitate an inclusive discussion about prioritising abstraction reduction.

In many places A%R deficits are relatively small: for example the Oughton deficit is only 0.4 Ml/d, the Mimram 2.9 Ml/d, the Stiffkey 1.1 Ml/d, and the Gypsey Race 1.6 Ml/d. In other places the deficits are considerable: for example 43.8 Ml/d on the River Gade and Bulbourne or 40.2 Ml/d on the Upper Lea. Even so, these deficits are all relatively small compared to those for the entire River Colne. The deficit for the whole Colne down to the Thames is 274 Ml/d (see the full table Appendix C.4). Excluding the lower main river, the deficit for all the Colne tributaries – Ver, Gade, Bulbourne, Chess and Misbourne and the upper Colne to the Ver confluence is 112 Ml/d.

However, the Gade downstream of the confluence with the Bulbourne is a very much modified system, mostly a canal, while the upper Colne upstream of the Ver is a mixed-geology stream, mostly incised watercourses rising on Thames Group clays, silts, sands and gravels. It is not a 'classic' chalk stream in the sense that the Ver or upper Gade are and it is heavily urbanised. If we therefore ordered these deficits, aiming to prioritise the classic Colne / Chilterns chalk streams, they amount to Ver 19.5 + Upper Gade 9.7 + Bulbourne 6.3 + Chess 9.8 + Misbourne 9.6 Ml/d = 54.9 Ml/d. This is still a large amount of water, but it is a very different number from 274 Ml/d and ecologically it is by far the more significant water.

If one then factored in flow recovery (see section 4.6.6) – not all of that 54.9 Ml/d would be lost to public supply, because a proportion would become available as surface water at the bottom of the catchment – then we might be looking at net deficit of 'only', say, 25 Ml/d to stop abstracting all the Colne chalk stream tributaries.

A prioritisation of abstraction deficits is needed according to whether they are ecologically essential, ecologically desirable, or of limited ecological benefit. The total deficits identified by the EA and put forward to national framework groups are so considerable that it will be impossible to address them all. National framework groups are charged with looking at the water resources options that give 'best value to customers, society and the environment, rather than simply focusing on the lowest cost' (see Section 4.4) however, cost will come into the equation, at which point **we need to ensure that the ecologically essential reaches of chalk streams benefit from the scale of abstraction reductions needed to properly facilitate their recovery** (in conjunction with measures to address water quality and physical habitat).

A%R pressure map and table

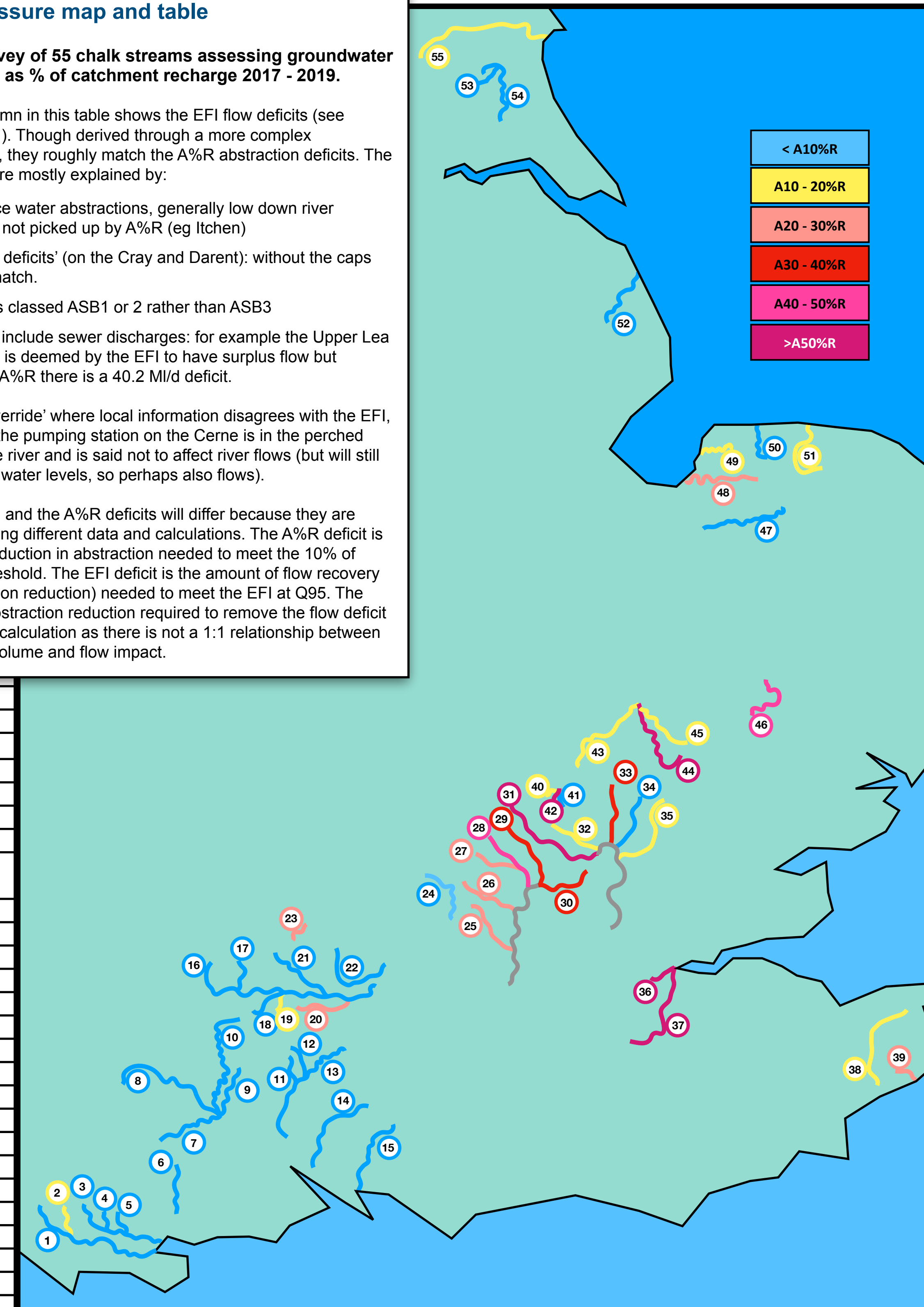
From a survey of 55 chalk streams assessing groundwater abstraction as % of catchment recharge 2017 - 2019.

The fifth column in this table shows the EFI flow deficits (see Section 4.6.1). Though derived through a more complex methodology, they roughly match the A%R abstraction deficits. The differences are mostly explained by:

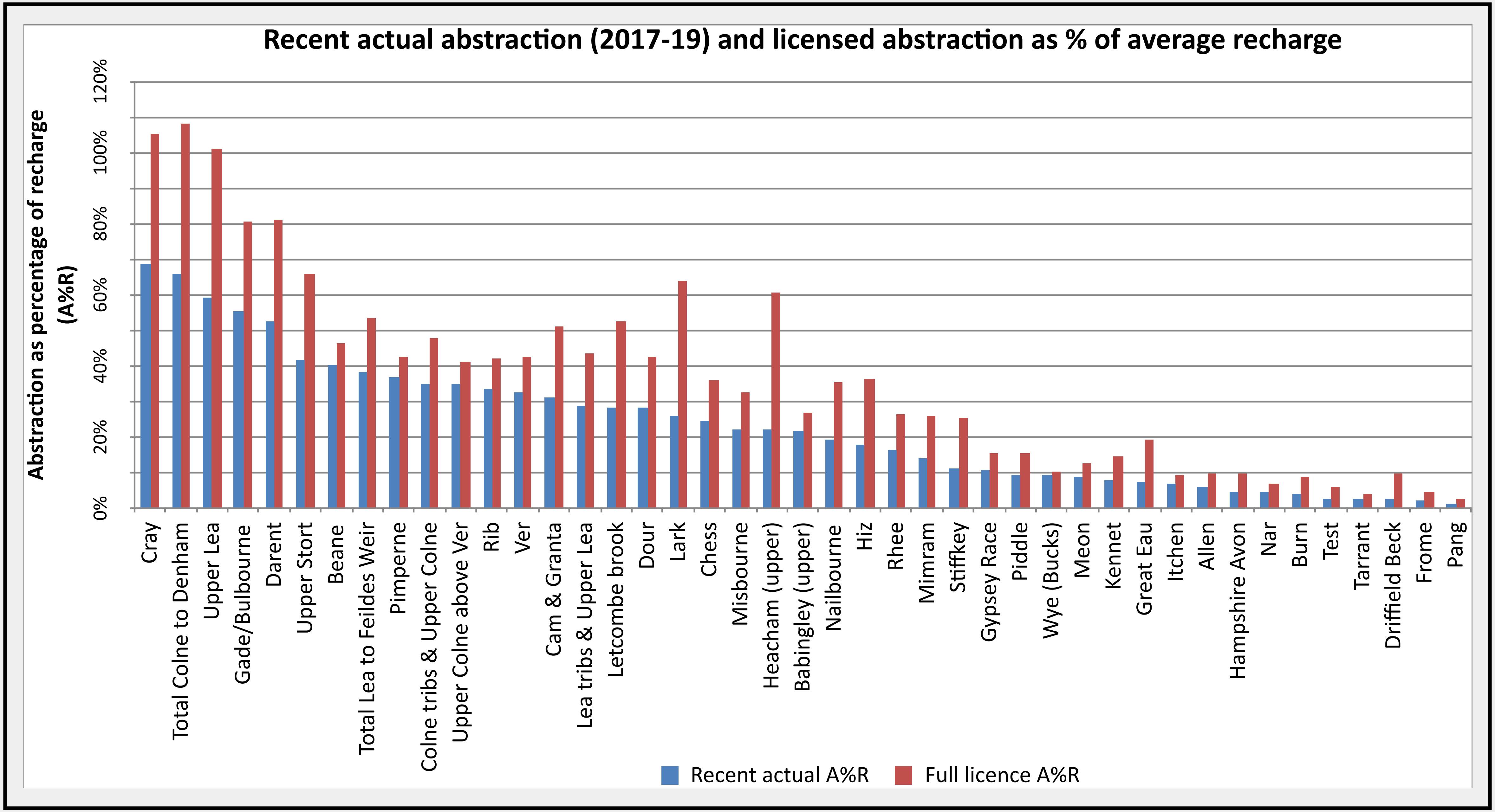
- large surface water abstractions, generally low down river systems and not picked up by A%R (eg Itchen)
- EA 'capped deficits' (on the Cray and Darent): without the caps they would match.
- Some rivers classed ASB1 or 2 rather than ASB3
- EFI deficits include sewer discharges: for example the Upper Lea at Water Hall is deemed by the EFI to have surplus flow but according to A%R there is a 40.2 Ml/d deficit.
- EA local 'override' where local information disagrees with the EFI, for example the pumping station on the Cerne is in the perched section of the river and is said not to affect river flows (but will still affect groundwater levels, so perhaps also flows).

The EA's EFI and the A%R deficits will differ because they are assessed using different data and calculations. The A%R deficit is simply the reduction in abstraction needed to meet the 10% of recharge threshold. The EFI deficit is the amount of flow recovery (not abstraction reduction) needed to meet the EFI at Q95. The amount of abstraction reduction required to remove the flow deficit is a different calculation as there is not a 1:1 relationship between abstraction volume and flow impact.

No	Name	A%R	Deficit to A10%R	Deficit to EA's EFI	Notes
1	Frome	2.1%	0	0	
2	Cerne	15.7%	2.8 Ml/d	0	
3	Piddle	9.5%	0	0	
4	Devil's Brook	8.5%	0	1 Ml/d	
5	Bere	4.5%	0	0	
6	Allen	5.8%	0	3 Ml/d	
7	Ebble	0.1%	0	0	
8	Wylye	5.8%	0	0	
9	Bourne (Wilts)	5.4%	0	0	
10	Avon upper	6.3%	0	0	
11	Anton	6.8%	0	0	
12	Bourne (Hants)	0.7%	0	0	
13	Upper Test	2.5%	0	0	
14	Itchen	6.9%	0	29 Ml/d	EFI includes deficit for large surface-water abstraction
15	Meon	6%	0	4 Ml/d	
16	Kennet	8.1%	0	0	
17	Og	1.7%	0	1 Ml/d	
18	Dun	2.1%	0	0	
19	Shalbourne	11.7%	0.2 Ml/d	0	EFI includes Shalborne STW effluent
20	Enbourne	23.3%	11 Ml/d	0	
21	Lambourn	3.8%	0	0	
22	Pang	1.1%	0	4 Ml/d	Recent abstraction only 1 Ml/d, so possibly EFI error
23	Letcombe Brook	28.5%	2.7 Ml/d	n/a	
24	Wye	9%	0	1 Ml/d	
25	Misbourne	22.3%	9.6 Ml/d	8 Ml/d	
26	Chess	24.6%	9.8 Ml/d	5 Ml/d	EFI includes sewer effluent.
27	Bulbourne	28.2%	6.3 Ml/d	0	
28	Gade (excl Bulbourne)	48.4%	9.7 Ml/d	11 Ml/d	
29	Ver	32.8%	19.5 Ml/d	24 Ml/d	
30	Colne upper	35%	29.6 Ml/d	n/a	
31	Lea upper	59%	40.2 Ml/d	0	EFI & A%R match in h'waters. EFI includes Maple Lodge STW effluent.
32	Mimram	13.9%	2.9 Ml/d	13 Ml/d	EFI exceeds recent actual abstraction so possibly EFI error.
33	Rib & Quin	33.6%	16.1 Ml/d	9 Ml/d	
34	Ash	3.1%	0	5 Ml/d	
35	Stort	18.5%	11.5 Ml/d	0	EFI includes sewer effluent
36	Cray	68.7%	45.6 Ml/d	19 Ml/d	EFI deficits are capped because the abstractions exceed the
37	Darent	52.5%	64.2 Ml/d	12 Ml/d	natural Q95 flows. A%R and EFI otherwise similar
38	Nailbourne	19.2%	7 Ml/d	11 Ml/d	
39	Dour	28.5%	13 M/d	10 Ml/d	
40	Oughton	18.4%	0.4 Ml/d	n/a	
41	Purwell	4.1%	0	0	
42	Hiz upper	58%	4.1 Ml/d	3 Ml/d	
43	Rhee	16.4%	7.4 Ml/d	n/a	
44	Cam upper	52%	12.3 Mld	3 Ml/d	EFI deficits include STW effluents.
45	Granta	19%	3.9 Ml/d	1 Ml/d	
46	Lark upper	43.9%	8 Ml/d	1 Ml/d	EFI deficit 'override' perhaps accounting for STW effluent.
47	Nar upper	4.5%	0	0	
48	Babingley	21.9%	8.9 Ml/d	5 Ml/d	
49	Heacham	15.9%	2.1 Ml/d	0	
50	Burn	4.1%	0	0	
51	Stiffkey	11%	1.1 Ml/d	0	
52	Great Eau	7.5%	0	15 Ml/d	EFI includes deficit for large surface-water abstraction
53	Driffield Beck	2.8%	0	1 Ml/d	
54	Driffield Trout Stream	3.7%	0	1 Ml/d	
55	Gypsey Race	10.9%	1.6 Ml/d	0	



The River Mel, one of several chalk tributaries of the River Rhee, near Cambridge: the Cambridge chalk streams are under considerable pressure from agriculture and development.



Recent actual abstraction (2017-19) and licensed abstraction as % of average recharge
Abstraction as percentage of recharge (A%R)
0%
20%
40%
60%
80%
100%
120%
Cray
Total Colne to Denham
Upper Lea
Gade/Bulbourne
Darent
Upper Stort
Beane
Total Lea to Feildes Weir
Pimperne
Colne tribs & Upper Colne
Upper Colne above Ver
Rib
Ver
Cam & Granta
Lea tribs & Upper Lea
Letcombe brook
Dour
Lark
Chess
Misbourne
Heacham (upper)
Babingley (upper)
Nailbourne
Hiz
Rhee
Mimram
Stiffkey
Gypsey Race
Piddle
Wye (Bucks)
Meon
Kennet
Great Eau
Itchen
Allen
Hampshire Avon
Nar
Burn
Test
Tarrant
Driffield Beck
Frome
Pang
Recent actual A%R
Full licence A%R

4.6.6 The potential of flow recovery

In addition to the strategic resource options listed in section 4.6, the potential of flow recovery to re-naturalise flows while maintaining a high proportion of the water as a resource to be abstracted lower down the catchment should be explored.

Section 4.6.5 briefly sketched out that deficits in the ‘ecologically essential’ Colne tributaries amount to circa 54.9 Ml/d. It is theoretically possible, with the right infrastructure and water-storage capacity, to use flow recovery to re-align abstraction so that this water is allowed to travel through its environment before it is taken for public water supply lower down the system. Giving this 54.9 Ml/d back to nature doesn’t have to mean a 54.9 Ml/d loss to public water supply.

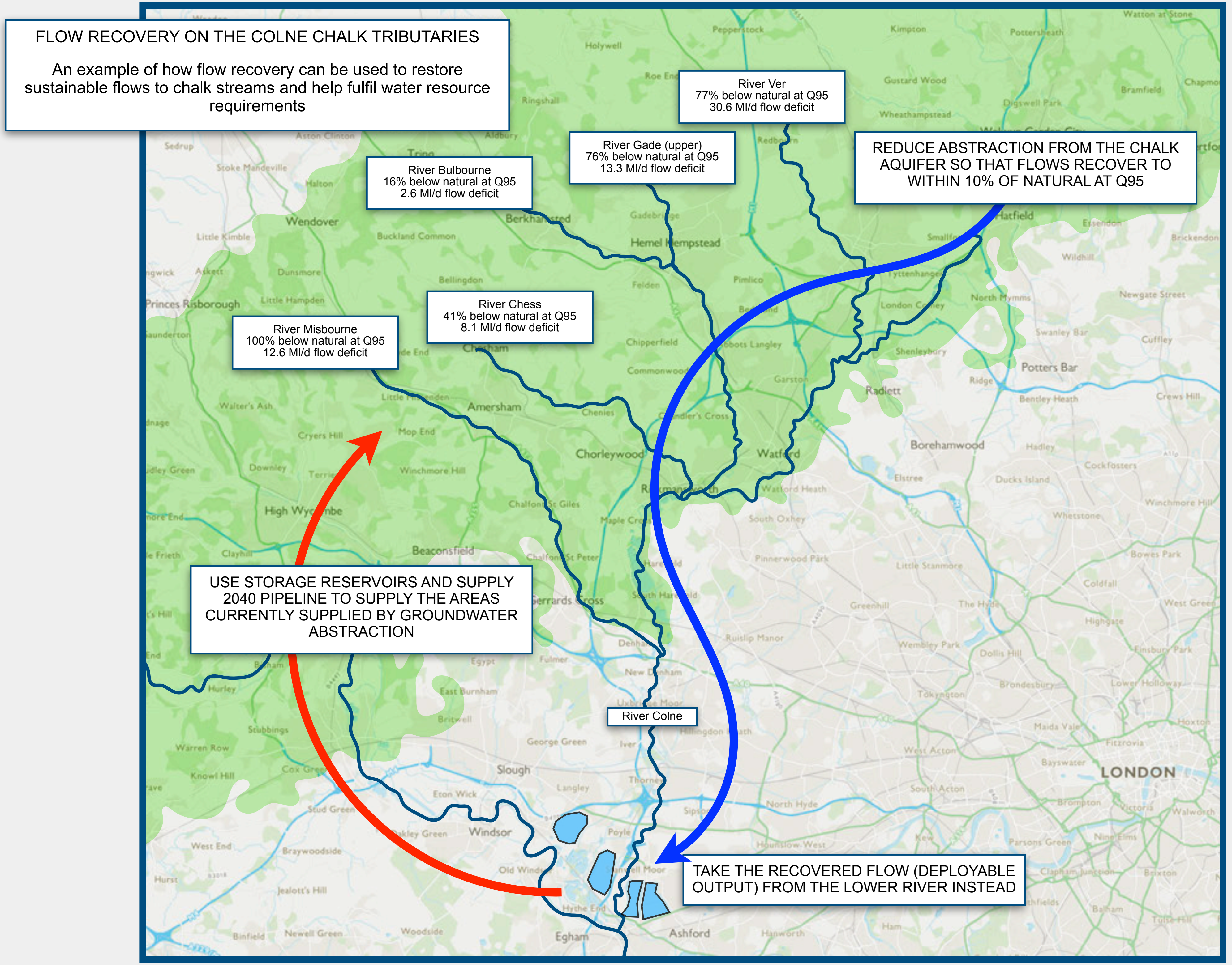
In simple terms we could stop taking the water from the aquifer, allow it to travel down the river and take it from the surface flows lower down the catchment instead. Rivers are universally used as conduits for water supply from reservoirs and this is the same concept, only in this case the aquifer is a reservoir and the chalk stream is the means of delivery.

Chalk Streams First (CSF) is an existing NGO proposal based on the potential of flow recovery as a means to re-naturalise the flows in the Chilterns chalk streams (which currently make up 20% of chalk streams whose flows fail the Water Framework Directive) with potentially only a small net loss to overall public water supply. CSF would make use of the way chalk streams function by moving the point of abstraction from the groundwater at the top of the valley, to surface water at the bottom of the catchment. From there it can be taken into storage in the reservoirs around London and / or redistributed through a network of pipelines called Supply 2040 to the towns currently supplied by groundwater abstraction. Supply 2040 is in Affinity Water’s business plan and is a vital component for other strategic infrastructure schemes currently under consideration, including Abingdon Reservoir.

Storage and pipeline infrastructure will be important components of any flow recovery scheme and extreme droughts still present an existential threat that water companies must plan for. Alongside strategic use of emergency groundwater abstraction, flow recovery should be investigated for its potential to re-naturalise flows in the chalk streams, but with a considerable % of the water which is not abstracted in the headwaters still being available for public water supply.

CSF could form a flagship model for how to re-align abstraction on other over-abstracted chalk streams, and could be delivered in the near future using the Supply 2040 infrastructure already planned-for and costed in the water-company management plans.

The River Chess May 2017 above and in December 2020 below: albeit 2020 was a wet autumn, headwaters abstraction has greatly reduced on the Chess and since that time the river in Chesham has been flowing.


FLOW RECOVERY ON THE COLNE CHALK TRIBUTARIES
An example of how flow recovery can be used to restore sustainable flows to chalk streams and help fulfil water resource requirements
River Ver
77% below natural at Q95
30.6 Ml/d flow deficit
River Gade (upper)
76% below natural at Q95
13.3 Ml/d flow deficit
River Bulbourne
16% below natural at Q95
2.6 Ml/d flow deficit
REDUCE ABSTRACTION FROM THE CHALK AQUIFER SO THAT FLOWS RECOVER TO WITHIN 10% OF NATURAL AT Q95
River Chess
41% below natural at Q95
8.1 Ml/d flow deficit
River Misbourne
100% below natural at Q95
12.6 Ml/d flow deficit
USE STORAGE RESERVOIRS AND SUPPLY 2040 PIPELINE TO SUPPLY THE AREAS CURRENTLY SUPPLIED BY GROUNDWATER ABSTRACTION
River Colne
TAKE THE RECOVERED FLOW (DEPLOYABLE OUTPUT) FROM THE LOWER RIVER INSTEAD
LONDON

4.6.7 Combining flow-recovery with the restoration of spring-line fens

Lowland fens are high priority for restoration under the Red List of European habitats as wells the Habitats Directive. Not only does the principle of flow recovery offer opportunities to restore ecological flow without a wholesale loss of resource, by moving the point of abstraction, it is a really good bridge to the landscape-scale recovery desired in section 6.7.

A shrunken River Gade at Great Gaddesdon: 76% below natural at Q95.

There is currently no mandatory water-efficiency product labelling in the UK, only the European water label and Waterwise UK's voluntary check mark. The Energy Saving Trust estimates that such labelling could save up to 30 litres per person per day, the equivalent of taking 23 million cars off the road (https://energysavingtrust.org.uk/water-labelling-every-drop-counts/)

For water-saving advice see: https://www.waterwise.org.uk/save-water/

4.7 Demand management & water metering

Reducing water demand should be a key tool in any strategy to restore natural flows to chalk streams. Using water efficiently helps to minimise the amount taken out of chalk streams and aquifers.

New infrastructure takes time and is expensive. It can have wider impacts on the environment. There is a carbon cost, for example, in pumping water from other sources. If we save water, we can reduce pressure on existing water resources. Above all, adopting habits of efficient water use makes our supply more resilient against the impacts of climate change and droughts.

The link between the ways people use water, and the impact they have on chalk streams must be recognised. There may be a growing trend in the UK towards more resource-efficient behaviour, but water use in England is still far too high.

Per capita consumption in some of our worst-affected chalk-stream areas is excessive. In the Chilterns area, water consumption rates are amongst the highest in Europe at approx. 155 litres per person per day: over 20 litres above the national average and 40 litres above the government's aspiration for per-capita consumption by 2050. We need action to reduce personal water use: education, labelling of goods, building regulations etc. We need to ramp up our collective efforts on this.

The Waterwise and Ideal Standard water efficiency annual tracking survey in Great Britain (2016) found that:

- 86% of adults who pay for their water via a fixed rate take actions to specifically reduce their water use, rising to 94% among those with a water meter.
- 82% of adults with a water meter reduce their water usage in order to save money.

To achieve wide-scale water efficiency, a water-saving culture must be developed throughout the UK. We know that most people take some actions to save water, but we also know that there is a lot more to do. Water efficiency needs to become the norm across all activities throughout everybody's lives – wasting water should be seen as going against the norm. Water-labelling regulations should be included in the Environment Bill.

Water efficiency in new developments

The housing white paper (2017) set out a need for 225,000 to 275,000 new homes per year to keep up with population growth. However, if these homes are not built to higher levels of water efficiency there will be an inevitable increased demand for water.

The Waterwise UK Water Efficiency Strategy calls for variable infrastructure charges for new developments in order to encourage water-efficiency measures. Waterwise is trialling this approach with Southern Water in Eastleigh. Developers in Eastleigh are being offered a 50% discount in their water infrastructure connection charge for new builds if they use fittings rated A or B under the European Water Label. The scheme is simple and easily verifiable and uses market incentives to reward developers for environmental improvements (see section 7.3.1 recommendations for planning and development rules for chalk streams)

Metering

The UK is one of the few countries in the developed world not to have either full water metering or a clear programme to implement universal metering. In England, water companies can compulsorily meter customers if they have been designated as being in an area of 'water stress' (designated by the Secretary of State based on evidence from the Environment Agency).

The Environment Agency recently consulted on 'Updating the determination of water stressed areas in England' (February 2021) and gave advice to the Secretary of State on the areas that should be determined as areas of serious water stress. The following company / areas have now (as of 2021) been classed as seriously water-stressed for metering purposes using the updated analysis that was included in the consultation (this list has been edited to cover the chalk streams regions only):

- Affinity Water
- Anglian Water – East Anglia
- Cambridge Water
- Essex and Suffolk Water
- Portsmouth Water
- SES Water
- South East Water
- Southern Water
- Thames Water
- Veolia Water
- Wessex Water
- South West Water – Bournemouth

Water companies in areas which are under serious water stress are able to charge all customers for the volume of water used. This is measured by a water meter on each property. They must evaluate compulsory metering alongside other options through their WRMPs.

Metering has been shown to change customer behaviour and save water.

Southern Water's universal metering programme has shown that domestic metering can save 16.5%. If people do not pay for the amount of water they use, there is no financial incentive to use water efficiently.

Metering enables not only customers, but also water companies to manage water more effectively. Customers can be incentivised to save money through tariffs, but the data collected can help to inform water companies where consumption is high, and therefore where water efficiency measures should be targeted.

Water meters in all chalk regions is the key to demand management, an incentive in itself and a tool to drive intelligent strategies and resource planning.

Tariffs

Metering with appropriate tariff structures - such as the rising block tariff (where the unit charge rises for progressively higher volumes of water taken by customers), or a seasonally-varying or aridity-indexed tariff (where water costs more per unit when it is less plentiful) – has the potential to be a major incentive for water efficiency in the future. Should the water that someone fills a swimming pool with really cost as little as the water everyone else makes a cup of tea or washes their hands with?

The flow gauging weir at Redbourne on the River Ver.

4.8 Collective action towards an agreed goal

From the Water Act of 1945 onwards the link between groundwater level and flows in chalk streams has not been fully accounted for in abstraction management and therefore chalk streams have not been properly protected by the law or in practice.

Even now, although the EA may revoke licences which cause serious damage, we lack a solid definition of what serious damage is, and revocation is rarely done in practice. Meanwhile the methodologies for managing abstraction fail to protect all chalk streams, especially their headwater reaches far upstream of discharges, assessment points and WFD waterbody boundaries.

However, the flow deficits recognised by the EA and now put forward to the regional groups of the national framework signal the possibility of a step-change in the way we manage abstraction on chalk streams. These deficits show just how depleted from natural flows chalk streams like the Ver and Beane really are.

The global deficits are so vast, however, that there is a clear need for regional groups to distinguish between those that are ecologically essential and those that might be desirable, but that are arguably of less benefit, especially when the comparative scale of the deficits between headwaters and lower main rivers is taken into account. And especially because any recovery in flow made in the headwaters will definitively benefit the lower main rivers anyway.

Having shown that this strategic approach to addressing over-abstraction is possible we must now collectively work together towards a **realistic, strategic and time-bound process of delivery.**

The recommendations for action on the following page identify the goal and what part the various partners must play in its delivery.

4.9 Water quantity: recommendations for action

1. Defining sustainable abstraction	**CaBA CSRG agrees to set a target for "sustainable groundwater abstraction" in chalk stream catchments as that which causes a maximum reduction from natural flows[1] of circa 10% at Q95[2] determined at appropriate assessment points[3], and in winterbournes a maximum 10% increase in drying duration. These will be the agreed destination targets for chalk streams[4], but CaBA CSRG recognises that bespoke less or more stringent targets may be necessary to ensure appropriate[5] levels of ecological protection assessed at a local level; and that as flow targets are neared an adaptive response to the delivery of benefits may reasonably drive a change in the flow target.**
2. Reviewing Abstraction Sensitivity Banding	**CaBA CSRG recommends a review of the Abstraction Sensitivity Banding. All chalk streams should be banded ASB3, unless there is evidence to support a lower band. ASB3 may not be appropriate on the lower reaches of very big chalk catchments or highly modified systems, for example the lower Colne or Lea, the lower Wey, Gade, Stort etc.**
3. Enhanced scenario for the national framework	**CaBA CSRG therefore endorses the national framework's 'enhanced scenario' for chalk streams but based on local evidence. The restoration of flow deficits should be grouped as being either ecologically 'essential', 'beneficial' or 'of limited benefit' and prioritised accordingly. See section 4.6 National framework and section 4.6.5 A%R .**
4. Waterbody boundaries and assessment points	**The Environment Agency should set and publish a timetabled undertaking to review all chalk stream WFD waterbody assessment points, associated targets and boundaries and make changes to ensure that the EFI methodology adequately protects ephemeral and headwater chalk streams and is appropriately applied in reaches where flow is of lesser significance such as the lower reaches.**
5. Time-bound goals towards sustainable abstraction	**Following items 1 - 4 government, regulators and industry should set and publish time-bound goals (short, medium and long-term) towards achieving 'sustainable abstraction' (see Action 1) on all chalk streams, in accordance with regional planning process and the recommended prioritisation articulated in Section 4.6.**

1. Modelling natural flows in abstracted streams is not an exact science: constant revision and refinement are necessary to enhance knowledge.

2. This figure is not a hands-off flow and it does not preclude conjunctive abstraction or the potential role of abstraction in the management of groundwater levels. The intention is to manage total annual groundwater abstraction in such a way that flows fall within 10% of natural at Q95.

3. A review of EA assessment points and their associated flow targets to "ensure that the methodology enables protection appropriate to the differing characteristics of ephemeral, and headwater and lowland chalk streams" is covered in a separate action: "appropriate" in this context must include that intention.

4. See Action 5. ref delivering time-bound (short, medium and long-term) commitments to the delivery of this target.

5. See Section '4.4 National framework' and the need to distinguish between and prioritise the restoration of flow deficits according to a tiered assessment of ecological sensitivity: "essential" "beneficial" "of limited benefit".

4.9 Water quantity: recommendations for action.

6. Evidence	Where existing (or future revised) methodologies indicate that abstraction is causing environmental stress or damage the EA should gather evidence: this will require investment in assessment points and monitoring.
7. Reviewing the Abstraction Incentive Mechanism (AIM)	Ofwat should review the Abstraction Incentive Mechanism to ensure that it is fit for purpose and if or how it can be adapted to increase effectiveness.
8. Demand management	All areas dependent on water-resource supply from chalk aquifer groundwater abstraction should be defined as Water-Stressed, enabling compulsory metering. Water companies should set and publish time-bound goals to achieve complete water-meter coverage in these areas. Joined-up action should be taken to influence customer behaviour to reduce demand for water, including education, labelling of goods and building regulations. A related call to drive water-efficiency standards is included in integrated policy recommendations for action section 7.4
9. Flow-recovery flagship	Government, regulators and industry should set a short-term goal to achieve sustainable abstraction in the chalk tributaries of the Colne and Lea catchments, where a technical solution is available within a shorter time-frame because of existing infrastructure plans, as set out in the *Chalk Streams First* proposal. This scheme has the potential to re-naturalise flows in the chalk streams most acutely impacted by groundwater abstraction, representing 20% of the chalk-stream waterbodies where flow does not support good ecological status.
10. Independent review of abstraction as a % of recharge (A%R)	CaBA CSRG recommends extending to all chalk streams the preliminary independent review of abstraction as a % of catchment recharge (A%R) for chalk streams in order to a) understand the scale of groundwater abstraction in chalk-stream catchments and b) to investigate A%R as a simple and accessible method for independent assessment of abstraction impact and prioritising action.
11. The importance of modelling and knowledge sharing	While A%R is a simple and accessible screening tool, CaBA CSRG also recognises the need for detailed models of run-off, aquifer recharge, groundwater levels and river flows as other components of the suite of tools and data that will support decision-making on chalk-stream restoration interventions. To include stakeholders in the discussion and decision-making, a participatory approach to modelling and data-sharing should be adopted.

5. Water quality: reducing pollution

5. Water quality

5.1 Water quality issues

In their natural state, chalk streams are 'gin clear' with little sediment, low nutrient levels and stable temperatures of around 10-11ºC. However, due to inputs from point sources such as sewage-treatment works and diffuse sources such as agricultural run-off, many suffer from elevated levels of nutrients, sediment and chemicals, such as pesticides.

5.2 Sediment

Clean river gravels are essential for many of the species typical of chalk streams, such as brook water crowfoot (*Ranunculus)*, invertebrates and fish.

Chalk streams are gentle rivers with limited natural flushing capacity, so are very susceptible to siltation of gravels. Problems arise when too much sediment enters the system and low flows allow the silt to settle out. These problems are then exacerbated by reduced interaction between the river and the floodplain, by over-sized channels, structures such as weirs and excessive weed-cutting.

Chronic deposition of fine material will eventually lead to colmation of the river gravels, when the finer sediment accumulates within the coarser substrate of the river bed. Colmation, also commonly referred to as siltation, is particularly damaging to chalk-river habitats. It reduces porosity and flow connectivity between groundwater and river water and causes the compaction of the stream bed, which gradually alters the bed structure and morphology. This has a direct impact on plants, invertebrates and fish-spawning habitat.

5.2.1 Sources of sediment

The main sources of sediment are diffuse pollution – particularly from agricultural runoff, but urban and road run-off can also be significant in some catchments.

Point sources can also be important, such as from fish farms and cress farms, although these are more easily controlled through permits to discharge.

Point-source sediment is typically organic, while diffuse sources are more generally inorganic soil particles. However, other pollutants can be transported with the sediment, such as nutrients and pesticides from farmland or hydrocarbons from roads. The organic content will vary depending on the source: slurry, for example, contains a high proportion of organic matter.

Scientific research over the past decade has greatly improved our understanding of the role of fine sediment (<2mm) in chalk stream ecosystems. Work on sediment

Left: In a chalk landscape, agricultural run-off is highly dependent on tracks and roads as hydrological pathways to the river.

fingerprinting demonstrates that fine sediment sources in chalk streams are derived from:

• cultivated fields (especially those left bare or lifted / ploughed in winter)

• pasture fields (especially as a result of overstocking)

• in-channel vegetation

• fish and watercress farms

• road-verge erosion (especially an issue on narrow, rural roads frequented by heavy farm traffic)

• sewage-treatment works

77% of fine sediments in England and Wales are derived from agriculture. In chalk streams, bank erosion is a minor source due to their low energy and low rates of bank erosion (although bank erosion can be significant where chalk streams are overgrazed, dredged or impacted by invasive signal crayfish or Himalayan balsam).

In strategising how to manage the impacts of fine sediment it is important to distinguish between fine sediment *delivery* and fine sediment *retention.* They are two halves of the same problem.

5.2.2 Road run-off.

Chalk catchments are noted for the naturally limited networks of river channels. In a natural chalk stream there are few hydrological pathways from the wider catchment to the river (there are rather more in a mixed-geology chalk stream). However, wet weather in a modern landscape turns every road into a potential tributary: the road system has become a vastly and unnaturally extended drainage network that operates to convey diffuse pollutants into the chalk stream. These pollutants include salt applied to the roads in winter, rubber from tyres, oils and fuels. In rural areas, large agricultural machinery crushes the verges of the narrow lanes these machines travel down, and the lanes themselves become virtual ‘streams', adding vastly to the total length of eroding ‘riverbank’ in any given chalk catchment. Finally, the roads are a means of conveyance of sediment eroded from farmland. Fields left bare in winter (crops like carrots and parsnips are lifted increasingly late into the autumn and even through the winter), maize fields and open-air pig fields are particularly problematic. Rainwater rushes across plough-lines and ruts in these fields, discharges onto the road network and flows rapidly downhill to the chalk stream where grips cut in the road verges allow the pollutant-laden water to spill directly into the river.

5.2.2. The impacts of fine sediment on fish & invertebrates

In 2017 Salmon & Trout Conservation (S&TC) published reviews on the impacts of fine sediment on invertebrates and fish (see link in Appendix A)

Healthy river systems require sediment input to maintain habitats and provide nutrient input, but *excessive* sediments loads can have a very significant impact on ecological health, primarily by swamping out and homogenising habitat, filling the interstices in the gravel bed, or cloaking the bed of the river in particulate matter to which are attached phosphorus and other toxic chemicals.

Excess sediment also causes unnatural turbidity in the water, with a range of knock-on negative impacts: on weed-growth, for example, and therefore oxygen levels, the inter-crown scour of the river bed, habitat heterogeneity and so on. Excessive sediment, in suspension and deposited, impacts directly on the health and diversity of a chalk stream’s invertebrate community by reducing scour, swamping interstitial habitat, burying the insect refugia, homogenising habitats, clogging gills and reducing primary production.

Similarly for fish, excessive sediment, in suspension and deposited, has a range of negative impacts, especially on salmonids. Sediment, particularly highly organic sediment, reduces salmonid egg survival by clogging the spaces in the gravel redd, effectively suffocating the eggs.

Excessive sediment has a range of sub-lethal impacts too. For example, it drives premature emergence of fry from the gravel redd, it reduces the ability of young fish to detect predators, it degrades fry habitat, causes gill irritation, alters blood physiology, and reduces feeding opportunities and rates.

In concluding remarks, S&TC highlighted a lack of assessment or a reference base for sediment limits emphasising that ‘the WFD objective of good ecological status cannot be achieved without addressing this important pressure’ and that ‘urgent action is required to identify more meaningful revised sediment targets for England and Wales’.

The report identified the aggravating or mitigating role of river morphology and flow regime, emphasising that ‘managing excess sediment requires prevention and restoration measures, all of which require sound understanding of the key sources’ concluding that ‘in order for sediment management to progress in England and Wales, better-informed sediment targets, and replicable monitoring methods are urgently required for compliance testing’.

Road run-off in the River Wissey catchment May 2021.

5.3 Nutrient enrichment

5.3.1 The importance and natural scarcity of nitrogen and phosphorus

Of the various chemicals dissolved in water, the macronutrients phosphorus (P) and nitrogen (N) are fundamental to primary productivity and to sustaining freshwater ecosystems.

Although essential, these two chemicals would nevertheless present in very low concentrations in the natural chalk stream, unaffected by man. Natural sources of P and N would include leaching from the catchment soils and decomposing vegetation, release of P from the geology, atmospheric deposition of N in rain and the biological N fixation of cyanobacteria, converting atmospheric nitrogen to ammonia. Very little P is available from natural geologies, especially chalk, and the natural chalk stream is exceptionally stable with little bank erosion. The nutrient levels would be largely dependent on retention and downstream spiralling within the system.

5.3.2 Anthropogenic sources of nitrogen and phosphorus

Farming and wastewater add significant amounts of P and N to both the chalk stream and the chalk aquifer.

The intensification and industrialisation of farming, especially in the post-war decades, added vastly to the quantities of fertiliser spread on farmland. Phosphorus and ammonium bind very easily to soil particles and sediment and wash into the streams via surface run-off, while nitrogen is highly soluble and mobile and is readily leached into the aquifer and river via subsurface flow. As a consequence there is now an enormous legacy of nitrogen in our chalk aquifers.

Human wastewater is usually dominated by dissolved inorganic nitrogen and phosphorus which is readily available for uptake by plants (known as bio-available) but the concentrations at the wastewater outfall will largely depend on the quality of treatment at the sewage works. Secondary treatment includes an element of settling and filtration, but tertiary treatment is necessary to remove more significant amounts of N and P.

5.3.3 Eutrophication - the result of excess levels of nutrient

Elevated nutrient enrichment (known as eutrophication) in chalk streams has a direct impact on plant populations, with secondary effects on other organisms, such as fish and invertebrates, which are dependent on plants for shelter, reproduction and food.

Eutrophication is responsible for toxic algal blooms, water anoxia, habitat and biodiversity loss, the degradation of estuaries and coastal areas. Nutrient enrichment can also affect human health by impairing drinking water.

Left: The final effluent outfall from Fakenham Treatment Works on the River Wensum, one of four SAC chalk streams.

There are four primary ways in which excess nutrient levels can affect chalk-stream plant communities:

• by excessively driving the growth rate of plants – which can cause problems with sediment retention, and the spiralling of nutrients when the plants break down in the winter

• by encouraging the higher-order plant species adapted to higher nutrient levels, skewing the balance of the plant community and reducing bio-diversity

• by boosting the growth of epiphytic, epibenthic, filamentous and planktonic algae

• by limiting the root depth of the higher-order plants like ranunculus, making them more susceptible to being ripped out in high flows

Although higher-order and important chalk-stream plants like ranunculus thrive best at very low, background natural nutrient concentrations, the first effect of nutrient enrichment is – counter-intuitively – an increase in the growth-rate of the higher order plants, but with commensurate weakening in root growth – making the plants vulnerable in high flows.

As nutrient levels increase further, the ecology shifts towards a dominance of the higher order plants that are more tolerant of nutrient enrichment, leading to a reduction in the overall bio-diversity of the plant community.

Finally, if nutrient concentrations keep on rising, the river's ecology switches to a more algal-dominated plant community. Benthic algae smothers the river bed and the interstices in the gravel in which many insect species live and epiphytic algae cloaks the leaves and stems of the higher-order plants, reducing their ability to photosynthesise. The prevalence of algae will also cause extreme diurnal variations in dissolved oxygen levels, which stress fish and insects alike.

5.3.4. Nitrogen and phosphorus limitation

The concept of nutrient limitation is important in strategising pragmatic improvements to water quality in chalk streams. As nutrient concentrations increase above natural levels, the plant community changes in the ways outlined above until a point is passed whereafter no amount of additional increase in the concentration effects any additional change.

If the nutrient concentration rises far above this trigger point (and on many chalk streams and chalk aquifers it has), then it needs to be reduced all the way back down to the trigger point and below before an improving effect is discernible (something that is further complicated by the legacy of stored nutrients in river-bed sediments and the aquifer).

Of the two nutrients, phosphorus is typically in shortest supply in freshwater systems, especially chalk streams. Research (Mainstone et al 1995) at 5000 sites surveyed in England and Wales has shown that wherever the phosphorus concentration is at a level that might conceivably be a limitation to growth (the trigger point), nitrogen is typically over 8 times the value and relative to phosphorus is surplus to requirements.

This finding is endorsed by more recent research (Jarvie et al, 2017) into nitrogen and phosphorus limitation in different types of river and headwater stream, where: 'preliminary assessments suggest that reducing P concentrations in the Lowland-High-Alkalinity headwater streams, and N concentrations in the Upland-Low-Alkalinity rivers, might offer greater overall benefits for water-quality remediation at the national scale, relative to the magnitude of nutrient reductions required. This approach could help inform the prioritisation of nutrient remediation, as part of a directional approach to water-quality management-based on closing the gaps between current and target nutrient concentrations'.

The same rationale informed the basis of the Hampshire Avon Nutrient Management Plan: 'as this is the chemical that is thought to be most significant in preventing favourable conservation status from being achieved across the catchment … Controlling anthropogenic enrichment of phosphorus in the River Avon at levels that limit the growth of plant species is necessary to restore and protect the characteristic biodiversity'.

Clearly, driving down both nitrogen and phosphorus is important to the restoration of chalk stream ecology, however, a combination of the sheer scale of the nitrogen problem and the fact that phosphorus is almost invariably the limiting chemical, means that prioritising reductions in phosphorus concentrations towards background levels is a vital step in the shorter term maintenance / and restoration of higher plant communities.

Moreover, many of the actions that will contribute to this incremental reduction of phosphorus in chalk streams, will also contribute to a reduction of nitrogen.

It is worth noting that there are some key actions such as the restoration of the fen habitat in headwater chalk catchments and around the spring-line and the restoration of hydrological connectivity between the river and the floodplain that would make significant contributions to the reduction of nitrogen.

5.3.5. How nutrients get into a chalk stream.

The ways in which nutrients get into and stay in a chalk stream are key to understanding how to plan and prioritise strategies to reduce their impact.

Nutrients gets into a chalk stream from 'point', 'diffuse' and 'intermediate' sources. Typically, point sources of nutrients are municipal wastewater, whereas diffuse runs off the agricultural landscape, into either the river or the groundwater, while intermediate sources include septic tanks and urban run-off.

The main point-source supply of P and N is through the human sewage system, but fish farms and cress farms are also point-sources: a large fish farm (40 tonnes annual production), for example, can generate as much P as a secondary sewage-treatment works serving 1000 people.

Diffuse-source nutrients (and other chemicals), on the other hand, flow in multiple pathways from the wider landscape, and particularly from farmland and get into the river by surface or shallow subsurface flow, especially during the winter. N from the aquifer is also a diffuse source.

5.3.6. The relative impacts of different sources of nutrients

The relative impacts that point and diffuse nutrients have on river ecology are not necessarily in proportion to the relative loading by weight from each source.

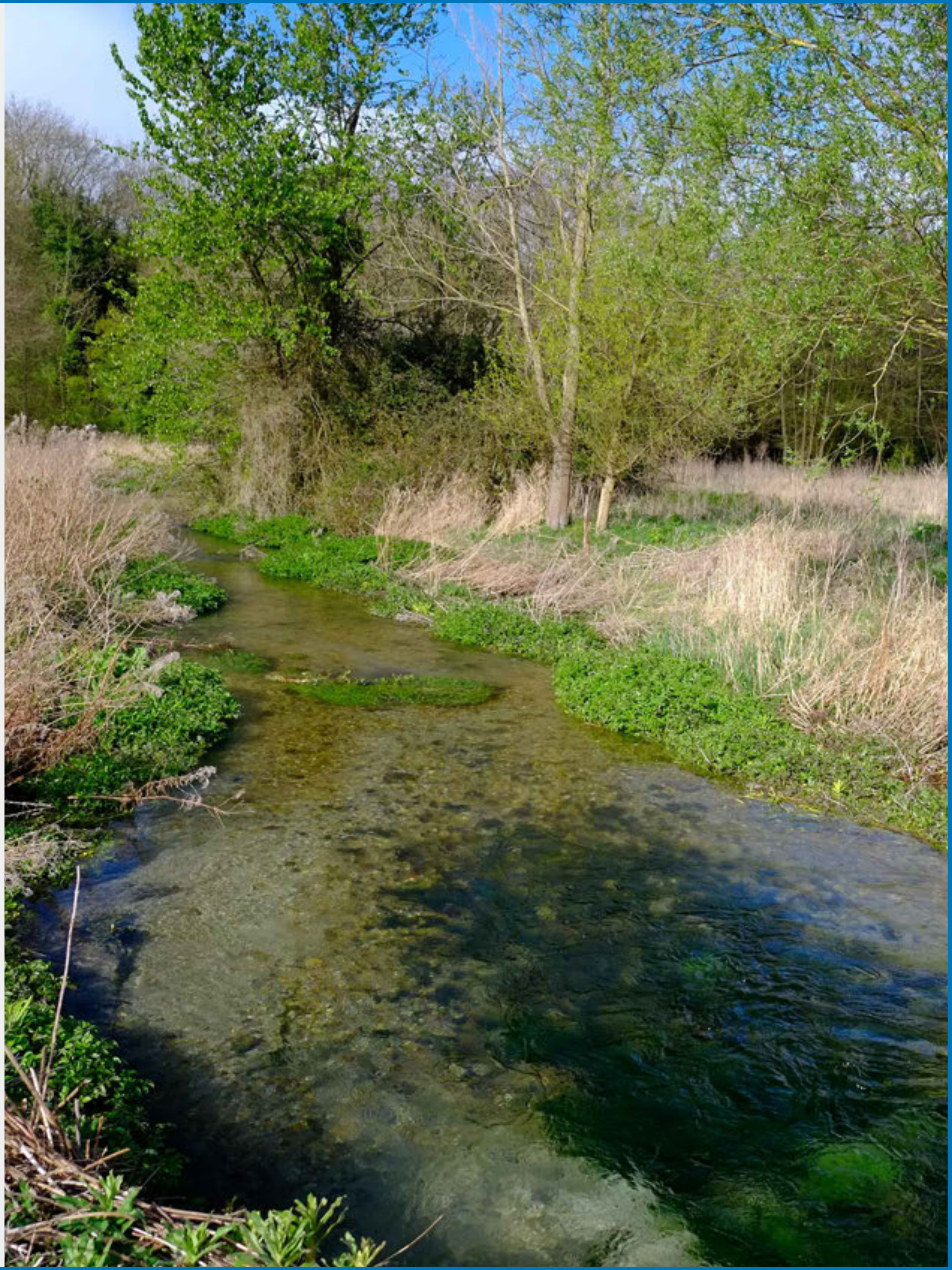
Point source P and N, especially from the human sewage system, is released directly into the river in a fairly constant stream (with spikes or flushes), and in a form that is readily available for uptake by plants and algae (known as bio-available), including during the growing season as flows diminish and temperatures and daylight hours increase: the constant supply of nutrient from sewage effluent, therefore, becomes more highly concentrated in the receiving chalk stream in sync with the biological activity (in the growing season) that precipitates its negative impact.

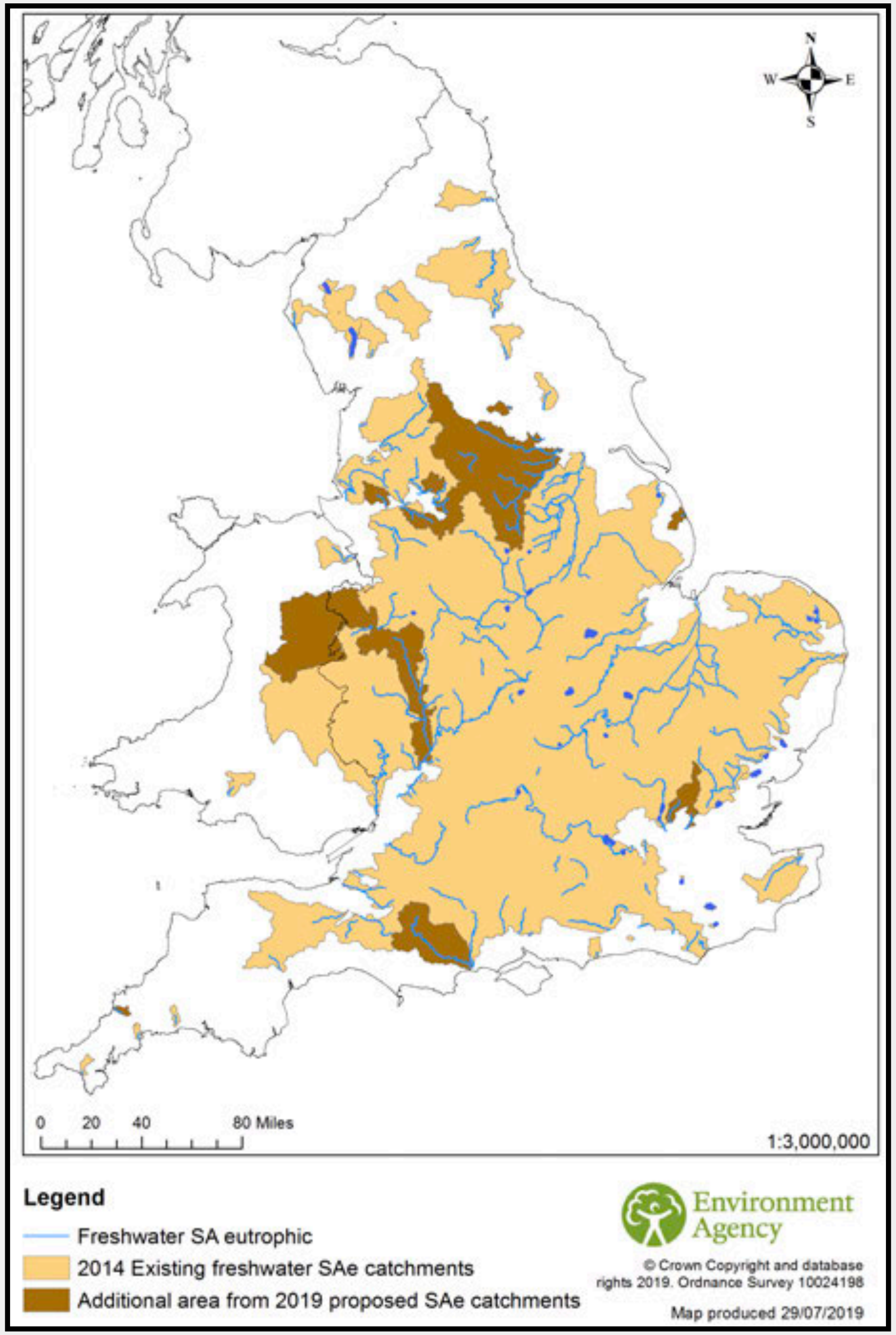
By contrast, much of the dissolved nutrient that washes into a chalk stream in the high flow and run-off events that bring the pollution from the landscape to the river, is flushed through the river by the same high flows and often outside the growing season. Nitrate, however, will wash down into the aquifer, while P readily binds to soil particles which then settle in the river. A proportion, high in places, of diffuse pollution can be organic too: for example, slurry and run-off through farmyards.

This is where nutrient and sediment pollution overlap and where it is also important to consider the physical condition of the channel. A free-flowing chalk stream with good hydrological connectivity with the floodplain will be less adversely impacted by nutrient / sediment pollution, than a dredged or impounded channel which cannot flush itself or escape onto the floodplain in high flows.

Ameliorating the impact of nutrient enrichment is one respect, among many, in which restoring the physical morphology of chalk streams and their catchments is a vital part of a holistic restoration strategy.

Right: the River Babingley is High status for phosphate and ammonia. The Ingol in the neighbouring valley is Poor status. There is no STW on the Babingley. There is a large (6,500 pop.) STW on the Ingol. 80% of chalk streams at High status have no STW. 83% of failures have STWs that do not remove phosphorus.





Map showing the distribution of Sensitive Area (eutrophication) eutrophication catchments.

5.3.7 Phosphorus

The Environment Agency's Phosphorus and freshwater eutrophication pressure narrative (see link in Appendix A) is an analysis of the progress made over the past 20 years and an assessment of the remaining challenges with regard to phosphorus pollution in rivers.

P concentrations in our rivers increased greatly between 1950 and the 1980s due to the introduction of P-based detergents, population growth and the growing use of artificial P fertilisers.

However, from a peak in the 1950-80s to 2020 total P loadings have been reduced by more than 66%. P stripping on the River Kennet, for example, has led to an overall reduction of 88%.

These gains have largely been driven by the Urban Waste Water Treatment Directive (UWWTD) and the Water Framework Directive (WFD) and have applied to relatively large sewage-treatment works (STWs), but with smaller STWs targeted in each price review, so that now many medium-scale STWs are fitted with phosphate-removing processes, especially in the vulnerable catchments designated by the UWWTD or by SAC and SSSI status.

Despite good progress in tackling phosphorus pollution since 1990, 55% of river water bodies in England do not meet WFD phosphorus standards for good ecological status.

The picture is slightly better for chalk water bodies at 37%. Phosphorus is *the most common cause of water quality failures* under the WFD in England. In addition, 50% of N2K rivers currently fail their long-term target for P. A small number of groundwater bodies are also at poor status for P.

Source apportionment and future risks

The largest source of P is still sewage effluent, but this varies between catchments. In failing waterbodies, the relative apportionment of P between sewage and agriculture is 60-80% sewage and 20-30% agriculture.

Future risks

Climate change could lead to more extreme flow regimes, with lower summer flows leading to increasing concentrations of pollutants and higher winter flows leading to greater run-off. Increased P-dosing of drinking water to meet tighter Drinking Water Directive standards and housing / population growth will also add to the risks, especially across our chalk streams.

Ecological recovery – a long road

Ecological recovery from nutrient enrichment can be lengthy and uncertain. Despite great reductions in P, there has to date been a disappointing ecological gain. This is partly because the P reductions have still not gone far enough. But it is also because so much P has been applied to the land over the decades and is locked into the soil and the sediments on our river beds (as is Nitrogen). P failures of WFD waterbodies also tend to coincide with sediment and morphology failures.

Point-source improvements

By 2015 60% of the population had been connected to STWs fitted with P removal. By 2027 with WFD reductions building on UWWTD reductions, 95% of the population in England will be connected to STWs fitted with P removal. The map on page 60 shows the rivers and catchments where the UWWTD stipulates that P removal must be fitted to large STWs.

The UWWTD and WFD will drive further STW P reduction measures through the current water industry national environment programme (WINEP) which covers the period 2020-25. This is mainly targeted at the water industry's 'fair share' of meeting WFD good ecological status for P and will improve some 5000km of river at a capital cost of around £1.65 billion. Under this programme, around 900 STWs serving a 15-million population equivalent will have new or tighter P reduction by 2027. This will result in reductions of 88% in the STW P loading to rivers compared to the position in 1995.

So far, so good: and yet the EA SAGIS (Source Apportionment GIS) SIMCAT (simulation catchment) models project that in spite of these actions, P compliance will only improve nationally by 2%: 'this is primarily because although the water industry is 70% compliant with its fair share of the P reductions needed to meet good status for river P, agriculture is only 48% compliant and this constrains the extent of progress towards the good status objective'.

Despite this, it is essential that water companies continue to innovate to improve P removal from sewage treatments at the same time as actions are taken to reduce P inputs from agriculture.

Diffuse pollution improvements

Until recently there were no direct regulatory controls on agricultural P application to soil or the prevention of P losses from farmland to rivers. However, the Reduction and Prevention of Agricultural Diffuse Pollution (England) Regulation - commonly known as the farming rules for water - came into force from April 2018.

These rules embed in law various good practices such as nutrient planning, soil and manure management and a step-by-step checklist aimed at ensuring that fertilisers are spread to meet crop and soil needs, when it is best to apply fertilisers, where to store manures and how to avoid pollution from soil erosion. Cross-compliance contains some measures such as those that protect soils which will indirectly control P losses.

In addition, P fertiliser use, livestock numbers and manure P inputs to land have all been reducing nationally in recent years mainly due to economic factors.

Not yet enough

Nevertheless, Defra analysis indicates that agriculture needs to reduce P loss by an average of 48% nationally to achieve the required WFD standards. This assumes that the burden of reductions should be proportionate to the contributions from water company discharges and agriculture.

Measures to tackle diffuse P pollution from agriculture are more cost-effective when parallel reductions in other pressures (sediment, nitrate, faecal indicator organisms) are considered. The benefits, in terms of reducing loss of P and N from the landscape, of nutrient-management planning, manure storage and separation of clean and dirty water in farmyards, are widely recognised.

Future scenarios

In considering potential strategies for managing P at river-catchment level it may be useful to consider the relative priorities for action of the following two scenarios:

• High P concentrations, often in high-alkalinity, lowland rivers (ie chalk streams), due to sewage and agricultural sources; with good local evidence of ecological harm (eutrophication) and high confidence that some reduction in concentration/load will be achieved but low likelihood it will be sufficient to achieve P standards and thus uncertainty over ecological improvement: **tackling P from sewage-treatment works is an essential starting point in these situations but agricultural sources are increasingly important.**

• Low P concentrations, often in sensitive, low-alkalinity or headwater river reaches, where local evidence of eutrophication is likely to be weaker, but deterioration needs to be prevented: **measures covering agriculture, small STWs and rural sewage sources (septic tanks) may reduce P concentrations from just failing to levels that will deliver ecological improvemen**t.

5.3.8 Nitrogen

The main concerns with high concentrations of N in water are:

• the risk to human health from drinking-water abstracted from ground or surface waters with high N concentrations

• eutrophication of surface waters

• nutrient enrichment in other sensitive habitats like groundwater-dependent ecosystems

N pollution is so endemic that nearly 30% of groundwater used for drinking water supply in England must now be blended, treated, or replaced in order to meet tap water nitrate standards.

Treatment is expensive, with a nitrate removal plant costing upwards of £8m, and this cost is ultimately passed on to the water consumer through higher bills.

Agriculture is the dominant source of N in water (about 70% of total inputs), with sewage effluent a secondary contributor (25-30%) nationally.

In general, N concentrations are greatest in the drier, arable-dominated chalk-stream catchments of southern and eastern areas of England.

55% of England is designated as a nitrate vulnerable zone (NVZ) due primarily to elevated N concentrations in groundwater and rivers. NVZ action programmes to reduce agricultural nitrate pollution have been in place since the late 1990s. During that time, river N concentrations have seen a general reduction, but not a dramatic reduction.

Groundwater N concentrations are broadly stable in many places except in southern England where they are still rising in some areas. This is partly because of the lag time or delay it takes for the peak agricultural N loadings of the 1980-90s to percolate through the water table.

The farming rules for water and nitrate vulnerable zones form the regulatory baseline. Catchment schemes, safeguard zone action plans and the proposed new Environmental Land Management scheme (ELMS) will have important roles to play in securing the necessary improvements.

For agriculture, the most effective measures (in terms of cost and reducing N leaching) are achieved through:

• nutrient-management plans and knowledge of the N content of manures, composts and slurries

• cover crops

• careful calibration of fertiliser spreaders

• land-use change, for example converting intensively farmed arable land to less intensively managed grassland or woodland or best of all to wetland, flushes and fen (this is the most effective and also the most cost-effective measure).

• reduced stocking density is the most effective measure to reduce N loading from livestock

Local circumstances would dictate which combinations of measures could be the most cost-effective

For sewage, conditions on permits for discharges are used to regulate the contribution of nitrate entering surface waters from sewage-treatment works and industry.

Conventional primary and secondary treatment at sewage works removes 20-30% of the N in raw sewage. Where effluent needs tertiary treatment, for example to meet Urban Waste Water Treatment Directive (UWWTD) requirements affected by eutrophication, levels of N reduction can be around 70-80% to meet effluent N standards of 10-15 mg/l.

Improvements to leaking sewers will reduce nitrogen loss to groundwater, and to surface waters where there is good connection with groundwater.

Leakage-reduction programmes for mains-water pipelines where N in drinking water is at relatively high concentration will have the additional benefit of limiting the return of this pollutant to groundwater.

Following billions of pounds of investment by water companies in sewage-treatment works, the agricultural sector must play its part in addressing the diffuse run-off that also pollutes our chalk streams and chalk aquifers.

5.4 WFD phosphorus (P) status analysis

5.4.1 All chalk streams

There are 249 chalk-stream waterbodies (some individual chalk streams are divided into several waterbodies). Of these 249 there are 97 (39% nationally) failures for P status (moderate or worse). As with flow the % of failure does not fall evenly across the map.

As can be seen in the chart opposite, WFD failure for P appears to correlate closely with the presence of STWs that do not remove P / and or CSOs and also the presence of upper greensand in a catchment.*

Moderate, poor or bad status for phosphorus

• Only 6% of the Failures for P are on waterbodies with no sewage-treatment works, upper greensand** or SOs (storm overflows . See section 5.8 below)

• Only 6% of the Failures have STWs which do remove P.***

• Upper greensand can be associated with 5% of the failures and a further 25% can be associated with upper greensand along with STWs and CSOs

• 58% of the failures are on waterbodies with discharging STWs which do not remove P.

High status for phosphorus

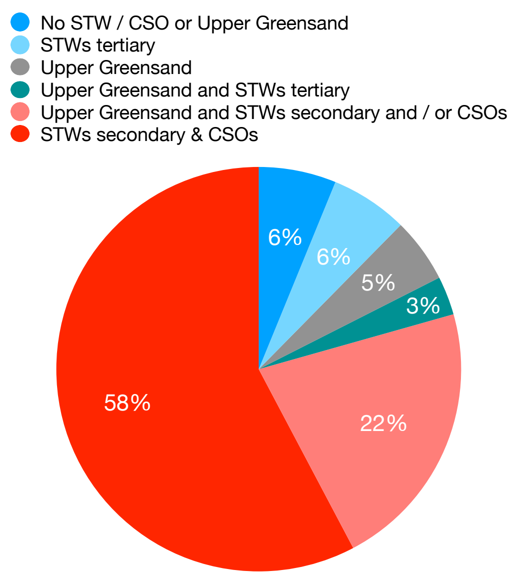
• Conversely high status for P correlates closely with an absence of any STW on a given waterbody or with the STWs operating to a standard that removes P.

• There are also **no** chalk streams of high status for P with upper greensand in their catchments.

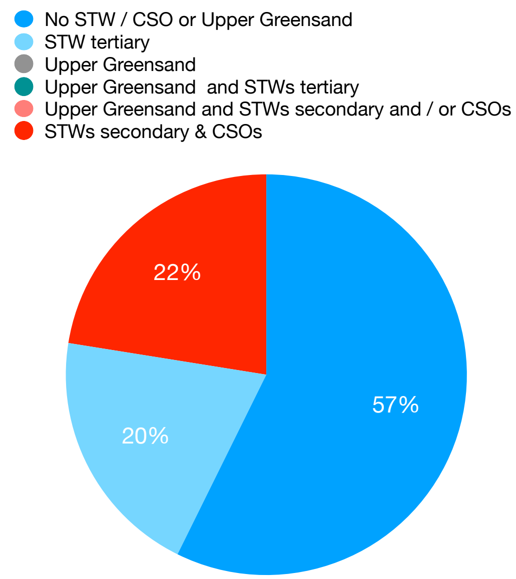
• 57% of high P status chalk streams have no STW / CSO or upper greensand, while a further 20% have STWs which remove P. 22% have STWs which do not remove P (though the P status of some of these STWs is unconfirmed).****

The WFD charts in Appendix E show WFD P data from three chalk streams, the Misbourne, Whitewater and Kennet.

Appendix F is a case study of P status in the Frome and Piddle catchments.



Chalk Streams MODERATE, POOR OR BAD STATUS for phosphate	
No STW, CSO or Upper Greensand	6
STWs tertiary only	6
Upper Greensand	5
Upper Greensand & STWs tertiary only	3
Upper Greensand & STWs and / or CSOs	21
STWs secondary only and / or CSOs	56



Chalk Streams HIGH STATUS for phosphate	
No STW, CSO or Upper Greensand	51
STWs tertiary only	18
Upper Greensand	0
Upper Greensand & STWs tertiary only	0
Upper Greensand & STWs and / or CSOs	0
STWs secondary only and / or CSOs	20

*Upper greensand is implicated in a very high % of failures. See section below.

** Four of these (the Wintringham, Gowthorpe, Shep and Cherry Hinton Brook) are small chalk streams subsumed into larger waterbodies of a different morphology and incorporating assessment points downstream of the chalk-stream reaches, while the Shep, Cherry Hinton Brook, Bourne Brook and Ewelme are all small, suburban chalk streams

** Of these the Caker is a small stream serving a large town (Alton), the Lee is impacted by Luton, Harpenden, Mill Green and Hatfield STWs (all tertiary), the Pix Brook is a small stream serving a large town (Letchworth), and the Slade, Quy and Kneeswell are small chalk streams subsumed into larger waterbodies of a different morphology.

**** All but three of these are small STWs on pure-geology chalk streams, while the Wye, Ver and Misbourne all have much higher P readings downstream of their STWs

5.4.2 Upper greensand

Detailed analysis undertaken for the SAC Nutrient Management Plan for the Hampshire Avon suggests that background P readings in the Avon chalk streams with upper greensand (UGS) in their catchments are much higher than for other purer chalk-geology streams. Chalk is known to bind P within the aquifer, whereas Greensand does not.

This correlates with the P readings in other chalk-stream catchments which feature an element of UGS in the geological make-up: the Upper Frome, the Nadder, the Kentish Stour. Also individual rivers like the Fontmell, Lavant, Lockinge, Lewknor, Shalborne and Tillingbourne.

100% of the failures south and west of the Thames catchment feature UGS in their catchments. A much smaller number of rivers north and east of this: eight in the Thames, two in the Kentish Stour, one in the Ouse catchments feature a significant amount of UGS in their catchments. These also all fail WFD status for P.

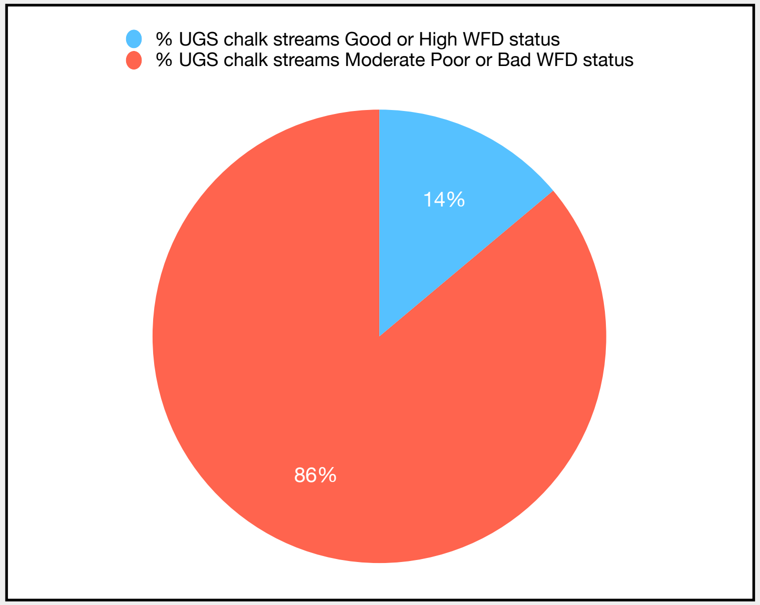
There is currently some debate as to what extent the higher P concentrations of groundwater from UGS aquifers are a natural phenomenon, however recent research by Penny Johnes et al into the origins of phosphorus in upper greensand catchments concluded: ‘Natural or near-natural P concentrations in the aquifer, deriving from the much slower dissolution of primary fluorapatite in the UGS would be substantially lower than current concentrations, based on this mineralogical, geochemical and modelling evidence’.*

It is also true that mixed-geology chalk streams tend to be more flashy in nature, featuring a higher proportion of impermeable surface soils and a greater density of hydrological pathways. Agricultural practice in these catchments is therefore likely to create a more significant diffuse run-off issue than it does on the classic ‘pure’ chalk streams, with their more limited pathways and more permeable soils.

In the upper Frome catchment, for example, an increasing amount of land is now used for maize production, which is fertilised with slurry from Dorset's large, industrialised dairy units. Anecdotally (from those who have known the upper Frome for many years) siltation, poor ranunculus growth, benthic algal growth and declining invertebrate numbers all point to a eutrophication problem that has developed in line with changing agricultural practices.

The evidence suggests, therefore, that upper greensand chalk streams are notably (among chalk streams) impacted by elevated groundwater P levels, which are likely to be further elevated by subtly distinct farming practices in these mixed surface-soil catchments. Poorly managed septic tanks are also likely to be a problem in these catchments, because of the density of hydrological pathways and the impermeable soils.

There is a case for examining the role for Water Protection Zones in upper greensand chalk catchments with bespoke mitigating tools designed to address the nutrient and sediment pollution issues. As well as, of course, utilising existing regulatory powers to the fullest extent that is practicable, in terms of regulating compliance and permitting sewage discharges.



% Pass or Fail WFD for phosphate of the 36 chalk streams with mixed chalk and Upper greensand geologies

* Determining the nature and origins of riverine phosphorus in catchment underlain by upper greensand / Penny Johnes, Evangelos Mouchos, Heather Buss, Sam Bingham (University of Bristol) and Daren Gooddy (British Geological Survey)

Mixed geology chalk streams with upper greensand in their catchments – like the River Frome – feature notably higher P concentrations than other chalk streams.

5.4.3 Designated chalk streams

Notwithstanding the impact of the upper greensand in the Avon (SAC designated chalk stream), affecting 14 of the 25 waterbodies in the catchment, it is clear that P standards in the designated SAC and SSSI chalk streams are much higher than across the other chalk streams.

• The Frome SSSI has 33% STWs with P removal and all 4 of its failures are associated with the STWs which do not remove P, and with upper greensand.

• The Avon SAC has 60% STWs with P removal and all 13 of its failures are associated with upper greensand, and some also with STWs and CSOs.

• The Test SSSI has 64% STWs with P removal and no failures.

• The Itchen SAC has 100% STWs with P removal and no failures.

• The Kennet SSSI, including the Lambourn SAC, has 61% STW's with P removal and only one failure which is associated with upper greensand, a secondary STW and a CSO.

• The Nar SSSI has 100% STWs with P removal and no failures.

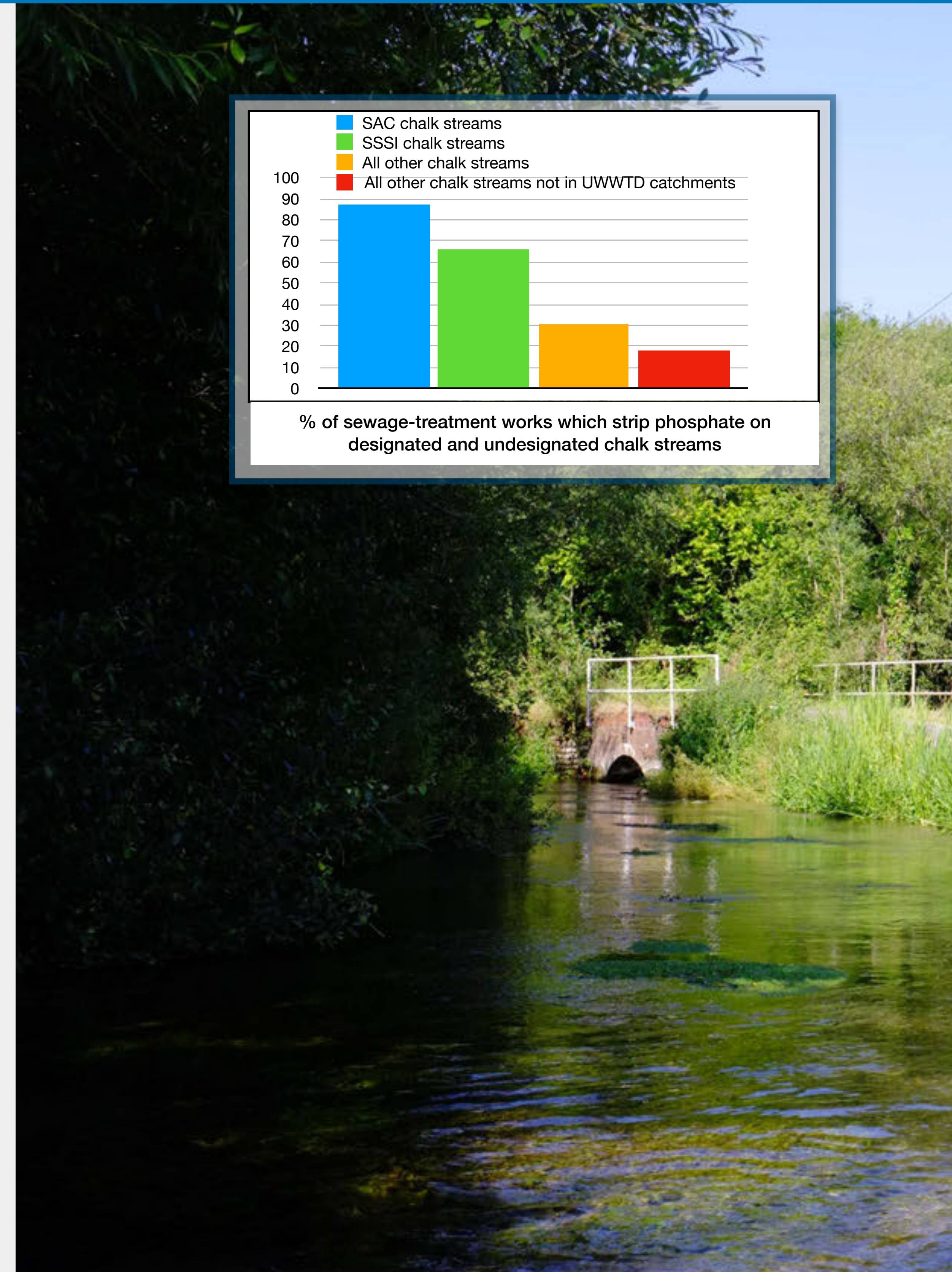
• The Wensum SAC has 100% STWs with P removal and no failures.

• The Driffield SSSI has 84% STWs with P removal and one failure, the Nafferton Beck, the only waterbody in the catchment with secondary STWs (two).

On average nearly 90% of STWs on SAC chalk streams and 65% of STWs on SSSI chalk streams strip P.

Conversely on undesignated chalk streams only 30% of STWs strip P.

That figure falls to 18% on chalk streams that are not in UWWTD SA(e) catchments.



% of sewage-treatment works which strip phosphate on designated and undesignated chalk streams

Right: chalk streams like the Lambourn in Berkshire, an SAC chalk stream in an SA(e) catchment, have benefited greatly from progress made over the last two decades to remove phosphate from sewage discharges.

5.5 Storm overflows

Storm overflows (SOs) are designed to allow exceptional discharge of sewage to rivers at times of heavy rainfall when the sheer volume of water threatens the capacity of the works, to prevent sewage backing up into homes and streets.

But a growing population, urban development and more intense rainfall means they discharge more often.

In 2017 WWF published an investigation of SOs – ‘Flushed Away’ – reporting that of the 80% of rivers then failing to reach ‘good ecological status’, sewage pollution was linked to the majority of the failures.

Data provided by one company indicated that 14% of their combined sewer overflows were discharging, on average, at least once a week, 50% once a month, while some were spilling hundreds of times a year. This is in spite of the Urban Wastewater Treatment Directive requirement that water companies should have measures in place to limit the pollution caused by SO’s such as ample capacity headroom and a limited number of permitted spills per year.

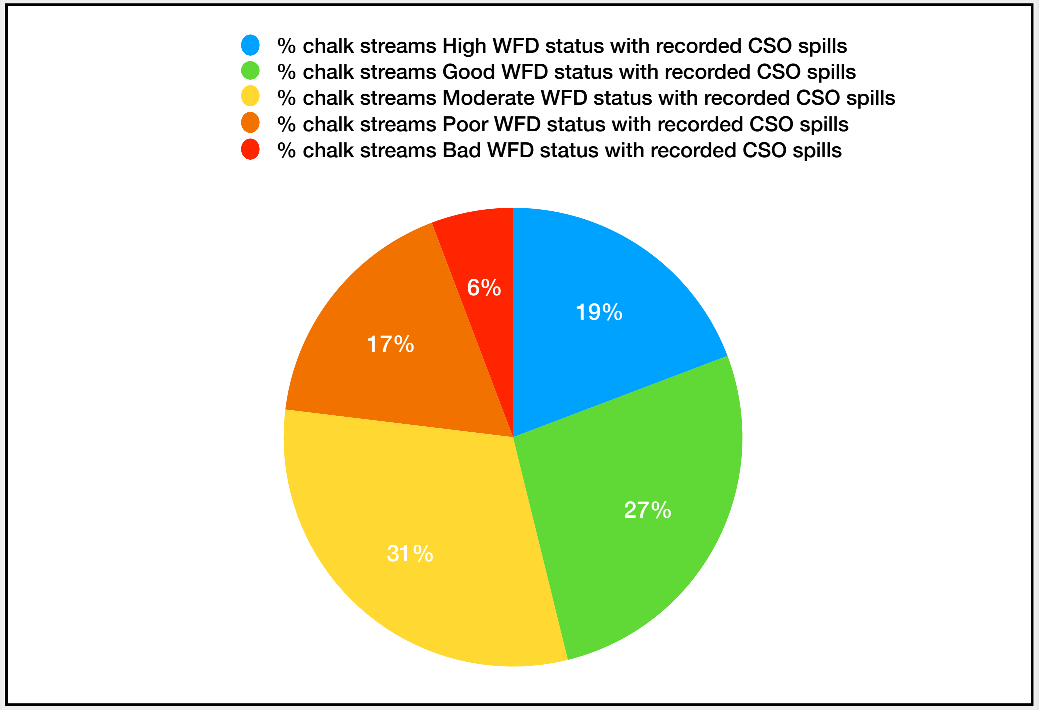
Infrastructure investment

WWF highlighted the fact that most of the present-day sewerage infrastructure was installed over half a century ago. Investment in sewerage infrastructure is not keeping pace with its deterioration or the increasing pressures and at the current rate of progress it will take 800 years to replace ageing assets.

Water companies are relying on storm overflows to compensate for under-capacity, as was strongly suggested in the recent Panorama exposé of storm overflows broadcast on BBC1 in April 2021.

There are 17,684 permitted sewer overflows across England and Wales, where water companies are allowed – under certain conditions – to discharge untreated sewage. 89% of these discharge to rivers. The table on page 58 gives details of the storm overflows to chalk streams in 2019.

A specific issue for chalk streams is groundwater infiltration to sewer networks, which means in wet winters, when groundwater levels are high, groundwater enters the sewers leading to extended operation of storm overflows. These spills can lead to a multitude of effects: risk to human health arising from bacteria and viruses; reduction in oxygen and therefore damage to the ecology; plus nutrient enrichment at a sensitive time for river ecology – early spring when groundwater levels are high and fish are spawning.



WFD status for P* of the 52 chalk stream waterbodies with significant recorded CSO spills in 2019

***Note this is indicative only: because storm overflows bypass the sewage works (albeit there is an element of settling) they discharge much more than just phosphorus. See section 5.5.2.**

Water companies should manage and maintain their sewer networks properly.

We need action to prevent surface water getting into sewers – a combination of sustainable drainage systems (SuDS), household behaviour, change initiatives and catchment management.

Government/Defra should empower water companies to control surface water entering their sewers, reviewing the right to connect surface water to combined sewers, powers to disconnect surface water from combined systems or discharge surface water to rivers and powers to rectify private drains that are allowing significant infiltration.

5.5.1 Storm overflow 2019 data

As can be seen from the 2019 data, storm overflows are implicated in 30 WFD P failures, while significant SO spills occurred on 54 chalk stream waterbodies in 2019.

Some notable recorded spills occurred in waterbodies that nevertheless are of Good or High status: the Sydling, the Till, the Wiltshire Bourne, the Kennet h'waters, the Lambourn, lower Kennet, Loddon, Bucks Wye, Quin, Hiz and Glaven. These tend to be either:

• SO's which (in 2019) spilled for a very high number of hours: for example the Sydling SO which spilled for 1813 hours, almost three months. These are likely to be caused by high groundwater ingress through leaky pipes and, if from a small agglomeration, may not show an impact in WFD monitoring.

or

• SOs that spilled only infrequently: for example on the Glaven there were 8 spills, totalling 88 hours, which is not outside the bounds of what the SO legislation allows for: only in the event of 'unusually high rainfall'.

The SO's that are likely to be contributing to WFD failure, and are almost certainly causing ecological damage, are more typically like the one at Bentley on the Wye, spilling in 2019 56 times (an average of once a week) for 344 hours. Or the large total of SOs spilling in Canterbury at the upper end of the Great Stour. Or the SO on the Chess (see Chess case study section 5.5.2) which is often triggered by groundwater ingress, but on a large sewage-treatment works. Note also that the first 10% time duration of a given overspill event is by far the most toxic, especially after a prolonged dry spell. Toxic spikes of this kind are unlikely to be picked up with any reliability by EA monthly monitoring.

SO's are now receiving a lot of attention from a general public concerned to find that raw sewage is routinely spilled into their local rivers. Monitoring is better, but still not good enough. Information on spills is more freely available, but here too there is room for more transparency.

It is vital that the permitting / enforcement of regulation and water company operation of SOs adequately protects and reflects the iconic global ecological and heritage value of chalk streams as the receiving waterbodies and that resources are directed at greatly reducing the volume and frequency of spills, if not eliminating these spills altogether.

Storm overflows on chalk streams 2019

HIGH STATUS | GOOD STATUS | MODERATE STATUS | POOR STATUS | BAD STATUS

Chalk Stream Waterbody	CSO Spill Records 2019
Bride incl Litton Cheney Brook GB108044009550	Burton Bradstock CSO 2019: 4 spills 4 hours
Hooke GB108044009800	Toller Porcorum CSO 2019: 29 spills 197 hours
Frome Upper GB108044009691	Maiden Newton CSO 2019: 32 spills 744 hours
Sydling GB108044009700	CSO 2019: 84 spills 1813 hours
Tadnoll Brook h'waters GB108044009660	Broadmayne CSO 2019: 51 spills 946 hours
Frome Lower GB108044009692	Dorchester Mill Stream CSO 2019: 30 spills 170 hours Wool CSO 2019: 29 spills 195 hours
Piddle Lower GB108044010080	Wareham CSO 2019: 15 spills 275 hours (spills to extreme DS of river)
Bere Stream GB108044009630	Milbourne St Andrew CSO 2019: 51 spills 1188 hours.
Shreen Water GB108043022450	Mere CSO 2019: 53 spills 405 hours & 28 spills 292 hours.
Iwerne GB108043016010	Iwerne Minster CSOs 2019: 26 spills 482 hours
Etchilhampton Water GB108043022430	Spaniels Bridge CSO 2019: 107 spills 2,200 hours
Avon East GB108043022410	North Newnton CSO 2019: 16 spills 351 hours
The Swan GB108043022540	Warminster Park CSO 2019: 68 spills 84 hours
Wylye GB108043022550	Hanging Langford CSO 2019: 177 spills 3450 hours via reedbed
Till GB108043022570	Shrewton CSO 2019: 112 spills 2522 hours
Wylye lower GB108043022510	Great Wishford CSO 2019: 3 spills 16 hours
Fovant Brook GB108043016190	Fovant CSO 2019: 68 spills 1339 hours
Nadder lower GB108043015880	Barford St Marton CSO 2019: 21 spills 323 hours
Bourne GB108043022390	Hurdcott CSO 2019: 213 spills 4367 hours
Horsenden Stream (included in Kingsey Cuttle Brook) GB106039030200	Princes Risborough CSO 2019: 20 spills 412 hours
Pang incl the Bourne GB106039023300	Bucklebury CSO via Briff Lane Stream 2019: 66 spills 1022 hours
Kennet h'waters GB106039023171	Fyfield CSO 2019: 49 spills 647 hours
Kennet middle to Hungerford GB106039023173	Marlborough CSO 2019: 87 spills 989 hours
Upper Dun GB106039017350	East Grafton CSO 2019: 23 spills 263 hours Great Bedwyn CSO 2019: 10 spills 128 hours
Shalborne GB106039017370	Shalbourne CSO 2019: 42 spills 148 hours
Kennet middle to Newbury GB106039023174	Kintbury CSO 2019: 36 spills 684 hours Hamstead Marshall CSO 2019: 62 spills 864 hours via Hamstead Stream
Lambourn GB106039023220	East Garston CSO 2019: 32 spills 319 hours
Kennet lower Lambourn to Enborne GB106039017420	Newbury CSO 2019: 17 spills 49 hours
Loddon h'waters GB106039017080	Basingstoke CSO 2019: 5 spills 54 hours

Chalk Stream Waterbody	CSO Spill Records 2019
Loddon middle GB106039017330	Sherfield on Loddon STW & CSO 2019 38 spills 298 hours via Bow Brook.
Wye GB106039023880	High Wycombe CSO 295 spills 6398 hours
Chess GB106039029870	Chesham CSO 2019: 2 spills 3 hours
Colne lower GB106039023090	Maple Lodge STW & CSO 2019: 13 spills 91 hours
North Wey at Alton GB106039017800	Newnham Lane CSO 2019: 3 spills 13 hours
North Wey GB106039017830	Holybourne CSO: 2 spills 1 hour Bentley CSO 2019: 56 spills 344 hours
Hogsmill GB106039017440	Hogsmill CSO 2019: 24 spills 225 hours
Wandle GB106039023460	Beddington CSO 2019: 23 spills 17 hours
Beane upper GB106038040110	Weston CSO 2019: 43 spills 435 hours Cottered CSO 2019: 15 spills 324 hours
Quin GB106038040120	Barkway CSO 2019: 17 spills 175 hours
Stort GB106038040130	Stansted Moutfitchett CSO 2019: 22 spills 30 hours Little Hallingbury CSO 2019: 15 spills 299 hours Hatfield Heath CSO 2019: 40 spills 752 hours via Pincey Brook
Great Stour GB107040019741	Bybrook Ashford CSO 2019: 10 spills 170 hours Kingsnorth Road CSO 2019: 23 spills 43 hours Dover Place CSO 2019: 18 spills 17 hours Canterbury Road Cemetery CSO 2019: 7 spills 16 hours Queen's Road CSO 2019: 2 spills 1 hour Field End Garden CSO 2019: 16 spills 65 hours Ball Lane CSO 2019: 25 spills 254 hours Mill Lane CSO 2019: 28 spills 273 hours Stonebridge Road CSO 2019: 5 spills 63 hours + 16 unmonitored CSOs
Great Stour lower GB107040019743	Fordwich Road CSO 2019: 12 spills 103 hours
Hiz incl Oughton GB105033037700	Hitchin CSO 2019: 52 spills 936 hours
Soham Lode aka Snail River GB105033042860	Soham CSO 2019: 27 spills 276 hours
Lark middle GB105033043051	Fornham All Saints CSO 2019: 52 spills 1202 hours
Wissey lower GB105033047630	Mundford CSO 2019: 56 spills 339 hours
Ingol GB105033053470	Ingol CSO 2019: 300 spills 295 hours
Burn GB105034055750	Burnham Market CSO 2019: 7 spills 60 hours
Glaven GB105034055780	Holt CSO 2019: 8 spills 88 hours
Laceby Beck GB104029067530	Laceby - Caister Road CSO 2019 55 spills 410 hours
Rase GB104029061870	Caister CSO. 2019: 107 spills 2001 hours (probs not impacting the chalk stream US of discharge)
Nettleby Beck (Caistor Canal Catchment) GB104029061920	Caister CSO. 2019: 107 spills 2001 hours (probs not impacting the chalk stream US of discharge)
Pocklington Beck incl Ridings Beck & Millington Beck GB104027063480	George St CSO 2019: 10 spills 4 hours
Goodmanholme Beck – incl in Foulness waterbody GB104026066690	Holme Road CSO 2019 87 spills / 569 hours

5.5.2 Storm overflow case study - the River Chess

The community-led ChessWatch project uses a sensor network as an engagement platform to raise public awareness of threats to the River Chess and to engage and include the public in the management and health of the river.

Funding for the initiative was provided by Thames Water together with the Centre for Public Engagement at Queen Mary University of London.

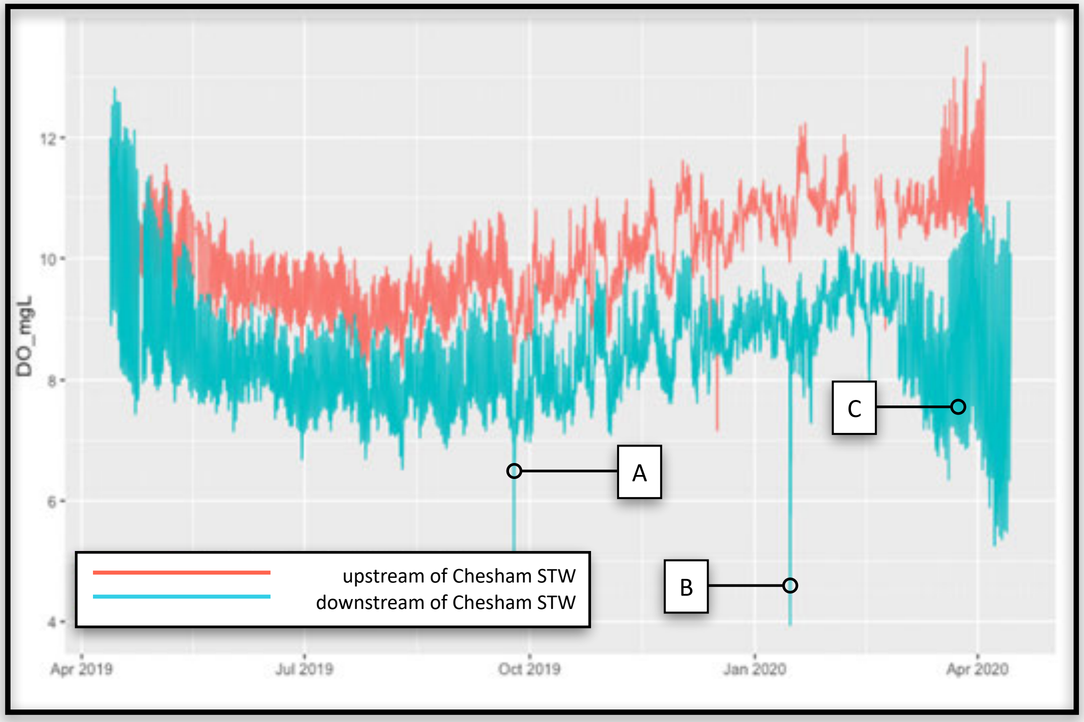
In 2019 four water-quality sensors were installed in the river to provide stakeholders with real-time water-quality data (15-minute intervals). The probes record water level, dissolved oxygen, pH temperature, turbidity, chlorophyll-a and tryptophan. The graph here shows preliminary results from the dissolved oxygen sensors.

From September 2019 to March 2020 five high-intensity rainfall events caused intermittent storm tank discharge to the river from Chesham STW. Our sensors show that not every storm tank discharge event has had the same effect on oxygen status, but some events (A and B) are characterised by a marked transient drop of 3 to 5 hours' duration in dissolved oxygen concentrations in the river.

C denotes a period during which groundwater levels were high and the sewage-treatment works was discharging excess flows from storm tanks due to groundwater ingress.

The gradual decline in oxygen concentrations at night during period C suggest that organic material settling on the riverbed is changing the river metabolism and enhancing respiration. Photosynthesis during the day enables oxygen levels to recover during daylight hours. The overall effect on ecology will depend on the duration of the repeated discharge.

The ChessWatch data indicates that there is a notable impact on oxygen levels from repeated storm tank discharges due to groundwater ingress.



Two parts of the River Chess running parallel, one clear and the other turbid with storm overflow discharge: this has been a regular sight since 2020, with the sewage works frequently overwhelmed by groundwater ingress and storm overflows.

5.7 Small sewer discharges (including septic tanks)

Septic tanks, cesspits and small sewage treatment plants are systems for collecting and treating domestic sewage in locations that do not have mains sewers. All systems must comply with the British Standards and Building Regulations in force at the time of installation and must meet the General Binding Rules (See Appendix G)

Sewage treatment plants

A small sewage treatment plant, also known as a 'package' plant, provides primary and secondary treatment. The primary treatment breaks the sewage down into gases, liquids and solids. The secondary treatment introduces air to the process, improving the quality of the effluent. Package plants should discharge effluent of a standard that allows it to be discharged either to a watercourse or to ground through a drainage field. This does not mean they will not add considerably to nutrient enrichment.

Septic tanks

Septic tanks break down sewage into gases, liquids, and solids. Gases are released through a vent, liquids overflow through an outlet into an infiltration system and any solids are left at the bottom of the tank. The solids which have settled in the tank need to be periodically emptied and disposed of.

The liquid created from the septic tank cannot be discharged into a watercourse and must go to ground via an infiltration system. A drainage field infiltration system is the only infiltration method that meets the GBRs.

Impacts on water quality

Septic tank effluent contains a wide variety of pollutants including pathogens, faecal bacteria, phosphorus (P), nitrogen (N), organic matter, suspended solids, household detergents and chemicals. When used and maintained properly small sewage treatment plants do their job well. However, septic tanks are not actively regulated or monitored by regulators, so in many cases, they may not be complying with the rules.

Septic tanks are a potentially significant source of nutrients to surface waters but few data exist in the UK to quantify their impact. Research by Withers, Jarvie and Stoate* showed that:

- nutrient emissions from septic tank systems affect water quality in rural areas;
- septic tank soakaways to impermeable soils failed to adequately treat the septic tank effluent;
- the downstream eutrophication impact of septic tank systems largely depends on stream discharge volumes;
- septic tank systems act as mini-point sources and need to be better managed in catchment-management planning.

There is a need for further investigation to identify septic tank hotspots in chalk stream catchments with action taken to improve their performance where pollution is identified.

Septic tanks must be maintained to ensure they do not cause pollution and that they meet the General Binding Rules. If they cannot meet the GBRs there are a number of options depending on the operator's situation, including:

- connecting to a mains sewer where available;
- if there are potential problems with the systems of more than one property in the area, the residents may be able to apply for first-time mains sewerage;
- replacing the septic tank with a package plant, to either meet the GBR or get an environmental permit.

Connecting to mains sewer

Sewerage undertakers have a duty to provide a public sewer under section 101A of the Water Industry Act 1991 (s101A), where certain criteria are met. These are that:

- the drainage of premises in a locality is giving rise, or is likely to give rise, to adverse effects on the environment or amenity;
- actual or likely adverse effects on the environment are from more than one building;
- the relevant premises are not currently connected to a public sewer;
- drainage of a premises is for 'domestic sewerage purposes': this includes the discharge of lavatories, water used for cooking and similar domestic activities, but it does not preclude non-residential buildings.

Applications under s101A are usually made by local residents or the relevant local council. The sewerage undertaker carries out an assessment of the application and decides whether they believe a duty exists to provide a public sewer connection under s101A. This assessment will take into account the comparative practicability and cost of alternative solutions.

The EA is responsible for the determination of appeals from first-time sewerage applicants who have been refused connection to the public sewers.

* 'Quantifying the impact of septic tank systems on eutrophication risk in rural headwaters' Environmental International, Vol. 37, April 2011

5.8 Integrated Wetlands - a cost-effective measure for polishing discharges from small STWs and other sources of pollution?

Integrated constructed wetlands (ICWs) may offer a cost-effective ‘polishing’ treatment and / or a staging-post to tertiary treatment at small, remote works which might currently not pass existing cost-benefit analysis (CBA) but, nevertheless have an ecological impact, especially on the undesignated and headwater chalk streams.

Richard Cooper et al* examined the nutrient-removal efficiency of two ICWs in Norfolk, on the River Ingol and the River Mun, 1-year and 5-years old respectively at the time of the study. Analysing water samples collected across the ICWs between February and September 2019, significant reductions in both effluent-nutrient concentration and load were recorded.

• Mean nutrient concentrations were reduced between inflow and outflow of the works by 34-62% for N and 27-64% for P, whilst nutrient loads were reduced by 56-72% for N and 58-69% for P.

• The higher nutrient-removal performance of the 5-year-old ICW indicated that the operational efficiency of ICWs increases over the early years of operation, with minimal maintenance required during this time.

• There is evidence to support the wider adoption of ICWs at smaller STWs that currently have no legal obligations to minimise effluent-nutrient concentrations through conventional treatment.

The overall conclusion was that ICWs may have a role to play in reducing nutrient load on smaller WWTP as an alternative to conventional tertiary wastewater treatment. While global studies show strong evidence that constructed wetlands in temperate regions remove total nitrogen and phosphorus, there is high variability in reported removal efficiency.

It is vital to contextualise the performance of ICWs relative to:

• the number of people linked to the works
• the size of the works (spatial area) and
• the size of the receiving stream
• the nature / natural capital of the land that is being proposed for construction of the ICW

In spite of good reductions through the works – River Mun total P reduced from 8.65 mg/l to 3.09 mg/l (-64.3%), total N from 60.7 mg/l to 23 mg/l (-62%) – nutrient levels remained high in both the Mun and Ingol. Instream total P and N reduced by approx 25% but at 1.57 mg/l and 17.9 mg/l remained well above levels needed to achieve ecological improvements. Harrington and McInnes** found that P removal is strongly correlated to functional area. The Mun site at 0.3 ha, serving 772 people is equivalent 2573 people/ha. The Ingol works, serving 6,056 people/ha is effectively 2.5 times smaller (the Ingol site area was designed primarily to address ammonia, not phosphorus). Biervalt et al*** conceded that the Mun site’s acreage was 'sub-optimal in comparison to the volume and nutrient concentrations to be treated’ comparing it to Glaslough ICW serving 800 people with 3.25 ha or 246 p/ha. The ratio of influent discharge / functional area of wetland of the Mun ICW was 237:1, and that of the Glaslough ICW was 32:1.

Water-quality experts on the CaBA CSRG expert panel have also highlighted that the performance of ICWs can reduce over time, that the sediment in the ICW can become saturated with P (and therefore act as a source not sump) and that preferential pathways develop-reducing water-residence time. ICWs require regular maintenance.

A cautious endorsement dependent on context

Agreeing a consensus position on wetlands among the expert panel was not easy. There was concern at the risk of wetlands being seized on as a quick, easy and cheap fix, when tertiary treatment would be better and / or when the ecological gain might well be marginal or even non-existent (see 5.3.4 nitrogen and phosphorus limitation).

Nevertheless, in the right context and *with due consideration of their limitations*, it was generally agreed that ICW’s may have a role to play in driving down nutrient levels in chalk streams where works are:

• remote from existing mains-drainage catchments
• attached to small agglomerations
• in rural areas with plenty of potentially available land
• unlikely to pass existing cost-benefit analysis

Page 76 is an example of the kind of setting where ICWs could potentially play a role in driving down bio-available P concentrations across a catchment.

* Assessing the environmental and economic efficacy of two integrated constructed wetlands at mitigating eutrophication risk from sewage effluent: Richard Cooper, Elizabeth Hawkins, Jake Locke, Terry Thomas and Jonah Tosney

** Harrington R, McInnes R (2009) Integrated constructed wetlands (ICW) For livestock wastewater management. Bioresource Technology 100:5498–5505

*** Can an Integrated Constructed Wetland in Norfolk Reduce Nutrient Concentrations and Promote In Situ Bird Species Richness? Olly van Biervliet & Robert J. McInnes & Jonathan Lewis-Phillips & Jonah Tosney

The River Stiffkey is in a self-contained catchment in Norfolk draining directly to the North Sea. Unlike on the River Wensum to the south, which is an SAC, there are no towns on the river. Existing CBA and statutory laws mean that 100% of the sewage works (STW) on the Wensum and 0% of those on the Stiffkey, treat to tertiary stage.

There are five STWs on the River Stiffkey, each serving small villages. The largest, Walsingham, has 800 inhabitants. WFD monthly data from the Great Snoring assessment point upstream of the STWs shows P levels peaking in the upper river in late winter, most likely driven by diffuse run-off, and average levels across the year under those required for High P status at 0.048 mg/l.

Downstream of four STWs at the Wighton assessment point, WFD monthly data shows higher P levels – generally 3x higher – peaking in the late summer, suggesting that the difference is driven by sewage discharges (which increase in concentration as flows diminish). Here and overall, the river is only at Moderate status for phosphate.

The River Stiffkey is a larger stream (greater dilution) than either the Ingol or Mun, with smaller sewage works (fewer people) and with lower background P levels (at least relative to the Ingol) from the river upstream of the five works. This is a speculative example, but through-works nutrient reductions of the order indicated by the literature* could – in this type of context – play a role in driving down nutrient concentrations towards a trigger point where a beneficial ecological impact is effected, either on their own, or more likely in combination with other measures to reduce overall nutrient loading and retention / cycling.

In conclusion ICWs may offer a cost-effective polishing treatment or staging post to full tertiary treatment on small, remote STWs which do not pass existing CBA. Context and design are key. This cautious endorsement in certain contexts should not be taken as a blanket endorsement or a reason to defer/avoid the investment necessary for conventional tertiary treatment when practicably possible.

Other applications

ICWs may also have a role to play in applications beyond small STWs, for example in polishing / treating discharges from aquaculture, road run-off or septic tank catchments. The appropriate design, scale and type of ICW is site and application specific. Bespoke and expert design are key.

* How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? A systematic review. Land et al, Environmental Evidence volume **5**, Article number: 9 (2016)

* A Review of Phosphorus Removal Technologies and Their Applicability to Small-Scale Domestic Wastewater Treatment Systems. Bunce et al, Frontiers in Environmental Science, Vol 6, (2018)

5.8.1 Using wetlands to tackle storm overflows

Each winter, at Hanging Langford on the River Wylye, the water table inundates the sewerage system. Historically, the Environment Agency (EA) had allowed Wessex Water, under emergency powers, to pump out the sewerage to the River Wylye. This is known as a groundwater ingress storm overflow. This was not an officially permitted arrangement. Nor was it sustainable.

A new groundwater land-drainage scheme would have been prohibitively expensive. Similarly, upsizing the sewer network's capacity and pumping to the downstream sewage works would also have been an expensive and a less sustainable solution (loss of flow). The most cost-effective and pragmatic solution involved an innovative intermittent treatment using a wetland.

Once Wessex Water had ensured that its sewerage system was sealed as far as practicable, the EA agreed to permit a pumped, screened overflow for periods when groundwater ingress was liable to cause property flooding. Wessex Water provided a reed bed adjacent to one of the nature reserve lakes to treat the storm flows prior to discharge to the River Wylye.

The storm reed bed, constructed in 2010, covers an area of 2000m². For most of the year it is kept wet using water from the adjacent lake. The bacteriological impact of the storm overflow on the River Wylye for the few days it is utilised each year is imperceptible.

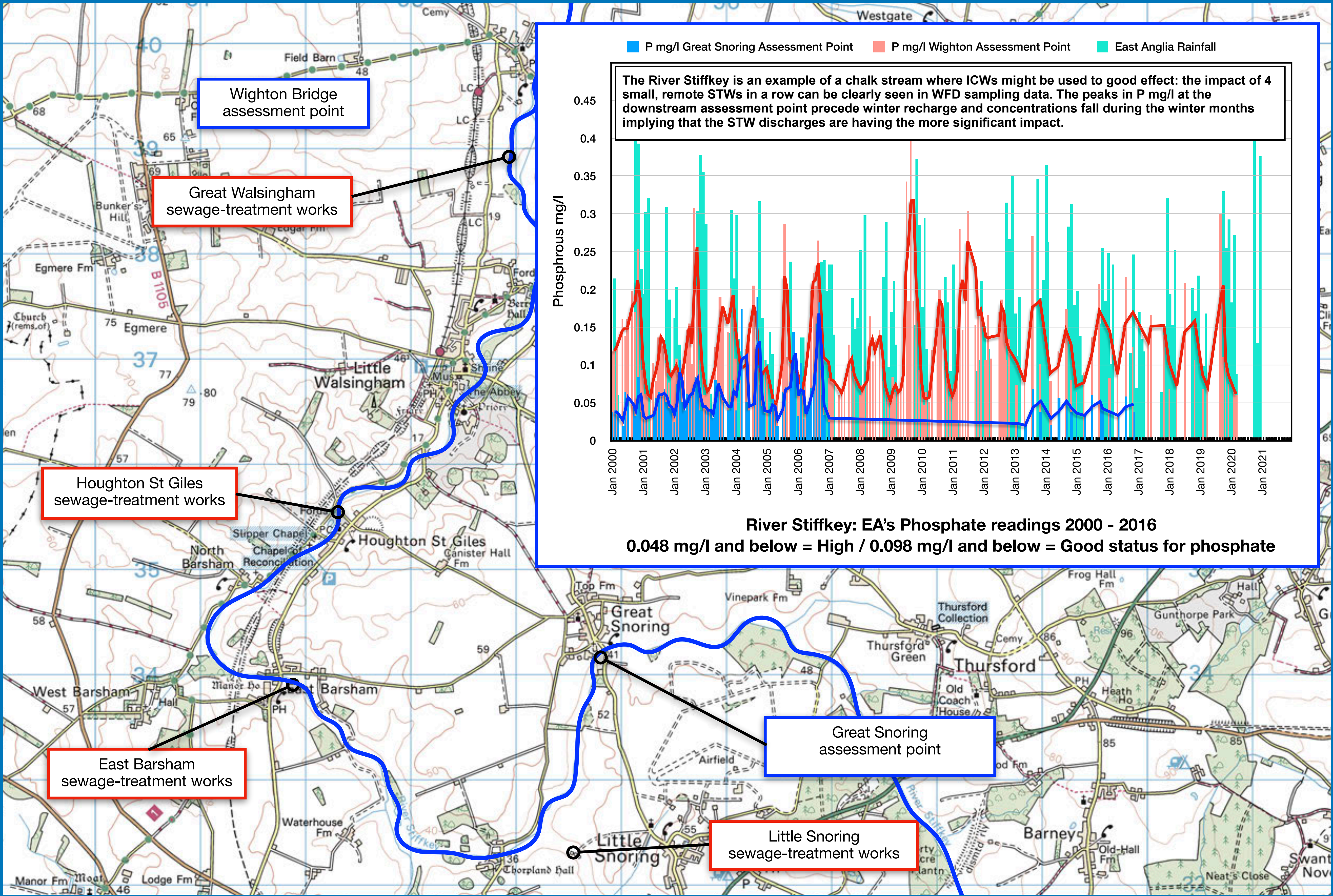
Sample sets were taken from the river upstream and downstream of the discharge point, and also of the treated flows from the reed bed. The river consistently shows higher bacteriological counts – both upstream and downstream – than are found in the reed bed effluent.

Wessex Water now works closely with Wiltshire Wildlife Trust to manage the reed bed, which provides a valuable habitat for a range of species such as dragonflies and warblers.

Where the STWs are small and there is available space, as at Hanging Langford, wetlands may have a role to play as one in a suite of measures addressed at driving down nutrient levels at the catchment scale.

Reviewing options

Appropriate options for treating storm overflows should be articulated through water company Drainage and Wastewater Management Plans (DWMPs) and the storm overflow assessment framework investigations.



P mg/l Great Snoring Assessment Point
P mg/l Wighton Assessment Point
East Anglia Rainfall
The River Stiffkey is an example of a chalk stream where ICWs might be used to good effect: the impact of 4 small, remote STWs in a row can be clearly seen in WFD sampling data. The peaks in P mg/l at the downstream assessment point precede winter recharge and concentrations fall during the winter months implying that the STW discharges are having the more significant impact.
Phosphrous mg/l
River Stiffkey: EA's Phosphate readings 2000 - 2016
0.048 mg/l and below = High / 0.098 mg/l and below = Good status for phosphate
Wighton Bridge assessment point
Great Walsingham sewage-treatment works
Houghton St Giles sewage-treatment works
East Barsham sewage-treatment works
Great Snoring assessment point
Little Snoring sewage-treatment works

5.9 Reducing diffuse sediment pollution from farmland to chalk streams and aquifers

5.9.1 Case study - diffuse pollution on a Norfolk chalk stream

A geomorphological appraisal of the River Nar made by English Nature in 2006 showed that sediment washing into the stream from the wider catchment was a significant problem on the River Nar, a chalk stream surrounded by arable, sugar beet and pig-rearing farmland in Norfolk.

The report revealed that – coupled with the historic canalisation of the river and a reduction in flows caused by abstraction – sediment pollution was having a considerable impact on the ecology of the river, smothering the substrate of the river bed and harming the plant, fish and insect communities.

The audit found that fine sediment mostly derived from:

- **arable fields –** especially when they are recently ploughed
- **pig units –** especially on steep land, close to the river
- **road-side verges –** especially when they are crushed each winter by farm vehicles too large for the roads they are driven down: this is a worsening problem
- **dirt tracks –** especially where these join up with the road network or run directly to the river

And enters the river via:

- **road crossings –** where road drains discharge into the river
- **footpaths, tracks and fords –** where they cross the river
- **intersections –** where the dry valley network meets the main river
- **drains and ditches –** especially in the headwaters

The floodplain of the upper Nar is characterised by low-intensity land use, which would ordinarily buffer the river against fine sediment run-off within the wider catchment. Points of ingress therefore were quite localised, though the area of origin may be broad.

The audit recommended that the issue of fine sediment pollution should be tackled strategically:

- **in the river –** dealing with the sediment once it is in the river – restoring connectivity
- **at the points of entry –** by identifying and dealing with the points of ingress
- **in the wider landscape –** encouraging catchment-sensitive land use so as to lessen the amount of soil lost to erosion in the first place

5.9.2 Farming rules for water

Farming rules for water were introduced in 2018 as a 'first step towards a new approach to regulating the agricultural sector that might be adapted more widely in the future with rules that are outcome focused and risk based'.

The intention was to create a clear and simple set of rules designed to help farmers optimise their use of manures and soils whilst also protecting the environment.

The rules address and govern various farm activities including:

- compulsory assessment of soil nutrient levels every five years
- the storage of manures and fertilisers away from springs and rivers
- the application of manures and fertiliser in wet weather
- the application of manures and fertilisers near springs and rivers
- reasonable efforts to control soil erosion
- the siting of livestock feeders near springs and rivers

In terms of enforcing compliance, the rules are advice-led, with enforcement 'proportionate and fair with the emphasis on working with farmers to achieve compliance'.

A challenging, evasive problem

Anyone who works intimately with chalk streams will know that agricultural run-off is a vast and shape-shifting problem. The run-off from one open-air pig or maize field can bring vast quantities of sediment into a chalk stream (eg. a rate of delivery from a pig unit in Nar catchment recorded at over one ton every 10-mins during a 30-minute storm event on the 28.9.2004. See River Nar Fluvial Audit). In addition, farmers have to earn a living in a challenging market-place and will change practice if and when market forces or subsidies dictate, meaning that a run-off problem solved today might very easily be unsolved tomorrow.

In this sense, making basic payment contingent on a simple set of rules was a good first step. But three years on any drive through chalk country in February will show that agricultural run-off is still a vast problem, with compliance conspicuously patchy. Evidence from Natural England and EA assessments (eg. Poole Harbour catchments) suggest a very low level of compliance. This bothers many farmers as much as anyone. It is irksome to follow rules in a competitive market place only to find a neighbour gaining advantage by not bothering and not being reprimanded either.

Effective regulation and enforcement are vital if either rules or incentives are to make a difference. Indeed, Defra advice to an EA proposal to set up a Water Protection Zone in the Axe SAC catchment was that regulatory compliance was a pre-requisite.

5.9.3 New sustainable farm incentive: recommended farming rules for chalk streams

In compiling this report, we canvassed a number of farmers in Dorset and Norfolk, all of whom expressed a desire for simple rules that are easy to follow and do not adversely impact the economic viability of the farm, but also that the basic rules should go further in protecting rivers, should be compulsory (because incentives are never high enough to compete with the most profitable and destructive forms of farming) and should be visibly enforced, because one or two high-profile cases will bring about compliance more effectively than any number of advice-led consultations.

These farmers offered the following simple principles for sloped land in chalk catchments, all of which are easy to do and none of which threaten the economic viability of the farm. These ideas are in sympathy with those being discussed by Defra for ELM and Sustainable Farm Incentive (SFI). CaBA CSRG strongly urges their adoption in chalk-stream catchments.

- **for 'destructive' but highly profitable farming such as outdoor pigs, carrots, parsnips, beet, maize, asparagus and potatoes – there should be a compulsory 20-metre buffer around the perimeter of the field**
- **for other arable crops there should be a 10-metre buffer**
- **there should be no ploughing within a 25-metre radius of field gateways**
- **there should be no gateways at the downhill edge or corner of any given field**
- **the plough should always be turned across the downhill corner and or edge of sloped fields**
- **there should be no crop-lifting after the end of October**
- **advisory zero-till, but as a minimum there should be over-winter cover crops to protect the soil**
- **the lethal effects on aquatic invertebrates of veterinary anthelmintic residues in manures suggest all wormer-treated livestock should be kept on level pastures, well removed from watercourses and unable to drain into them**

The new SFI should be contingent on compliance with the above. The following could also apply as incentives:

- **zero till**
- **green swales runnings through field dips**
- **settlement ponds**
- **restoration of hedges, especially those running perpendicular to slope**

February 2019: three years on from the introduction of farming rules for water and sediment run-off to watercourses remains a widespread problem in chalk catchments.

5.10 Aquaculture - potential impacts of fish and salad farming / processing

The cool, filtered water of the chalk aquifer water is a valuable resource in aquaculture, in watercress- and fish-farming and more recently in salad washing. Salad and fish farms tend to be located in the upper reaches of chalk-stream catchments, taking advantage of the high-quality aquifer water, which is then discharged back into the river after use.

The quantity and quality of the effluents from salad and fish farms differs between production systems and is affected by various treatment processes prior to discharge. However, the primary pressures exerted by aquaculture on natural chalk-stream systems are:

- altered hydrological regimes
- elevated levels of suspended solids
- nutrient enrichment
- release of chemicals

Hydrology

Both watercress and fish farms depend on abstracted water. Watercress farms tend to rely on groundwater springs or artesian boreholes, whereas fish farms generally – but not always – abstract directly from the river. Some fish farms are also sited on springs, sometimes in old cress beds.

The drawdown effect of groundwater abstraction can impact the local water balance and groundwater level, affecting localised flow regimes in the river, potentially reducing flow upstream of the farm (where groundwater levels may be repressed) or conversely providing a form of flow augmentation via discharges downstream of the farm, with the concomitant benefits and disadvantages of any form of flow support where the natural hydrological regime is altered. Unnatural changes to the flow regime can adversely impact water temperature, sedimentation, waste degradation rates, scour, and flow cues for migratory fish.

Sedimentation

The routine cleansing of watercress beds can result in high and sporadic in-river suspended solid concentrations. Elevated levels of suspended solids are also present in fish-farm discharges, deriving from uneaten feed, fish faeces and excreta.

Healthy freshwater ecosystems require sediment inputs to maintain habitat and nutrient fluxes, but excessive loading can have a significant impact on river ecosystem function. The main physical effects are a reduction in habitat availability and the modification of habitat biogeochemical conditions. As silt accumulates in river gravels, the survival of both invertebrate and fish eggs and juvenile fish declines due to lack of interstitial water flow and consequent reductions in dissolved oxygen. Sediment suspended in the water column can also cause sublethal effects from turbidity and direct physical damage, particularly to fish species.

Nutrient enrichment

Chalk-river water naturally contains very low background levels of phosphorus, one of the nutrients essential for plant growth. In cress farming – as in many other forms of plant farming – additional phosphate is applied to increase the size of the crop and the rate of growth. Not all of the phosphate will be used by the crop and so the discharge from cress farms may contain elevated levels of phosphate. Fish farm effluent also contains excess nutrients from fish faeces and uneaten feed.

The Environment Agency has calculated that, using mean flow data and the long-term soluble reactive phosphorus (biologically available) average for the River Itchen, watercress beds contribute 5.4% and fish farms 3.2% of the total SRP load in the river (Natural England commissioned report NECR027 p.16). This figure is based on current monthly monitoring which, as the graph below highlights, may potentially under-represent the true load. Unnatural amounts of nutrients entering watercourses can have a significant impact on the ecology of the stream. See section 5.3 Nutrient enrichment.

Chemical releases

A number of chemicals are used or released in routine aquaculture processes, notably the salad washing. These can occasionally have lethal impacts on the fauna – especially invertebrates – in a chalk stream. But even when sub-lethal there may be a significant impact on wildlife from chronic, low-level and cumulative exposure to combinations of different pesticides and chemicals from discharges.

For example, there is concern about the exposure of fish and invertebrates to phenethyl isothiocyanate (PEITC). PEITC is produced by watercress in response to physical damage, it can be released from watercress farming via irrigation water following disturbances such as harvesting and other crop-damaging activities or via the discharge of salad wash effluent from the rinsing of watercress. PEITC has been shown to have toxic effects on macro-invertebrates and the early life stages of brown trout.

A variety of chemicals is routinely used in fish farms, from water treatments, to drugs that control disease or increase production. Research has shown that only a proportion of the chemical loading of antibiotics, for example, is taken up by the fish while the remaining 70-80% is transmitted to the environment. The impacts of such effluents are largely unknown, particularly regarding sublethal, cumulative effects of chemical mixtures on freshwater biota, or the risks of shared anti-microbial resistance. Veterinary medicines are not currently included on permits.

Policy

In 2012 for the first time the EA set limits – in the Itchen SAC catchment – to the level of phosphates permitted in discharges from watercress farms. However, thus far these limits apply only to a dozen cress farms in the Itchen catchment, primarily because of its SAC status. Section 5.3 makes a clear case for the need to reduce P concentrations in chalk streams as far as possible towards natural and that every reduction is a further positive step towards this evidentially desirable goal.

Notwithstanding the successful contribution to P loading that these limits have had on the Itchen, the revised permits are based on an annual average limit for P, which still may not be sufficient to protect the environment. Research presented in the graph below (commissioned by S&TC) shows P concentrations orders of magnitude higher than the average limit, and significantly higher than the EA monthly spot samples. The impact these peaks and fluctuations have on chalk stream ecology is not currently known.

In 2018 S&TC also raised concerns with the EA over the potential impact of pesticides discharged from a salad washing factory in the headwaters of the River Itchen. The EA's follow-up investigation showed that traces of pesticide, including the neonicotinoid acetamiprid, were being washed from salads into the river. The site has now closed.

There had been no monitoring requirements for pesticides because it is currently the permit holder's responsibility to notify the EA of any potentially hazardous chemicals in their discharge. In this instance, self-policing was inadequate.

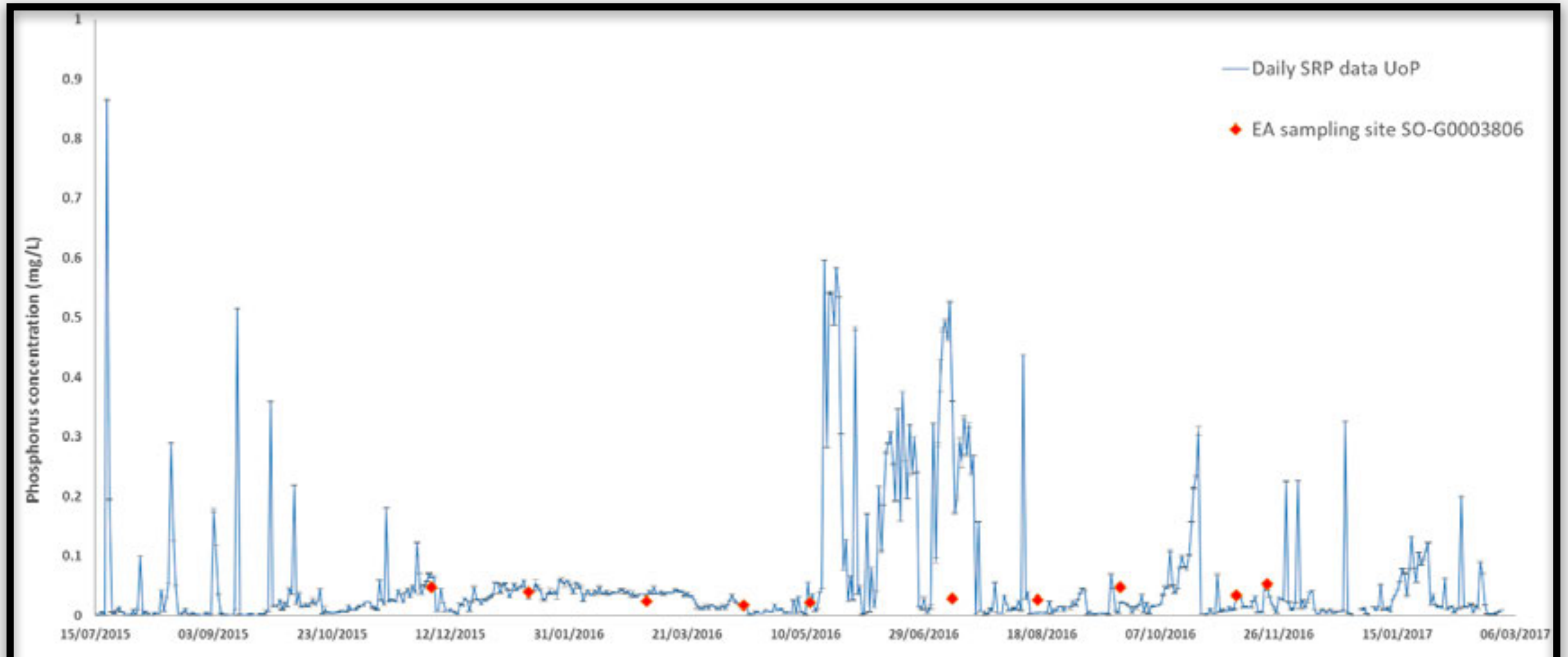
Recommendations for action:

• the EA should work with relevant trade associations to provide updated technical guidance notes for cress and fish farming and review its existing permitting practice to ensure it adequately protects the ecology of the receiving chalk streams

• this review should include consideration of monthly and annual limits to phosphate, other nutrient and sediment discharges, taking into account the potential cumulative impacts

• permits and licences need to be in sufficient technical detail for the receiving waters to be protected from damage at all times and enforced through random monitoring to ensure compliance

• research should be undertaken into the potential cumulative impacts of peaks and fluctuations in the discharge of nutrient, chemical and sediment from aquaculture



Instream daily soluble reactive phosphate (SRP) data and EA spot sample data from 15/07/2015 - 06/03/2017 on the river Itchen.

The River Wensum is impounded along the majority of its upper course: in terms of processing sediment the river is almost completely disabled. Sediment run-off and the morphological condition of the channel are two halves of the same problem.

5.11 A strategic approach to reducing pollution in chalk streams

Siltation and nutrient enrichment are significant water-quality issues affecting chalk stream ecological health. However, although the *range* of issues is common to most chalk streams, the comparative levels of impact vary from river to river.

In undesignated, suburban rivers close to London the nutrient enrichment from large sewage-treatment works is likely to be a comparatively more significant issue than agricultural run-off. On the other hand, on a designated rural chalk stream where the sewage-treatment works have benefited from a lot of investment, then agricultural run-off is likely to be the more significant problem. On a mixed-geology chalk stream where background levels of phosphorus are already higher than in purer-geology chalk streams, and where there is more surface and sub-surface run-off, farming as well as septic tanks are likely to have a comparatively larger impact than in pure-geology chalk streams.

It is also important to remember that sediment *supply* and sediment *retention* are two parts of the same problem. The negative ecological impacts caused by diffuse sediment pollution largely depend on the sediment remaining in the river. This it does to a greater extent in an impounded, dredged and canalised channel, than in a channel with a natural, gradient and flood-plain connectivity. For example on the River Wensum – the worst-performing river in the S&TC's fly census – out of a total fall of 34 metres from upstream of Sculthorpe Mill to Hellesdon Mill, 60% of that fall occurs at 14 mill structures. Almost 70% of the river is impounded by mills. Most of the river has been dredged and there are léeves along most of both banks. In terms of processing its sediment load, the River Wensum is almost completely disabled. Therefore, efforts to reduce diffuse pollution and sediment supply must go hand-in-hand with efforts to reduce or control its retention, through river-morphology restoration.

With regard to STWs and other point-source supplies, the WFD evidence suggests that on the numerous chalk streams still impacted by STWs which do not strip P, the national programme of P stripping must continue into the headwaters of these rivers and at the smaller works at which the existing statutory driver does not currently compel the investment needed.

In purely ecological terms, there is much to be gained now by focusing on the uppermost parts of a given chalk stream and working downstream. Over the last twenty years total point-source P has been drastically reduced, but mostly on protected rivers or from large works which tend to be quite far down a given catchment. This has left many smaller and headwater chalk streams behind.

5.12 Water quality: recommendations for action.

1. Sewage-treatment works that do not strip phosphorus	CaBA CSRG recommends the EA reviews the status the sewage-treatment works on all chalk-stream waterbodies that are at poor, moderate or bad status for phosphorus, and prioritises and timetables remediation via WINEP. Tighter phosphorus limits should be considered for designated priority habitat.
2. Integrated constructed wetlands	Notwithstanding changes to CBA (See Action2 under integrated recommendations) CaBA CSRG endorses the use of integrated constructed wetlands (ICW) at small, remote works where conventional treatment is too difficult or expensive and of catchment-scale nutrient-reduction strategies so that the benefits afforded by nature-based solutions (such as ICWs) can be maximised whilst ensuring that ecological targets are met using STW upgrades where necessary.
3. Waterbody boundaries and assessment points	As with water quantity recommendation 4, the Environment Agency should set and publish a timetabled undertaking to review all chalk stream WFD waterbody assessment points and boundaries to ensure that they provide adequate means of assessing and protecting chalk-stream health.
4. Storm overflows	CaBA CSRG recommends all necessary actions be taken to achieve significant reductions in the frequency and volume of overflows to chalk streams to ensure they are adequately protected from ecological harm and that their iconic status be recognised, including adoption of the findings of the storm overflow taskforce
5. Groundwater ingress at small works	CaBA CSRG recommends an investigation of the practicability of using ICWs as a cost-effective measure to mitigate the impacts of storm overflows caused by groundwater ingress into the sewer network. With a view to the limitations of ICWs ref size of works and spatial area of available land, this is likely to relate to smaller works in rural settings.
6. Septic tank hot-spots	CaBA CSRG recommends a review of SAGIS and / or a programme of research to identify septic tank 'hot-spots' in chalk stream catchments and based on evidence of harm a pilot trial of monitoring and policing poor septic tank performance.
7. Septic tank point of sale	CaBA CSRG recommends a law that requires homeowners at point of sale to register and bring septic tanks up to standard.
8. Farming rules for chalk streams	CaBA CSRG recommends that the compulsory rules for farming in chalk stream catchments set out in section 5.9.3 be adopted into the new Sustainable Farming Incentive (SFI).
9. Farming incentives for chalk streams	CaBA CSRG recommends that new ELM incentive schemes beyond SFI be structured so as to enable changes to habitat restoration at the catchment scale, taking critical land areas out of production, prioritising the restoration of headwater, spring-line fens and flushes, riparian zones and large tracts of floodplain.
10. Highways	Roads are the primary pathway of sediment to chalk streams from their catchments and therefore roadside drainage grips should not feed directly into chalk streams or unplugged drains which feed into chalk streams. Highways Agency standard practice for construction / maintenance of roadside grips that discharge run-off to chalk streams must either: discharge to plugged ditches or to settlement areas.
11. Aquaculture	EA to work with relevant trade associations to provide updated technical guidance notes for cress and fish farming and also to review permitting approach.

6. Physical habitat: restoring process

6. Physical habitat quality

6.1 River restoration

Restoring high-quality physical habitat to the chalk stream is fundamental to realising the full potential of any other improvements made in flow and water quality. Habitat quality is where all elements of a good restoration strategy come together.

And yet, while it is relatively easy to appreciate that an unnaturally depleted, dry or heavily polluted river is in a poor state, it is much more challenging to read a river and interpret what is wrong with it physically. It is all too easy to prescribe 'restoration' that only makes the problems worse. A classic version of this is structures that further impound an already impounded stream – imported gravel bars usually – inadvertently adding to, rather than subtracting from, problems associated with sediment retention.

Good-quality river restoration requires a resolved understanding of what one is trying to restore, informed by a knowledge of the history of the river and the processes which have shaped and continue to shape it.

Scale is key. Even if projects are carried out on an opportunistic basis at the reach scale – as is so often the case, because that is simply how these things come about – it is much better if these projects can tie in to an overarching strategy and vision. But this has hardly been possible until recently. Funding streams have been so small and intermittent that restoration work has often depended on the passionate efforts of individuals who have had no opportunity to consider the catchment scale.

This CaBA Chalk Stream Restoration Strategy represents a great opportunity on the chalk streams to drive restoration towards that catchment-scale vision and to make a strong case for restoring the fundamental thing that has been removed from chalk streams over centuries of physical modification: **process**. The capacity for the river and the ecological elements within it, to operate naturally.

Because they are such gentle rivers, chalk streams are uniquely vulnerable to physical modification and to the consequent de-coupling of process, to becoming imprisoned by whatever we do to them. It is vital that river restoration avoids becoming just another layer of anthropogenic imposition, further or differently imprisoning what should be a dynamic system. A good restoration strategy outlines and then delivers whatever it takes to let the river be a river.

6.2 Defining the reference conditions of a natural chalk stream

The paper 'Defining reference conditions for chalk streams' (see Appendix A) attempts to identify key features of the natural chalk stream.

Studies of post-glacial chalk streams in Dorset and Hampshire point to relatively wide, shallow river-channels and a complex mosaic of wet, open woodland in the riparian zone. A review of studies focusing on semi-natural, groundwater-dominated streams, describes the features listed in the table opposite.

The key ideas in terms of helping to visualise the natural chalk stream are:

• the high width-to-depth ratio and relatively shallow channel

• the long duration of bank-full flows, creating a high water-table and an open wet-woodland / herbaceous riparian zone

• the importance of in-stream plant communities in shaping complex dynamics of flow and scour

• the duration time and importance of fallen trees in shaping the mosaic of habitats in the chalk stream channels and the floodplain

Wide, shallow and sinuous

The high width-to-depth ratio of chalk streams correlates with relatively unmodified spring-fed streams globally, in New Zealand, and North and South America. Groundwater streams, wherever they are, tend to be distinguished by relatively equable flow regimes. The flow regime on its own favours the development of instream plant communities (they do not get blown out in floods) but spring-fed streams in general and chalk streams in particular, tend to be fertile, mineral-rich streams whose lush plants pack out the flow and hold up water levels as flows diminish through the summer.

Calcareous spring-fed streams (chalk and the more globally widespread limestone) also tend to develop a concrete-like tufa on the bed of the river which, along with bed materials made of glacial deposits of flinty gravels, means that the river beds are relatively much more resistant to erosion than the banks: hence the limited development of gravel bars (riffles) compared to higher-energy rivers.

The long time duration of bank-full flows, shored up by macrophyte growth, combined with the relative armouring of the bed, means that chalk streams, of definitively low erosive power, will erode their banks more than their beds: this of course becomes a self-defining morphology, because as the banks widen the stream power lessens.

Key features of the natural chalk stream

• low drainage density / limited tributary network

• low stream power relative to catchment area

• relatively high width-to-depth ratios ie. shallow and wide channel cross-sections

• a mix of single, meandering channels with side channels and in lower reaches, anastomosed multiple channels

• limited in-channel coarse sediment storage (bars or "riffles")

• high residence time of large organic matter (woody debris)

• presence of woody debris islands but few debris dams

• high-floodplain water tables leading to organic-rich floodplain soils

• low rates of lateral channel adjustment

• limited accumulation of fine sediments on bed surface in undisturbed catchments

• tufa deposition and concretion of gravels at points of groundwater upwelling

• long duration of bank-full / out-of-bank flows

• high density of aquatic macrophytes that facilitate flushing of fines

• relatively open woodland with dominance of herbaceous plants due to high-floodplain water tables

• marsh habitat with open groundwater pools in floodplain where strong coupling with groundwater is evident

• winterbourne, ephemeral reaches which dry naturally, usually in the summer, as the groundwater level and therefore the saturated zone of the valley recedes

Even within the range of chalk stream types this varies considerably, with the more energetic, mixed-geology streams like the Frome, lower Nadder and upper Avon being relatively more deeply incised, with more prominent riffle-to-pool sequences, especially notable in the headwaters. Moreover, the make-up of the floodplain material will also help to define the width-to-depth ratio: clayish / silty material being more resistant to erosion than sandy / loamy material.

The importance of trees

This characteristic suite of high, bank-full flows and low stream power, means that in chalk streams the long residence time of large woody material (when a tree falls in it tends to stay there and if that tree is an oak, it will stay for a very long time) is the most significant factor in determining and ensuring a varied physical habitat. A tree fall will catalyse a whole sequence of channel adjustments: pushing the river's flow down into the river bed or into the bank, throwing up bars of gravel.

The episodic, but continual cycling of fallen trees interacting with the flowing river will, over time, lead to a varied and complex morphology.

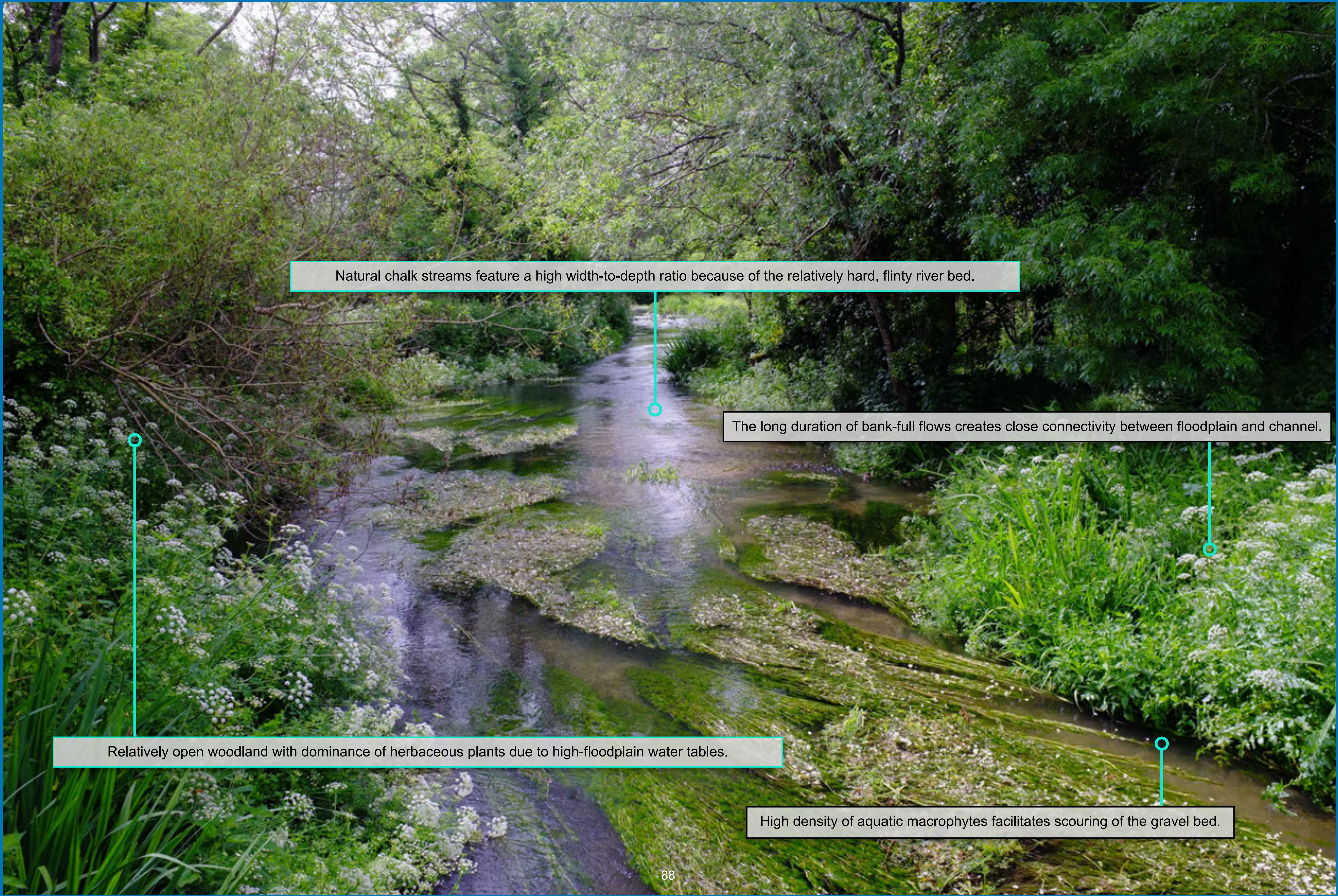
Once upon a time, of course, beavers contributed greatly to this cycling of woody material and process.

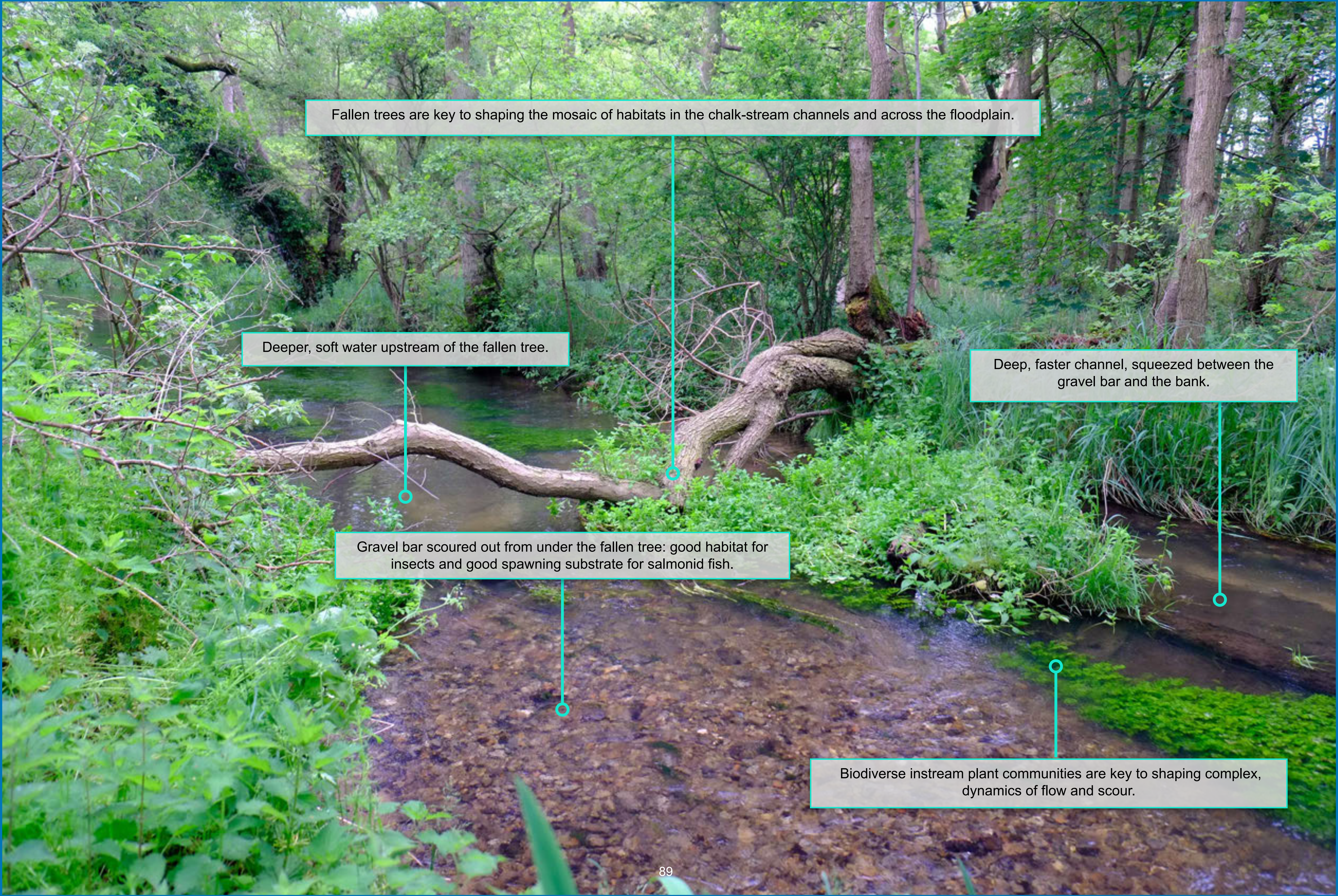
Inherited morphology

Another key point is the concept of the inherited morphology. Stream power in some way determines the capacity of a river to restore itself, once modified. Put simply, it does not take long (in the scheme of things) for an energetic, upland river to erase the hand of man, and it would be almost impossible to so corral the power of the river as to incapacitate its natural processes.

This is not true of chalk streams: they are such benign rivers that once modified (and almost all have been modified) they more or less stay modified. In terms of the impact of dredging, for example, where the bed substrate has been removed and there is no replacement supply, it would quite literally take another ice-age to re-set the clock and allow chalk streams to evolve to their natural state once again. In terms of riverine process, everything happens in slow motion on a chalk stream: the complex habitat evolves over centuries, not years or months.

This raises some vitally important issues and challenges when it comes to river restoration and suggests that in order to avoid 'restoration' becoming the imposition of just another state of modification, the thing one must most concentrate on restoring is the chalk stream's capacity for process.


Natural chalk streams feature a high width-to-depth ratio because of the relatively hard, flinty river bed.
The long duration of bank-full flows creates close connectivity between floodplain and channel.
Relatively open woodland with dominance of herbaceous plants due to high-floodplain water tables.
High density of aquatic macrophytes facilitates scouring of the gravel bed.


Fallen trees are key to shaping the mosaic of habitats in the chalk-stream channels and across the floodplain.
Deeper, soft water upstream of the fallen tree.
Deep, faster channel, squeezed between the gravel bar and the bank.
Gravel bar scoured out from under the fallen tree: good habitat for insects and good spawning substrate for salmonid fish.
Biodiverse instream plant communities are key to shaping complex, dynamics of flow and scour.

6.3 A Brief history of modifications to chalk streams

6.3.1 Early human history 3000 BC to 900 AD

If the natural chalk stream was a wide, shallow, sinuous and braided river system, threading through a mosaic of wet woodland and park-like grassland, then we started to change all that as long as 6000 years ago.

In Britain, deliberate tree-felling began before widespread farming and domestication. Evidence of the early impact of humans, in the pollen, mollusc fossil record and the stratigraphy of our floodplains – the tilling, soil erosion and the slumping / accretion of soil at the base of slopes and in gullies – shows that there was an increase in forest clearance from the late Neolithic onwards. Large-scale, longer-term agricultural clearings and land division accelerated in the Middle Bronze Age as the populations of people and livestock increased.

Throughout later prehistory, into the Iron Age and the Roman occupation, settlement and industry were focused in river catchments, with forest clearance and regeneration intensively managed for charcoal production and iron smelting. Despite the retreat of the Roman administration, pollen evidence shows little diminishment in the intense use of land in the Early Medieval period. With the introduction of the heavy plough and the the increase of water-milling, from the 5th century onwards our chalk streams and their floodplains and surrounding valley sides gained little reprieve from human modification and exploitation.

6.3.2 Mills

Most significant were the mills: by the time William-the-Conqueror invaded there were 5,600 watermills in England, and most were on the malleable chalk-streams. Unlike the Norse mills in the north – built to the sides of the main river, fed by leats with mill wheels horizontal with the current – the chalk-stream mills were ‘Roman’. These mills feature a vertical mill wheel which is turned through gears to the horizontal milling stone. Their efficiency is proportional to the extent to which they obstruct and impound the flow.

Mills were constructed towards the edges of the floodplain and fed by leats: diversions which carried the flow from the centre line of the valley along a much shallower contour line at the edge of the floodplain, until enough of a height difference had been established to turn the wheel, either as an under-shot, a breast-shot or and over-shot mill-wheel. Natural river channels flowing along the valley floor were generally retained as relief channels, with water-control structures at the diversion of the leat. Once the water had dropped across the face of the mill wheel it flowed via the mill race back to the natural channel. Or on down the next mill leat.

The linear length of valley needed to build up the head to drive the mill – defined by the valley gradient – defined the spacing of the mills, but most chalk streams were at mill saturation point by the time William audited his new Kingdom in 1086.

Over the centuries mills were adapted again and again, from flour to flax to paper, electricity, cardboard, wire, grinding whalebones and all sorts of light industrial uses. Generally, they remained in use until the middle of the twentieth century, but their legacy of modified channels is almost more significant now that they are no longer in use. The relief channels that were the relics of the original river are generally lost, filled in, disused. The mill leats have tended to become the primary mapped river, and the millboards are very rarely lifted nowadays, meaning that the impounding impact of the mills has been fixed into the river morphology and the mill leats have become repositories for accumulated, nutrient-soaked, sediment.

6.3.3 Locks and barges

Chalk streams have even be used for commercial transport, first by the Romans and then busily from the Middle Ages onwards. On the River Nar, for example, crude flashlocks were constructed so that the canalised stream could be used to float barges laden with stone upstream and down, to be used in the construction of all the abbeys and priories.

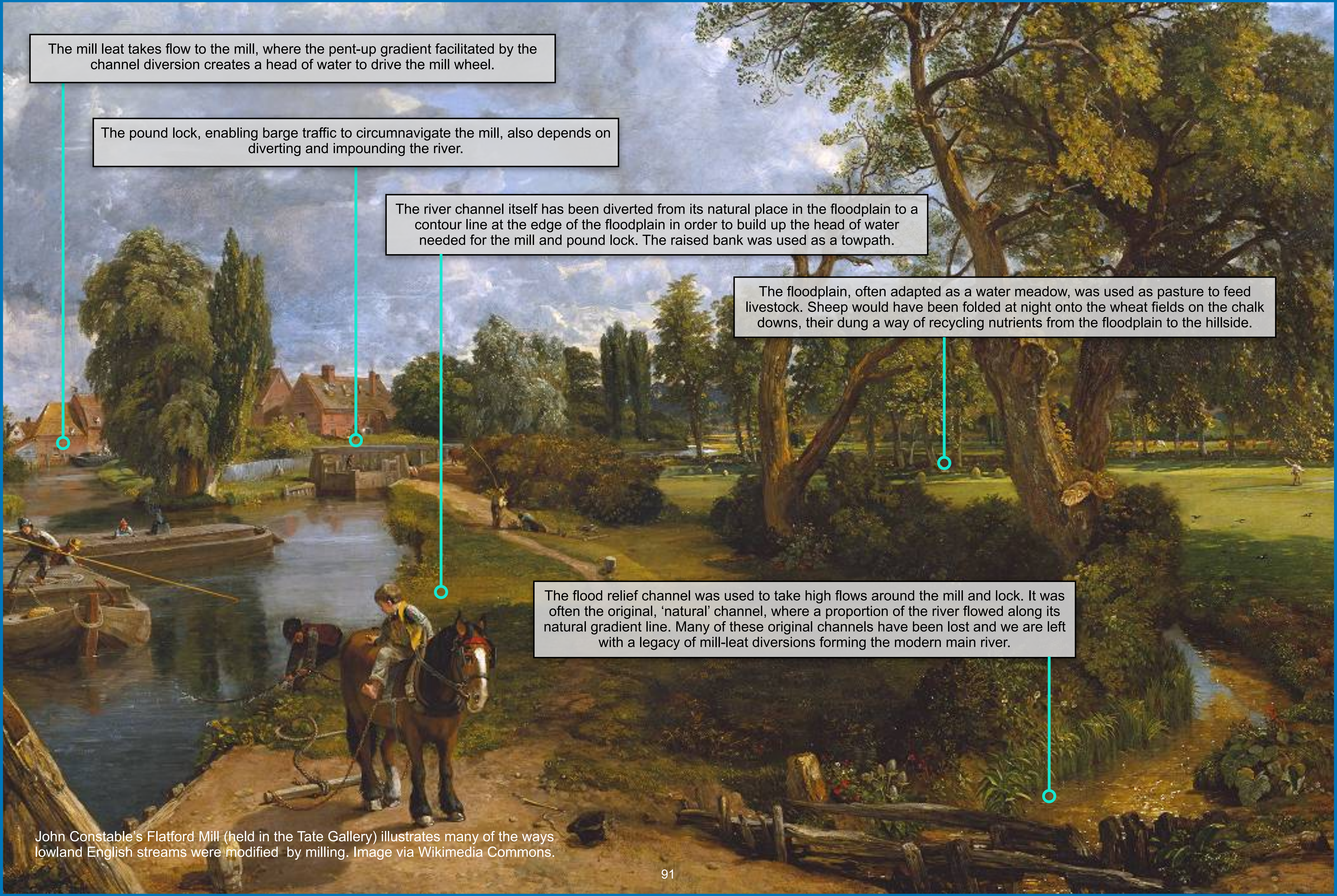
A flash lock is a crude opening in an impounded wall: the barge will ride downstream on the flood, or be pulled upstream, lock by lock. Flash locks were unpopular with millers, however, given it might take a day to restore the head of water.

Pound locks were better, locking the elevator of water between two pairs of gates, exactly as used on canals today. Pound locks came to England circa 1560. From then on they turned our lowland rivers into invaluable means of transporting goods, and in this role were not superseded until the railways.

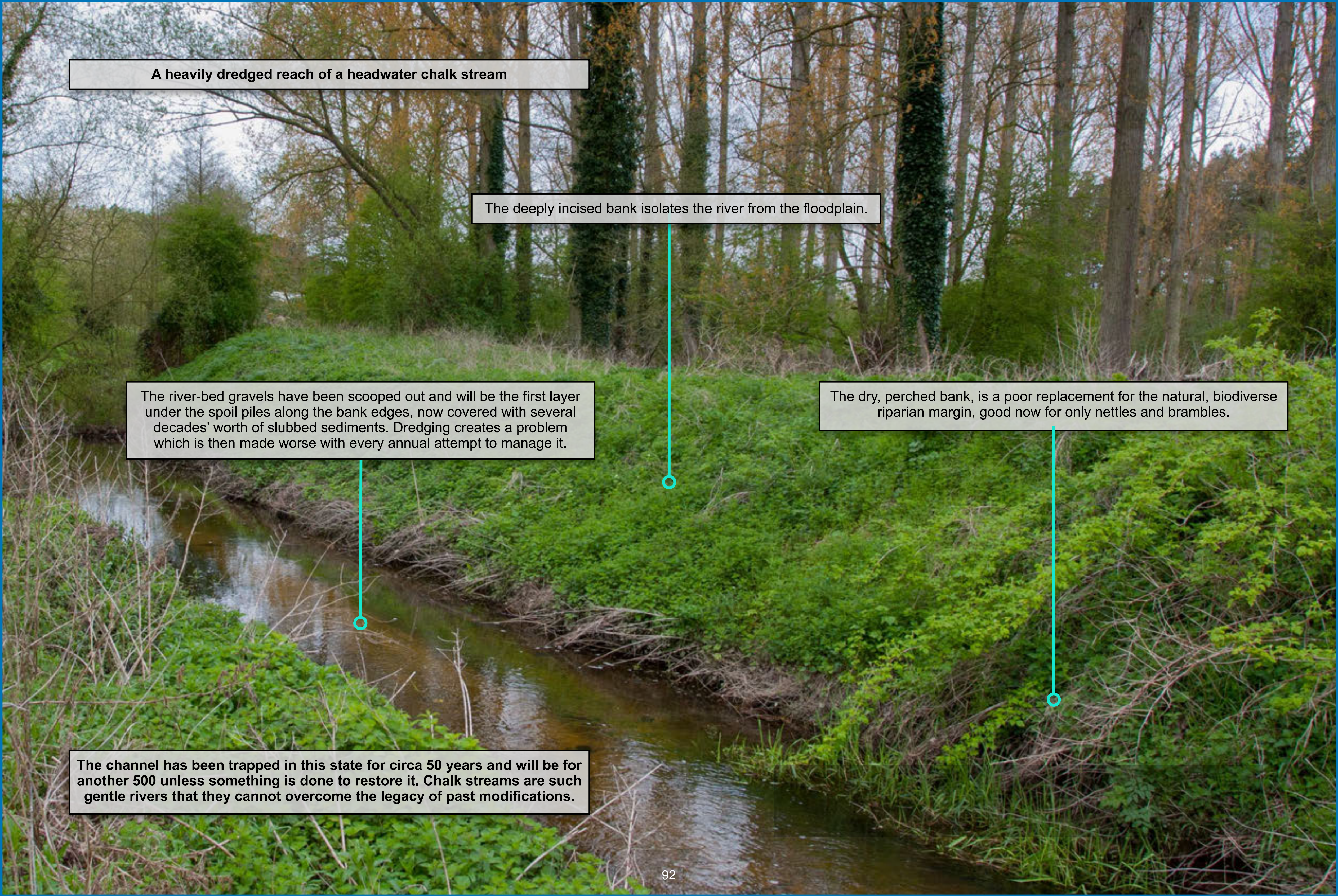
6.3.4 Water meadows

In England, water meadows date from about the same period as flash locks: late Jacobean. It is not known who exactly dreamt them up and the idea may well have floated across from the continent, just like mills and pound locks. But Rowland Vaughan of Herefordshire is credited with the notion, having one day noticed how green the grass was around a breach in the mill leat caused by a mole.

Vaughan set about creating a watery utopia in the golden valley of the River Dore, wrote about it and eventually the idea caught on, driving a second agricultural revolution (the first being 1000 AD and the invention of the heavy plough), especially on the chalk streams of Wessex, the earliest examples of the truly intricate ‘floated’ water meadows that so characterise our chalk streams.



John Constable's Flatford Mill (held in the Tate Gallery) illustrates many of the ways lowland English streams were modified by milling. Image via Wikimedia Commons.


A heavily dredged reach of a headwater chalk stream
The deeply incised bank isolates the river from the floodplain.
The river-bed gravels have been scooped out and will be the first layer under the spoil piles along the bank edges, now covered with several decades' worth of slubbed sediments. Dredging creates a problem which is then made worse with every annual attempt to manage it.
The dry, perched bank, is a poor replacement for the natural, biodiverse riparian margin, good now for only nettles and brambles.
The channel has been trapped in this state for circa 50 years and will be for another 500 unless something is done to restore it. Chalk streams are such gentle rivers that they cannot overcome the legacy of past modifications.

Water meadows worked by carrying water along a higher-level 'carrier' channel, before releasing it through a series of catch drains and hatchways, across ridged and furrowed meadows, to gather in the natural river channel at the foot of the valley.

The idea was to keep a thin film of water moving across the grass all through the winter: this kept off the frost, and gave an early boost to the pasture. Water meadows trebled the number of sheep a farmer might keep, which more than trebled his yield of wheat. Thus, water-meadows were really about recycling the goodness of the floodplain to the drier hillsides via the digestive systems of sheep, which were 'folded' onto the hills at night: a sustainable, on-farm, way of recycling nutrients which we could learn from today.

Water meadows, like mills, will have had an adverse ecological impact, by impounding the river, and diverting flow. On the other hand, they more or less guaranteed that the floodplain was utilised to filter excess nutrients from floodwaters, and in their own, ornate way, replicated the anastomosed channels of earlier times.

6.3.5 Dredging and canalisation

If deforestation, water-meadows, mills and pound locks took a huge toll on the natural chalk stream, shifting the baseline of what we regard as natural or ecologically good, the twentieth century brought three more calamitous changes to chalk streams – abstraction, acute diffuse and point-source pollution and finally dredging / land drainage. These changes reached their zenith of impact in the drought years of the 1970s and 80s, and were the catalyst for the birth of the river restoration movement in England.

Dredging and land drainage were driven by the determination of post-war Britain to be self-sufficient in food production. Traditional pasture land in floodplains was given over to arable or intense livestock production and to drive that water tables had to be lowered.

It was ultimately a failed experiment, because it is more or less impossible to lower a water table all the way to the sea: high points and pinch points were left behind – under bridges and power lines and through immovable woods – meaning that dredging more than anything turned chalk streams into a series of sediment sumps, engine rooms of excessive plant growth which did little more than choke the stream and compel the drainage engineers to go back year after year, endlessly slubbing out the mud.

We were still dredging chalk streams until very recently. The threat of doing it again never quite goes away.

But dredging as a management concept is based on a misunderstanding of a river's morphology. It is a definitively unsustainable operation because it fights the physical forces that shape a river, and it is usually counter-productive, in that while it is possible to drain an upper catchment meadow with a ditch, that process will only send unnaturally high sediment loads downstream to fill all the sumps that have been dredged lower down the river.
The whole operation, carried out on the scale it was in the 1950s to 80s, massively increases sediment supply (from the drainage and ditching) and retention (in the widened and deepened channels) at the same time destabilising the river and ultimately contributing to – if not actually causing – flooding, when the whole intention was the opposite.

6.3.6 Invasive species

A number of invasive, non-native species (INNS) are now present on our chalk streams, notably Japanese knotweed (*Fallopia japonica*), Himalayan balsam (*Impatiens glandulifera*), and signal crayfish (*Pacifastacus leniusculus*). INNS have a significant modifying impact on the natural chalk stream.

Japanese knotweed and Himalayan balsam

Japanese knotweed and Himalayan balsam were introduced by Victorian naturalists, but they long ago escaped their garden setting and both are now common on British riverbanks. They are a significant threat because of how easily they spread, how difficult they are to eradicate and because they outcompete other plants, causing erosion and reducing biodiversity.

Japanese knotweed has extensive, deep rhizomes and can spread from the smallest cutting. It is very challenging to control: its rhizomes, or all parts of the plant are notified as 'controlled waste' and must only be disposed of at registered landfill sites. It is probably best to destroy the plant on site, if possible, by burning. It is exceptionally difficult to dig up however, and usually some small part will be left behind and the plant grows again. It takes three or four seasons to kill knotweed with glyphosate, which would need very careful use anywhere near a chalk stream. All in all, it is probably best to get professional help to deal with Japanese knotweed.

Himalayan balsam produces innumerable seed pods which split and twist when ripe, especially if they are disturbed, hurling the seeds several metres from the plant. Himalayan balsam – which is widespread on chalk streams – forms dense, tall clumps which swamp out other plants, reducing riparian macrophyte diversity. Then it dies away in the winter, leaving bare river banks, which are vulnerable to erosion. Balsam can do as much bank damage as herds of livestock. It seems to do particularly well on the more flashy, mixed-geology chalk streams like the Frome or Bure, probably because their more deeply incised channels create very favourable riparian conditions for setting seed. The seeds of balsam will float downstream and can remain viable for two years.

Himalayan balsam, though more pervasive than knotweed, can be defeated by home-spun efforts, applied with persistence. You can strim it before it sets flower and if you keep on strimming it, eventually it will die. But this will take a season or two and you have to be thorough, because one plant can start a new infestation in next-to-no time. Or you can pull it, again ideally before it sets flower, though it is much easier to spot individual plants when they have flowered. It pulls up very easily and you can leave it in the sun to dry. But you have to go back again and again, and be strategic. Balsam bashing can be a very useful activity for volunteers.

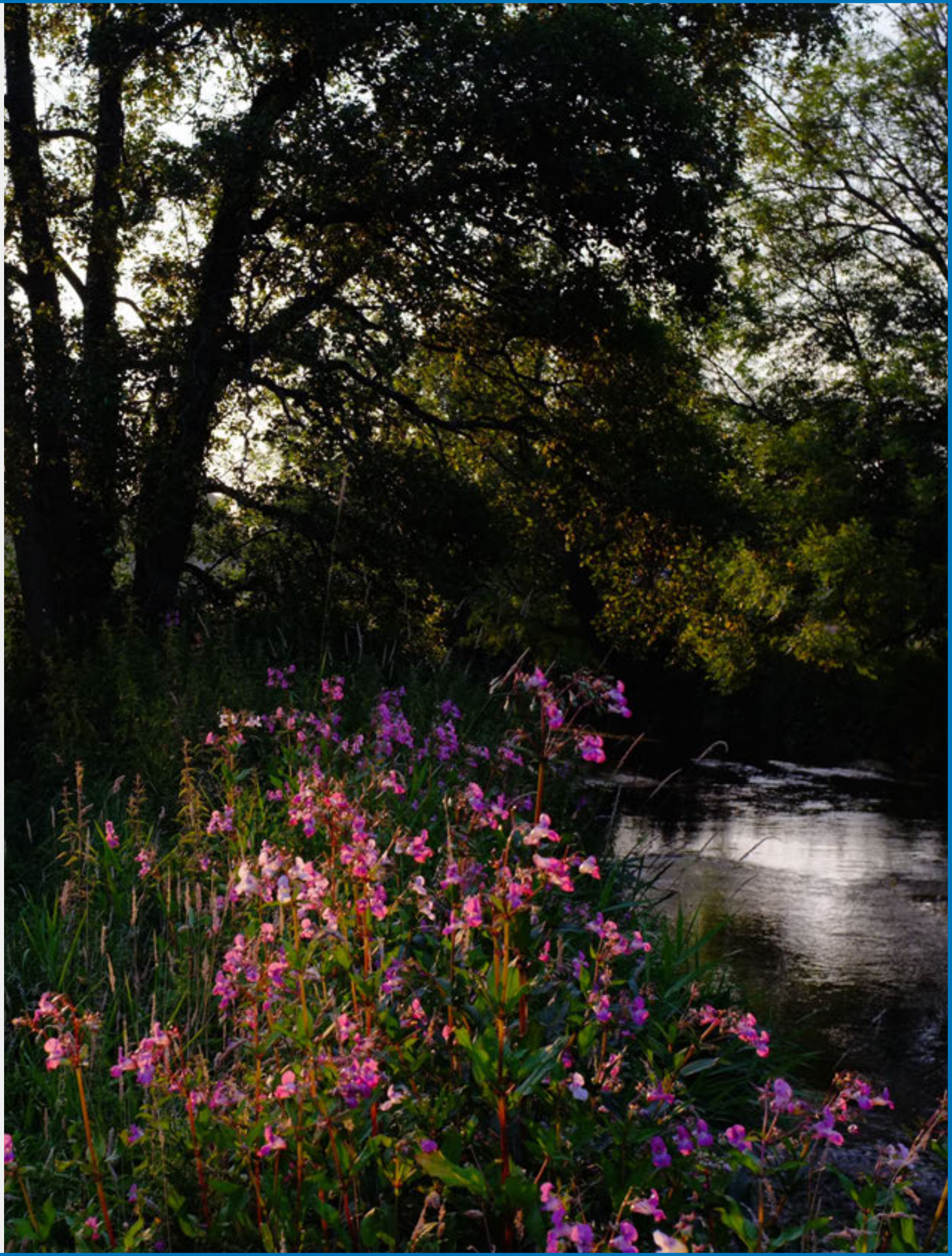
Some research has been conducted into controlling Himalayan balsam with rust fungus. Thus far two strains of the rust fungus *Puccinia komarovii var. glanduliferae* have been deployed, with results indicating a large variation in resistance and susceptibility among different stands of balsam. There are numerous biotypes of balsam in the UK. Future successful control via this method will depend on the balsam biotypes being matched with the most virulent rust strains.

Signal crayfish

American signal crayfish were introduced by the UK government in the 1970s as a commercial product to export to the Scandinavian market. They soon escaped and spread rapidly through British waterways, where they have outcompeted and infected our smaller, white-clawed crayfish (*Austropotamobius pallipes*). White-clawed crayfish are well adapted to English chalk streams, but are increasingly rare and in danger of being wiped out. They do not survive an infestation of signals and signal crayfish are spreading rapidly: once in a river system they can move through it easily and they are also being spread unwittingly from river to river, either by people trapping them for food and then not cleaning their nets, or via boots, boats and vehicles.

Apart from the threat signal crayfish pose to our native white-clawed crayfish, they are voracious predators and will eat juvenile fish, invertebrates, amphibians and plants. They also burrow into soft riverbanks. The burrowing causes the river banks to collapse and progressively the stream widens. As more and more sediment is released into a widening channel the macrophyte and invertebrate communities spiral downhill. Their constant warring stirs up the silt and the stream becomes turbid, further cutting down primary production.

Invasive species like Himalayan balsam have a significant negative impact on the physical integrity, biodiversity and natural function of chalk streams: as with phosphorus, the mixed geology chalk streams seem to be particularly vulnerable.



There is some controversy about what you can do to control signal crayfish. Some experts maintain that trapping is futile, because it tends to pull out the larger crayfish, above the size at which they achieve sexual maturity. Larger crayfish predate on smaller crayfish, and so not only does trapping fail to remove the breeding population, but it does remove a significant predator, and thus the population actually goes up, even if the average size goes down. On the other hand, some methods of trapping have been shown to be effective: neutering and returning the larger males, while removing all others has been shown to have an impact. Refugia traps catch juvenile crayfish as well as older ones. Really intensive trapping can make a localised difference. And predatory fish like trout, chub and eels can exert an impact.

Habitat manipulation can also make a difference: crayfish thrive in tall earth banks, in which they burrow. Redressing the impact of dredging with bank re-sectioning can limit their habitat, as can armouring the banks with gravel. With enough resources and persistence, the localised destructive impact of crayfish can probably be ameliorated, even if it is probably impossible to get rid of them entirely.

Longer term the best hope is Direct Inheritance Gender Bias (DIGB), which could theoretically eliminate the signal crayfish altogether, by skewing the sex of the crayfish, leading to a population crash. This is a new science, and controversial (although it uses gene editing, not the insertion of alien DNA), but it has been proven effective in controlled settings and there are safety protocols that can be built into its deployment.

CaBA CSRG supports such ongoing research into the control and eradication of damaging invasive species, especially Himalayan balsam and signal crayfish and endorses the prioritisation of action on chalk streams.

6.3.7 Chalk stream river keeping and fishery management

A large part of the cultural heritage of chalk streams is bound up with their importance as fisheries. Chalk streams were at the heart of the early evolution of dry fly fishing in the late nineteenth century, made famous by pioneers like Frederic Halford, Selwyn Marryat and Francis Francis.

This cultural heritage, combined with the pastoral beauty of rivers like the Test, Itchen and Kennet, made these and a handful of other chalk streams famous the world over for their profuse hatches of insects and for the trout which were a challenge to catch on an artificial fly. Anglers would travel from far afield to fish the renowned waters of the home-county chalk streams. Fishing clubs were formed and river keepers were engaged to tend the streams, to trim weeds, scythe the grass, to stock with trout and remove unwanted so-called ‘coarse’ fish.

In some senses this practice of shaping the stream to serve the pursuit of angling has been a force for good; or at least the economic value that drove it has. The value of fisheries on rivers like the Test and Itchen has protected the streams and considerable swathes of riparian ground from intensive agriculture and development in the post-war years, and from dredging. On chalk streams a little farther from London and with less financial value, farming activities have tended to take precedence over the value the streams have as fisheries: these less well-known streams, financially more an inconvenience than an asset to their owners, have been much more extensively dredged and drained as a result.

But the fishing heritage and river-keeping culture can have negative impacts too. The caché of streams like the Test, their value today as venues for corporate entertainment where results are expected, and where the vagaries of wild nature are tamed to provide them, has led to a form of intensive management that is not always beneficial to the ecology of these special rivers. Trees are removed when they fall in. Banks are mown until they resemble lawns, and bank profiles are shaped to provide firmer ground for anglers underfoot. Channel margins are cleared of naturally encroaching vegetation. Submerged plants are cut so that a fly line can be floated effortlessly across the marbled currents. Trout are stocked, sometimes in large numbers. Historically, other fish species that are native to chalk streams, such as grayling, dace, chub, pike and perch, have been removed on a large scale to reduce competition with trout. This culture of tidy management still prevails in certain places, especially on fisheries operated on a highly commercial basis.

Elsewhere and increasingly, fishing clubs and individual owners are taking a lead in promoting a more ecologically sensitive form of fishery management, driving habitat restoration projects, leaving trees in when they fall, only cutting the weed occasionally or not at all, with the anglers pursuing wild trout and valuing the other fish species that inhabit these streams, the perch, pike, dace and grayling, just as much as the trout.

The CaBA CSRG is fully behind this move towards wilder, less intensively managed chalk stream fisheries and the work of organisations like the Wild Trout Trust which publishes guidelines for best practice in fishery management and provides on-hand advisory visits to fishery owners from experts in ecologically-sound fishery management.

Stocking with farm-reared fish

Stocked fish can play a role in supporting fisheries where other factors – abstraction, and the legacy of dredging – are limiting the ability of the river to be self-sustaining. However, stocking is increasingly the exception rather the rule and there is a general desire – evidenced by the role of the Wild Trout Trust in providing advice – to further reduce stocking and to move fisheries to wild-only status. Generally, fewer fish are stocked nowadays than in 1997 when the Wild Trout Trust was formed. Following the publication of the Environment Agency's National Trout & Grayling Fisheries Strategy, trout that are stocked must be triploid (sterile) brown trout. There are encouraging signs that this reduction in stocking, as well as more sensitive habitat management, is resulting in healthier stocks of wild fish.

Nevertheless, concerns have been raised around the potential impacts of farmed triploid trout on wild native fish (of all species) and also on the impact of stocked rainbow trout, especially large rainbow trout; there is a need for further research to look into the interactions between wild and native fish. Rainbow trout, for example, can be used to extend the trout-dominated reaches of a chalk stream, potentially displacing rheophilic cyprinids and grayling. The ability of triploid brown trout to over-winter in greater numbers than farm-reared diploid trout may cause damage during the winter and may be exacerbated if owners and fishery managers winter feed. Over-winter feeding of stocked trout in the river is prohibited by law.

Elsewhere, the EA and NE are under increasing pressure from coarse angling interests on mixed fisheries to address declining numbers of coarse fish through stocking. This pressure has mostly been resisted by the EA but even so large numbers of coarse fish are annually stocked to chalk rivers, under the auspices of remedial, or enhancement stocking. Many of these fish originate from the EA's own fish farm at Calverton. The consequences of these fish stocking activities on indigenous stocks is also under-researched.

Habitat management

Interpretations of the right amount and type of stream management can vary greatly. There is a culture of riparian management on some chalk streams designed to produce a genteel, pastoral fishing experience, with mown paths and cut riparian vegetation. But while an occasionally strimmed path and vegetation that is managed to make the riverbank reasonably accessible – especially for elderly anglers – need not be damaging to the ecology of the stream, a closely mown bank twenty yards deep does not leave much space for wildlife. It is all a question of degree. On balance, the CaBA CSRG supports a minimally intrusive form of river management, one that does not preclude keepering, but that does encourage light-touch work, where riparian vegetation is managed with a keener eye to habitat richness and diversity than ease of angling. This is in keeping with the evolving preferences of anglers anyway, more and more of whom are looking for an immersive and genuinely wild experience.

The same goes for the management of instream plants. There is a heritage practice around the weed cut, especially on the famous chalk streams like the Test, and Itchen, with designated weed-cutting periods agreed between all owners, when the weed is cut and sent downstream and taken out at extraction points. Each fishery is responsible for its own interpretation of best practice but the communal weed cut does facilitate a scale of weed cutting the ecological impact of which may not always be good and is relatively unresearched.

If a wilder fishing experience is the end goal, it is questionable whether weed cutting needs to be practised as intensively as it is on parts of the famous chalk streams or is necessary at all in reaches of river that are in good condition. A swift-flowing stream with meanders, pools and gravel riffles and near-natural nutrient levels, will tend to be self-managing when it comes to weed growth, as is well evidenced by high-quality reaches on streams where the weed is not cut. Leaving marginal encroaching vegetation, so characteristic of natural chalk streams and such a vital part of the habitat mosaic, creates much better habitat for natural trout recruitment and creates a more natural landscape within which to fish. Further, many fisheries are beginning to recognise the benefits of reduced weed cutting during periods of low flows, where an abundance of instream vegetation helps to buoy water levels that would otherwise be receding.

On the other hand, the legacy of dredging and the river's attempts to self-repair by dropping sediment can yield vast crops of aquatic plants that smother a stream. Nutrient enrichment from agricultural and sewage pollution only makes this worse. Where decades of drainage management, and nutrient enrichment have created unsustainable weed growth, the answer is not simply ceasing to control the weed. The answer is physical restoration to the point where the stream achieves a self-sustaining balance.

As is made clear elsewhere in this strategy, riparian trees and the fallen wood they generate are an integral part of the evolution of a complex and dynamic physical habitat mosaic in chalk streams. Chalk streams are generally low-energy rivers and rely on fallen trees to drive the creation of a mosaic of habitats, including deeper pools, point bars, scoured riffles, and silt beds. Historically, both anglers and the Environment Agency have been too quick to remove fallen trees, in the name of tidiness, or because they are deemed a flood-risk. But in terms of river ecology tidy is not good and in terms of flood risk, unless the tree is right next to houses, or would cause flows to erode and collapse the banks of a perched channel, it is unlikely to be a risk at all and it may well help by slowing the flow, and reconnecting the river to the floodplain: which is the best form of flood management.

Given all the above, it is also worth noting that the current Environment Agency environmental permitting process is heavily bureaucratic and – compared to the preceding process – acts as a disincentive to habitat-restoration work: a review of environmental permitting for beneficial restoration works would be very much in order.

Fishery management: recommendations.

- **CaBA CSRG fully endorses moves in fishery management towards encouraging wilder, less intensively managed fisheries.**

- **Fishery managers should aim to minimise stocking, especially where self-sustaining wild trout are present and to minimise or cease stocking non-native rainbow trout.**

- **Fishery managers should mark stock fish and encourage catch & kill of marked fish towards the end of the season in order to minimise any potential ecological impact though the winter.**

- **Fishery managers should promote light-touch, extensive river keeping.**

- **Fishery managers should refrain from wholesale, non-selective weed cutting of the stream channel and margins and generally minimise weed cutting, especially where the river is in good physical condition and the weed cut does not actually benefit the environment.**

- **Naturally mixed-stock parts of the chalk stream should be managed as such, with value and emphasis placed on the full range of characteristic fish assemblages, including the grayling, chub, dace and pike as well as any wild salmonids that may be present.**

- **All relevant stakeholders should actively encourage efforts to restore physical habitat to enable self-sustaining, wilder chalk streams.**

- **The Environment Agency could consider a review and facilitation of environmental permitting for ecologically beneficial restoration.**

- **Fallen trees should be left in the river unless there is a clear flood risk or risk to bridges or property.**

6.3.8 The potential impact of climate change: scenarios and resilience

The UK Climate Projections (UKCP) published by the Met Office in 2018 assesses how the UK climate may change in the future. General climate-change trends suggest an increased chance of warmer, wetter winters and hotter, drier summers along with an increase in the frequency and intensity of weather extremes. UKCP projects an extension of the convective season from summer into autumn, with significant increases in heavy hourly rainfall intensity in the autumn.

Warmer, wetter winters

Warmer, wetter winters may increase aquifer recharge during the winter months, and therefore lead to higher flows, a migration upstream of the perennial head and an extension of the winterbourne reaches into the upper parts of chalk catchments.

Hotter, drier summers.

However, a combination of warmer, wetter winters and hotter, drier summers may mean that across the year the overall annual infiltration to groundwater remains about the same, although its reliability and distribution may change (Hughes et al, 'The impact of climate change on groundwater recharge: national-scale assessment for the British mainland'). Warmer and drier summers are likely to increase the soil moisture deficit through the summer months and effectively shorten the winter recharge period. Lower rainfall in spring could also impact on groundwater levels, and the volume of base flow in chalk streams during the following summer.

A decrease in soil moisture, in combination with other land-use challenges and changes may increase the demand for water from the agricultural sector and indeed hotter summers are likely to increase overall water demand from the general public too.

Increased frequency and intensity of extremes and droughts

Data suggests there will be an increase in the intensity of rainfall across all seasons, with an increase in frequency of heavy summer rainfall events and significant increases in heavy, hourly rainfall intensity in the autumn. Heavy, intense, but short-duration rainfall does not seep into the soil or recharge aquifers as efficiently as longer-duration, less intense rain. Heavy rain tends to flash across the land and can lead to localised flooding instead. Increased run-off is also likely to wash pollutants from roads, farmland, urban areas and through storm overflows.

Shifts in rainfall patterns may lead to an increased risk of multi-year droughts if winter recharge is disrupted, as seen during the recent dry years of 2016-2019. Whilst groundwater resources tend to be fairly resilient in single-year droughts and can be used to support depleted surface-water abstractions, those lasting two or more years are far more serious both for the environment and abstractors.

Impacts on chalk-stream ecology

The impact of these more extreme scenarios on flow and water quality is likely to be mixed: an increase in flow and aquifer recharge can improve water and physical habitat quality. On the other hand, an increase in run-off from roads and farmland, and the potential for an increase in the duration and frequency of storm overflows from sewers is likely to have an overall negative impact on water quality.

Chalk streams are groundwater-fed and so may be slightly more resilient to increases in temperature than other river types. However, hotter summers still pose significant threats to water quality: higher water temperatures in combination with low summer flows will increase algal growth and decrease oxygen levels.

Higher river flows may dilute pollutants but intense rainfall patterns are likely to increase the overall amount of pollution via leaching, sewage overflow and diffuse sediment. Historically, winter-spawning salmonids have benefited from stable riverbed gravels, with drier-than-average winters usually resulting in improved spawning success rates. Increased winter-flow velocities, associated with climate-driven changes in rainfall patterns, may result in the wash-out of salmon and trout redds in some chalk-stream locations or poorer survival rates.

Although winterbourne reaches may be extended via higher groundwater levels in winter, the increased rate of change from the flowing to the dry state and an extended duration of the dry state through hotter summers will exert pressures on the specialist winterbourne biotic communities.

Increasing resilience to counter multiple climate-change scenarios

Regional water-resources planning groups must plan for future climate change scenarios as outlined in the national framework for water resources (see Appendix A). Natural flood management techniques to slow the flow – such as reconnecting chalk streams to their natural floodplains – should be used to reduce run off, increase infiltration and trap fine sediment. This reduces the risk of flooding but has significant additional benefits for water quality and biodiversity.

Management of chalk stream habitats will need to consider how to help control summer temperatures. Increased shade will be essential as salmon in the southern chalk streams are already at the limit of their temperature tolerance. Actions to keep chalk stream channels cool should be initially aimed at those rivers that still support a population of Atlantic salmon, as well as east-coast chalk streams that have indigenous grayling *Thymallus thymallus* populations. These two species are at risk with any significant rise in mean water temperatures.

Tree planting and natural regeneration to increase shade can help maintain lower temperatures associated with groundwater inputs (cold water refuges). Any planting would also have biodiversity benefits and will be most effective if strategically planned.

Resilience in a changing climate – recommendations:

- **CSRG recommends that research should be commissioned to further understand the likely impacts of climate change on England's chalk streams and understand what mitigation and adaptation measures will be required to protect them.**

- **Infrastructure planning must take future climate scenarios into account. Regional water-resources planning groups must ensure climate change scenarios are accounted for when assessing future water-resources needs, including the use of nature-based solutions. Water companies must plan for increased heavy rainfall events in their Drainage and Wastewater Management Plans.**

- **Natural flood-management techniques should be used to reduce flood risk and increase wider benefits to water resources, water quality and habitat creation.**

Hotter, drier summers are likely to increase water demand across all sectors, in spite of probable increased winter rainfall: infrastructure planning must account for future water-resources pressures.

6.4 River restoration

The government's stated ambition in the 25-year Environment Plan is to **"leave the environment in a better state than we found it"** and that, with regard to chalk streams, is our challenge.

All the ways we have modified chalk streams over the centuries, all the ways we continue to modify and manage them today, contrive to disable the natural processes that create a dynamic, biodiverse ecosystem. Our job is to restore that ecosystem and we will do that best by restoring process. In restoring process we let the river do much of the work, concentrating primarily on relieving the pressure of whatever it is that is inhibiting process. A healthy ecology then starts to shape its own physical habitat.

A newly cut channel on the River Nar, replacing a diverted and dredged channel.

Photograph © Peter Christensen

6.4.1 River-bed gradient

Most of the ways we have modified chalk streams have compromised the gradient and longitudinal connectivity of the river channel. In short, mankind has turned the steady slope of the river beds left behind by the last Ice Age into a staircase of channel diversions in order to harness the power of the river to drive mills, or to use it for transport or to get it out of the way of farming activities.

Staircasing the chalk steams in this way has had serious ecological consequences:

• Interrupting the passage of migratory fish like salmon. Salmon would once have been indigenous to all English chalk streams but we had shut most of them out by the Middle Ages. There is evidence that our only remaining chalk stream salmon are genetically distinct. They could well be amongst Britain’s longest-resident animals, as salmon would have been able to survive in spring-fed rivers on the edge of the ice sheets. Lamprey, eels, and sea trout all also depend on open migratory pathways in the river channel.

• Altering the balance of the plant community: some of the key chalk stream macrophytes, like ranunculus, need swift flows to grow. Ranunculus is home to millions of blackfly larvae which filter diatoms from the water: the perfect example of an ecological engineer (operating at a scale you might never guess at) facilitated by natural channel morphology, or disabled by unnatural channel morphology.

• Altering the balance of fish and insect communities: many key chalk stream invertebrates and fish species are rheophilic, thriving in cool, swift, well-oxygenated water. Impounded channels accumulate sediment and favour a limited range of plants and invertebrates. The naturally flowing chalk stream is far more biodiverse than the impounded chalk stream.

• Increasing the residence time of water in impounded channels: there is a world of difference between slowing the flow via natural fen and saturated floodplain habitat and slowing the flow with impounded mill leats or dredged channels: the former helps to address nutrient enrichment, restore a natural flow regime and to stabilise temperatures: the latter drives up water temperature and nutrient levels through the accumulation of sediments, leading to more eutrophic conditions.

Restoring natural gradient restores a key driver to natural ecological process.

Circumnavigating mill leats

Restoring gradient can be as easy as removing an old farm weir, but it is usually rather more complex as the gradient tends to be compromised either by mill leats (attached to expensive mill houses) or dredging. Of the two, mill impoundments are technically easier to deal with, either by lifting the boards under the mill, allowing the river to flow freely underneath, or by diverting some or most of the flow around the mill through a version of the original flood relief channel. But mill owners tend to be very wary of this kind of proposal and attach a lot of value to the mill leat. Many have been persuaded, however, either by the ecological gains, or by the examples that now exist (for example Glandford Mill on the River Glaven, a project managed by Tim Jacklin and the Wild Trout Trust) of beautiful, swift-flowing channels that have successfully replaced anoxic, silt-filled mill leats.

6.4.2. River-bed cross-section: restoring dredged channels

The widespread dredging of chalk streams in the 1950s to 1980s took these naturally wide, shallow and bank-full rivers and locked them inside a jail. Dredging is a form of impoundment – albeit the effect is made by unnaturally lowering the river and the impoundments become the parts of the channel that were left behind, under power lines, under bridges.

However, dredging is the most damaging and difficult-to-fix modification of all, because once the gravel has been taken out off the river bed, there is just no bringing it back this side of another Ice Age. It is usually smeared in a thin film on the flood-plain peat and buried under decades’ worth of slubbed sediment, crowned with a line of nettles.

Historically, river managers have replaced river gravels with imported, graded gravel from quarries. This is not the best option. Graded gravel is peculiarly immobile once placed in the river, and cannot be sifted or winnowed by the flow. Plants don’t like it and and fish don’t seem to spawn on it. River-bed gravels should be restored ‘as dug’, ideally from very close by, to ensure they are appropriate for the stream. Luckily the dredgers only ever removed gravel from the river bed and so the undamaged gravel floor of the floodplain is usually only a few yards away from the edge of the bank.

Provided there is space and a willing landowner, a double habitat gain can be effected by digging the gravel from ‘borrow-pits’ beside the river, then refilling these as shallow depressions and pseudo oxbows that can be inundated by groundwater or flood flows in the winter. They can be connected to the channel to form refuge habitat for fish.

Another option is to restore the gravel bed and the meander planform by excavating a new channel to the side of the dredged one. This can actually involve moving less material than pulling gravel out of borrow pits into the existing channel, as all you have to do is peel the floodplain peat aside and let the water flow through: you don’t have to move the gravel.

It is worth doing the former if you are restoring gravel to an original, meandering planform channel in the centre of the floodplain. But if that channel is itself a diverted and canalised one, then the better option might be to recreate, or restore (if you can find it) the original course of the river. The photos on pages 77 and 80 are examples of this approach.

6.4.3. Meanders

Meanders are a vital part of the functioning process of a river. Because rivers are water moving over a surface, a process in which friction unevenly slows the passage of liquid, all river channels are shaped by the same physical forces – albeit operating at differing intensities and timescales – and conform to the same basic mathematical formula.

In a river channel, friction acts on the water at the edges and bed of the channel more than in the middle: this sets up a divergence in flow velocity that translates into circular back flows along the edges. These back-eddies grow in a downstream direction, pulling the water from the middle to the sides, but can never grow to a diameter greater than half the width of the channel because they will always meet a similar eddy emanating from the other side.

The eddies do not slide downstream in perfect opposition however: instead they grow and shrink in opposing pattern, pulling the river from side to side, creating a waveform in the channel shape (seen from above) that is reliably described (if many meanders in a given river are measured and averaged) by the formula 2 x π x channel width.

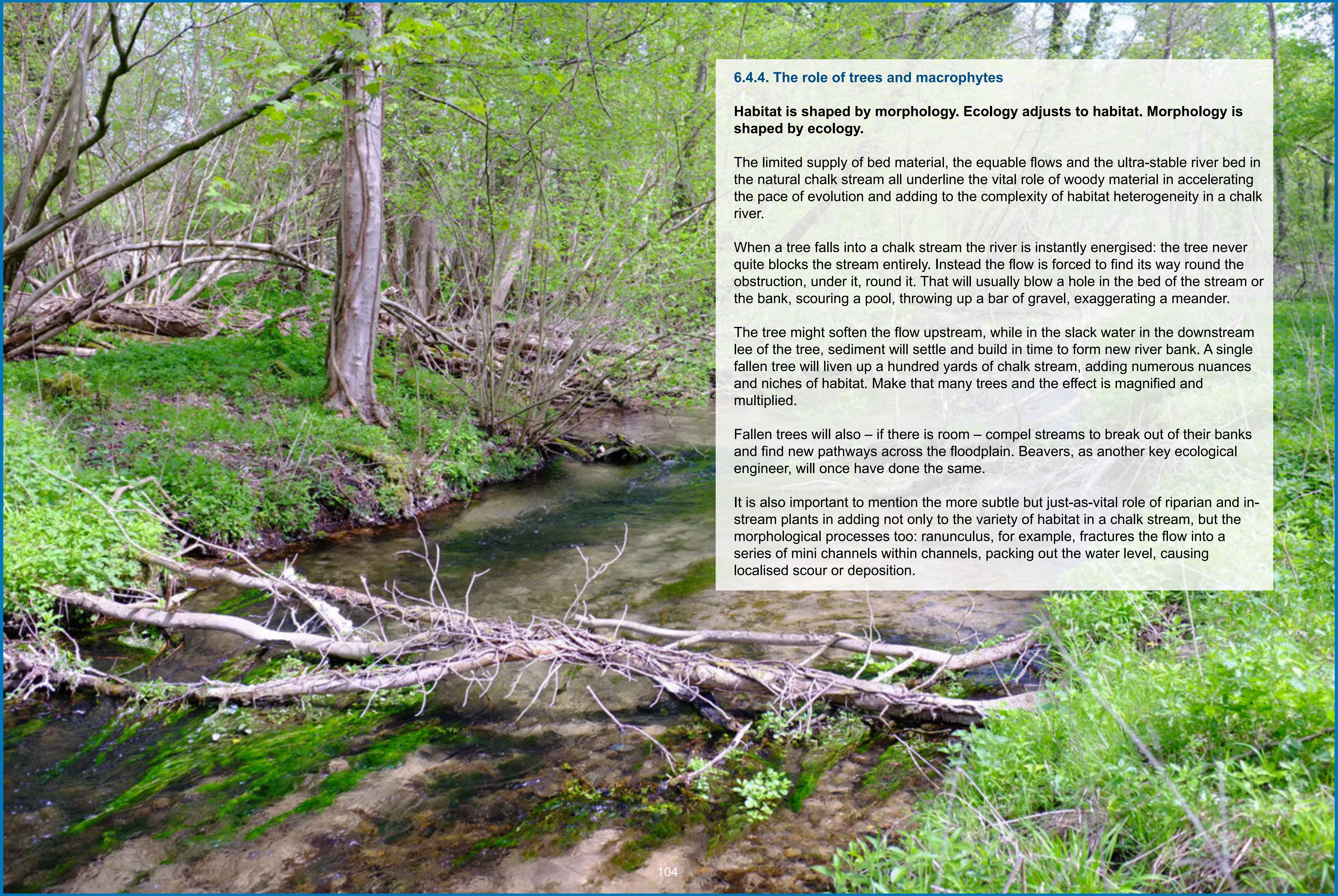
The meandering motion of the river pushes the erosive force of the water on to the outside of each bend. In addition there is a corkscrew circular motion in the water as it travels down "the tube" of the river channel. The erosive force moving from one side to the other and the corkscrew motion of the water as it travels downstream, have the effect of scouring material from the bed and banks on the outside of the bend, creating a pool. The scoured material then drops out of the current and is deposited in a riffle downstream, or is shifted from the outside of the bend in spiralling back eddies until it drops out of the slower flow on the inside of the bend.

This is a very simplified description of the shape of the river bed, which in reality is sculpted by the flowing water into very subtle humps and hollows, synclines and anticlines. A river, therefore, acts as a conveyor of material: the gravels, sands and sediments move steadily downstream and must be replaced by an equal amount coming from the catchment, headwaters and banks of the river. A stable, natural river is one where this supply and transport of bed material is in balance.

But in a natural chalk stream the supply is very limited – because of the spring-fed nature of the system, with very little surface run-off – but then again the transport of sediment is also limited – because of the equable, low energy flows and river bed hardened by tufa.

Left: The ornate, multi-channelled planforms of relatively unmodified spring-fed streams in places like New Zealand give insights into what our chalk streams were once like.

These meanders on the River Glaven look like they have been there forever, but were in fact designed according the principles described on page 102 above by Richard Hey in 2014 on behalf of the Norfolk Rivers Trust & Wild Trout Trust.



6.4.4. The role of trees and macrophytes

Habitat is shaped by morphology. Ecology adjusts to habitat. Morphology is shaped by ecology.

The limited supply of bed material, the equable flows and the ultra-stable river bed in the natural chalk stream all underline the vital role of woody material in accelerating the pace of evolution and adding to the complexity of habitat heterogeneity in a chalk river.

When a tree falls into a chalk stream the river is instantly energised: the tree never quite blocks the stream entirely. Instead the flow is forced to find its way round the obstruction, under it, round it. That will usually blow a hole in the bed of the stream or the bank, scouring a pool, throwing up a bar of gravel, exaggerating a meander.

The tree might soften the flow upstream, while in the slack water in the downstream lee of the tree, sediment will settle and build in time to form new river bank. A single fallen tree will liven up a hundred yards of chalk stream, adding numerous nuances and niches of habitat. Make that many trees and the effect is magnified and multiplied.

Fallen trees will also – if there is room – compel streams to break out of their banks and find new pathways across the floodplain. Beavers, as another key ecological engineer, will once have done the same.

It is also important to mention the more subtle but just-as-vital role of riparian and in-stream plants in adding not only to the variety of habitat in a chalk stream, but the morphological processes too: ranunculus, for example, fractures the flow into a series of mini channels within channels, packing out the water level, causing localised scour or deposition.

6.5. Principles of chalk stream restoration

Chalk streams were shaped by forces that have long since retreated from the landscape.

Once damaged or modified, chalk streams are prisoners of their own equable nature, lacking the stream power for self-repair.

Compared to higher-energy streams, chalk streams are more dependent on ecological processes: on macrophytes interacting with flow, on tree fall, on spawning salmonids (mobilising gravel), even on blackfly larvae in ranunculus beds filtering diatoms from the water. Recent research underlines the importance of these ecosystem engineers.

The common chalk-stream modifications – mills and other impoundments, canalisation, dredging – combine to alter the natural physical condition (eg. altering slope or denuding flow) and thus disable the eco-hydrological processes (eg. plant community structure, salmonid spawning.)

Therefore the ‘restoration’ in chalk stream restoration, should be a restoration of that which catalyses process.

The restoration of process depends on:

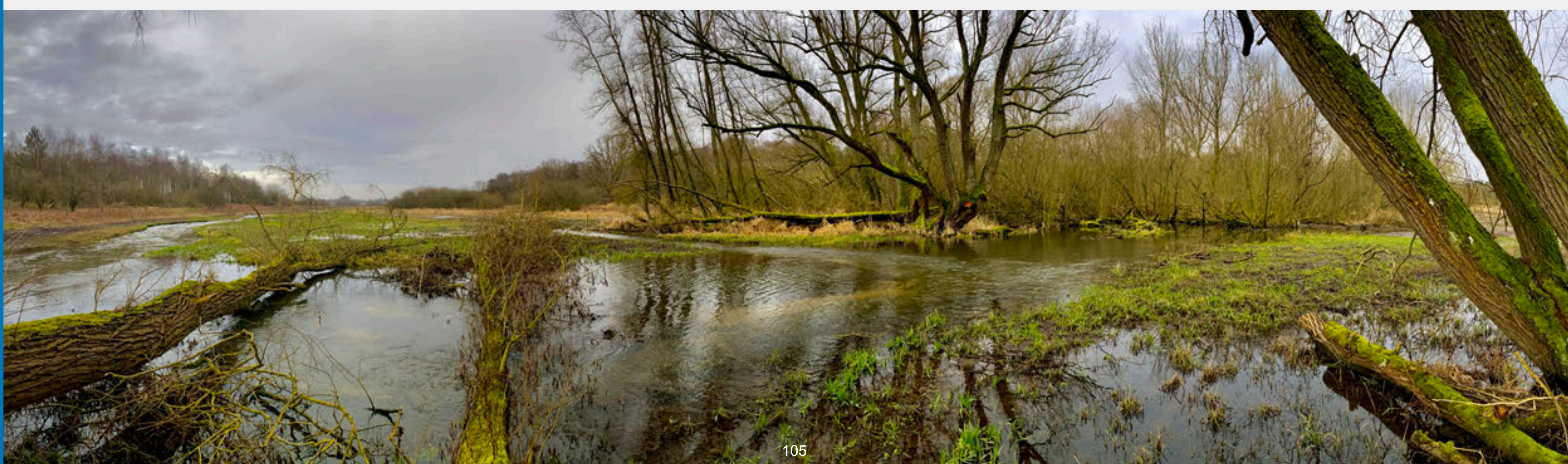
• he restoration of stream slope (longitudinal connectivity)

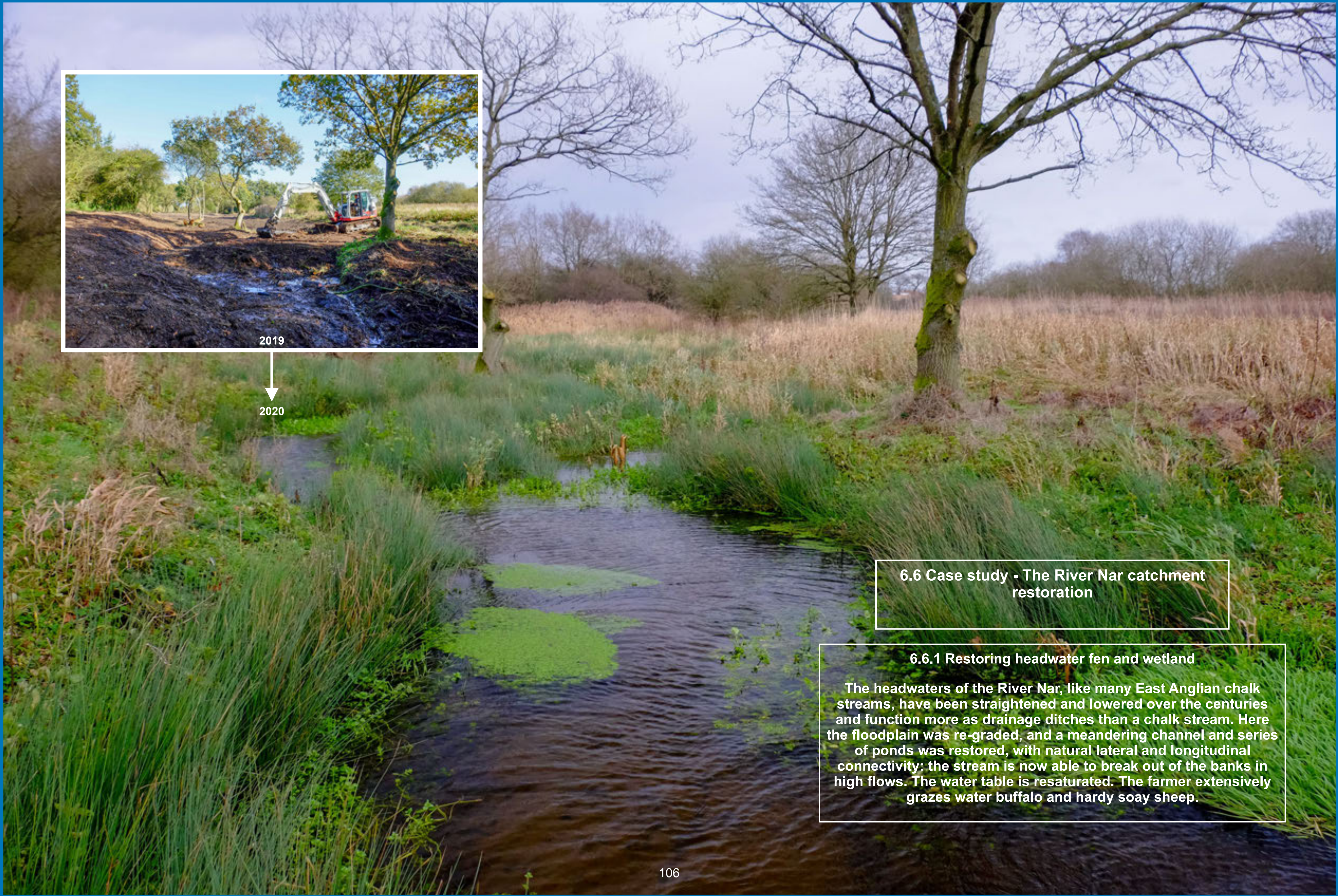
• the restoration of an intact gravel-bed (by returning gravel to the existing channel or by restoring, or reconstructing the original one)

• the restoration of a dynamic interaction with fallen trees and living riparian trees

• the restoration of a dynamic interaction with the floodplain (lateral connectivity)

• through all the above, the restoration of the ecological processes and the habitat requirements of the ecosystem engineers (fish, insects, mammals and plants) that shape a truly heterogenous and dynamic habitat





6.6 Case study - The River Nar catchment restoration

6.6.1 Restoring headwater fen and wetland

The headwaters of the River Nar, like many East Anglian chalk streams, have been straightened and lowered over the centuries and function more as drainage ditches than a chalk stream. Here the floodplain was re-graded, and a meandering channel and series of ponds was restored, with natural lateral and longitudinal connectivity: the stream is now able to break out of the banks in high flows. The water table is resaturated. The farmer extensively grazes water buffalo and hardy soay sheep.

6.6.2 Restoring gravel to dredged reaches

The river bed in this meadow on the River Nar had been lowered by half a metre, resulting in a silt-laden channel choked with bur reed. Gravel was taken from borrow pits beside the river and used to restore the natural bed level and gradient. Now the channel contains starwort and ranunculus, and has yielded record fish numbers in EA surveys. The borrow pits form wetted hollows, like old relic channels, and have added to the biodiversity of the site.

6.6.3 Restoring meanders and gradient

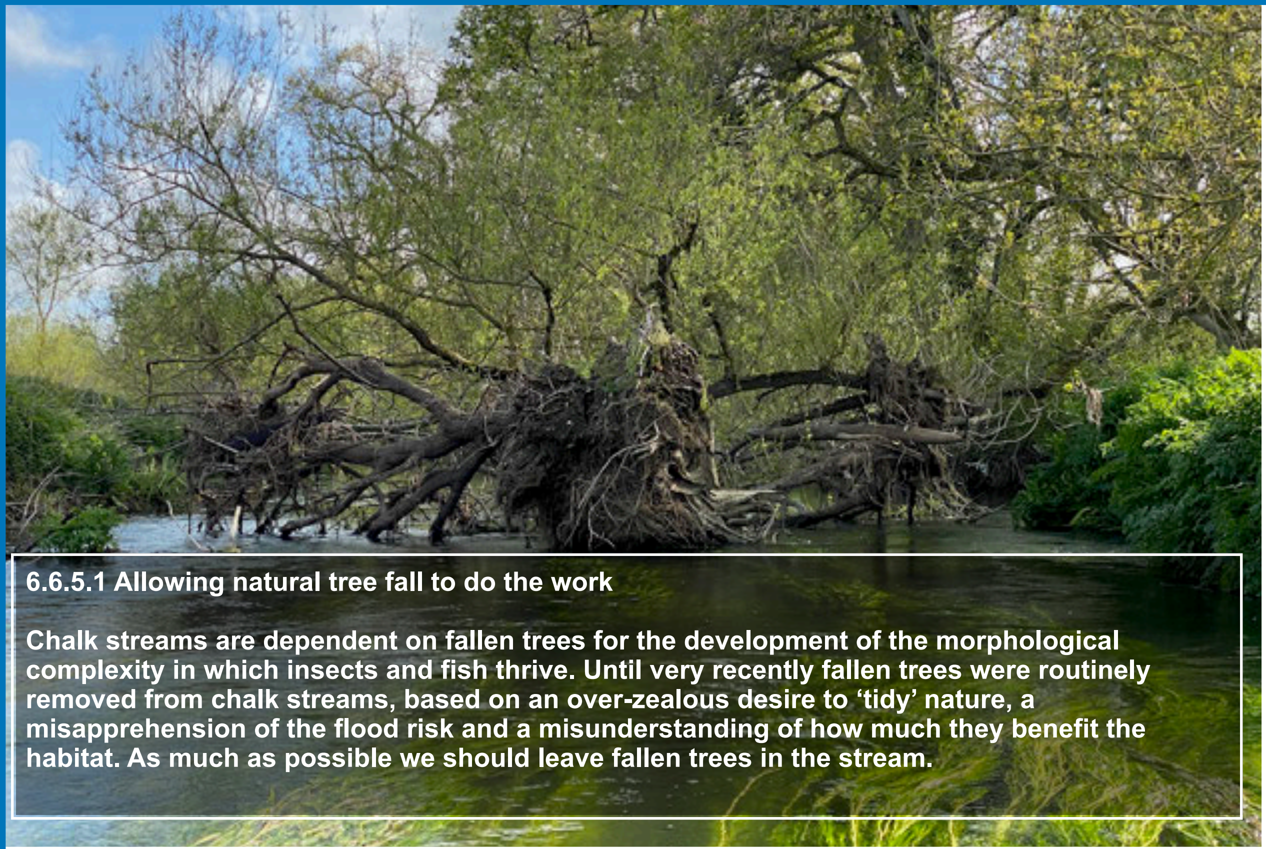
The river through Castle Acre Common was diverted hundreds of years ago to the side of the floodplain, into a perched contour-line leat of a much lower gradient than natural. In the mid-20th century this channel was then dredged, further isolating the chalk stream from its floodplain. With a Water Environment Grant (WEG), the Nar Restoration Group has recreated a 2km swift-flowing, meandering channel in the middle of the flood-plain and have pinned into it dozens of 'fallen trees'. The old channels have been retained as fen-like oxbows adding to the habitat variety and biodiversity across the width of the floodplain.

6.6.4 Restoring longitudinal connectivity: bypassing mill leats

Most chalk streams feature mill leats, diversions of the original channel designed to build up a head of water to drive a mill. These leats are perched at the sides of the floodplain and impounded by the mill. The original channels, which were once preserved as the mill's flood-relief channel, are often disused nowadays and have grown in. At the lower end of Castle Acre Common, the restored channel now bypasses the perched mill leat, and is back where it used to be, at the foot and centre of the floodplain.

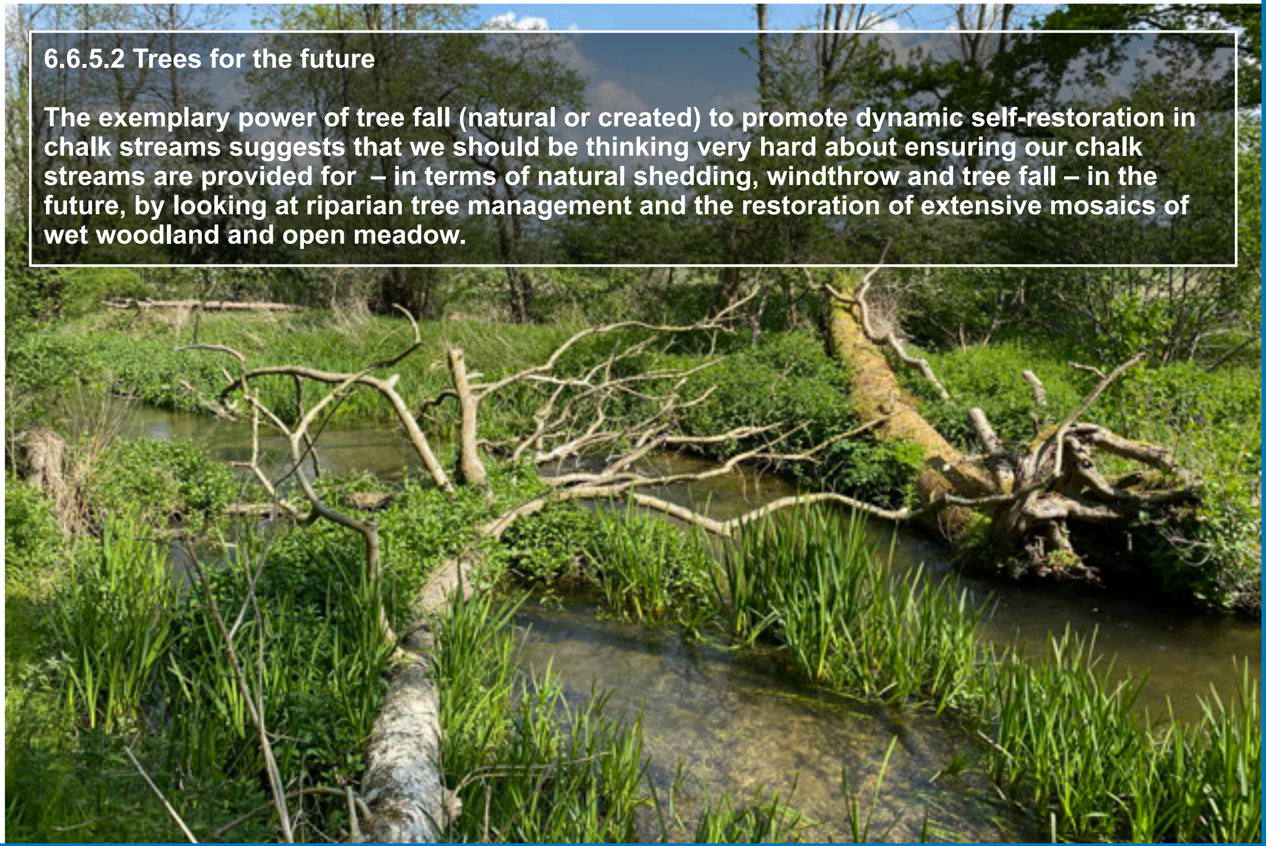
6.6.5 Restoring dynamic interaction with trees

This reach of the River Nar was incised, overshaded, and much wider than the natural channel, with little in the way of cover for fish. The surrounding woodland was semi-commercial, but overgrown and unnaturally dense. The riparian area and channel were restored by imitating the impact of a storm, felling dozens of the multi-stemmed alders across and along the edges of the channel. The result has been the creation of an almost primeval stream, with marshy, riparian habitats, a swift-flowing central channel, full of cover and now full of fish.



6.6.5.1 Allowing natural tree fall to do the work

Chalk streams are dependent on fallen trees for the development of the morphological complexity in which insects and fish thrive. Until very recently fallen trees were routinely removed from chalk streams, based on an over-zealous desire to ‘tidy’ nature, a misapprehension of the flood risk and a misunderstanding of how much they benefit the habitat. As much as possible we should leave fallen trees in the stream.



6.6.5.2 Trees for the future

The exemplary power of tree fall (natural or created) to promote dynamic self-restoration in chalk streams suggests that we should be thinking very hard about ensuring our chalk streams are provided for – in terms of natural shedding, windthrow and tree fall – in the future, by looking at riparian tree management and the restoration of extensive mosaics of wet woodland and open meadow.

6.6.6 Floodplain reconnection

Pushing the canalised and unnaturally extended headwaters out of their confined, ditched channels and across the floodplain offers multiple benefits to biodiversity, natural catchment function, and the attenuation of siltation and agricultural run-off. It is cost-effective and easy to do if the landowners are willing.

6.7 Chalk stream restoration in the context of landscape-scale nature recovery

Ideally, chalk stream restoration should not be confined to the river corridor and floodplain, but should encompass the broader sweep of the landscape which supports the chalk stream.

As with restoration of process at the river scale, restoring nature at the landscape scale is largely about controlling or eliminating the adverse pressures of human activities, and giving biodiversity the space and conditions to thrive.

Chalk streams, from their winterbourne reaches all the way downstream to where they are large chalk rivers, should be seen as one component of the ecosystems that need to be cherished and restored within chalk stream catchments: from the grassland, scrub and woodland mosaics of downlands, to the springs, flushes and fens of headwater and valleyside areas, to the wetland, grassland and woodland mosaics of floodplains.

Integrating the recovery of these various ecosystems through landscape-scale planning of nature recovery strengthens the actions taken on each component and maximises the natural capital benefits. Restore downland habitat mosaics and the water quality and recharge of chalk aquifers is improved for all downstream ecosystems dependent on water. Restore natural hydrological function to headwater and valleyside springs, flushes and fens and the flow, sediment and water quality regimes of the winterbournes and perennial chalk streams that flow from them are restored. Restore naturally functioning floodplain wetland mosaics and the ability of chalk streams to support their characteristic wildlife takes another huge leap forward. Restoring natural function to chalk streams themselves is an integral part of restoration of the wetlands they are naturally associated with, from their headwater beginnings to their saline endings.

Targeted re-establishment of natural and semi-natural habitats

A good way to start this landscape-scale approach is to facilitate a reversion to natural and semi-natural vegetation mosaics across critical parts of the catchment, at the same time ensuring that land use in the rest of the catchment is as supportive of wildlife as possible and makes as large a contribution as possible to restoration of natural catchment processes. For example, through effective soil conservation and efficient nutrient management on farms.

Selecting which areas to prioritise for reversion to natural / semi-natural vegetation relies on a good understanding of how the catchment functions naturally, particularly in terms of the natural pathways (and associated volumes) of water through the landscape and how underground pathways naturally pop up and feed wetlands and pools and then streams and river channels. Land reversion is best targeted in and around these pathways to support the restoration of naturally functioning habitat mosaics.

Recommendations for landscape-scale nature recovery:

- **Riparian and wider floodplain lands alongside chalk streams are an obvious target, working in tandem with physical restoration of the channel to help restore natural hydrological and ecological relationships between channel and associated land (as described in section 6.6).**

- **Headwater and valley-side areas are particularly important, where impacts from intensive land use can be eliminated at source and the benefits can be felt by the whole of the downstream catchment.**

- **Natural headwater chalk streams have been channelised and artificially extended by drainage systems, so that it can be very difficult to understand the difference between a degraded stream and an artificial ditch. Restoration of naturally functioning fens by blocking drains, in conjunction with restoring natural aquifer flows, is a critical activity.**

- **So too is reversing the upward creep of intensive agriculture into the natural and semi-natural grassland, scrub and wooded mosaics of downland, since this is the starting point for chalk-stream siltation and pollution downstream.**

- **Towards the base of valley sides, catch-drains have often been dug to catch drained spring-flows and divert them away from the floodplain – targeted removal of catch drains to re-naturalise spring flows is critical to restoring naturally functioning fens within floodplain fringes.**

Targeting land in this way is the art of the possible.

There will of course be catchments and parts of catchments where such restoration is more feasible and where landowners are more amenable to change. This ought to be a key selection criterion in the flagship catchment restoration scheme detailed in the following section.

Equally, some locations will prove problematic because of constraints associated with urban areas and essential infrastructure (for instance, urban areas that have developed where groundwater levels have been historically suppressed by heavy abstraction).

It is a question of targeting the best locations given local opportunities and constraints. The Nature Networks Evidence Handbook (Natural England 2020) provides guidance on how to approach the targeting of land for nature recovery, and how to factor in socioeconomic objectives.

Targeted reversion to natural and semi-natural grassland, woodland and scrub is a key contribution to good water quality and reduced siltation throughout the catchment: targeting landscape in this way is the art of the possible.

6.7.1 Maximising nature-based solutions to support chalk-stream recovery

Working with natural processes can help to restore the natural ecosystems of catchments, rivers, floodplains and coasts. Actions that utilise natural processes (often called nature-based solutions) can, for example, promote rainwater infiltration and groundwater recharge, can help to store water and slow down the rate at which it enters and moves through river systems. Nature-based solutions yield multiple benefits, including helping to improve biodiversity and mitigate the effects of climate change.

The current emphasis on utilising nature-based solutions to help address the challenges of climate change has led to the creation of potentially useful funding mechanisms which ought to be considered when planning the restoration of chalk streams and their catchments. For example, emphasis on the carbon, nutrient and water cycles is driving nature recovery through farm assurance schemes and financial mechanisms such as ‘nutrient neutrality’. Ideally these need to be integrated into chalk-stream restoration strategies in order to maximise benefits and prevent inefficient trade-offs or losses of opportunity.

Specific examples of nature-based solutions that contribute to chalk stream restoration might include:

• Features that help to attenuate run-off across fields and along tracks and pathways can complement natural processes by connecting surface run-off with access points such as soakaways, ponds, wetlands and fen that drain to or connect with groundwater.

• Soil management that promotes the recovery of organic matter (zero-till, for example, or winter cover crops) can help to buffer intense rainfall events and the associated run-off and pollutant losses to surface- and ground-water. Good soil health improves the retention and infiltration of rainwater, increases soil carbon content and its resilience to erosion, and minimises losses of sediment and nutrients from soil to river and aquifer.

• Riparian woodland can play an important role in mitigating temperature extremes whilst also helping to restore riparian habitat. Note that careful consideration of tree planting (location, species and density) is important where water resources are scarce.

• Measures that enable the capture and the storage of rainwater on farm reservoirs during peak flows or high rainfall can reduce the pressure on water abstraction during the summer months.

• The re-connection of river and floodplain in combination with the restoration of a more natural channel morphology (especially width and depth) will help to promote the restoration of wetland habitats in the floodplain.

6.7.1.1 Aquifer recharge

Nature-based solutions can potentially play an important role in enhancing recharge to aquifers.

Although rainwater infiltration in chalk catchments is relatively significant, modern land management in combination with a more extreme climate and intense but short duration rainfall events are likely to have reduced the efficiency with which chalk catchments capture their rainfall: the more intensely managed the catchment, the more significant the impact is likely to have been.

There may be significant potential for increasing infiltration through careful land-management and the attenuation of run-off at the edges of till or clay. Enhanced recharge in higher topographical areas is likely to have a longer lag time than in lower areas and may therefore provide flow resilience during the summer.

Water, soil and land management practices could be adapted to promote recharge or storage via the following interventions:

• improving infiltration on the till soils that dominate the plateau by focusing on soil health, soil management and roughness strips within fields;

• adapting cropping and land cover to improve the water budget: while rough scrub and woodland promotes rainwater infiltration conifers, for example, are very water-hungry;

• infilling or blocking ditches, catch drains and other man-made drainage channels where the water table lies close to the surface on the valley sides and floodplain edges will help to restore and inflate the hyporheic zone and promote the restoration of fen habitats;

• improving the resilience of streams to low groundwater levels in the chalk by re-naturalising the channel and storing more water within the valley floors through riparian restoration.

All of the above techniques for improving aquifer recharge will have concomitant benefits in terms of attenuating run-off, natural flood management, climate change resilience, carbon, water and nutrient cycles etc.

6.8 The role of different delivery mechanisms

Key elements of biodiversity strategy in England post-2020 are the **Nature Recovery Network (NRN)** and **Local Nature Recovery Strategies** (**LNRSs)**.

These will be vehicles for planning the restoration and re-establishment of wildlife-rich habitats in our landscapes, and will work in combination with measures to implement good and best agricultural-management practices, with a particular view to minimising the wider-reaching potentially negative impacts of farming activities.

Development of the NRN and LNRSs is in the early phases but stakeholder engagement is now building and biodiversity partnerships are forming.

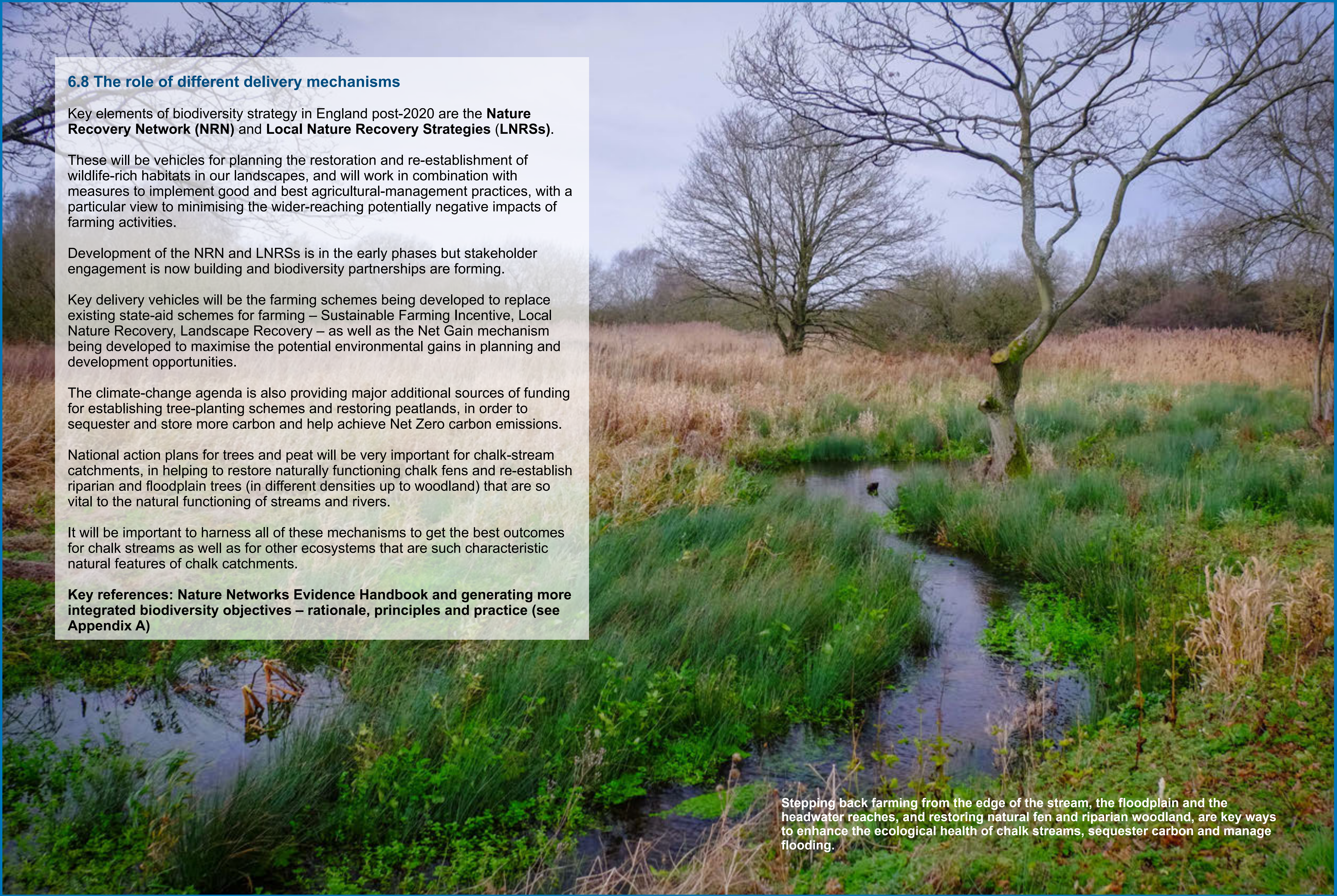
Key delivery vehicles will be the farming schemes being developed to replace existing state-aid schemes for farming – Sustainable Farming Incentive, Local Nature Recovery, Landscape Recovery – as well as the Net Gain mechanism being developed to maximise the potential environmental gains in planning and development opportunities.

The climate-change agenda is also providing major additional sources of funding for establishing tree-planting schemes and restoring peatlands, in order to sequester and store more carbon and help achieve Net Zero carbon emissions.

National action plans for trees and peat will be very important for chalk-stream catchments, in helping to restore naturally functioning chalk fens and re-establish riparian and floodplain trees (in different densities up to woodland) that are so vital to the natural functioning of streams and rivers.

It will be important to harness all of these mechanisms to get the best outcomes for chalk streams as well as for other ecosystems that are such characteristic natural features of chalk catchments.

Key references: Nature Networks Evidence Handbook and generating more integrated biodiversity objectives – rationale, principles and practice (see Appendix A)



Stepping back farming from the edge of the stream, the floodplain and the headwater reaches, and restoring natural fen and riparian woodland, are key ways to enhance the ecological health of chalk streams, sequester carbon and manage flooding.

6.8.1 Using the priority habitat driver for chalk streams

Action to restore biodiversity on non-designated sites is focused on priority habitats and species listed under Section 41 of the NERC Act 2006. Chalk rivers are part of the definition of priority river habitat, and this should create additional impetus for their protection and restoration. A framework has been developed to allow stakeholders to use the priority habitat driver to try and secure more action on their chalk streams, adding weight to the prioritisation received under water planning processes. All aspects of this framework can be accessed via the priority habitats website hosted by the Freshwater Biological Association (FBA).

Mapping the chalk stream resource – A refined map of chalk rivers is being developed to take account of the gaps identified by stakeholders, particularly in the coverage of small headwater chalk streams and winterbournes. A provisional revised map has been available on the FBA website since January this year, and is currently in the process of being finalised through stakeholder feedback. This will form a basis for targeting and evaluating whether delivery mechanisms are focusing sufficient attention on chalk streams.

Protecting our most natural remaining examples from future impacts – An official map of priority river habitat has been generated to highlight the most natural remaining examples of all types of river and stream in England. This acts as a vehicle for protecting these sites from deterioration. The map is used to assess applications under water-permitting processes and development-planning processes. The map is under regular review and sites can be added via an assessment of naturalness that can be undertaken by stakeholders via the FBA priority habitats data portal.

Restoring chalk streams – The FBA data portal includes a facility for stakeholders to highlight priority locations for restoration. This process is independent from Water Framework Directive prioritisation processes and will be used to overlay biodiversity priorities on top of WFD priorities. Various types of restoration can be highlighted, from hydrological to water-quality, physical and biological (e.g. control of non-native species). Local chalk-stream partnerships can have their own workspaces, and individual stakeholders can get involved. The map is in the early stages of development but will grow over the course of the next year.

All of these facilities feed into the targeting of action on nature recovery under post-2020 biodiversity strategy in England. The more they are used by stakeholders to highlight chalk streams, their status and restoration needs, the better the outcomes will be for chalk streams.

Right: There are unrecorded natural gems in the headwater stream resource just waiting to be put on the map and given protection under the priority habitat driver.

6.9 Urban chalk streams

A large number of chalk streams flow through urban spaces. A few are almost wholly urban: for example the Wandle, Hogsmill and Cray in London, while some others flow almost continuously through towns and suburbs: for example the Wye in Buckinghamshire. But many, many chalk streams flow through towns and suburban spaces: the Frome flows through Dorchester, the Allen through Wimborne, the Avon through Salisbury, the Itchen through Winchester.

These urban riverside spaces are where many people, perhaps even most people, have an opportunity to see and experience a chalk stream. They provide a great opportunity to engage the general public with the health of their chalk stream in particular and with chalk streams and rivers more widely. The mental and physical health benefits of getting outside and engaging with nature are well known. The recent Covid crisis only underlined the need for the public to have access to green spaces and if these spaces have a healthy river flowing through them, so much the better.

The de-industrialisation of Britain has brought something of an ecological renaissance to urban streams. The Wandle, in south London, was a renowned chalk stream until the late 19th century. Isaac Walton referred to its trout 'spotted like tortoises'. But by the mid-20th century it had become an open, industrial sewer. In recent years that has changed: civic groups have got together to clean it up, to carry out river-restoration projects, and to re-stock the stream with trout reared in local classrooms. The Wandle is a brilliant example of how a river can engage a local community to the benefit of both people and wildlife.

The restoration of urban chalk streams and public riverside spaces is something the CaBA CSRG would like to encourage and endorse.

• Local planning authorities, working with CaBA partnerships and rivers trusts, should consider identifying and nominating these spaces for Biodiversity Net Gain.

• Urban and public chalk stream spaces should be considered for NRN and LNSR (see section 6.8 above) .

• It would be good to see at least one urban chalk streams nominated for a flagship catchment restoration project.

The River Wye in High Wycombe: urban and green riverside spaces provide a great opportunity to engage people with their local chalk stream.

6.10 National network of flagship catchment restoration projects

Aim: To facilitate and catalyse this catchment-scale ambition, the CaBA Chalk Streams Restoration Group is working towards the creation of 12 flagship catchment restoration projects.

These projects will be in addition to work on the SSSI- and SAC-designated chalk streams which already have catchment restoration strategies. The aim is to realise on these flagships streams all the dimensions of ambition the CaBA strategy has articulated to show what is possible and to act as exemplars to assist in the restoration of other chalk catchments.

Scale: The aim is to restore the whole chalk stream catchment over a 10-year period. Identification of the candidate chalk catchments will need to take into account:

• size: the plan is to identify 10-12 medium-sized chalk streams (c.15km long) widely distributed across the chalk from Dorset to Yorkshire

• active stakeholder engagement and support: it is important to have local passion driving the projects forward

• the number of landowners and their willingness to participate

The project will be split into two main phases:

Phase 1 – Development of catchment restoration plans

The guiding principles for development of the catchment restoration plans are:

1. They must be developed collaboratively with local stakeholder groups.

2. The aim is to restore natural physical and ecological processes to restore ecosystem function.

3. The plan should be at a catchment scale to show the ambition for the whole river, but broken down into accessible units detailing the problems to be addressed and actions required in each part of the river, including costs and timescales for delivery.

4. The plan must be user-friendly and accessible for local people.

The full catchment-restoration strategy should cover proposals:

• to achieve sustainable abstraction

• to reduce point source and diffuse pollution

• a reach-by-reach physical habitat restoration

• restoration of the wider landscape

• with an overall aim to achieve good or even high ecological status

We would expect the proposals to cover actions which restore the catchment over a 10-year period. The strategies will be developed in the next 1-2 years, in time to inform PR24. Where resources and/or actions are deliverable in current business plans they should progress as soon as possible.

Phase 2 – Plan delivery

A programme manager will need to be identified to co-ordinate delivery. The programme manager must work with local stakeholder groups to deliver the programme of work outlined in the plan.

We expect to develop wider catchment-restoration drivers for PR24, which would enable water company actions to be included in the water industry national environment programme (WINEP) in PR24. The 5-10 year plan horizon would require actions during the AMP8 and AMP9 water company plans.

Who should do the work and funding?

The projects should be led by Rivers Trusts, Catchment Partnerships, and other river groups and associations. Grassroots stakeholder involvement is fundamental to the plan.

All sources of funding should be explored, but to give long-term certainty, we see the water companies as a key contributor or preferably, taking a lead on funding this work, as specific funding could be secured through water company business plans.

We will seek to identify one or two exemplar catchments in each water company region which the water company could ‘adopt’ and focus attention on. Core funding from the water companies to develop the catchment plans could kick-start additional funding from government/Defra/EA via grants and other catchment partnership funding.

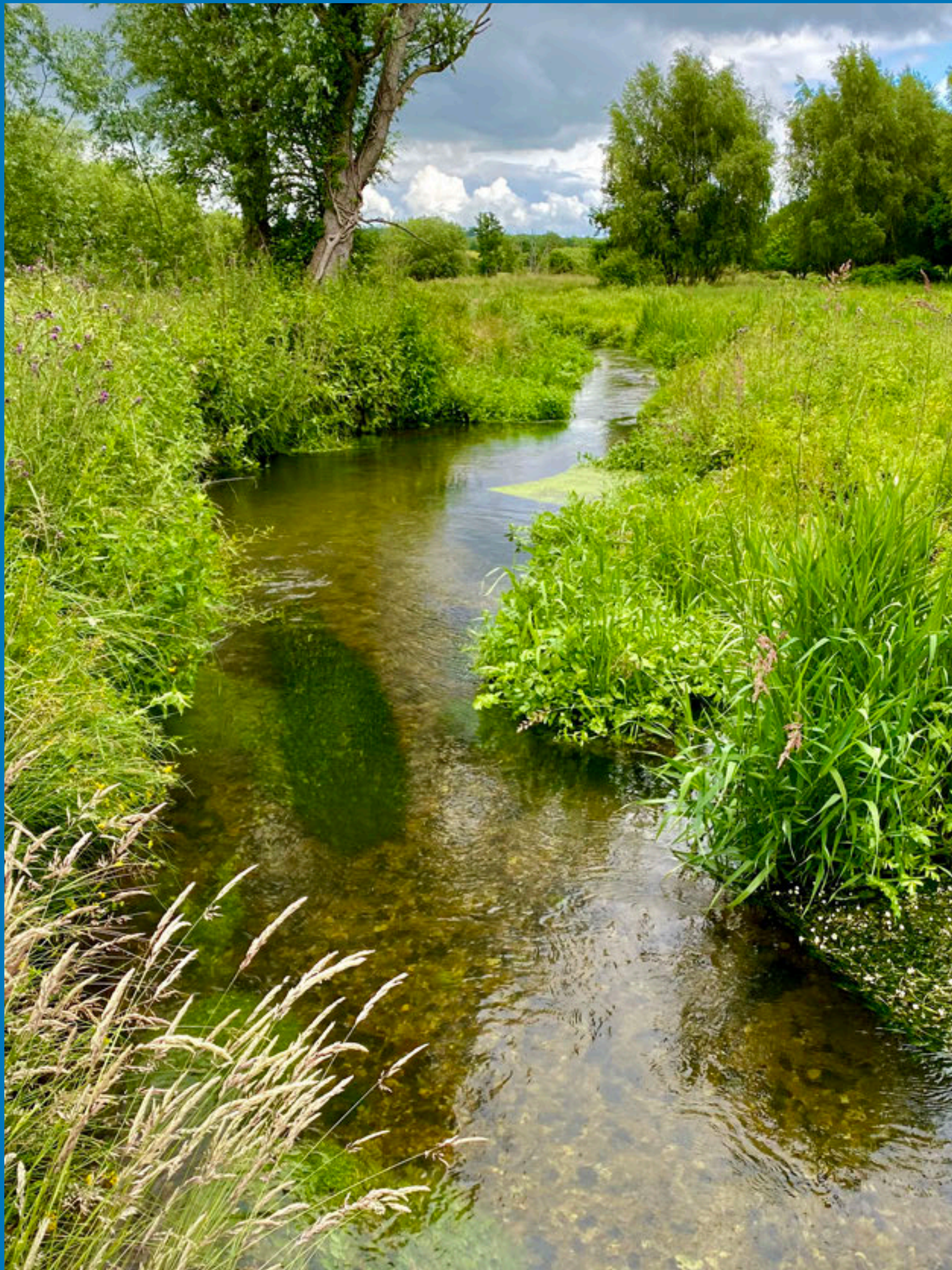
Co-ordinating with nature recovery initiatives

There is clearly enormous scope to co-ordinate these flagship projects with other nature recovery and restoration schemes including local nature recovery (LRN), Landscape Recovery (LN), Woodlands for Water, Nature4Climate and Biodiversity Net Gain (BNG).

6.11 Physical habitat: recommendations for action.

1. Principles of chalk stream restoration	CaBA CSRG endorses the key foundations and principles of chalk stream restoration set out in Section 6.6 and 6.6.1 agreeing that the chalk stream restoration, should be a restoration of that which catalyses process: the natural gradient of the river, an intact river bed, a dynamic interconnection between the river and the floodplain, and through all the above the restoration of the ecological processes and the habitat requirements of the ecosystem engineers (fish, insects, mammals and plants) that shape a truly heterogenous and dynamic habitat.
2. Flagship restoration projects	CaBA CSRG will work with water companies and other partners to deliver a national network of flagship catchment restoration projects as set out in Section 7. The aim is to realise on these flagships streams all the dimensions of ambition the CaBA strategy has articulated, to show what is possible and to act as exemplars to assist in the restoration of other chalk catchments.
3. Urban chalk streams	CaBA CSRG endorses the use of urban and public chalk stream spaces as sites for Biodiversity Net Gain and for inclusion in Nature Recovery Networks and Local Nature Recovery Strategies.
3. Monitoring and appraisal	CaBA CSRG endorses the development of a simple, replicable and standardised monitoring initiative, covering the key components of habitat, biology, quality and flow in perennial and winterbourne reaches. Delivery through engaging citizen scientists and conservation volunteers would help to build links between various stakeholder communities and lead to better appraisal of the evolution of environmental projects and their long-term impacts.
4. Sharing best practice / pooling expertise	In addition to and complementing this flagship initiative, CaBA CSRG is working towards the establishment of: • a CaBA chalk stream online data and information hub. This will be hosted by the Rivers Trust. It will include data and knowledge to help empower and facilitate grass-roots catchment advocacy and river restoration • a manual of best-practice restoration principles and guidelines and a forum for sharing best practice and experience • a annual CaBA chalk stream restoration conference and programme of site visits, again to promote an open and exciting exchange of information, experience and best practice among those who are passionate about rivers in general and chalk streams in particular
5. Research into reference conditions	There is a need for further research into the reference conditions and characteristics of the different groups of chalk streams to inform our knowledge and understanding of the practice and aims of river restoration.
6. Database of reference reaches	Although they are rare, relatively natural reaches of chalk streams do exist, as do reaches where naturalness is being recovered through river processes or restoration. These reference reaches should be recorded, mapped and surveyed to add to our knowledge base.
7. Chalk-stream map	An important first step in the protection of a natural resource such as a chalk stream is to accurately map the resource. Natural England is working on a complete and agreed map of all English chalk streams. This will be published by Natural England but it will also be included on the CaBA Chalk Stream online hub.

7. Integrated Policies



7.1 One big wish: protected status for chalk streams

This strategy proposes proposes that the government should create **an overarching statutory protection and priority status for chalk streams and their catchments to give them a distinct identity and to drive investment in water-resources infrastructure, water treatment and catchment-scale restoration**.

Currently, few chalk streams have protected site status. There are drivers, such as priority habitats status and the Water Framework Directive. However, thus far, these have failed to deliver enough improvement for chalk streams. Discussions within the CSRG and overwhelmingly the message from consultation feedback shows that there is a clear need for a status mechanism that can add impetus and drive investment across multiple policy levers e.g. water company price review process, ELMs, local nature recovery and Landscape Recovery strategies, Biodiversity Net Gain and protections through the local authority planning processes. It is important that this new mechanism delivers in an integrated way: chalk stream channel (water), floodplain (biodiversity) and aquifer (landscape-scale nature recovery).

7.1.1 What we want the chalk-stream status to achieve

Any new status will need to drive ecological improvement using multiple policy levers delivered by multiple organisations. It will need to leverage investment to restore flow regimes, tackle pollution, restore their physical form and function, and generate more natural vegetation in their riparian zones and other hydrologically connected areas (including valley-head springs and floodplain fens).

This report acknowledges that: *"it will take some time to get to the destination – to think otherwise would be to underestimate the scale of the undertaking or the ambition".* Therefore, such a status will need to provide long-term commitment and a certainty of delivery. It must not be reliant on voluntary compliance or mere guidance. It must stand the test of time and provide certainty for investors.

The status should drive investment and mobilise resource from a number of places including:

The water company price-review process and protections through water resource management and drainage and wastewater management statutory plans.

Environmental Land Management, including the option for chalk-stream investment via the local nature recovery and Landscape Recovery elements.

Government grants and funds such as the Water Environment Grant and green recovery fund, green climate & net zero funds.

Local Nature Recovery Strategies and protections through the local authority planning process (including ensuring impacts on chalk streams are given sufficient weight in local Water Strategies, planning decisions) and mechanisms such as **Biodiversity Net Gain.**

Water Framework Directive measures including targeting of enforcement, advice and funding through Catchment Sensitive Farming.

7.1.2 Why set chalk streams above other rivers?

Other types of river and stream are also in great need of investment, as are lakes, fens, bogs and drier habitats. An integrated approach to restoring all types of habitat and associated species helps to deliver multiple biodiversity and natural capital benefits (see 'Generating more integrated biodiversity objectives – rationale, principles and practice' Appendix A). Nevertheless, this report argues that the global rarity of English chalk streams provides a potent justification for singling this river type out amongst others. There are other justifications too, for example the fact that chalk streams are under particular stress because they flow through a highly developed landscape, have been especially stressed by historic management and have particular biodiversity, cultural and heritage value and for hydrological reasons they are far less capable of self repair than higher energy rivers. Natural England has established precedent to the concept of addressing particular species and habitats – the Hen Harrier Action Plan, Back from the Brink focused on specific 20 species. Any additional elevation of chalk streams in status would also act as an 'exemplar' to show how such an integrated approach can be used for these streams, ultimately showing the way for nature recovery of *all* rivers, streams, fens, lakes and other freshwater habitats.

7.1.3 Current mechanisms for protection and restoration

Various approaches have been suggested for elevating the status of chalk streams, for example through regional water resource and water quality planning processes.

The Water Framework Directive provides the general framework for protecting the water environment, with its objectives for high and good ecological status and high and good ecological potential. But WFD has so far failed to achieve the level of protection and restoration needed. Given the public disquiet over their failing ecological health there is clearly a need to use other mechanisms to elevate the status of chalk streams and drive real change.

However, as an interim measure, Defra could instruct EA and NE to treat chalk streams as either SAC or SSSI for RBMP purposes, in the way that Ramsar sites are treated as SACs. This would associate chalk streams more with conservation use/status rather than just WFD status and it would mean that the Common Standards (CSMG) P targets would apply, which are more stringent than the WFD standards for GES.

In addition, Defra could instruct the Environment Agency via Ministerial guidance on RBMPs to recommend no less stringent objectives than good for chalk rivers, even if it is not cost-beneficial. This would help to circumnavigate the cost-benefit analysis (CBA) limitations that tends to curtail investment (see section 7.2).

Protected site status

There are various protected site designations, from domestic SSSIs to European SACs, to international Ramsar designations. SACs have had success in securing additional attention in water-planning processes, securing greater levels of action on water quality improvements and a ratcheting down of licensed water abstraction. The fortunes of non-SAC SSSIs have been more mixed because all regulation apart from the Habitats Regs includes a requirement for cost-benefit analysis.

Protected-site mechanisms are not designed to confer protection to widespread habitat features. The strength of these mechanisms is in their limited spatial application – the greater the extent of their use the more like a wider environment protection mechanism they become. Widespread use of protected-site mechanisms is even more problematic for freshwater habitats where the condition of sites is influenced by all of the activities occurring in the catchment. They are not a panacea for the lack of priority assigned to the chalk-stream resource.

The resourcing of a river SSSI or SAC, from notification to overseeing its management, is a substantial undertaking. Natural England does not believe designation of the entire suite of 200+ chalk streams, or the aquifer, to be practical nor achievable nor a timely way to address the issues facing the streams.

Priority habitat status

Biodiversity strategy outside of protected sites is focused on priority habitats and species listed under Section 41 of the NERC Act 2006.

Under the original UK Biodiversity Action Plan chalk rivers were the only river type included in the priority habitat list, but in 2010 the scope of priority river habitat was extended to include a broader number of river and stream types (H3260, active shingle rivers, headwater streams) as well as watercourses containing priority species. This inevitably diluted the biodiversity focus on chalk rivers, exacerbated by the loss of funding to BAP working groups which eventually led to the disbanding of the Chalk rivers HAP working group.

While priority-habitat status confers a framework to define ambitions for chalk-stream protection and restoration, historically it has not been considered a strong enough driver to garner resource and investment. When chalk streams were the only priority habitat there were BAP drivers in the water-company national environment programme which drove significant investment.

Combining mechanisms and securing investment

There are various delivery and protection mechanisms available that can be used to drive additional action on chalk streams (such as regional water-resource planning) but they all depend on chalk streams being assigned a higher priority status than they are currently given.

A particular case for a more ecologically integrated approach to restoration of the chalk-stream resource relates to calcareous fens. Chalk-stream catchments are extremely important locations for fen restoration. These occur naturally around spring lines down into floodplain fringes in natural upwelling areas of floodplains where raised bog develops. They have been eliminated and degraded by drainage of valley slopes and floodplains as well as groundwater abstraction and their recovery through restoration of natural hydrological and chemical regimes and associated vegetation management is a critical priority.

A recent Natural England report (Carbon storage and sequestration by habitat: a review of the evidence: see Appendix A) makes clear the potential that integrated restoration of chalk-stream catchments could play in terms of climate change. Floodplains are important carbon sinks and have the potential to store significant amounts of carbon, but, subject to intensive management, they can become sources of carbon not sinks. Chalk streams seem to be more sensitive to organic matter inputs, potentially causing hotspots of carbon dioxide and methane.

For these reasons, it is critical that a new status is able to drive investment not only for the chalk-stream channel, the surrounding floodplain and the underlying aquifer to drive nature recovery at scale.

7.1.4 Proposals to realise elevated status

Our recommendations for means of delivering the “one big wish” of elevated status for chalk streams include:

• **through the Environment Bill**: a statutory Environment Bill biodiversity target for chalk-stream catchments that would elevate the status of all chalk streams and provide long-term certainty of government ambition and commitment for protection and restoration.

• **through the 30 x 30 Nature Compact**: A new form of designation / statutory protection for all chalk streams, a White Belt for chalk streams, through the Green Paper on Habitats Regulations.

• **through the Nature Recovery Network**: Make chalk streams a stated priority of the Nature Recovery Network and support the water sector to lead on chalk-aquifer / catchment -cale Nature Recovery Areas.

• **through the Water Framework Directive:** A stronger policy steer for chalk streams, for example, through the Ministerial Guidance on River Basin Management Plans and strategic policies statement to Ofwat.

It is vital, however it is done, that the one big wish is delivered in a form that is comprehensible, genuinely potent and that inspires confidence.

7.2 Reviewing economic appraisal / cost-benefit analysis

Item 2 under 'integrated policies recommendations and actions' proposes a review of Economic appraisal in order to ensure that cost-benefit analysis (CBA) methodologies used by water companies and regulators adequately quantify the ecological value of chalk streams. At the request of the CSRG group Jonathan Fisher has kindly prepared a preliminary survey and made recommendations.

7.2.1 Economic appraisal of chalk streams

Economic appraisal is a key component in the decision-making process that governs where investments are made by the water industry to improve the water environment in the most efficient way possible. Economic appraisal helps to assess and compare benefits versus cost for the various improvements deemed necessary for a water body to meet good ecological status. For water bodies that are not subject to specific designations for ecological quality, the Environment Agency uses economic appraisal when setting objectives for water bodies in the river basin planning process. Water companies also use economic appraisal to determine whether proposed improvements are cost beneficial when developing their business plans.

7.2.2 Water industry surveys

Ofwat sets a requirement of the water companies that their business plans offer good value for money and have customer support. Water companies address this requirement through customer surveys. They use what are known as choice experiments (CE) to derive nominal values for improvements to the water environment alongside various other potential service improvements, such as to the taste and smell of drinking water, or reducing supply interruptions or sewer flooding. In PR19 the environmental attributes included: pollution / river flows / river-water quality / bathing-water quality / renewable energy / conservation, wildlife and diversity. Aspects of each attribute were described to provide context and customers were then asked to place a value against a given attribute and metric.

Customers were then asked to state whether and how much they might pay for various levels of the metric. For example Option A might comprise X number of miles of river improved for flows with a decrease in the water bill, while option B might comprise X+Y number of miles of river improved for flows with neither a decrease nor an increase in the bill, while option C might comprise X+Y+Z miles of river improved for flows with an increase in the water bill.

There is no standardised CE format. Each water company designs their own although all are expected to be in line with best-practice recommendations.

The limitation of the approach is that environmental attributes are only considered as one of the many services that water companies provide. Customers are asked to compare many attributes and the descriptions of these attributes are necessarily limited and do not fully cover the major environmental impacts for chalk streams as set out in Sections 4 & 5 of this strategy and specifically in Appendix B.5. Illustrations are only occasionally used. This is because there are limits to the amount of information about the many attributes covered that respondents can realistically take in during a CE survey, without compromising the robustness of the results due to respondents' loss of interest.

There are therefore doubts about whether respondents can give an adequate relative preference and valuation for abstract environmental benefits compared with the other attributes such as the colour, taste, smell or safety of water coming out of their taps, which are much more tangible. Whilst companies do undertake more in-depth surveys on specific issues, these must always be limited by the overall willingness to pay and relative preferences for different attributes, established within the overall choice experiment. For these reasons it is questionable whether the choice experiment is the appropriate mechanism for establishing appropriate levels of investment for something that is of national significance, such as chalk streams.

7.2.3 Environment Agency surveys

In 2007, NERA and Accent surveyed 1487 householders for their valuation of various states of water bodies in England and Wales.

Accent conducted extensive focus-group discussions to clarify people's understanding of the issues and to frame the questions. The different states of the main types of water bodies were described and illustrated. Respondents were informed about existing conditions and possible improvements. Participants were then asked what they would be willing to pay (in terms of annual water bills and higher prices for other products) for improvements in water-body states.

To prepare for the second River Basin Management Plans (RBMP) in 2012 the Environment Agency updated the 2007 values in terms of £/km of water body improved and took account of changes in population and more recent thinking on valuation techniques and peer review comments. Then, in 2013, the Environment Agency developed their Water Appraisal Guidance (WAG), which was used with the updated NWEBS values to assess improvement options for RBMP2.
WAG assigned one-sixth of the NWEB values to six components of a waterbody's ecological status – clarity / fish / invertebrates / range of plants / flow and condition of channel / safety for recreational contact – and gave detailed descriptions of each of these components for water bodies in good, moderate, poor or bad conditions, descriptions that relate fairly well to the environmental parameters for the condition of chalk streams in the CaBA strategy.

WAG enables the benefits from improvements to the headwaters of a chalk stream to be included. Therefore, NWEBS could cover most of the environmental benefits of chalk-stream schemes (although low-flow and sewage-pollution problems are arguably not fully covered). But NWEBS is dated. Environmental valuations could be expected to have risen since the survey was carried out in 2007. If this approach is to continue to be used to justify improvements required for chalks streams, NWEBs would need to be updated with a new survey that explicitly covers chalk streams.

7.2.3 Specific original valuation study of the River Mimram

Neither NWEBS nor water-company customer surveys address the scarcity and iconic value of chalk streams. A tailored benefit valuation for chalk streams like the one the Environment Agency conducted in 2002 for the River Mimram could address these limitations. Like NWEBS, this involved extensive focus-group deliberative work to draw on respondents' knowledge about the river – including photos of what it was like historically. This helped to clarify people's understanding and concerns about the River Mimram so as to frame the questions which were then put to 650 households living close to the river and at various distances up to 130kms away. A review workshop in 2003 concluded that the Mimram study values were the best available values for water-resource improvements that were included in the EA's benefits assessment guidance (BAG).

7.2.4 Regional water resources groups

Regional Water Resources Planning groups are now (in 2021) the main mechanisms being used collaboratively to tackle water-resource problems in the south and east of England. They propose a best-value appraisal approach to strategic water-resources options. This sets out the problems, options and constraints, who makes decisions, who to consult and how, then proposes a scoring and weighting multi-criteria analysis (MCA). It is currently unclear how well this methodology will cover the environmental impacts on chalk streams set out in this strategy.

WRSE's proposed best-value programme is only applied once first consideration is given to statutory requirements – the most significant of which is achieving security of water supplies. There are therefore concerns that compliance with the fundamental legal requirement of securing water supplies may leave no or little room for supplementary "best-value" ecological options for chalk streams. However, it should be noted that a statutory designation for chalk streams would correct this shortcoming and enable chalk stream requirements to be considered only secondary to meeting basic water-supply requirements.

7.2.5 Other issues affecting cost benefit techniques

The methodology for estimating how many people benefit, and to what degree, from ecological improvements to a waterbody has a considerable bearing on the adjudged value of any given proposal. The iconic status and international rarity of chalk streams suggests they are likely to be more highly valued by local residents and even non-locals than other river types. Water-company customer surveys are not designed to pick up this distinction. With a payment vehicle of customer water bills, these surveys are only addressed to each individual water company and addressed relative to the other improvements in service proposed by the company. This is likely to underestimate the value of ecological improvements to chalk streams, both locally and farther afield.

7.2.6 Recent developments

The climate emergency and biodiversity crisis has caused the water sector as a whole to review the approach that has been adopted to date to justify environmental improvements to be delivered by the water industry. Whilst the current approach has been effective at securing substantial improvements in water quality, there is some doubt as to whether it is fit for purpose for meeting the challenges ahead. As a result, the EA has convened a task force to develop proposals for reform and evolution of the methodologies utilised to develop the water industry national environment programme, proposals for which were subject to public consultation. The draft WINEP methodology is designed to:

- focus on delivering outcomes
- support the delivery of wider environmental outcomes
- have a longer-term focus
- accommodate a systems- and catchment-oriented approach embracing innovation and company collaboration, including a greater use of nature-based solutions
- support co-design co-delivery and co-funding of solutions
- make best use of and improve available data

As part of this process, the EA has also committed to working collaboratively to produce revised optioneering and appraisal guidance which will present an opportunity to review the approach used for CBA.

7.2.7 Cost-benefit analysis* – recommendations

To adequately assess the full range of benefits to society and the environment of improving chalk streams CSRG recommends the following initiatives:

• water companies' customer surveys for PR24 should ensure that they fully cover the environmental impacts of water-company assets on chalk streams and make the importance of these iconic habitats clear to respondents, including in-depth studies where chalk streams cover a significant component of their area served

• Defra / EA should review how the proposals for WINEP reform and revised optioneering and appraisal guidance could be strengthened to ensure that improvements to chalk streams are valued appropriately

• Innovative approaches to capturing the full range of benefits generated by improvements to chalk streams should be trialled on the chalk-stream flagship projects

• Consideration should also be given to carrying out a new valuation survey for a chalk stream similar to the earlier study for the Mimram

7.3 Planning and development – recommended development rules for chalk streams

Population growth and demand for new housing is high in the chalk counties of southern and eastern England, increasing the multiple pressures on chalk streams in terms of land use, demand for water, water quality and habitat loss. Much of the development currently planned – around Cambridge, for example – is in areas that are already recognised as water-stressed, both in terms of quantity and quality.

To reduce the impact of development, it is essential that adequate infrastructure is in place *before* development proceeds, to ensure there is no increase in unsustainable abstraction or overloading of the sewer network or sewage treatment infrastructure. The National Planning Policy Framework (NPPF) sets out government's planning policies for England and how these are expected to be applied. CSRG recommends that the NPPF should be reviewed to ensure it is fit for purpose for protecting chalk streams.

This should include a set of "development rules for chalk streams" similar to those for farming set out in Section 5.8.3 above which set out enhanced standards that must be followed in chalk catchments. This could include measures such as: a requirement for buffer strips precluding development alongside chalk streams, SUDS maintenance standards, and water-efficiency standards.

It should be a planning requirement for large scale developments to promote truly ambitious water efficiency, aiming for water-neutrality, making use of the highest water-efficiency standards, use of grey-water and sustainable drainage systems, and ensuring water treatment infrastructure is conjunctively made more than adequate to meet the demands of the new housing.

Building regulations in chalk catchments should protect chalk streams by setting more demanding water-efficiency targets than the current optional standard of 110 l/h/d. This could be incentivised, for example, by the use of variable infrastructure charges such as those trialled by Southern Water in Eastleigh (see Section 4.7 on water efficiency in new developments).

There is also scope for maximising environmental net gain through good planning responses to development opportunities. The Environment Bill will require the Biodiversity Net Gain of any development to exceed the pre-development value by 10%. This Biodiversity Net Gain could be targeted to enhance chalk-stream habitats.

Local Nature Recovery Strategies will support delivery of mandatory Biodiversity Net Gain and provide a focus for a strengthened duty on all public authorities to conserve and enhance biodiversity. The aim of Local Nature Recovery Strategies is to identify areas that are already of importance and should be used to guide where to focus Biodiversity Net Gain. It will be essential for chalk-stream habitats to feature strongly in Local Nature Recovery Strategies, which will influence future planning and development.

Right: the River Wye, a Chilterns chalk stream that is heavily impacted by development.

7.3.1 Recommended development rules for chalk streams:

- **LPAs should take account of implications for water resources and sewerage systems of major housing developments in their Local Plans and when reviewing proposals for major housing developments.**

- **Planning approval must be contingent on the pre-existence of or parallel investment in more than adequate supply and treatment infrastructure with no additional burden on chalk aquifer abstraction. Developers should make water-company developer contributions to help cover the costs of addressing such impacts.**

- **Chalk-stream 'no development' buffer zones to protect chalk stream riparian corridors from encroaching development.**

- **SuDS (sustainable drainage systems) on all new, large-scale developments (housing, roads, car parks) in chalk catchments.**

- **Highest standards of water efficiency for new development in 'water-stressed' chalk catchments, more ambitious than the current optional standard of 110 l/h/d: recommend a minimum of 90 l/h/d.**

- **Chalk streams and their associated habitats should feature strongly in Local Nature Recovery Strategies and Biodiversity Net Gain.**

7.4 Integrated policies: recommendations for action.

1. One big wish*	CaBA CSRG recommends that the government create an overarching statutory protection and priority status for chalk streams and their catchments to give them a distinct identity and to drive investment in water-resources infrastructure, water treatment, stronger planning controls and catchment-scale restoration. This is the one big ask arising from this strategy, and is the key to unlocking so many of the other components.
2. Review of cost-benefit analysis / economic appraisal*	CaBA CSRG recommends a review of cost-benefit analysis: • water companies' customer surveys for PR24 should ensure that they fully cover the environmental impacts of water company assets on chalk streams and make the importance of these iconic habitats clear to respondents, including in depth studies where chalk streams cover a significant component of their area served • Defra / EA should review how the proposals for WINEP reform and revised optioneering and appraisal guidance could be strengthened to ensure that improvements to chalk streams are valued appropriately • innovative approaches to capturing the full range of benefits generated by improvements to chalk streams should be trialled on the chalk-stream flagship projects • consideration should also be given to carrying out a new valuation survey for a chalk stream similar to the earlier study for the Mimram
3. Development Rules for chalk streams	CaBA CSRG recommends that the National Planning Policy Framework should be reviewed and include 'development and planning rules for chalk streams' (matching the 'farming rules for chalk streams' outlined in 5.8.3). Guidelines and recommendations for these rules are set out in Section 7.3.1 above.
4. Commitment to develop and publish an implementation plan.	CaBA CSRG will publish within 12 months an implementation plan for the headline actions identified in this strategy.

* In theory, a reformed cost-benefit analysis process, one that adequately values the iconic status of chalk streams and the measures needed to improve their ecological status, would drive investment in many of the ways in which a statutory protection & priority status would. However, an explicit statutory protection & priority status would be more potently symbolic and comprehensible to the general public and so remains a fundamental CSRG recommendation. Either way, Defra might consider how the recommendation for a new statutory protection & priority status raises the importance of chalk streams and thus the need for priority attention to be given to specific aspects and benefits (arguably improvements to a designated site should accrue more benefits). The challenge, with or without a new statutory protection, is to ensure that the CBA process duly delivers such benefits.

8. Next steps: developing an implementation plan

Photograph © Peter Christensen

8. Next steps: moving the recommendations forward

The table below and on the following pages lists all recommendations in one place and indicates the organisation(s) which will lead the next stage of development. Lead organisations will explore each recommendation in detail and work collaboratively with their partnering organisations to deliver.

As described in ‘consultation feedback and next steps’ on page 6, in some cases – such as the flagship project proposals – work has begun and progress has already been made. In others, this next stage of work will be to evaluate the best approach to drive the recommendation forward, considering also the impact and alignment of each recommendation with other major programmes e.g. water-resources regional-planning timeline, Local Nature Recovery Strategies and other new powers available for the protection of nature that are expected under the Environment Bill.

For these recommendations there will now be a scoping phase October 2021 to March 2022 and a planning phase from March to October 2022

The Chalk Streams Restoration Group commits to meet again in Spring 2022 to review and update progress and to publishing an Implementation Plan in Autumn 2022, based on this table below and on the work deriving from the scoping and planning phases described above.

8.1 Table of recommendations / leading organisations / key partners / notes

Recommendation number:	Recommendation	Leading organisation(s)	Key partners	Notes	Mechanism in place
Integrated Policy 1.	Designation for chalk streams	Defra		Options under consideration.	
Integrated Policy 2.	Review of cost-benefit analysis / Economic Appraisal	Water companies Environment Agency	Defra	Options under consideration.	
Integrated Policy 3.	Development rules for chalk streams	Defra			
Integrated Policy 4.	Commitment to develop and publish an implementation plan	CSRG		Agreed.	
Water Quantity 1.	Agreed definition of sustainable abstraction	CSRG		Agreed. Delivery will now depend on the remaining recommendations under Water Quantity.	
Water Quantity 2.	Review Abstraction Sensitivity Banding	Environment Agency		Options under consideration.	
Water Quantity 3.	Enhanced scenario for chalk streams	Water Resources South East Water Resources East		Options under consideration.	Yes
Water Quantity 4.	Review of waterbody boundaries and assessment points	Environment Agency		Options under consideration.	
Water Quantity 5.	Time-bound goals towards sustainable abstraction	Environment Agency	Defra Water companies	Via Abstraction Plan and will need a focus on chalk streams.	Partly

Recommendation number:	Recommendation	Leading organisation	Key partners	Notes	Mechanism in place
Water Quantity 6.	Evidence of stress or damage	Environment Agency			
Water Quantity 7.	Ofwat to review Abstraction Incentive Mechansism	Ofwat	Water companies		
Water Quantity 8.	Demand management / chalk regions defined as water stressed	Defra, Water companies		Defra has recently accepted the Environment Agency recommendations to extend the water-stressed designations. Water companies should now consider compulsory metering in these areas.	Yes
Water Quantity 9.	Flagship flow recovery in the Chilterns	Water Resources South East	Ofwat RAPID Water companies	Options under consideration.	Partly
Water Quantity 10.	Independent review of A%R	CaBA CSRG	Defra Environmenat Agency	Preliminary review completed.	Yes
Water Quantity 11.	Modelling and knowledge sharing	Environment Agency	Water companies		
Water Quality 1.	STWs that do not strip phosphorus	Environment Agency	Water companies Ofwat	Planning for PR24 is underway. Need to review guidance to water-quality planners on planning for P-removal schemes for the WINEP.	Partly
Water Quality 2.	Integrated constructed wetlands	Water companies	Local planning authorities Developers	Some ICWs are being constructed in the current AMP period, alongside trials to review their performance. Changes to WINEP guidance are being consulted on to encourage the use of catchment- and nature-based solutions.	Partly
Water Quality 3.	Review of waterbody boundaries and assessment points	Environment Agency		Review options under consideration.	
Water Quality 4.	Storm overflows	Defra	Environment Agency Water companies	The government has confirmed that the Environment Bill will include new legal duties to tackle storm overflows. These are: a duty on government to publish a plan by September 2022 to reduce sewage discharges from storm overflows; a duty on government to report to Parliament on progress in implementing the plan; and a duty on water companies to publish data on storm-overflow operation on an annual basis.	Yes

Recommendation number:	Recommendation	Leading organisation		Delivery mechanism / notes	Mechanism in place
Water Quality 5.	Groundwater ingress at small STWs	Water companies	Environment Agency	This is being considered by the storm overflows taskforce.	Yes
Water Quality 6.	Research septic tank hotspots	Environment Agency	Defra	Funding needed to commission the investigation. Resources required for monitoring and enforcement.	
Water Quality 7.	Septic tank point of sale	Defra		General Binding Rules currently apply to anyone who has a septic tank or sewage treatment plant that makes a small sewage discharge.	Yes
Water Quality 8.	Farming rules for chalk streams	Defra		The rules for the new Sustainable Farming Incentive (SFI) are currently being developed.	Yes
Water Quality 9.	Farming incentives for chalk streams	Defra		The rules for the new ELM schemes are currently being developed.	Yes
Water Quality 10.	Highways rules for chalk streams	Highways Agency Local highways authorities			
Water Quality 11.	Review aquaculture permitting	Environment Agency			
Physical Habitat 1.	Principles of chalk stream restoration	CaBA CSRG		A manual of river-restoration principles and techniques for chalk streams is in the planning stages.	
Physical Habitat 2.	Flagship restoration projects	CaBA CSRG		The Minister has written to the water companies to ask for their support. Some have committed to sponsor flagship projects. Defra setting up a programme board.	Yes
Physical Habitat 3.	Monitoring and appraisal	CaBA CSRG	Rivers Trust	Funding needed. Build on work of the modular survey Queen Mary University https://modularriversurvey.org	Partly
Physical Habitat 4.	Chalk-stream hub and sharing best practice	CaBA CSRG		Work on the data and information hub. Funding needed.	Yes
Physical Habitat 5.	Research into reference conditions	CaBA CSRG		Funding needed.	
Physical Habitat 6.	Database of reference reaches	CaBA CSRG		Funding needed.	
Physical Habitat 7.	Chalk-stream map and index.	Natural England, CaBA CSRG		99% complete	Yes

Glossary

Abstraction – taking water from rivers or the aquifer to supply homes, farms, industry

AIM - Abstraction Incentive Mechanism. A regulatory mechanism devised by Ofwat / WWF to encourage water companies to abstract less water from environmentally sensitive sources at sensitive times or when other sources are available

ASB - Abstraction Sensitivity Band. The banding given to a WFD waterbody to indicate its sensitivity to abstraction

Aquifer – an underground body of water

ALF - Alleviation of Low Flows. A programme of abstraction reduction / flow recovery began by the National Rivers Authority in the early 1990s that evolved into the Restoring Sustainable Abstraction (RSA) scheme

BAP – (UK) Biodiversity Action Plan was published in 1994, and was the UK Government's response to the Convention on Biological Diversity (CBD), which the UK signed up to in 1992 in Rio de Janeiro. The CBD called for the development and enforcement of national strategies and associated action plans to identify, conserve and protect existing biological diversity, and to enhance it wherever possible

BNG – Biodiversity Net Gain is an approach to development, and/or land management, that aims to leave the natural environment in a measurably better state than it was beforehand

CaBA – Catchment Based Approach is an inclusive, civil society-led initiative that works in partnership with government, local authorities, water companies, businesses and more, to maximise the natural value of our environment

CAMS – The EA's Catchment Abstraction Management Strategies

CBA – Cost-benefit analysis compares the costs and benefits of achieving environmental improvements

Catchment - the area of land that feeds rainwater to a river

Chalk Streams First – a combined NGO proposal to re-naturalise flows in the Chilterns by moving the point of abstraction to the lower parts of the Colne and Lea catchments

CSF – Catchment Sensitive Farming raises awareness of diffuse pollution from agriculture by giving free training and advice to farmers in selected areas in England. The aim of the advice is to improve the environmental performance of farms

CSRG – Chalk Stream Restoration Group is a subgroup of the CaBA National Support Group

DNSG – does not support good ecological status

DWMPs – Drainage and Wastewater Management Plans

EA – The Environment Agency

Ecosystem Services – the benefits humans get from natural resources

Ecological engineering – the ways in which plants and animals manage their physical habitat

EFI – Environmental Flow Indicator is used to indicate where abstraction, or flow regulation, may start to have an undesirable impact on river habitats and species.

ELMs – Environmental Land Management schemes – there are 3 new schemes that will reward Environmental Land Management: sustainable farming initiative, local nature recovery and Landscape Recovery. Through these schemes, farmers and other land managers may enter into agreements to be paid for delivering environmental improvements

GBRs – General Binding Rules set out the conditions in the Environmental Permitting Regulations that allow a septic tank or sewage treatment plant to be used without an environmental permit

GES / good ecological status – the target required status for all waterbodies, including ecological, chemical and morphological condition assessments

Green Recovery Fund – A short-term competitive fund to kick-start environmental renewal while creating and retaining a range of jobs in England

Groundwater – water in the chalk aquifer, which feeds the chalk stream

Groundwater level – the height AOD of the saturated part of the aquifer

ICW - Integrated constructed wetlands. A form of artificial wetland used to treat, or polish waste water.

INNS - Invasive non-native species

Lateral connectivity – the connection between the river, its riparian margins and the floodplain

LR – Landscape Recovery is one of three new Environmental Land Management schemes, alongside the Sustainable Farming Incentive and Local Nature Recovery Strategies

LNRS – Local Nature Recovery Strategies (are a flagship measure in the Environment Bill. They are a new system of spatial strategies for nature which will plan, map, and help drive more coordinated, practical, focussed action and investment in nature's recovery to build the national Nature Recovery Network

Longitudinal connectivity – the connectedness along the linear length of the river, interrupted by artificial structures and barriers to fish migration, such as weirs

Ml/d - Megalitres per day. 1 Ml/d = 1 million litres. A standard measure of water volume for example as river flow or abstracted water

MCA – Multi-criteria analysis is when a project is evaluated by more than just monetary terms

Nature4Climate – is a strategic communications platform designed to help raise the profile of natural climate solutions and to catalyse action on the ground

NbS – Nature-based solutions involve working with nature to address societal challenges, providing benefits for both human well-being and biodiversity

NE – Natural England

NGOs – Non-government agencies - non-profit groups that function independently of any government

NMP – Nutrient Management Plan identifies sources of nutrients that are entering a river and steps that can be taken to manage them

NRA - National Rivers Authority

NRN – Nature Recovery Network is a commitment in the government's 25-Year Environment Plan and part of the forthcoming Nature Strategy. It will be a national network of wildlife-rich places. The aim is to expand, improve and connect these places across the country

NWEBS – National Water Environment Benefit Survey

Optioneering – is a used term to describe the consideration of a number of options to find the best or preferred option

PR24 – Price Review (2024) is the process by which Ofwat review the prices that water companies can charge their customers. This takes place every five years. The next review will be published in 2024. It results in an Asset Management Plan (AMP)

RAM – Resource Assessment and Management framework is a technical framework for water-resource management including abstraction licensing

Ramsar – convention on wetlands of international importance

RAPID - Regulators' Alliance for Progressing Infrastructure Development has been formed to help accelerate the development of new water infrastructure and design future regulatory frameworks. The joint team is made up of the three water regulators Ofwat, Environment Agency and Drinking Water Inspectorate

RBMP – River Basin Management Plans set out how organisations, stakeholders and communities will work together to improve the water environment

RSA - Restoring Sustainable Abstraction. An EA programme of works to restore sustainable abstraction in stressed catchments

RWP - Regional Water Resources Plan

SAC - Special Area of Conservation

SA(e) – Sensitive Area (eutrophication) designated under the UWWTD. The UWWTD describes eutrophication as 'the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned'

SAGIS – Source apportionment geographical information system is a GIS-based tool to apportion loads and concentration of chemicals to WFD water bodies. SAGIS operates in conjunction with the Environment

Agency's SIMCAT (simulated catchment) water-quality model, together referred to as SAGIS-SIMCAT

SFI – Sustainable Farming Incentive scheme will pay farmers to manage their land in an environmentally sustainable way

SO - Storm overflow: when a water company bypasses the sewage works and discharges raw sewage into a watercourse

SSSI - Site of Special Scientific Interest

S&TC – Salmon and Trout Conservation

SPS – Strategic policy statement for Ofwat, which sets out the government's strategic priorities for Ofwat's regulation of the water sector in England

STW – Sewage-treatment works

WAG – Water Appraisal Guidance assessment of benefits for economic appraisal of measures which affect the water environment

WEG – the Water Environment Grant scheme is part of the rural development programme for England (RDPE). The scheme closed at 5pm on 11 May 2018

WRMP – Water Resources Management Plans are used by water companies to set out how they intend to achieve a secure supply of water for their customers and a protected environment

UWWTD - Urban Waste Water Treatment Directive. A directive governing wastewater standards in certain catchments.

WFD - Water Framework Directive

WINEP – Water Industry National Environment Programme – a set of actions the EA sets the water industry to contribute to meeting their environmental obligations

Woodlands for Water – an incentivised woodland creation scheme

WRSE & WRE – Water Resources South East & Water Resources East are alliances of the water companies that cover the South East and East region of England, whose aim is to secure the water supply for future generations through a collaborative, regional approach to managing water resources.

WWTP – Wastewater treatment plant

Winterbourne – the ephemeral part of the chalk stream that routinely and naturally dries for a short period each summer (spelt as winterborne in Dorset)

Editor's note on capitals: the consistent use of capitals in a report which cites so many reports, papers, schemes, projects and programmes can become quite tricky. We have tried to follow the Ofsted style guide and use capitals:

- generally as little as possible except for the usual use with proper nouns and the names of individual people, places and organisations
- for government government (and non-government) schemes, policies and programmes

Otherwise we have used sentence case for:

- headings
- titles of journals, government and non-government documents, reports and research papers

Acknowledgements

The CaBA CSRG panel is extremely grateful to everyone who has made a contribution to this strategy, whether through the formal consultation process, on the river-walks held in August 2021 or in direct correspondence with the CSRG chair. Your expertise and passion have been invaluable, adding numerous ideas and much information, as well as photographs, edits and factual corrections. You are all co-authors of this strategy. Thank you.

Stuart Brooks	Abbots Hall Syndicate
Ellie Powers	Affinity Water
Nick Josephy	Aldbourne Drainage Improvement Group
Martin Bowes	Cam Ely Ouse Partnership
Kelvin Allen	Angling Trust Eastern England
Sandra Manning Jones	Arun and Rother Rivers Trust
Eddie de Vere Hunt	Axe Vale Rivers Association
Andrew Hinchley	Bury Water Meadows Group
Ian Campbell	Bury Water Meadows Group
Simon Cain	Cain Bio-Engineering
David Brooks	Cam Valley Forum
Stephen Tomkins	Cam Valley Forum
Libby Ranzetta,	Chalk Aquifer Alliance
Sharon Moat	Chalk Aquifer Alliance
Dr. Wendy Morrison	Chilterns AONB
Alan Beechey	Chilterns Chalk Stream Project
Richard Knowles	Cotswold Fly Fishers
Doug Kennedy	CRAG
Uffe Westerberg	Danish chalk streams
Richard Miller	Dorchester Fishing Club
Natalie Poulter	Dorset Catchment Partnerships
James Potter	Eastbury Community (River Lambourn)
Gavin Lane	Farmer
John Austen	Farmer and estate manager
Michael Rae	Farmer
Will Best	Farmer
Sue Wells	Friends of Cherry Hinton Brook
John Barker	Friends of the Ems
Charles Edward Rowe	Friends of the Rib and Quin
Mark Wilkinson	Friends of the Rib and Quin
Susan Buckingham	Friends of the River Cam
Sandy Galloway	Friends of the River Ems
Ron Mungovan	Friends of the River Shep
Mike Overall	Friends of the River Wye
Anna Stonor	Friends of the Westbrook and Stonebridge Pond
Richard Slocock	Frome and Piddle Association
Sarah Perry	Herts and Middlesex Wildlife Trust
Howard Slater	Hobson’s Conduit Trust
Alan Jones	Humber Nature Partnership
Alan Hughes	Independent
Anna Gannon	Independent
David Fisher	Independent
Dr Anne Rowe	Independent
Frank Gollogly	Independent
Ian Littlewood	Independent
Jason Payne	Independent
Malcolm High	Independent
Mike Foley	Independent
Nick Voysey	Independent
Patrick Heininger	Independent
Peter Evans,	Independent
Peter Levantis	Independent
Robert Pendlenton	Independent
Roger Harrison	Independent
Susan Holmes	Independent
Dr Peter Spillet	Institute of Fisheries Management
Paul Coulson	Institute of Fisheries Mangement
Mark Bradfield	Letcombe Brook Project

Ruth Craig	Lincolnshire Chalk Streams Project and Chalk Streams Trust
Professor Ian Reid	Loughborough University
Will Oliver	Maidenhead to Teddington Catchment Partnership
Dr Kerry Sims	Meon valley resident / Ex- EA
Professor Peter Landshoff	Natural Cambridgeshire Local Nature Partnership
Charitos Zapitis	Natural England
Doug Kite	Natural England
Helen Wake	Natural England
Jenny Wheeldon	Natural England
Silas Walton	Natural England
Michael Payne	NFU Watercress Association
David Diggens	Norfolk Rivers Trust
Jonah Tosney	Norfolk Rivers Trust
Dr Geoff Brighty	Norfolk Rivers Trust & Environmental Sustainability Associates
Rachel Stubbington	Nottingham Trent University
Clive Pavely	Panshanger Anglers / River Mimram
Matt Owen-Farmer	Portsmouth Services Fly Fishing Association
Dave Standing	River Beane Restoration Association
Dave Stimpson	River Beane Restoration Association
Steve Shaw	River Beane Restoration Association
Gwen Yarker	River Cerne riparian owner
Paul Hayes,	River Chess Association
Paul Jennings	River Chess Association
Stephen Crowley	River Darent Preservation Society
Stuart Merrylees	River Darent Preservation Society
Ian Shepherd	River Glaven Conservation Group
Jim Stephens	River Lark Catchment Partnership
Maureen Brierley	River Mel Restoration Group
Mark Naura	River Restoration Centre
Martin Janes	River Restoration Centre
Dr Derrick Guy	River restoration volunteer, Buntingford (River Rib)
Dennis Willis	River Wensum Riverfly Coordinator
Dr Cyril Bennet	Riverfly Partnership
Professor Anne Robertson	Roehampton University
Alistair Gammell	RSPB (retired) & Global Ocean Legacy
Christopher Mathews	SAFEM
Dave Holroyd	Salisbury & District Angling Club
Andreas Topintzis	Salisbury and District Angling Soc
Nick Measham	Salmon & Trout Conservation
Paul Knight	Salmon & Trout Conservation
Simon Saggers	South Cambs Conservation Consultants
Petra Davies	South East Rivers Trust
Catherine Moncrieff	South East Rivers Trust & Chilterns Society
Jeremy Legge	Test and Itchen Association
Ann Forbes,	Thames Rivers Trust
Bob Wellard	The Piscatorial Society
Robert Wellard	The Piscatorial Society
Ian & Beth Hall	The RevIvel Association
Mark Lloyd	The Rivers Trust
Clare Higson	Thetford River Group
Kelvin Peh	University of Southampton / Conservation Science
Graham Roberts	Upper Itchen Initiative
Andrew Baird	Upphall Fishing Syndicate
John Pritchard	Ver Valley Society
Cath Ranzetta	Ver Valley Society & Chalk Aquifer Alliance
Julian Jones	Water-21
Dave Rumble	Wessex Rivers Trust
John Bass	Wessex Rivers Trust
Fiona Bowles	Wessex Rivers Trust
Rebecca Lomax	Wilbraham River Protection Society.
Tom Putnam	Wiltshire Fisheries Association
Adrian Edward Simmons	Wiltshire River Keeper's Association (retired).
Liam Colin Deeney	Winterbourne Whitchurch Parish Council
Richard Breakspear	Wood Group UK
Jon Trail	Yorkshire Wildlife Trust
Dr. Vicky Warren	to whom special thanks are due for long hours of proof-reading