Keep The Streams Clean

The New Inn Stream

Water Quality Monitoring Project

LARC Report Streams 2022-2023

LARC

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Llanteg and Amroth Renaturing Community

‘Keep The Streams Clean’

The New Inn Stream Water Quality Monitoring Project

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Author Biographies

Dr Tom Bailey, BSc, BVSc, MRCVS, CertZooMed, MSc, PhD, Dip ECZM, RCVS Specialist in Zoo and Wildlife Medicine. Tom grew up on a family dairy farm in Surrey, trained as a veterinarian in Bristol and now lives on a small farm in Pembrokeshire. Tom has worked in a variety of free-living and captive wildlife projects and hospitals in Africa, the Middle East and UK during his career. Tom was part of a team in the 1990s that established the *National Avian Research Center*, a large captive breeding and restoration project for bustards in the United Arab Emirates where he was fortunate to do his PhD and write the first book on the care of this species in captivity. Tom returned to the UK in 2001 to do the MSc in Zoological Medicine at the *Zoological Society of London*. After a year in the UK, the Middle East beckoned again and Tom worked at the *Dubai Falcon Hospital* and the *Wadi Safa Wildlife Center* in Dubai until 2011. Tom holds a Diploma of the European College of Zoological Medicine (Avian), has published numerous journal and book articles and edited newsletters on raptor conservation and wildlife conservation. From 2011-2014, Tom was Head of Aviculture and Health at *International Wildlife Consultants*, responsible for the veterinary care and aviculture programme of a large raptor conservation and falcon breeding project in Carmarthen. Tom currently works for a local company, *Origin Vets*, as a consultant vet providing services for zoos, wildlife breeding centres and non-traditional exotic pets in South Wales as well as some international wildlife projects. In his spare time, Tom is part of an enthusiastic group of residents running a community nature recovery group called the Llanteg and Amroth Renaturing Community, as well as trying to live more sustainably on a small farm that is being renatured. Tom helps his wife Theri run an eco-campsite on their farm in the Pembrokeshire Coastal National Park. CV available on request.

Dr Kevin J. Caley BSc JHons (Wales) PhD (Leeds / NHM)
Kevin is an ecologist with a major interest in taxonomy and identification. Previously, he was a lecturer in Ecology and Biodiversity in the department of Continuing Education at the *University of Nottingham*. He was also an Honorary Assistant Professor in the Department of Ecology and Biodiversity (DEB) in the *University of Hong Kong* (1998-2004). Kevin was appointed as the Research and Conservation Executive at *Twycross Zoo* during 2010 – 2013, and became a member of the steering committees for Research and for Field Programmes in *BIAZA (the British & Irish Association of Zoos & Aquariums)*. He has published several articles, both in the scientific community and in a local and national capacity, the most influential of which were probably a foreword for one of the volumes in the *Handbook of the Birds of the World* (2007) and (as co-author) the '*BIAZA guidelines to implementing and managing field conservation*' (2012). He is also editor on several biodiversity-related ventures, e.g., *Encyclopedia of Earth* and the *Hong Kong Field Guides,* and was a contributor / facilitator to an international project that brought biodiversity education back into universities across 60 universities (*The Biodiversity Consortium: 1992-1999*). More recently, he moved to Pembrokeshire, where, since 2016, he has been working as a freelance ecologist. Kevin also studies the biodiversity on his own six acres, as he renatures the land, with a focus on pollinators and warblers. Kevin is Chair for *LARC*, and, on occasion, continues to provide talks at local venues. CV available on request.

Mr Andrew Dawe
Having graduated with a degree in Materials Science, Andy spent most of his career working in research, development, marketing and management roles within the metals and ceramics sectors at home and abroad. Subsequently, Andy worked at WRAP, the Waste & Resources Action Programme, leading on recycling and waste prevention within the packaging, food and retail sectors, culminating in becoming Head of Sustainable Food. For the past 9 years Andy has run an organic smallholding in Pembrokeshire on a self-sufficiency basis while managing the land for the benefit of nature. CV available on request.

Dr Trish Cormack holds a BSc and a PhD in Microbiology from the University of Leeds. She conducted research in bacteriology and antibiotic resistance in the University of Leeds, and later in the University of Bradford, where she also lectured part time in biological sciences and statistics for biologists. She is the author of several papers published in peer-reviewed scientific journals on antibiotic resistance in skin bacteria. She is now happily "retired" in Pembrokeshire. CV available on request.

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Executive Summary

In 2022, a conservation group, the Llanteg and Amroth Renaturing Community (LARC), decided to undertake a one-year water quality study on a small, but locally important stream that feeds into Amroth Bay close to the New Inn pub. This beach and the whole bay is an important tourist attraction in Pembrokeshire. LARC members had observed that the stream and its tributaries suffered pollution events from time to time over several years and so the Keep the Streams Clean project (KTSC) was conceived.

The primary objective of this citizen science project on water quality was to gather and test samples and look at the effects of nutrient pollution from land run-off on the network of streams feeding into the New Inn Stream. The sampling took place from August 2022 to July 2023, from one of the furthermost tributaries at Furzy Park down to the New Inn Bridge at Amroth. Water samples were tested for levels of ammonia, nitrates and phosphates.

The quality and amount of data generated far exceeded project expectations. During the 12 months of repeat surveying, over 268 nitrate, ammonia and phosphate tests were recorded by volunteers. In addition, volunteers and friends of the project identified and reported five episodes of visible pollution feeding into the New Inn Stream to Natural Resources Wales (NRW) via their 24hr Incident Hotline (0300 065 3000) between April 2022 and August 2023.

The project proved to be successful in terms of the involvement of volunteers, the acquisition of useful data and starting conversations about local water quality within the Llanteg and Amroth communities. Unfortunately, the findings are not unique and correspond with what is reported elsewhere in West Wales and the rest of the United Kingdom, with respect to the frequency of discharges from private sewage plants, slurry runoff from intensive dairy farming and pollution incidents from domestic residential and commercial properties. Whilst our project did not identify any incidents specific to Welsh Water, we are aware of reports in the local press, data from Surfers Against Sewage and discussions at a well-attended LARC community meeting on October 20th 2023 with the River Quality Liaison Manager from Welsh Water (Kelly Jordan) that there have been discharges of untreated sewage into Amroth Bay. In other words, the poor quality of the river at the New Inn is a community problem and we, '*the community*', are all culpable in large and small ways by the nature of how *we* run our lives and businesses. This is very much a '*we*' problem and whilst this report may make uncomfortable reading and solutions to the issues are probably not immediately obvious to any of us, the authors want to reiterate that pointing a finger of blame will not solve the poor quality of water in our streams and, by extension, our sea. We can only improve the situation if we care to look for solutions and if we care to run our businesses and domestic lives with more sensitivity to the environment.

It is beyond the expertise of a small citizen science group, such as LARC, to go into the fine technical details of our results, so we chose to follow the example of the Surveying the Waterway Environment for Pollution Threats (SWEPT) volunteer project 2018-19. This citizen science project surveyed the Milford Haven Waterway in Pembrokeshire and followed nitrate and phosphate thresholds utilised in the Clean Water for Wildlife Survey when observing whether water samples were 'polluted' or not (Biggs *et al.*, 2016).

We used the SWEPT guidelines to interpret our phosphate results measured as PO_4-P mg/l and nitrate results measured as NO_3-N mg/l. The SWEPT guidelines classified nitrate and phosphate results into three categories of river water quality; 1) clean, 2) some evidence of pollution or 3) as high levels of pollution. We used the ammonia standards for rivers from the UK Government's Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 to interpret our ammonia results measured as NH_3-N. The Water Framework Directive guidelines classified ammonia results into four categories of river water quality, namely 1) high quality, 2) good quality, 3) moderate quality or 4) poor quality.

Our results for nitrate measured as NO_3-N mg/l show a wide scale distribution of pollution along the entire stream. Only 2 of 89 (2.2%) samples were less than 0.5 mg/ml and would have been classified as clean water according to the SWEPT criteria. Four of 89 (4.5%) water samples showed some levels of nitrate pollution (0.5 - 1.0 mg/l) and 83 of 89 (93.2%) of water samples had nitrate levels exceeding 1.0 mg/l consistent with high or very high levels of nutrient pollution. Levels above 5 mg/l (and even >10 mg/l) were not uncommon. The highest levels of nitrate 30 mg/l, 15.6 mg/l and 7.1 mg/l were recorded at sites 7 (Factory Lane), 4 (upstream from Goetre) and 8 (New Inn bridge) respectively.

Our results for phosphate measured as PO_4-P mg/l show a wide scale distribution of pollution along the entire stream. With regards to phosphate, Government guidance recommends that rivers should not exceed annual mean concentrations of 0.1 ppm (equivalent of 0.1 mg/l). Using the SWEPT classification for phosphate results; 18 of 89 samples (20.2%) were less than 0.05 mg/l in the 'clean' category, 25 of 89 (28.1%) were in the range of 0.05-0.1 mg/l (some evidence of pollution) category and the majority, 46 of 89 samples (51.7%), exceeded 0.1 mg/l and were in the high or very high levels of nutrient pollution category. The highest levels of phosphate were recorded at site 4 (upstream from Goetre) and nine of 11 samples exceeded the 0.1 mg/l threshold and the highest value recorded was 2.09 mg/l.

Using the Water Framework Directive Standards classification for ammonia 78 of 90 (86.7%) of samples were less than 0.3 mg/l in the high water quality category, 3 of 90 (3.3%) were 0.3-0.6 mg/l in the good water quality category, 5/90 (5.6%) were 0.6 – 1.1 mg/ml in the moderate water quality, 4 of 90 (4.4%) were in the 1.1 – 2.5 mg/l in the poor or worse water quality category (three of these exceeded the 2.5 mg/l limit for poor water quality). Maximum levels of ammonia ranged from 0.23 to 9.99 mg/l. The highest levels of ammonia (9.99 mg/l) were recorded at Factory Lane (site 7) and Furzy Park (site 1) both linked to agricultural slurry events upstream or in the surrounding fields.

The Water Framework Directive Standards threshold for unionised ammonia (as N) is 0.021 mg/l. Levels of calculated unionised ammonia exceeding 0.021 mg/l were recorded 5 times across all sites, including once at each of sites 3 (Spiritwood bridge), 4 (upstream from Goetre), 7 (Factory Lane) and twice at site 8 (New Inn bridge). The highest levels of unionised ammonia (as N), 0.256 mg/l, was recorded once at site 4 (upstream from Goetre).

In addition, visible signs, including photos of river pollution, were recorded as part of the survey. As had been requested by the West Wales Rivers Trust and NRW, pollution incidents noted during the monitoring project were reported to NRW via their 24hr Incident Hotline. Further pollution events that were not reported to NRW were also observed and recorded. The majority of reported and non-reported pollution incidents appear to be linked to application of slurry in contravention of the Water Resources (Control of Agricultural Pollution) (Wales) Regulations 2021 (CoAPR).

The report concludes with a series of broad recommendations, as well as a section on 'what we can do' as individuals. We hope that this report will be a catalyst to start conversations within the community about the very poor state of our waterways in general and encourage other groups to monitor their streams and waterways. The report provides useful information to organisations that are concerned with the quality of our waterways including Amroth Community Council, Pembrokeshire County Council, Natural Resources Wales, Welsh Water, the West Wales Rivers Trust, the Pembrokeshire Coastal National Park Authority, The National Trust and the Pembrokeshire Nature Partnership. Like a mirror, our streams, rivers and seas reflect back to us exactly what we have allowed them to become. We are looking at ourselves and how we treat the world that we live in. Improving water quality is complex and will involve the aforementioned organisations working closely with local communities and farming businesses.

Whilst this report was being written, we learnt that concerns about the water quality at Amroth and Wisemans Bridge had been raised by members of the local business community with the Amroth Community Council (ACC). There are concerns that local beaches may be at risk of losing their Blue Flag status if the quality of the water continues to deteriorate in Carmarthen Bay. A public meeting in February 2024 is being organised by ACC, including representation and presentations from Welsh Water, Pembrokeshire County Council Environmental Health and NRW to help develop a plan to improve water quality. This report by LARC on the New Inn Stream is therefore highly relevant to this discussion and a copy has been submitted to the ACC.

We have found that including local people in local environmental issues aids awareness and understanding of human impacts. This provides real impetus for environmental protection from the ground up. LARC has also initiated projects to cut the verges along our roads with more empathy for biodiversity and has recently been awarded a grant from the Pembrokeshire Nature Partnership to conduct a biodiversity assessment of our area by an independent professional ecologist. Members of LARC have been actively involved in planting native broadleaf trees and restoring wild flower meadows within our ward. LARC also organises a series of evening talks over winter to inform the community of the natural heritage of our region and what is being done by a wide range of individuals and organisations to help this beautiful corner of Pembrokeshire that we all care so deeply about.

This report summarises the key findings from the Keep the Streams Clean project. It is designed to be useful to other groups and individuals who are interested in running a similar initiative. For this reason, all project outputs are included in the appendices. These are available as editable word documents from the project lead.

Authors' Reflection

The New Inn Stream is not a large and iconic waterway. It is a small and rather non-descript stream that starts its life in the emergence of countless springs in corners of fields and hedges, and then gathers the runoff that the Pembrokeshire rain washes from the fields, roads, driveways and gardens that make up its catchment to the south and east of Tavernspite. As its small tributaries flow south, they collect into the larger stream, known locally as the "New Inn Stream". This flows through the tangled woodlands at the bottom of the valley at the western edge of Marros Mountain and to the south and below Factory Lane until it runs alongside the New Inn public house and thence into the sea.

The runoff from our watershed is not selective. It gathers the natural - the fallen leaves, the twigs, the soil, the decaying bodies of small animals - as well as the by-products of human lives - the litter and plastic waste we throw into our verges and hedgerows, the slurry from our cows, the herbicides and pesticides that are sprayed on our crops in the fields, the discharges of our own sewage leaking and leaching from our septic tanks and water treatment plants and the chemicals we use in our houses and gardens. The stream even contains microplastics and the excreted metabolites of the medicines we have used to treat our pets, our farm animals and ourselves. The natural and the manmade, are gathered altogether and mixed by the stream's turbulence into a liquid chemical cocktail of human life in our villages in the 21st century. After bearing the detritus of field, farm, forest and our complicated lives, the water will finally reach the pebble embankment at the shore below the New Inn Bridge and filter through those great stones into Amroth Bay.

The New Inn Stream may be 'non-descript', but it is 'our stream' and, if we take the time to look into her waters, they will share their story. Like a mirror, our stream reflects back to us exactly what we have allowed it to become. We are looking at ourselves and how we treat the world that we live in.

This report is both a technical report full of methods and results and a story of a group of people who wanted to understand why this stream, like many others across our country, appears lifeless, unlike the streams that were so full of life that we remember from our childhoods. We do not pretend to have the answers to solve a problem that is embedded in our local economy, in the way we farm, in the way we live our lives and dispose of our waste, in the way that regulatory bodies seem so emasculated in their ability to respond, or in the way that large water companies have tried to hide their 'dirty secrets' of leaks and discharges. What we can do is shine a light on the state of 'our' stream and start an honest conversation within the community.

Before you read this report, please take a few minutes to read the following passage called *Tawelan Brook*. It has been specially written by a friend of LARC, Professor Carl Jones, BSc, MSc, PHD, MBE. After you have read *Tawelan Brook*, Carl's childhood stream near St. Clears, perhaps reflect upon memories of a stream, a river or the sea that is special to **your** heart.

We copy Carl's Wikipedia entry below because he is a local boy from St. Clears, his uncle was a drinking buddy of Dylan Thomas and considered to be the inspiration of Butcher Beynon in 'Under Milk Wood'. For those of you who may not have heard of Carl, he is understood to have 'saved' more species from extinction than any other living person. He is a legend in conservation circles, now living near Llandovery and deeply rooted in West Wales.

Carl Gwynfe Jones MSc PhD MBE is a Welsh conservation biologist who has been employed by the Durrell Wildlife Conservation Trust since 1985, and a founding member and scientific director of Mauritian Wildlife Foundation. Additionally, he is Chief Scientist at the Durrell Wildlife Conservation Trust and an honorary Professor in Ecology and Conservation Biology at the University of East Anglia. Often outspoken on the importance of knowing your species and using intuition, empathy and practical knowledge over dogmatic education, Jones is best known for his work in recovering the Mauritius kestrel from just four individuals in

1974, to an estimated 400. Working in Mauritius since 1979, Jones has led five successful bird restoration projects where the starting population has numbered less than 12 individuals; as a consequence, Mauritius has averted more bird extinctions than any other country. [Source: Wikipedia (2022). Carl G. Jones. URL: https://en.wikipedia.org/wiki/Carl_G._Jones]

Tawelan Brook by Carl Jones, MBE

I grew up near Carmarthen, and half a field away from my home was the Tawelan Brook that became my haunt as a young boy getting to know the world. With my friends we explored down to where our stream became languid, and merged with the River Towy, and upstream to where it was a youthful brook, and we would dare each other to jump across. We named each section, the rapids and shallows, and our favourite fishing spot, with its dark, deep waters, where we caught trout and eels, we named "Paradise Pool". Further upstream half a mile from my house was a marshy, waterlogged area surrounded by clogged drainage ditches where reeds grew. This was the Rushy Field where I saw my first water rail and where reed buntings lived.

I got to know the stream, to understand her moods, the gentle sparkling trickle of summer and the tempestuous autumn spates. To me she was alive and pulsing with personality. The banks had been undercut by the winter floods, and gnarled Alder and Willows overhung the water, and among the tangled roots and shelving banks the biggest trout lurked. In May the elvers arrived in their thousands, glassy and transparent. We would catch them in jam jars to look at them closely, and could see their backbone and internal organs. Later in the summer the Sewin, vibrant and silver, travelled up from the sea. Salmon spawned in the winter and on clear frosty nights I ventured forth with a strong light to watch them winding their way up stream, their dorsal fin breaking the surface as they moved over the shallow rapids.

My friends and I referred to the brook rather grandly as the river, and in my mind she was grand, and still occupies that sacred place full of a happy childhood memories, of kingfisher and dragonfly summers, and dabchick winters. It was on the banks of the Tawelan I learned the skills of a naturalist and the template of my life was set. I left Wales to become a conservationist and during quiet moments of contemplation I have often drifted back to the hours spent on and in the brook, as a trout-tickler, bird watcher and childhood explorer.

After half a century I revisited the river and walked in my young footsteps. Paradise Pool is still there although I saw no fish. Further up towards my old home, much of the stream has been canalized, sanitized, no more undercut banks and no leaning Alder and Willow. Eels are now Critically Endangered and I doubt many Salmon ever breach the shallows. The Rushy Field where the moorhens skulked and bred has been drained and is now a housing estate. I stood on the bank looking into the brook; I was returned to what was and what could be.

What would the World be, once bereft
Of wet and of wildness? Let them be left
O let them be left, wildness and wet;
Long live the weeds and the wilderness yet.

Gerald Manley Hopkins

Background to Llanteg and Amroth Renaturing Community

The Llanteg and Amroth Renaturing Community (LARC) is an unincorporated community association established in 2022 and registered with the Pembrokeshire Association for Volunteers (PAVs). The aims of LARC are:

1. To facilitate the conservation of biodiversity in the local environment.
2. To raise awareness as it pertains to the local environment.
3. To create an inclusive community that facilitates local people to engage with the environment.
4. To record and map habitats and species in the local area.
5. To encourage renaturing of local habitats.

Support for Llanteg and Amroth Renaturing Community (LARC)

The committee of LARC is comprised of the following members of our local community in alphabetical order: Theri Bailey (Meetings /Events Secretary), Tom Bailey (Secretary), Kevin Caley (Chair), Andrew Dawe (Treasurer), Georgina Gardner (non-executive committee member), Jack Gradidge (Communications Officer) and Caz Pattinson-Phillips (non-executive committee member).

As of November 13th 2023, there are 32 Supporters of the organisation and many others attend the talks.

The Condition of Waterways in the United Kingdom and Wales

The quality of our waterways is not just a local issue, the condition of the waterways and seas off the coast of the British Isles is a matter of national concern and debate (Bevan, 2020; Environmental Audit Committee, 2022; Rivers Trust 2023a; Surfers Against Sewage, 2023). Almost all of the UK's waterways are polluted and hardly a week goes by without further revelations of the poor quality of our seas and rivers in the media. Most recently, Welsh Water has admitted to spilling untreated sewage into the Teifi estuary, Cardigan, for over a decade (Horton, 2023).

The UK is ranked consistently as one of the worst countries in Europe for coastal water quality (Surfers against Sewage, 2023) and six of the UK's most polluted rivers are in Wales (Phillips, 2023). In 2022, a House of Commons Committee report on the state of UK rivers concluded that no river in England was free from chemical contamination and only 14% of UK rivers had a "good" ecological status (Environmental Audit Committee, 2022. For the classification of 'ecological status', see EEA report 7/2018) and Kristensen *et al.* (2018).

The Environmental Audit Committee (2022) of the House of Commons consider that both agricultural runoff and the release of untreated sewage are leading causes of river pollution in the UK. Water pollution episodes, particularly those caused by agricultural runoff, regularly cause mortality outbreaks of wildlife in Wales (BBC Farming Today, 2020; Bevan, 2020; Messenger, 2018, 2021; Wales Environment Link, 2021). In an announcement made in November 2018, Lesley Griffiths (Cabinet Secretary for Environment and Rural Affairs, Welsh Government) said tougher regulations would be introduced in 2020 and rules on spreading and storing fertiliser and slurry would be tightened. Ms Griffiths stated, "*As we move into winter, I am already receiving reports and images of bad practice and the number of incidents this year has already exceeded last year's figure. This is unacceptable. Our rural communities, which depend on tourism, angling and food industries, must be protected*."

In 2021, Lesley Griffiths reported that there are at least three river pollution events a week in Wales caused by poor farming practice (Messenger, 2021; BBC, 2021). These pollution events are causing major problems higher up the food chain. Notably, there has been a steady decline in the numbers of sea trout returning to Welsh rivers since the late 1990s, while 21 out of 23 salmon rivers in Wales are now classified as 'at risk' or 'probably at risk' by Natural Resources Wales (NRW) (Anon, 2019). Indeed, salmon and sea trout could disappear from Welsh rivers with stocks reaching unprecedented lows according to NRW (Anon, 2017, 2019).

With increasing frequency, there have been reports of people falling seriously ill after swimming in the sea off Amroth. Some recent incidents have been reported in the local and national press (Evans, 2023; Lough, 2023) and the finger of blame has been pointed to discharges of human sewage by Welsh Water, as well as private treatment plants near Wisemans Bridge. A well-attended LARC community meeting to listen to Kelly Jordan, River Quality Liaison Officer, Welsh Water, deliver a presentation entitled 'Welsh Water and Our Environment' was held at the Wanderers Rest pub on October 20th 2023. A number of attendees raised concerns about incidents of gastroenteritis in visitors and residents following swimming in the sea and that most go unreported. One campsite owner was concerned that this could have a detrimental impact on tourism to Pembrokeshire if visitors felt that the sea was not safe to swim in. These concerns are not without a basis in reality. Already, elite athletes who use the marine environment for swimming and windsurfing are ceasing to train in British waterways and are relocating abroad because of pollution concerns (Brown, 2023; McInnes, 2023).

It is sobering to think that Britain was once dubbed "the dirty man of Europe" after it joined the European Union in 1973 because it was the only country in western Europe that failed to control pollution from cars, power stations and farming, that tried to undermine European pesticide controls and evaded nitrate regulations and bathing water directives (Vidal, 2016). To our shame, Britain has now regained this unwanted accolade and international media organisations have once again rebranded us the dirty man of Europe (Anon, 2023e; Buckley, 2023).

Agriculture in Pembrokeshire

Dairy farming has a greater environmental impact on water courses than any other farming sector (Franklin *et al.,* 2021). The trend towards greater intensification and higher productivity in milk production has been accompanied by increases in the use of both organic (slurry and manure) and inorganic nitrogen and phosphorus fertilizers (Burton, 2020; Anon, 2023e). Rebanks (2020) has discussed the changing practices that have occurred as dairy farming has intensified since the 1970s in his critically acclaimed book *English Pastoral: An Inheritance*. Modern dairy farming places a greater emphasis on the feeding of silage (made from monocultures of a single strain of rye grass) to adult dairy cows which are generally housed in cubicles rather than straw yards. Dietary and husbandry changes have led to changes in the type and volume of animal waste that is produced by dairy farms. A modern dairy cow produces about 1.59m^3 slurry a month or about 20m^3 a year (Ashbridge, 2009). Traditionally, the waste by-product from dairy farms was manure (mainly solid waste comprising faeces and bedding) and this was spread on to fields in the summer from 'muckspreaders'. In contrast, modern dairy farms produce mainly large volumes of slurry, which is a liquid mixture of faeces and urine, without any bedding. The production of large volumes of slurry needs to be stored and spread on the land, most commonly sprayed from slurry tankers or dribbled onto fields from pipes. If liquid slurry is spread on waterlogged ground, or if there is rainfall shortly after application, then the nutrients will be washed off into adjacent waterways. Neither can the nutrients from slurry be used efficiently by grass or other crops that lie dormant over winter (Crooks *et al.*, 2019). In this area of Wales the ground is often waterlogged, meaning that the nutrients will usually be washed into waterways or leach into the aquifer without being utilised effectively by the plants.. The application of animal manures and slurry at the right time and in the right quantities allows farmers to make the most of the growing season in West Wales. Conversely, the application of slurry at the wrong time and in the wrong place leads to pollution.

Dairy farms predominate over arable in Pembrokeshire. Many farms are increasing their dairy herd size, resulting in much greater production of slurry (Biggs *et al.*, 2016). Unfortunately, some farms do not increase their slurry storage capacities or acquire more land, due to cost, and therefore must spread slurry more frequently on fields that do not need fertilizers, or in weather conditions not suitable for spreading (Burton 2020). For example, a dairy farm with 600 cows would need to be able to safely store about 1.7 million gallons (about three and a half Olympic-sized swimming pools) of slurry for four months to be able to comply with the *Storing Silage, Slurry and Agricultural Fuel Oil Regulations* (SSAFO) that came into effect in 2020 (Stevens, 2019; https://www.gov.uk/guidance/storing-silage-slurry-and-agricultural-fuel-oil). This is quite an undertaking and the volume of slurry that is stored on dairy farms would probably be a surprise to those not involved with industrialised milk production. Given the challenges of storing slurry combined with increasingly wet winters, it is not uncommon to see slurry being spread by tractor-drawn slurry tankers or from networks of pipes on waterlogged fields and even before or after yellow weather warnings across Pembrokeshire. Instead of the slurry being valued and used as a natural fertilizer, it is often viewed as a waste by-product that needs disposing of, often extremely urgently over winter after runoff from heavy rainfall caused slurry lagoons to fill. There is little legislation in place to tackle nutrient overloading unless direct pollution is caused (i.e., when slurry, silage leachate or any other damaging substance actually enters a watercourse, be it by storage failure or inappropriate spreading).

There are Agricultural Codes of Practice that farmers should follow, but these are not legislation, and therefore not enforceable. Indeed, it has been widely known and has even been reported in an investigation by the Bureau of Investigative Journalism and the Guardian that even serious pollution incidents may not be prosecuted, while farms that have caused pollution continue to receive subsidies (Wasley *et al*, 2017a; 2017b). Some large farms that were penalised for non-compliance were considered by inspectors to view the penalties as part of the farm running costs. This particular article reported that there were three farms in Carmarthenshire where the enforcement history could meet the definition of a "criminal lifestyle" (Wasley *et al*, 2017a; 2017b).

Water Resources (Control of Agricultural Pollution) (Wales) Regulations 2021 (CoAPR)

Farmers and land managers in Wales must comply with the Water Resources (Control of Agricultural Pollution) (Wales) Regulations 2021 (CoAPR) which came into force on 1 April 2021 (Anon, 2021; Shane Thomas, pers. comm. 2023). The CoAPR regulations are very clear in explaining the requirements and restrictions when slurry (or other organic manures) must not be spread on land for agricultural benefit (Anon, 2021).

The requirements of the CoAPR regulations are legally binding and include requirements for keeping records and preparation of plans, calculations and maps (Anon, 2021). The CoAPR regulations apply to all farm businesses in Wales. Under CoAPR farmers:

- Should, before spreading any fertilising material including slurry, carry out an inspection to consider the risk of causing pollution or damage to the soil.
- Should not spread any fertilising material including slurry if there is a significant risk of pollution, taking into account the slope of the land, particularly if the slope is more than 12 (equivalent to "20%" or "1 in 5"); ground cover; the proximity to surface water; the weather conditions; the soil type; and the presence of land drains.

- Fertilising materials including slurry must not be spread if the soil is waterlogged, flooded or snow covered, is frozen or has been frozen for more than 12 hours in the previous 24 hours. Manufactured nitrogen fertiliser must not be spread within 2m of surface water. Organic manure must not be spread within 50m of a borehole, spring or well or within 10m of surface water (6m if precision spreading).

The Condition of Waterways in Amroth Ward

As a community organisation, we are concerned about the poor condition of our waterways in the Amroth area. This concern arose through observations of chronic and low grade pollution incidents, the frequent observation of malodorous foam and slurry runoff in streams and the presence of 'sewage fungus' (i.e., colonies of pollution-associated colonial bacteria, including *Sphaerotilus natans, Beggiatoa alba, Carchesium polypinum* and *Flexibacter spp.*), rather than healthy aquatic vegetation in many locations, most notably in the final stretch of the New Inn Stream, adjacent to the New Inn public house. The presence of 'sewage fungus' in waterways is an obvious, although non-specific, visible sign of poor water quality (Quinn and McFarlane, 1985; Rivers Trust, 2023b and Appendix 3). Additionally, a number of LARC members have heard anecdotal information from older residents on great historical fish abundance in the New Inn Stream, with the presence of brown trout and eels that were caught and eaten. Trout large enough for humans to eat are not observed in the New Inn Stream today, although we have observed small trout not more than 12-16cm long, while small eels (<8-10cm long) have been recorded in the stream during 'kick' sampling monitoring events. Kick sampling is a technique used by environmental scientists to sample the macroinvertebrate community in shallow streams by kicking up the gravels on the bed of the river and catching everything that is disturbed in a net (Moolna *et al.*, 2020). Opportunistic testing in 2021 and 2022 using aquarium test kits (Freshwater Master Test Kit, API, Waltham-on-the-Wolds, LE144RS) detected high levels of ammonia, nitrates and nitrites, indicating that many streams in the Amroth ward failed to reach threshold levels that are regarded as signs of a healthy river system. These observations initiated off-the-record discussions with representatives of NRW and provided the catalyst for the 'Keep The Streams Clean' (KTSC) project.

The New Inn Stream Monitoring Team

LARC has established a small group of like-minded, environmentally conscious residents in the Llanteg and Amroth area who undertook training with the West Wales Rivers Trust (WWRT) in 2021. A preliminary meeting was held with the local WWRT representative (Harriet Alvis, Chief Executive Officer, WWRT). The WWRT were aware of concerns that local aquifers, which are utilised as commercial spring water by Princes Gate Water (see https://princesgate.com/), have rising levels of nitrates, and were encouraged to hear about the formation of LARC.

A first group of 12 people, including families and their children, were trained by the WWRT in biological techniques on 15th July 2021 at a practical session held at Colby Woodland Gardens (the local National Trust property) (see Figure 1). Subsequent to the session, a number of current LARC supporters monitored the tributaries that feed into the New Inn Stream as part of the Riverfly Monitoring Programme (Moolna *et al.*, 2020; see https://www.riverflies.org/). These data are recorded on the publicly accessible online Rivers Trust database. The Riverfly Partnership uses an invertebrate survey method using kick sampling (see Figures 2, 3 and 4) to detect changes in local water quality (see: https://www.riverflies.org/extended-riverfly). 'Riverflies' (in particular, upwing-flies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera), the so-called EPT) are key invertebrates in freshwater ecosystems and are a vital link in the aquatic food chain (Albini *et al.*, 2023), and consequently are used in Riverfly (EPT) scoring (see Figures 3 & 4 for sample setup and examples).

Figure 1. Riverfly Partnership Project: community training event organised by the West Wales Rivers Trust in July 2021.

1a) Theory session hosted at Goetre Farm;

1b) Practical kick sampling session hosted at the Colby River in the National Trust Colby Woodland Gardens;

1c) Riverfly sorting and counting session hosted at Goetre Farm.

1a

1b 1c

Figure 2. Kick sampling in the New Inn stream at site 6.

Figure 3. An example of the sorting system used during the Riverfly project, highlighting EPT groups. **E** = Ephemeroptera (3 groups), **P** = Plecoptera (1 group), **T** = Trichoptera (2 groups), **O** = other (3 groups)

Figure 4. Some examples of organisms collected from the New Inn Stream as part of the Riverfly Partnership project.

4a) **E**phemeroptera (Upwing-flies)

Dark Olives (Baetidae)

Flatbodies (Heptagenidae)

Burrowing Mayflies (Ephemeridae)

Blue-wing Olives

4b) **P**lecoptera (Stoneflies)

Stripetails (Perlodidae)

4c) **T**richoptera (Caddisflies)

Cased Caddisflies (various)

Caseless Caddisflies (various)

4d) Significant Other species groups

Freshwater Shrimp (Gammaridae)

Odonates (various)

It became apparent to the monitoring teams involved that the acquisition of accurate, reliable and portable equipment to monitor the chemical pollutants most commonly found in pollution incidents would be a valuable addition to this project. Further discussions with NRW led to LARC purchasing equipment from Hanna Instruments (URL: https://www.hannainstruments.co.uk/) as this company supplies the same equipment to NRW field officers. It was felt that if we reported pollution incidents using the same equipment as used by NRW field operatives, then our results would be taken more seriously by regulatory authorities.

Grant Application and Purchase of Chemical Monitoring Equipment

In March 2022, LARC submitted a successful grant application to The Fisheries Charitable Trust of the Fishmongers' Company, London for £1,065. This enabled the purchase of the following portable analytical monitoring equipment and testing reagents from Hanna Instruments;

- Low Range Phosphate checker HI 713 and HI713-25 low range phosphate tests.
- Medium Range Ammonia checker HI 715 and HI715-25 medium range ammonia tests.
- Nitrate Portable Photometer HI 97728 and HI93728-01 nitrate tests.

Importance of River Monitoring

River monitoring can help provide a snapshot in time, giving an indication of the current health of a waterbody. To fully assess the impacts on a river, monitoring over a long time period and at various stages during the year is helpful to gauge the general health of a river. Returning to the same section of waterway over several years will provide an understanding of whether the water quality is improving, declining or remaining the same over time.

Objectives of Keep the Streams Clean

- To monitor the levels of phosphate, nitrate and ammonia at eight sites in the streams that feed into the New Inn Stream every month for one year between August 2022 and July 2023;

- To report the findings to the following organisations -

    - Fisheries Charity Trust.
    - Natural Resources Wales.
    - The West Wales Rivers Trust.
    - Pembrokeshire Coastal National Park Authority.
    - Welsh Water.
    - Amroth Community Council.

- To raise awareness of the threats to our waterways by sharing findings with our local community and start a conversation within the community about how water quality might be improved;

- To encourage monitoring of further streams of interest or concern by new groups of interested residents;

- To assist in the training of new groups of citizen science river monitoring teams;

- To encourage other communities to start their own community groups engaging with local environmental issues.

Engagement with Local and National Organisations

LARC has made contact with community engagement representatives from the following local agencies -

- Pembrokeshire National Parks Authority.
- Natural Resources Wales.
- West Wales Rivers Trust.
- Princes Gate Water.
- Welsh Water.

Sampling Sites

Riverfly monitoring of the invertebrates using kick sampling methodology (Moolna *et al.*, 2020; see https://www.riverflies.org/) at three sites of the New Inn Stream started in July 2021, continuing on a monthly basis until August 2022 at sites 1, 2 and 6. The results from this invertebrate monitoring were reported into the Riverfly Partnership Recording Database (ARMI) and are not presented in this report.

The first period of this research (July 2021 to August 2022) involved selection of sites based on location within the stream to provide enough coverage, as well as on accessibility, safety and time constraints during sampling and analysis, with the subsequent main study on these established sites presented in this report extending from 09.08.2022 to 17.07.2023. The null hypothesis (H_o) would be that there were no pollutants in the water, but it was soon realised that there were high levels of phosphate present in the river, notably at the Goetre Farm Riverfly site (site 6), where high phosphate values coincided with suppressed population levels of Riverfly invertebrates. High phosphate levels are indicative of sewage effluent, in particular from sewage treatment works and losses from agricultural land (Environment Agency, 2019). Upstream from site 6 are two important tributaries, one from the Llanteg Park housing estate, which has its own private sewage treatment plant with permitted discharge into the New Inn Stream (NRW permit BH0067301; see: https://datamap.gov.wales/layers/geonode:nrw_water_quality_permits), and one from Llanteg village and Llanteglos holiday accommodation estate also with its own private sewage treatment plant with permitted discharge into the New Inn Stream (BN0044801). There are numerous other properties that back onto this area. Sites were therefore chosen on these tributaries (sites 4 and 5 respectively) to determine the source of these high phosphate readings from September 2021. In September 2022 and subsequent months leading up to the end of the year, there were reports from a number of residents and visitors to Amroth of a "continual foul stench" in the stream that runs down through Factory Lane, above Factory House. This led to the allocation of a further site (site 7 on the map) adjacent to the public footpath, with sampling beginning in December 2022. The intention behind expanding on how the sites were chosen is to show that, for the most part, they were observation led. Other sites were tested in this initial phase and some, notably the Riverfly Project sites on the tributary through Furzy Park (site 1) and on Ely Mill, as it passes the fish ponds (site 2) were retained in the study. Locations of these sites and their details are shown in Figure 5 and Table 1. Images of the eight sampling sites are presented in Figure 6.

Figure 5. Map of Llanteg / Amroth and the New Inn Stream, showing the location of the eight sampling sites, in addition to important landscape features of conservation interest (Map courtesy of Habitat Info, Solva).

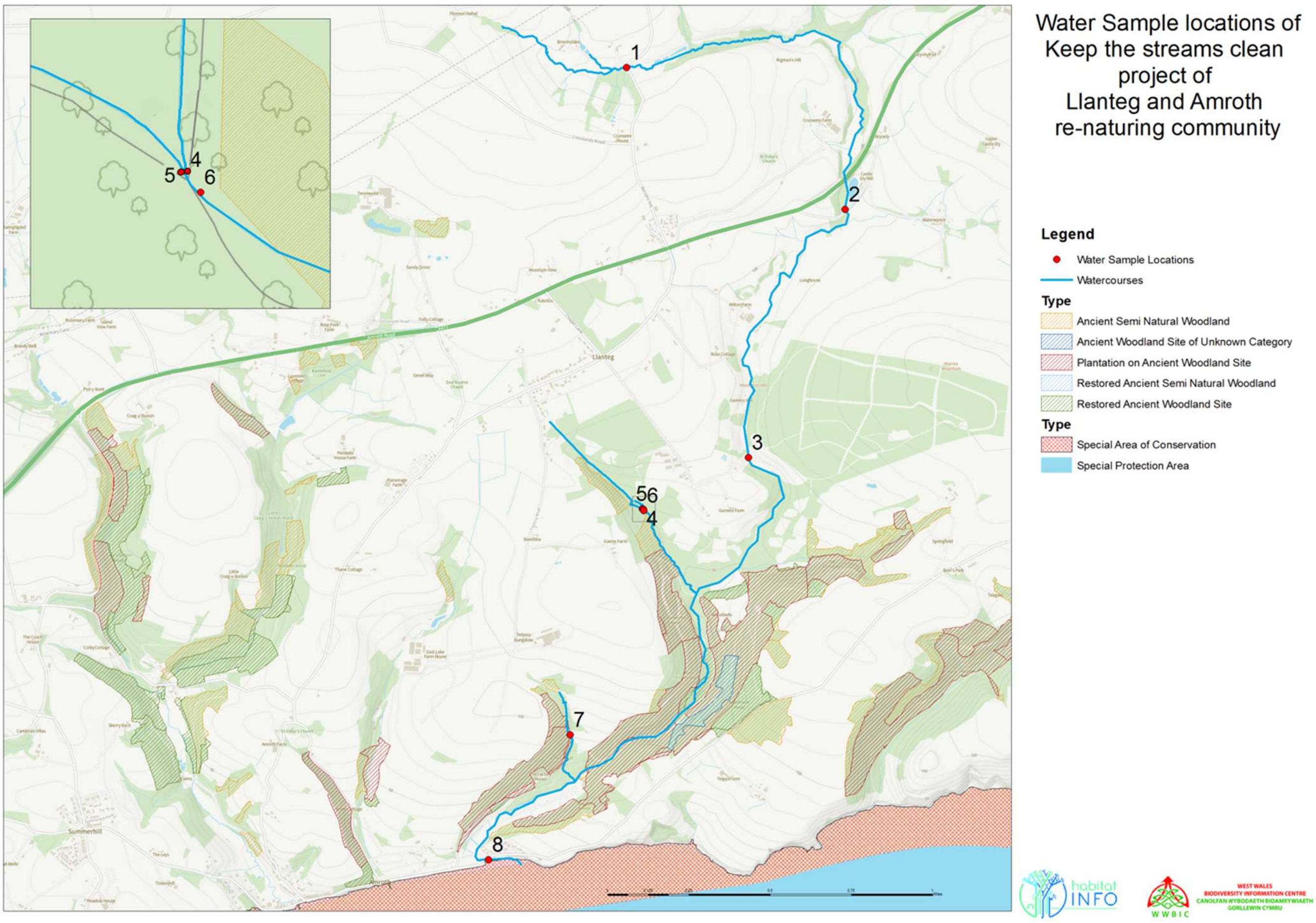


Table 1. Location of sampling sites. Location and format of what3words nomenclature (3-metre square accuracy) sourced from https://what3words.com/. Sites grouped into the three sections (upper, middle and lower) used in the analyses. Note that sites 4 and 5 are so close together that they can only be differentiated by eye, rather than satellite / What3Words positioning.

Location	Site Code	ON grid reference	Latitude	Longitude	Elevation (m asl)	What3words
Furzy Park	1	SN17961118	51°46'11" N	4° 38' 23" W	134	///elaborate.fidelity.tissue
Castle Ely Mill	2	SN19041048	51°45'49" N	4° 37' 25" W	97	///purely.fresh.automatic
Spiritwood bridge	3	SN18560926	51°45'09" N	4° 37' 48" W	74	///slept.gliding.warmers
Upstream influx above Goetre *	4	SN180400899	51°44’59" N	4° 38' 14" W	66	///nylon.alive.styled
Llanteg Village influx @Goetre *	5	SN18040899	51°44’59" N	4° 38' 14" W	67	///nylon.alive.styled
Goetre (Riverfly)	6	SN18050898	51°44'60" N	4° 38' 14" W	66	///surfaces.dares.floating
Factory Lane	7	SN17670789	51°44'24" N	4° 38' 32" W	66	///field.spearhead.captions
New Inn bridge	8	SN17280725	51°44'03" N	4° 38' 51" W	6	///crumple.spare.imported

Figure 6. Site location images. Sites grouped into sections as described in the analyses.

Upper Section

6a. Furzy Park (Site 1).

6b. Castle Ely Mill (Site 2).

Middle Section

6c. Spiritwood bridge (Site 3).

6d. Upstream site from Goetre (right site 4) and Llanteg Village influx @Goetre (left) (Site 5). These are less than 3m apart.

6e. Goetre Riverfly (Site 6).

Lower Section

6f. Factory Lane (Site 7).

6g. New Inn bridge (Site 8).

Materials and Methods

A standardised approach was used based on established methods used by citizen science groups monitoring the river Wye (Friends of Upper Wye Citizen Science webpage; Anon, 2023a, 2023b, 2023c). Water samples were collected at monthly intervals from 09.08.2022 to 17.07.2023 (see Table 3).

The following in-field information was collected for each site (see Figure 7 for example of collection):

date / time of sampling / location / weather conditions / sample collection personnel / electrical conductivity / temperature (in °C) / pH / stream depth (cm):

Information was recorded on a data capture form (Appendix 2). The following pieces of equipment were used in gathering the in-field stream data:

- Electrical conductivity and temperature were measured in the streams as samples were collected using a Pancellent™* TDS and EC and temperature probe. The unit measures temperature from 0-80°C, conductivity from 0-9999us/cm and TDS from 0-9999ppm.
- pH was recorded using Pancellent™* pH meter and was measured in the streams as samples were collected. pH meters were calibrated using the following standardised buffer solutions (company details) before use. The measurement range of this instrument is 0.00-14.00 pH with a resolution of 0.01pH and an accuracy of +/- 0.01pH.
- The stream depth was measured with a standard ruler in cm.

* "Pancellent" is a registered trademark of the company Pan Jianteng, China

- Water samples were collected into 500ml plastic bottles for chemical analysis (phosphate, nitrate, ammonia). Samples were not filtered before analysis and were tested within 1-2 hours of collection at facilities belonging to KTSC members (Figure 8).

- Nitrate was measured using a Nitrate Portable Photometer HI 97728 with HI93728-01 nitrate tests according to manufacturer's instructions. The range of this instrument is 0.00-30.0mg/l of nitrate nitrogen (measured as NO_3^--N). The accuracy of this unit is +/- 0.50mg/l @25°C.

- Phosphate was measured using a Low Range Phosphate checker HI 713 with HI713-25 low range phosphate tests according to manufacturer's instructions. The range of this instrument is 0.00-2.50ppm (measured as PO_4^{3-}). The accuracy of this unit is +/- 0.04ppm @25°C.

- Ammonia was measured using a Medium Range Ammonia checker HI 715 with HI715-25 medium range ammonia tests according to manufacturer's instructions. The range of this instrument is 0.00-9.99ppm (measured as NH_3-N). The accuracy of this unit is +/- 0.05ppm @25°C

Data were included in a Microsoft Excel spreadsheet. These were analysed for mean, standard deviation and number of samples. The raw results for all the data recorded for each site are available from the authors on request.

A total of 96 water samples were tested over the 12-month period and 268 nitrate, phosphate and ammonia tests were analysed. The results are reported in Appendix 1, Tables 3-12 and presented graphically in Figures 10-12.

Figure 7. Sampling the stream and taking *in situ* readings.

Figure 8. Analysis of water samples by the Keep The Streams Clean team at Goetre farm.

Units and Conversion of Units

Nitrate

Nitrate was measured as nitrate nitrogen (NO_3^--N) mg/l using the Nitrate Portable Photometer HI 97728. NRW reports all nitrate results as nitrate nitrogen (NO_3-N) mg/l. In the discussion we refer to nitrate nitrogen (NO_3^--N) values as reported in Tables 3 and 4.

Phosphate

Phosphorus concentrations in water are recorded in units of ppm (mg/l) and 1ppm = 1mg/l. We use mg/l units in this report.

Phosphate was measured as PO_4^{3-} ("orthophosphate") on the Hanna instruments Phosphate unit HI 713. Agencies such as NRW report concentrations in terms of PO_4^{3-} -P ("orthophosphate as phosphorus") and this is also what phosphorus standards are most commonly set as (Hatton-Ellis & Jones, 2021; Anon, 2023a). A molecule of orthophosphate (PO_4^{3-}) weighs 3.06 times more than a molecule of PO_4^{3-}-P orthophosphate as phosphorus. The PO_4^{3-}-P ("orthophosphate as phosphorus") is calculated by dividing the Hanna instrument "PO_4^{3-} ("orthophosphate")" result by 3.06.

Thus, we report two sets of values for phosphate. The first is measured as orthophosphate mg/ml PO_4^{3-} and represents the results as reported by the Phosphate meter (Tables 5 and 6). The second values are calculated as orthophosphate as phosphorus PO_4^{3-}-P which are used to determine phosphorus standards. In the report we refer only to the calculated orthophosphate as phosphorus PO_4^{3-} -P values in Tables 7 and 8.

Ammonia

Ammonia concentrations in water are recorded in units of ppm (mg/l) and 1ppm = 1mg/l.

Ammonia was measured as NH_3-N mg/l on the Hanna instruments Ammonia unit H1715 (Tables 9 and 10). NRW results are reported as "total ammonia as nitrogen" and are considered to be directly comparable with the Hanna value of NH_3-N (Paul Edwards, pers. comm, 2023). In the report we refer mainly to the total ammonia as nitrogen presented in Tables 9 and 10.

Unionised ammonia as mg/l was calculated from ammonia NH_3-N using a conversion factor of 1.214 according to the manufacturer's instructions and an online calculator with reference to the pH and stream temperature values that were measured on the day of sampling at each site. The online ammonia calculator was found at https://www.svl.net/unionized-amonia-calculator/. The reason for this calculation is that unionised ammonia is toxic to aquatic life. Unionised ammonia results are reported in Tables 11 and 12. There were 5 readings (highlighted yellow in Table 11) that exceeded the WFD (2015) threshold for unionised ammonia (as N) of 0.021 mg/l and these are identified in Figure 12. Unionised ammonia is further referred to in the discussion mainly relating to the toxicity of pollutants to aquatic organisms.

Dilutions

When testing the samples, some values exceeded the upper ranges. These samples were retested, having diluted the sample 1:10 with distilled water. The new result was multiplied by 10 to give the final result for that sample.

Identification and Reporting Visible Signs of Pollution

In addition, signs, including photos of river pollution, were recorded as part of the survey (Figures 17a-f). Appendix 11 presents a poster entitled ‘How to spot river pollution’ showing images of river pollution (Courtesy of the West Wales Rivers Trust). The *Wye citizen science water quality monitoring field guide* (2021) includes information on some of the most common, easy-to-spot signs of pollution found in UK rivers and streams (Anon, 2023b,c). As had been requested by the WWRT and NRW, pollution incidents were reported to NRW via their 24hr Incident Hotline, 0300 065 3000. Pollution incidents other than elevated water quality readings are reported in Table 2.

Table 2. Pollution incidents in New Inn Stream. This table includes two incidents outside of the 12-month New Inn monitoring period.

Location (site)	Date	Description	Action
Furzy Park (1)	17th April 2022	Foul cow slurry-like odour and dark discoloured water Acute slurry discharge	Reported to NRW via their 24hr Incident Hotline
Furzy Park (1)	January 2023	Foul cow slurry-like odour and dark discoloured water Acute slurry discharge	Reported to NRW via their 24hr Incident Hotline
Factory Lane (7)	October-December 2022	Foam, foul ammoniacal odour, sewage fungus*. Chronic farm pollution discharge over 2-3 months	Reported to NRW via their 24hr Incident Hotline
New Inn Bridge (8)	10th August 2023	Foul odour, pale discoloured discharge Domestic pollution of unknown duration through storm drain at New Inn bridge	Reported to NRW via their 24hr Incident Hotline

*‘Sewage fungus’ is actually a mass of particular types of filamentous bacteria, and not a fungus. It grows in high nutrient environments, such as those around sewage discharges. It is a sign of medium to long-term contamination issues (Appendix 3).

Table 2 shows that in addition to invisible, but measurable pollution, there was a surprising number of pollution events that were both visible and malodorous. Recently, LARC was informed that, during October-November 2023, three pollution events were noted when the Colby River changed colour and smelt of slurry.

Further pollution incidents into the Factory Lane stream were also reported to LARC by visitors to Amroth in October and November 2023. These were not reported to NRW as far as we know. The Colby incidents arise from a different watershed to that which feeds into the New Inn Stream, the principal subject of this report.

Over the four weeks in December 2023, while this report was being drafted, slurry was applied to fields using pipes and slurry tankers in the New Inn Stream catchment on three separate occasions immediately (within 24 hours) before or after heavy rainfall (yellow weather warnings in place issued by the Meteorological Office; see: https://www.metoffice.gov.uk/weather/forecast/) and when flood alerts had been issued by NRW for the area. Fields in the vicinity of the slurry application were known to be waterlogged. One of these three events was checked (but not reported) as a 'hypothetical' incident with an Environment Officer from NRW and confirmed by NRW to be a breach of CoAPR regulations. These observations over one month for just one farm along with the reported pollution incidents listed in Table 2 indicate the wider scale of the problem within the watershed of the New Inn Stream and across Pembrokeshire more generally.

Results

Nitrate results measured as NO_3-N mg/l are reported in Tables 3 (by month) and 4 (by average over project). Our results for nitrate measured as NO_3-N mg/l show a wide scale distribution of pollution along the entire stream (Table 3, Table 4, Figure 10). Only 2 of 89 (2.2%) samples were less than 0.5mg/ml and would have been classified as clean water according to the SWEPT criteria. Four of 89 (4.5%) water samples showed some levels of nitrate pollution (0.5 - 1.0mg/l) and 83 of 89 (93.2%) of water samples had nitrate levels exceeding 1.0mg/l consistent with high or very high levels of nutrient pollution. Levels above 5mg/l (and even >10mg/l) were not uncommon. The highest levels of nitrate 30mg/l, 15.6mg/l and 7.1mg/l were recorded at sites 7 (Factory Lane), 4 (upstream from Goetre) and 8 (New Inn bridge) respectively.

Phosphate results measured as PO_4^{3-} mg/l are reported in Tables 5 (by month) and 6 (by average over project) (original Hanna instrument values). Phosphate as PO_4^{3-} mg/l was converted to Phosphate PO_4^{3-} -P mg/l using a conversion factor of dividing by 3.06 and results are reported in Tables 7 (by month) and 8 (by average over project). In the report we refer only to the calculated orthophosphate as phosphorus PO_4^{3-} -P values in Tables 7 and 8. Our results for phosphate measured as PO_4-P mg/l show a wide scale distribution of pollution along the entire stream (see Table 7, Table 8 and Figure 11). With regards to phosphate, Government guidance recommends that rivers should not exceed annual mean concentrations of 0.1ppm (equivalent of 0.1mg/l). Using the SWEPT classification for phosphate results; 18 of 89 samples (20.2%) were less than 0.05mg/l in the 'clean' category, 25 of 89 (28.1%) were in the range of 0.05-0.1mg/l (some evidence of pollution category) and the majority, 46 of 89 samples (51.7%), exceeded 0.1mg/l and were in the high or very high levels of nutrient pollution category. The highest levels of phosphate were recorded at site 4 (upstream from Goetre) and 9 of 11 samples from that site exceeded the 0.1mg/l threshold and the highest value recorded was 2.09mg/l.

Ammonia results measured as NH_3-N mg/l are reported in Tables 9 (by month) and 10 (by average over project) (original Hanna instrument values). In the report we refer mainly to the total ammonia as nitrogen presented in Tables 9 and 10. Using the Water Framework Directive Standards classification for ammonia 78 of 90 (86.7%) of samples were less than 0.3mg/l in the high water quality category, 3 of 90 (3.3%) were 0.3-0.6mg/l in the good water quality category, 5 of 90 (5.6%) were 0.6 – 1.1mg/ml in the moderate water quality, 4 of 90 (4.4%) were in the 1.1 – 2.5mg/l in the poor or worse water quality category (three of these exceeded the 2.5mg/l limit for poor water quality). Maximum levels of ammonia ranged from 0.23 to 9.99mg/l (Table 9, Table 10 and Figure 12). The highest levels of ammonia (9.99mg/l) were recorded at

Factory Lane (site 7) and Furzy Park (site 1) both linked to agricultural slurry events upstream or in the surrounding fields.

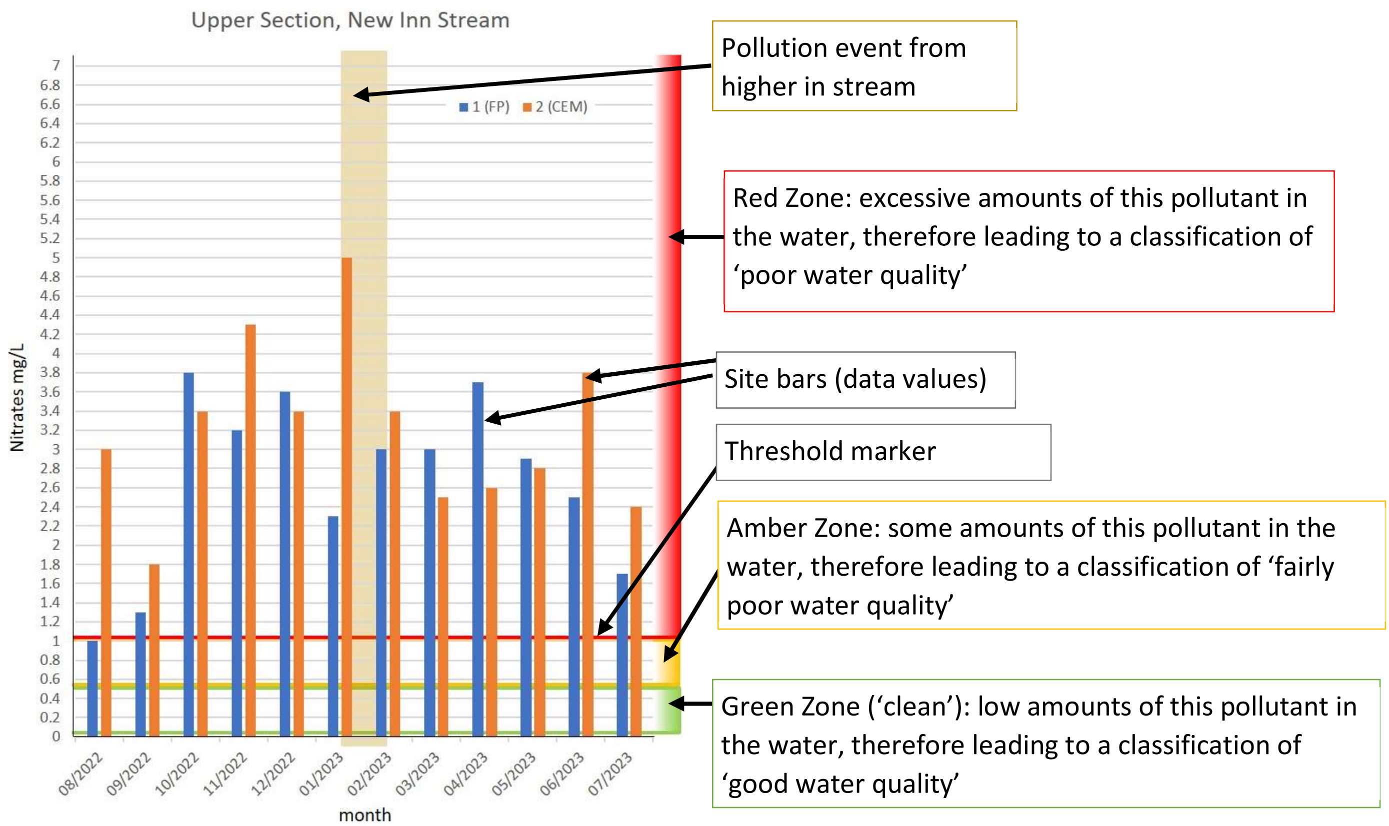
Unionised ammonia as mg/l calculated from ammonia NH_3 using an online calculator and the pH and temperature values are reported in Table 11 (by month) and 12 (by average over project). The WFD (2015) threshold for unionised ammonia (as N) is 0.021mg/l. Levels exceeding 0.021mg/l were recorded 5 times across all sites, including once at each of sites 3 (Spiritwood bridge), 4 (upstream from Goetre), 7 (Factory Lane) and twice at site 8 (New Inn bridge). The highest levels of unionised ammonia (as N), 0.256mg/l, was recorded once at site 4.

The following pages present the data in a standardised graphical form (Figures 10-12), with the sites clustered into an upper section (2 sites), a middle (4 sites) and a lower section (2 sites). Each graph is overlain by those observed, reported pollution incidents highlighted during the sampling period in Table 2 (pale brown vertical bar : shown in the downflow charts only), as well as by the national standard classifications for the individual pollutants, here represented by a traffic light colour coding system where green is good, yellow is mediocre and red is bad (see Tables 13 and 14 for values): these zones of water quality are shown to the right of each graph, but with their threshold values shown as a horizontal line of the same colour across the graph (to facilitate the reader in noting where the stream values exceed the recommended values and progressively poorer thresholds). A labelled example graph is shown in Figure 9. The data are presented as blocks, colour-coded to site. These sites are abbreviated to their initials and site numbers as follows:

- Upper Section: 1 (FP) = Furzy Park, 2 (CEM) = Castle Ely Mill;
- Middle Section: 3 (SB) = Spiritwood bridge, 4 (UG) = upstream from Goetre, 5 (LV) = Llanteg village influx, 6 (GF) = Goetre Farm stream site;
- Lower Section: 7 (FL) = Factory Lane site, 8 (NIB) = New Inn bridge.

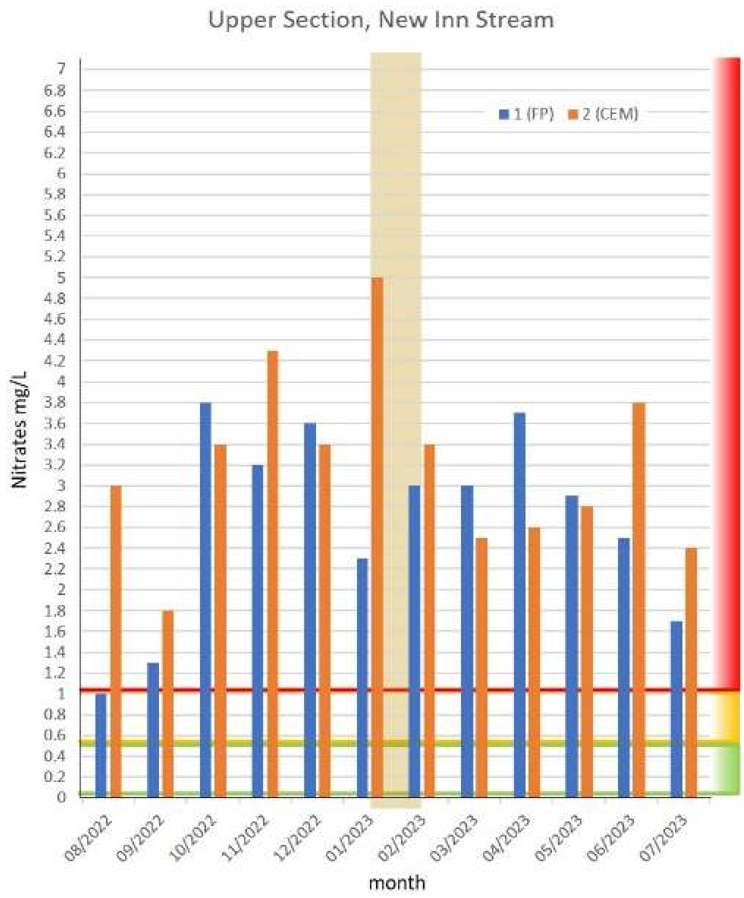
Raw data for the results presented here are available on request. See pages 52-63 for Tables 3 – 12.

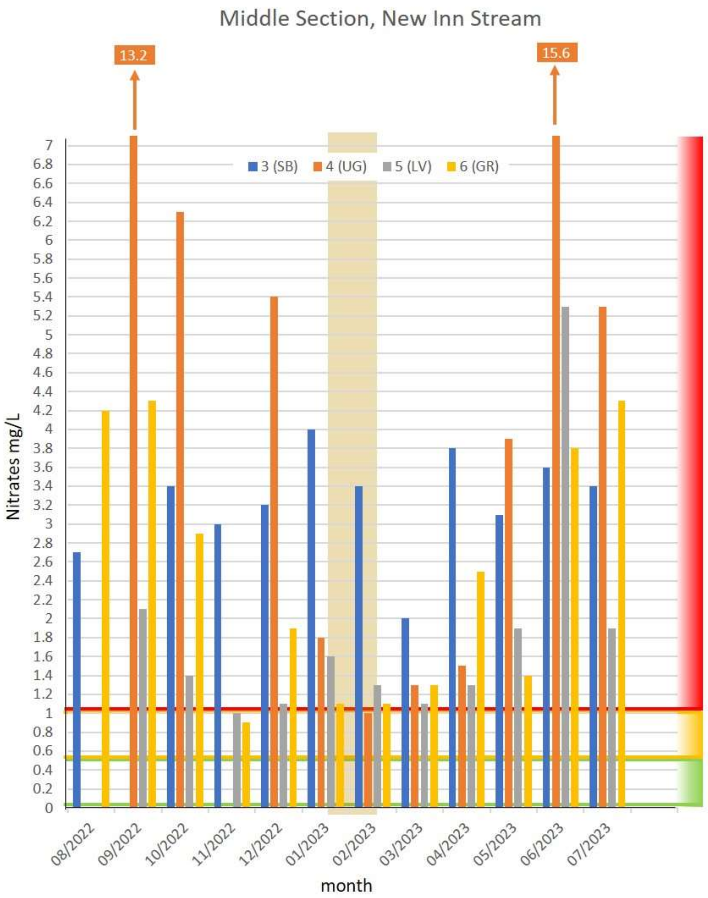
Figure 9. A labelled example for use with figures 3-5 (using Figure 10 upper section) –



In all graphs, it is obvious that the nitrates (Figure 10), in particular, and phosphates (Figure 11) fail to meet quality standards for significant parts of the year, even without doing any statistical analyses. Ammonia levels are generally in line with the water quality requirements (Figure 12), but there are still a number of anomalies noted (in particular, a January record for Furzy Park, and three occasions in the Lower Section from November to January, all of which coincide with the pollution events noted in Table 2). Toxic unionised ammonia events are also noted on Figure 12: these are important as they will have a major effect directly on the populations of animals (invertebrate and vertebrate) within the stream ecosystem. Many values for nitrates and phosphates are extremely high, indicating that the stream is in very poor health for these pollutants, in all stream sections for nitrates, but concentrated in the middle section for phosphates. Tables 13 and 14 show where these values exceed the recommended standards, also using a traffic light warning system.

Figure 10. Nitrate (NO_3-N) mg/l concentration levels in New Inn Stream, divided into Upper (sites 1 & 2), Middle (sites 3-6) and Lower (sites 7 & 8) sections. Vertical pale brown bars relate to pollution incidents as described in Table 2. Horizontal coloured lines + right hand column refer to nutrient (nitrate) pollution categories laid out in Table 13 (green = clean, <0.5 mg/l; gold = some pollution, - 0.5-1 mg/l; red = high to very high levels of pollution, >1mg/l).





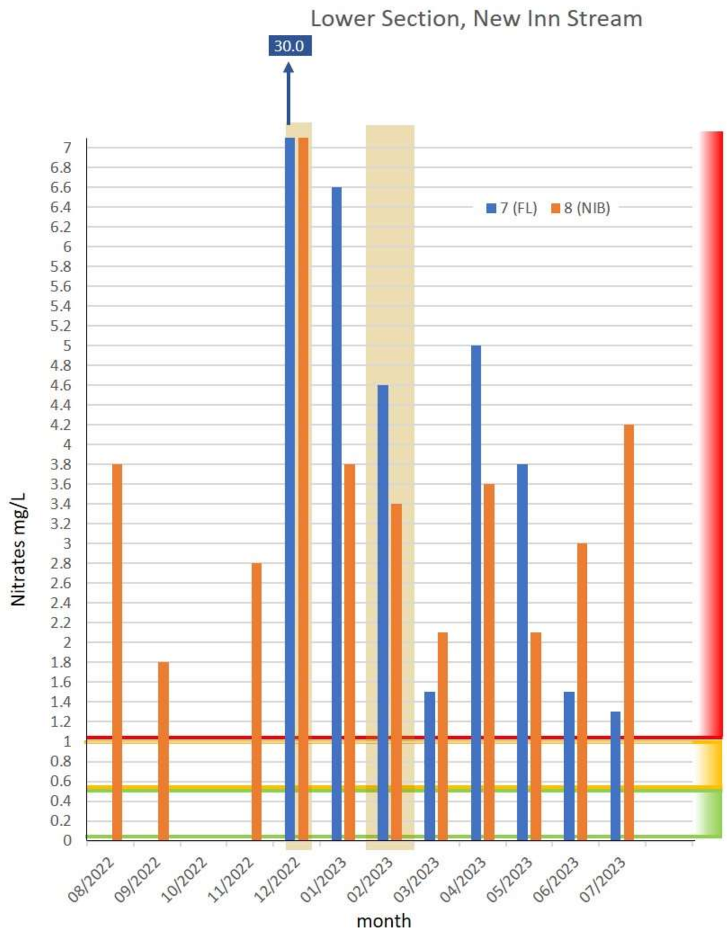
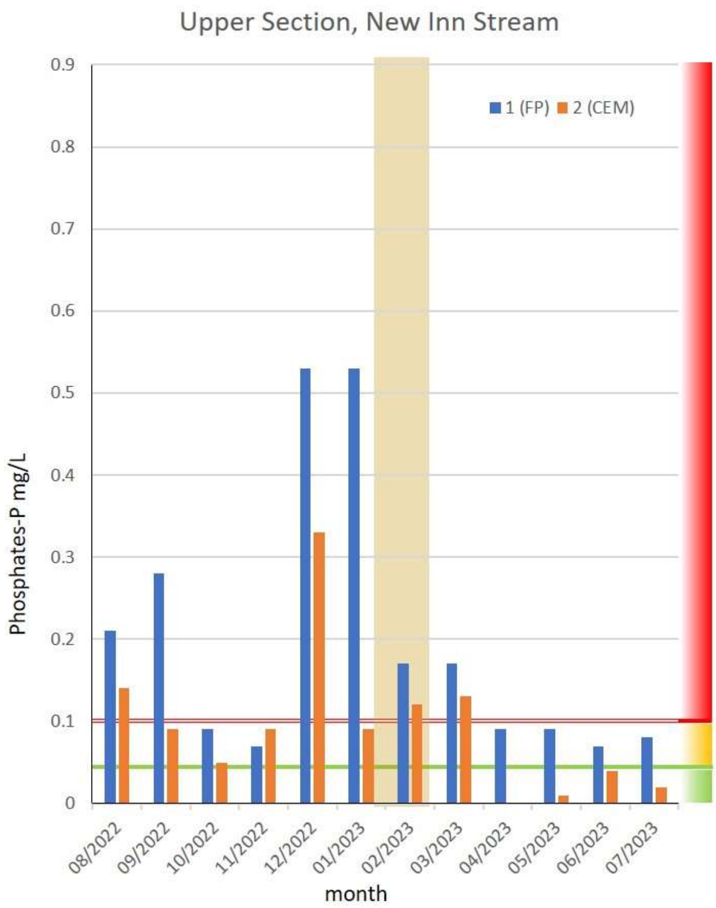
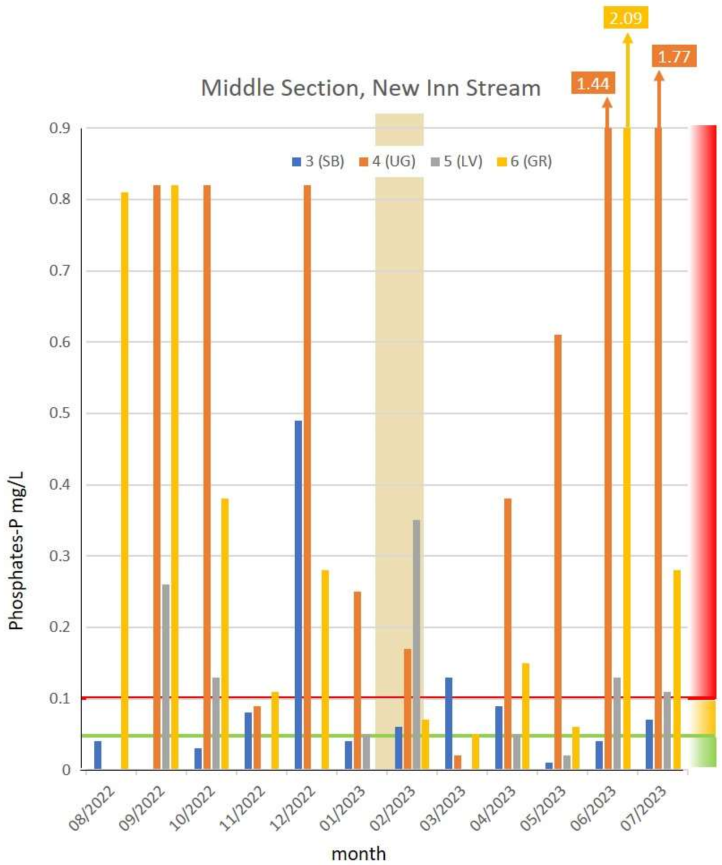
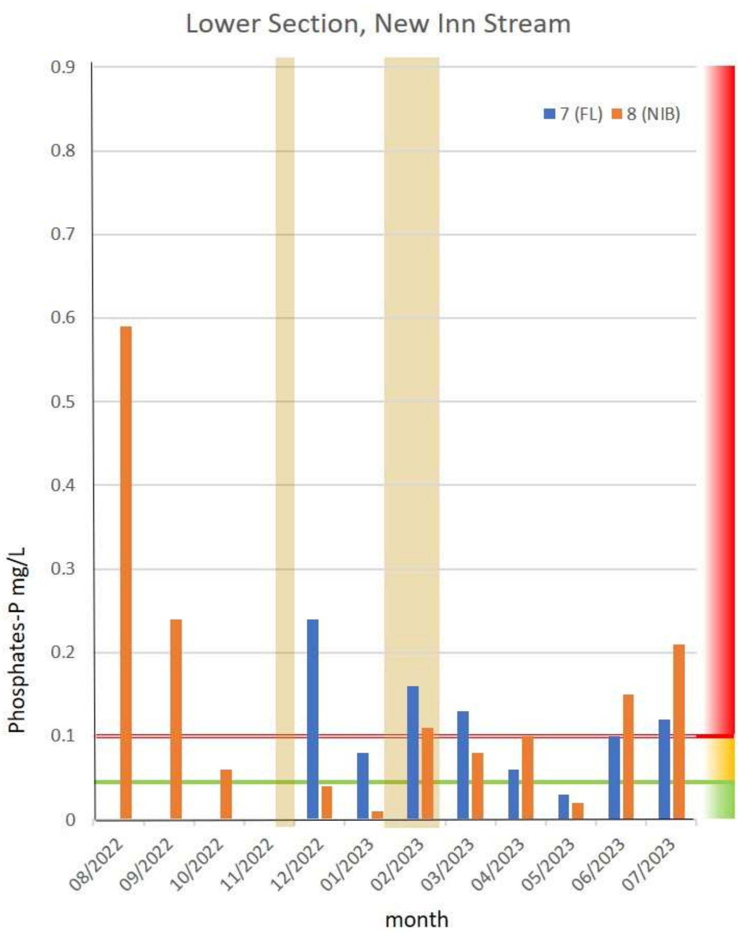


Figure 11. Phosphate (PO_4^{3-} -P) mg/l concentration levels in New Inn Stream, divided into Upper (sites 1 & 2), Middle (sites 3-6) and Lower (sites 7 & 8) sections. Vertical pale brown bars relate to pollution incidents as described in Table 2. Horizontal coloured lines + right hand column refer to nutrient pollution (phosphate) categories laid out in Table 13 (green = good health, <0.05 mg/l; gold = moderate health, 0.05-0.1 mg/l; red = poor health, >0.1 mg/l).



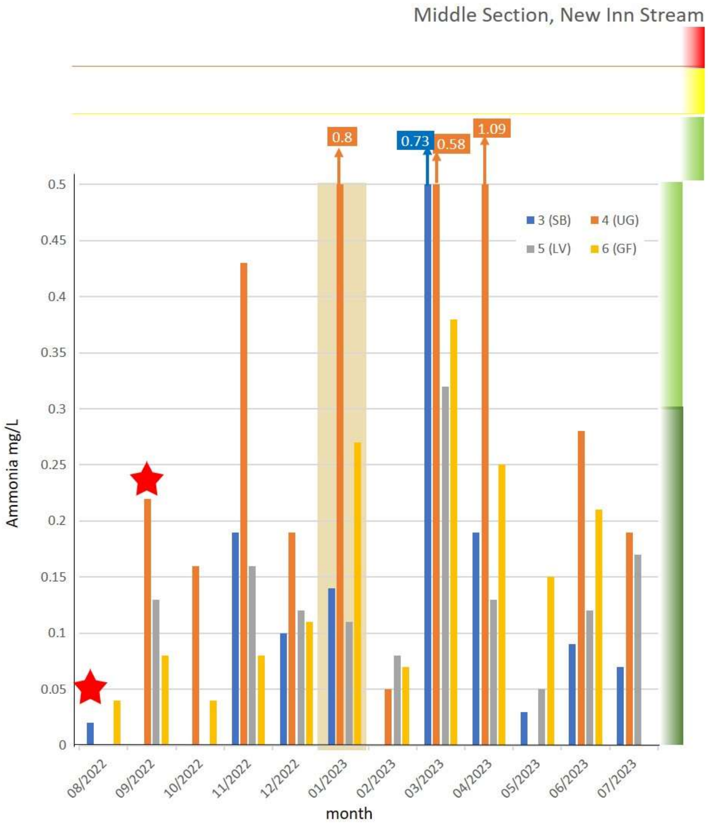




Concentrations of phosphate (PO_4^{3-} -P) at New Inn Stream on about 45-50% of records fail to meet the 'clean water' requirements. 54% of results for the middle section fall into the 'poor health' category.

There is a general fluctuation, with poorer readings coinciding with holiday periods. While this is also the case in the middle stream, the summer peak seems to be at its most extreme early in the season, i.e., June & July, with the sites most affected being Goetre Riverfly and Upstream-from Goetre (site 4).

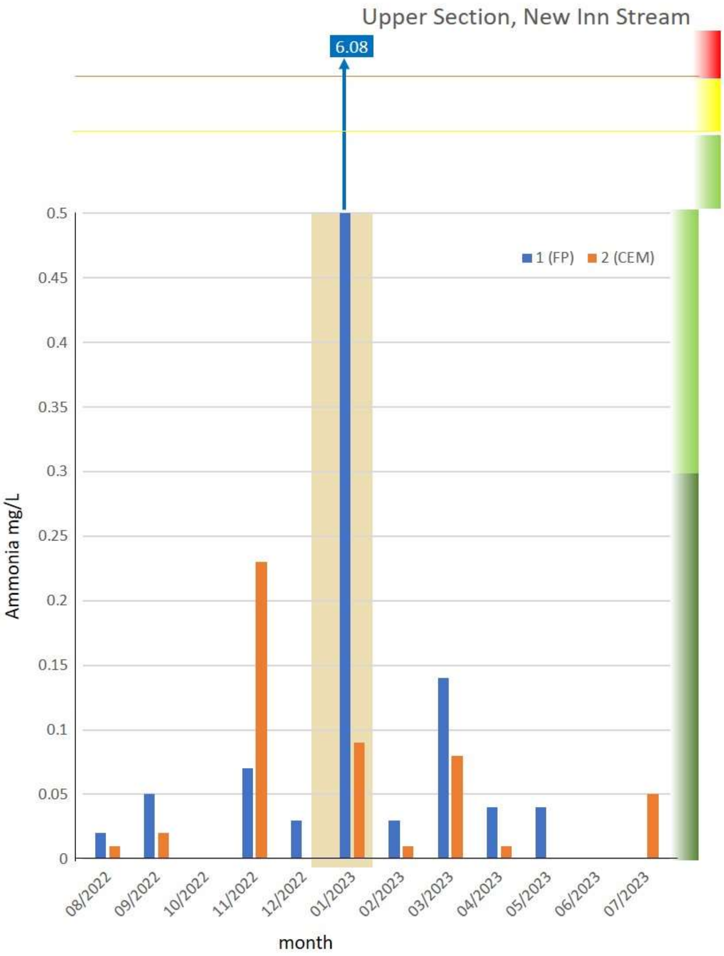
Figure 12. Ammonia (NH_3) concentration mg/l levels in New Inn Stream, divided into Upper (sites 1 & 2), Middle (sites 3-6) and Lower (sites 7 & 8) sections. Vertical pale brown bars relate to pollution incidents as described in Table 2. This set of graphs show a modified version of the Traffic lights, as there are four categories involved, as laid out in Table 14 for a type 3 stream (dark green = high quality, <0.05 mg/l; light green = good quality, 0.6-1.1 mg/l; gold = moderate quality, 1.1-2.5 mg/l; red = poor quality, >2.5 mg/l).

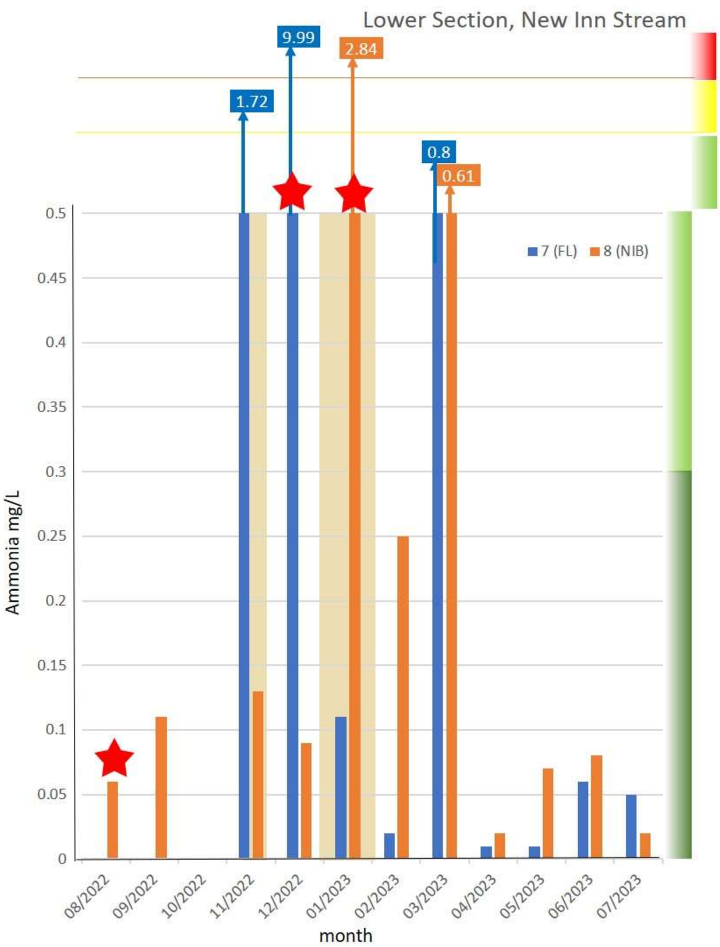


Concentrations of ammonia (NH3) in the upper and middle sections of the New Inn Stream are consistent in meeting the 'clean water' requirements as per NRW (i.e., high and good quality). However, the lower section shows at least three occasions in which values fall within the moderate to poor categories, as listed in Table 14.

The five readings that exceeded the WFD (2015) threshold for unionised ammonia are identified as stars: these are included because unionised ammonia is toxic.

Note: unionised ammonia values are calculated on the basis of pH and temperature. The relationship of unionised ammonia and ionised ammonia is complicated.





Environmental Quality Standards for freshwater bodies in Wales

To understand why chemical analysis of a river is performed, it is important to understand Environmental Quality Standards (EQS) (Wye Salmon Association, https://www.wyesalmon.com/water-quality/). These are set by the EU for Priority Hazardous Substances under the Water Framework Directive (WFD). This includes providing a standard limit for pollutants such as nitrate. The standard maximum contaminant level for nitrate is 10ppm (parts per million). EQS provide a base line for how a river is assessed to be in good health or not. For example, a nitrate level that exceeds 20ppm (parts per million) would need to be reported to NRW (Wye Salmon Association, 2023).

Analysis and interpretation of the results of chemical testing is complicated by many factors including temperature, salinity, turbidity and water flow. The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 is a long and detailed document that is used by scientists working in agencies like NRW to interpret their findings and classify levels and types of pollution in waterways.

It is beyond the expertise of a small citizen science group such as LARC to go into the fine technical details of our results, so we chose to follow the example of the Surveying the Waterway Environment for Pollution Threats (SWEPT) Volunteer Project 2018-19. This citizen science project surveyed the Milford Haven Waterway, from tidal limits at Haverfordwest and Canaston Bridge all the way down to Dale. The SWEPT project tested water samples for levels of nitrates and phosphates from 2018 - 2020. SWEPT followed thresholds utilised in the Clean Water for Wildlife survey when observing whether water samples were 'polluted' or not (Biggs *et al.*, 2016). We used the SWEPT guidelines (Table 13) to interpret our phosphate results measured as PO_4-P mg/l and nitrate results measured as NO_3—N mg/l. The SWEPT guidelines classified nitrate and phosphate results into three categories of river water quality; 1) clean, 2) some evidence of pollution or 3) as high levels of pollution. The nutrient pollution categories for nitrate and phosphate defined by Biggs *et al.* (2016) are listed in Table 13.

Table 13. Nutrient pollution categories for nitrate and phosphate as defined by Biggs *et al.* (2016). These values are highlighted as 'traffic light' zones on Figures 9 and 10, respectively.

	Category	nitrate (mg / L)	phosphate (mg / L)
	clean water	<0.5	<0.05
	some evidence of pollution	0.5-1	0.05-0.1
	high or very high levels of nutrient pollution	>1	>0.1

This definition of clean water is equivalent to the EU Water Framework Directive (WFD) 'High' status.

We used the ammonia standards for rivers from the Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 (Table 14) to interpret our ammonia results measured as NH_3-N. The Water Framework Directive guidelines classified ammonia results into four categories of river water quality, namely 1) high quality, 2) good quality, 3) moderate quality or 4) poor quality. NRW classifies streams according to certain criteria and this becomes important when interpreting results for pollutants such as ammonia. Paul Edwards (pers. comm., 2023) informed us that the NRW sampling station on the New Inn Stream is at an altitude of 8m and has a mean alkalinity of 65mg/l, and it is classified as a Type 3 stream (Paul Edwards, pers. comm., 2023). The results are compared to the 90 percentile of the Type 3 stream. The NRW laboratories measure total ammoniacal nitrogen (NH_3-N and NH_4-N) and after discussions with Paul Edwards (pers. comm., 2023) it was considered that the NH_3-N reading given by the Hanna meter should be directly comparable with this standard and NRW data without needing any conversion. Thus, Tables 13 and 14 were used to compare with WFD values. Note that Ammonia NH_3-N results (90 percentile) greater than 2.5mg/l are considered 'bad' (Paul Edwards, pers. comm., 2023).

Table 14. Ammonia standards for rivers (from: The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 (legislation.gov.uk). Colour highlights shown here refer to Figure 12.

Ammonia standards for rivers (rivers categorised by type in accordance with paragraph 1 (1) of Schedule 2)				
Total Ammonia as nitrogen (mg/L)				
(90 percentile)				
Type	high	good	moderate	poor
1, 2, 4 and 6	0.2	0.3	0.75	1.1
3, 5 and 7	0.3	0.6	1.1	2.5

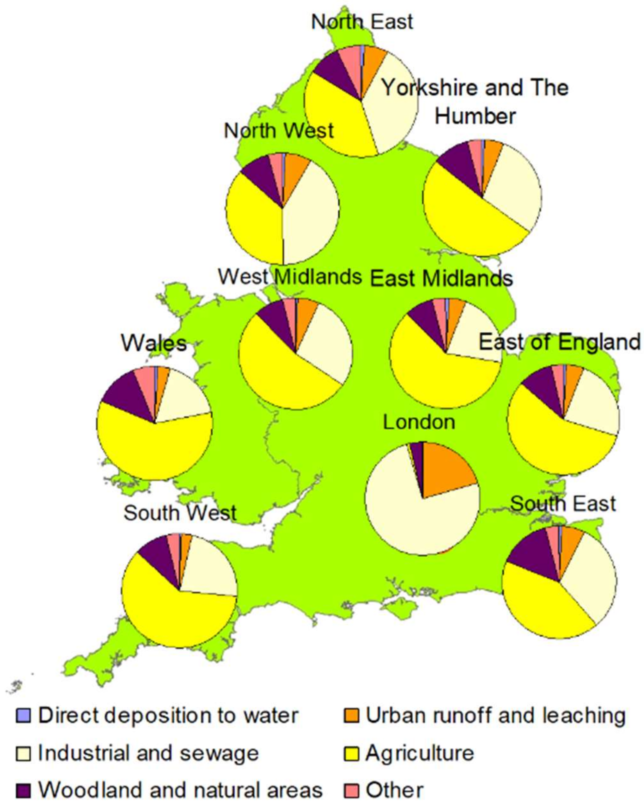
NRW no longer uses unionised ammonia for WFD classification in freshwater (Paul Edwards, pers. comm. 2023). We discuss unionised ammonia in the report because it is the component that is highly toxic to aquatic life.

Discussion

Nitrate levels:

Our results for nitrate measured as NO_3-N mg/l show a wide scale distribution of pollution along the entire stream (Table 3, Table 4, Figure 10). Gooday *et al.* (2016) discuss the role agriculture plays in the Milford Haven catchment in increasing the levels of nitrate. They suggest that for the Milford Haven waterway to reach good ecological status a significant reduction in livestock head would be necessary, as improvements in practices alone would not allow for enough of a reduction in the nitrate load entering the system. The authors of this report were unable to find any information on a critical assessment of the role of agriculture in the poor quality of the rivers in south Pembrokeshire. This may be a fruitful area for future investigation by agriculture or environmental science students from local colleges or universities. Figure 13 shows the sectorial contribution to nitrate and clearly shows that agriculture is responsible for over half of excess nitrate in river systems in Wales.

Figure 13. Sectoral contribution of nitrogen to watercourses in England and Wales. Copied from Environment Agency (2021): Nitrates: challenges for the water environment. Page 13.



Nitrate pollution is of great concern for groundwater management. Nitrates are commonly found in fertilizers and manures and are also released by industrial processes. High nitrate levels cause eutrophication and have caused the collapse of aquatic ecosystems around the world, most famously Lake Eyrie. Lough Neagh in Northern Ireland has become the most recent example of a waterbody in the UK that has become severely affected by eutrophication and toxic algal blooms, mainly caused by agricultural runoff over a large watershed (McCracken, 2023).

Excessive nitrate levels can also have a negative effect on human health through leachates into the water table, from where they are abstracted via boreholes for drinking water, leading to methemoglobinemia, diabetes, clotting issues and ischemia (Linsha *et al.*, 2018; Bannerjee *et al.*, 2023). The authors are also concerned about long term (= chronic) rising levels of nitrates in the aquifer. Although this topic falls outside the scope of the river sampling, a local resident of our area whose water is derived from a borehole on their property gave us the data in Table 16 that was derived from statutory testing of the residential water. The rising levels of nitrates from 2015 (40 mg/l) to 2020 (54 mg/l) breached the statutory threshold for potable drinking water of 50 mg/l. In 2020 an expensive filtration system had to be installed, resulting in their drinking water nitrate levels being reduced to 15 mg/l in 2021 and 2022.

The majority of nitrate in groundwater in the UK is derived from diffuse pollution from agriculture with the rest from sewage sludge disposal to land, atmospheric deposition and point sources such as sewage outfall sites. The British Geological Survey (https://www2.bgs.ac.uk/groundwater/quality/nitrate/home.html accessed 2023) consider that the loading has significantly increased due to post-1945 agricultural intensification through ploughing of grassland and increased fertiliser application. The area around this particular resident is sparsely populated and intensively farmed, with repeated applications of slurry through the year. Trends in nitrate concentrations in UK groundwater are rising at an average 0.3-0.4 mg/l/year (Environment Agency, 2021; British Geological Survey, 2023). In the case of this resident, the nitrate levels rose 2.8mg/l /year, almost 10 times the national average.

Groundwater is a major source of drinking water supply. In 2021, the Environment Agency reported that nearly 30% of groundwater used for that purpose in England must be blended, treated, or replaced in order to meet tap water nitrate standards (Environment Agency, 2021). Table 15 indicates that pollutants are not just washed off the land into the streams; they also leach through the soil into the aquifer. This leaching of nitrates (and of course other pollutants and chemicals) into the local aquifer should be of concern to us all. After all, it is just a few miles from this local resident to the Princes Gate Water Company, which is a significant local company employing 49 staff.

Table 15. Nitrate levels in domestic water of a local resident (Laboratory analysis organised by Pembrokeshire County Council).

	units	limits	2015	2016	2017	2018	2019	2020	2021	2022
Nitrate	mg NO3/l	50	40	44	46	49	53	54	15	15
pH		6.5-9.5	6.7	6.4	6.8	6.6	6.8	6.6	6.4	6.3
Conductivi	microS/cm	2500	392	458	457	465	411	366	432	480

Nitrate in drinking water is also expensive to treat. A new nitrate removal plant for groundwater can cost some £8m for example, with annual running costs of some £250k (Environment Agency, 2021). These costs are ultimately funded by water consumers. Our current mindset appears to allow the water companies and the industrialised farming sector to pollute our waterways. The cost of not having the appropriate infrastructure to manage human and animal waste is borne by the environment. In some ways agricultural pollution is a consequence of consumers not paying the right price for our food (dairy products in our area) that factors in the costs farmers need to invest in slurry management. The issues with the water companies appears to be different. Most recently, a BBC Panorama documentary 'The Water Pollution Cover-up' shown on 4/12/2023 (See: https://www.bbc.co.uk/programmes/m001t4g5) used data leaks by whistleblowers from United Utilities to demonstrate massive dumps of sewage into lakes, rivers and the sea that were covered up to give the impression that environmental targets were being met for profit and reputational reasons (Crowley, 2023). In this case the government has been accused of turning a blind eye to corruption at the heart of the water industry (Crowley, 2023).

Nitrate levels impact freshwater animals such as invertebrates, fish and amphibians (Camargo *et al.*, 2005). For example, a nitrate concentration of 10 mg NO3-N/l can adversely affect freshwater invertebrates and amphibians (Camargo *et al.*, 2005). Camargo *et al.* (2005) consider that maximum levels of 2 mg NO3-N/l would be appropriate for protecting the most sensitive freshwater species. Some authors (e.g., Hecnar, 1995) consider that the toxic effects of water pollution with nitrate fertilizers may play a role in global amphibian declines.

In aquatic organisms, nitrate toxicity causes swimming alteration, growth retardation and histopathological changes, neurotoxicity and endocrine disruption (Bannerjee *et al.*, 2023). Ultimately, excess nitrates can lead to death. Simultaneous exposure to both low pH and elevated nitrate concentration increases maintenance costs and reduces oxygen uptake, which negatively impacts on growth and activity of animals.

Phosphate levels:

Our results for phosphate measured as PO_4-P mg/l show a wide scale distribution of pollution along the entire stream (see Table 7, Table 8 and Figure 11). The high levels of phosphates recorded at site 4 come from upstream, where a community sewage treatment plant (Llanteg Park) is located within 100m of this sampling point. There is also a private sewage treatment unit (Llantegloss estate) and many private houses with septic tanks that are located further upstream from site 5 (greater than 700m upstream). Further testing up both tributaries would be helpful to determine the contribution these plants and private houses make to phosphate levels in the stream. Phosphates are a common component of human sewage, and the high phosphate content of most detergents and cleaning products is a significant contributor to the presence of phosphates in sewage. To address this issue, many sewage treatment plants are being designed to remove phosphates from wastewater (Bunce *et al*., 2018). Another way to reduce phosphate levels in sewage effluent is to choose no-phosphate detergents and cleaning products.

Elevated nutrient concentrations increase the risk of adverse ecological impacts such as algal blooms, loss of nutrient-sensitive species and deoxygenation of river substrates (Hatton-Ellis and Jones, 2021). Consequently, phosphorus targets to protect water quality and minimise the risk of negative ecological impacts have long been at the heart of the sustainable management of river ecosystems (Environment Agency, 2019; Hatton-Ellis and Jones, 2021). Mainstone and Parr (2002) summarised that excess phosphorus can degrade the plant and algal community by altering the competitive balance between different aquatic species. This has consequences for the whole ecosystem, including excessive growth of pollutant-tolerant algae and plants, a correlated increase in competition for light, greater bacterial loading and a consequential reduction in free oxygen availability. In addition, excess phosphates and nitrates can favour blooms of species (HABs) with known toxicity to higher organisms, as in the case of freshwater cyanobacteria (often, incorrectly, called 'blue-green algae').

Ammonia levels:

Ammonia in the New Inn Stream is under investigation by NRW for a deterioration from 'High' water quality to 'Good' status under the WFD 2021 classification (Emma Taylor, 2022, pers. comm.). NRW reported results from the New Inn sampling point were below 0.3mg/l (the Good/Moderate boundary for the most sensitive rivers) (Emma Taylor, 2022, pers. comm). The NRW laboratories measure total ammoniacal nitrogen (NH_3-N and NH_4-N), which is comparable to the NH_3-N results analysed by the KTSC team.

Our results for ammoniacal nitrogen measured as NH_3-N mg/l show that 81 of 90 (90%) water samples were in the good and high quality water categories with values less than 0.6mg/l. Although only 9 of 90 (10%) samples were in the moderate to poor quality water categories, a wide scale distribution of pollution along the entire stream (Table 7, Table 8 and Figure 12). Three samples exceeded the 2.5mg/l limit for poor water quality. The highest levels of ammonia (9.99mg/l), recorded at Factory Lane (site 7) and Furzy Park (site 1), were both linked to agricultural slurry events upstream or in the surrounding fields.

The WFD (2015) threshold for unionised ammonia (as N) is 0.021mg/l. Levels exceeding 0.021mg/l, the WFD threshold for unionised ammonia, were recorded 5 times across all sites (Table 13), including once at each of sites 3 (Spiritwood bridge), 4 (upstream from Goetre), 7 (Factory Lane) and twice at site 8 (New Inn bridge). The highest levels of unionised ammonia, 0.256mg/l, was recorded once at Site 4. The high levels of unionised ammonia recorded at site 4 is likely to come from the same upstream source as the high phosphate levels. Further testing up both tributaries would be helpful to determine the contribution treatment plants and private houses make to ammonia levels in the stream.

Ammonia is an environmental toxicant that is especially problematic for aquatic organisms (Levit, 2010). Ammonia oxidises to nitrate and contributes to the nutrient load in waterways. Total ammonia is comprised of two components: unionised ammonia (NH3) and ionised ammonia (NH4+). The proportion of unionised to ionised ammonia shifts in relation to the pH of the water and water temperature. The percentage of un-ionised ammonia is greater at higher temperatures and higher (alkaline) pH's and is proportionately lower at lower temperatures and lower (more acidic) pHs. While ionised ammonia is not toxic to fish, unionised ammonia is extremely toxic (Levit, 2010). The toxic effects of ammonia have been studied for over 50 years, with the primary focus on fish (Zhang *et al.*, 2023). Excessive (unionised) ammonia in the aquatic environment can lead to 'acute ammonia intoxication', which is a factor in the death of aquatic organisms. In fish, five hypotheses have been proposed regarding the mechanism of this toxicity (summarised in Zhang *et al.*, 2023): 1) Ammonia stress causes an imbalance in the osmotic regulation of the internal environment, leading to tissue damage; 2) Excessive concentrations of endogenous ammonia lead to cytopathic changes in the nervous system and other tissues; 3) Ammonia stress can directly damage gill epithelial cells and lead to asphyxia; 4) Ammonia stress can cause changes in mitochondrial permeability, resulting in a breakdown of ionic gradients; 5) Excess ammonia may also be excreted through the gills, disrupting ion transporters and ultimately leading to cellular dysfunction and tissue damage. Zhang *et al.* (2023) highlight that a report published in 2013 by USEPA (United States Environmental Protection Agency) analysed a large amount of acute toxicity data on ammonia and found that invertebrates (i.e., shrimp, crabs, shellfish, and zooplankton) were more susceptible to ammonia than vertebrates. This increases the threat of excess (unionised) ammonia in the aquatic environment, where the majority of organisms present are invertebrates, and are lower in the ecological food pyramid, so what affects them affects their predators and, ultimately those who prey on them (including humans). Ammonia pollution is caused by discharges from ammonium nitrate fertiliser, wastewater treatment plant effluents, sewer and storm overflows, septic tank effluents and slurry from farm animals, such as pigs and cows (Randall and Tsui, 2002).

The concentrations of ammonia that cause toxicity to fish depend on the length of exposure. Lower concentrations may not kill or adversely affect fish over short periods of time, but the same concentrations could kill or impair aquatic life under longer time frames. USEPA (1999) recommends an acute total ammoniacal nitrogen criterion of 2.9 or 5.0mg/l (for short-term exposure) and a chronic criterion of 0.26 or 1.8mg/l (for long-term exposure). Water with concentrations of less than 0.02mg/l unionized ammonia is considered safe for fish reproduction (EPA 1989). The mean acute toxicity value for 32 freshwater species of fish is 2.79mg NH_3/l (Randall and Tsui, 2002). Unionised ammonia causes gill damage at approximately 0.05mg/l and death at approximately 2.0mg/l (Anon., 2023d). It is important to remember that aquatic organisms can adapt to high concentrations of ammonia in the environment and there is variation in sensitivity to ammonia toxicity between different species (Jahanbani *et al.,* 2023).

Nutrient pollution is considered to be a marker for other pollutants which are too difficult or expensive to measure (e.g., pesticides, heavy metals, antibiotics and microplastics). Water bodies affected by nitrate pollution caused by farming in their catchments are quite likely also to be exposed to unnaturally high sediment runoff and intermittent pesticide pollution. Likewise, nutrient-rich runoff from residential areas will often have high levels of heavy metals, sediment, pesticides and sewage waste (Biggs *et al.*, 2016).

A useful source of information that lists the source of these and other pollutants in water courses can be found on the Foundation for Water Research website (see references).

If we imagine what it is like to be a fish, a frog or a caddis fly, whose entire life is spent in waterbodies that are continually mixed with the waste products of our farming and our sewage, it is hardly surprising that organisms living in aquatic ecosystems are considered to be under so much threat. This is an issue not only locally, but at a national and international level (UK Gov, 2022; Dudgeon, 2019; WWF 2020; Albini *et al.*, 2023).

Under-reporting of pollution incidents

This is a sensitive and complicated issue for a small rural community. One resident will not report frequent pollution events in the stream near to their house because of a fear of 'upsetting the local landowning family'. In the case of the Colby incidents, these events were reported to us by residents with a deep knowledge of the countryside and sustainable farming. They didn't report incidents to NRW as their perception had been that nothing they had previously reported had been followed up. In the case of another resident, they recounted an event when the stream below their house was running foul and smelt of slurry so a sample was collected and the problem was reported to NRW. By the time an NRW investigative team arrived a few days later there had been heavy rain and the river looked normal and NRW did not use the water sample collected by the resident at the time of the pollution incident.

When the preliminary findings of the stream monitoring project were presented in February 2023 at the LARC AGM (which had an audience of about 25 people), it was apparent that many people were unaware that pollution incidents could be reported to an NRW hotline. It was also noted that, for most people, there was a distinction on the relative importance of crimes against people and property versus crimes against the environment: when the LARC audience were shown a picture of a fight between youths in a town centre, the majority of the audience raised their hands when asked if they would report this to the appropriate authorities. When a picture of dead fish in a discoloured foamy river was shown, very few hands were raised when the audience was asked if they would report this to the appropriate authorities.

In summary, from our observations, events do not get reported because of –

- ignorance of the reporting process;
- a perception that the authorities do not penalise water companies or other polluters
- social fear in small communities
  and
- the feeling that environmental crime is not a real crime.

This suggests that a change of attitude needs to be encouraged at all levels, stakeholders and legal bodies both, including greater involvement in the local communities on both sides of the perceived pollution fence.

Farming in the Community

Pollution of the environment presents a real dilemma for a rural community. The principal author was brought up on a family dairy farm and understands the difficulties that farming families are under, juggling seemingly insoluble problems of maintaining farm viability in the face of rising fuel, animal feed and fertiliser costs, declining farmgate prices for milk, tighter environmental regulations and uncertainty on future levels of government support following changes to the single farm payments since Brexit (from 2018-2022 and thereafter). Then you must consider that there are factors caused by our modern life, but beyond human control as climate change drives more capricious weather systems with greater periods of intense rainfall, which complicates crop cycles, harvesting and animal waste management, as we have already seen in 2023.

It is beyond the scope of this report to find solutions to these real and serious problems that face the farming sector, but we can, hopefully, make helpful and empathetic observations. We need a thriving farming community. We also need a healthy environment. Is it impossible to think that we cannot have a thriving farming sector **and** a thriving environment that is managed with sensitivity to nature? Do we have degraded and polluted landscapes because, as consumers, we won't pay farmers fairly for the food they work hard to produce, and consequently they cannot afford to manage the land with sensitivity to the environment? Does the farming community expect the non-farming community to turn a blind eye to the signs that all is not right in our environment, that the rivers are polluted, that pollution may even be leaching into the aquifer? Is there only one model of an industrialised farming system that produces ever cheaper food, but at the expense of environmental degradation? On the other hand, what of the cost to the mental health of so many in the farming community who feel pressured by so many factors that they cannot control (Rannard, 2021; Blackett 2022)? Is it fair that farming costs such as fertiliser and animal feed rise and the price of milk falls? How is this sustainable? How can a local community help support our local farming community? Initiatives like Pembrokeshire Fresh and Dai's Dairy vending machines and Greenacres market garden shop are excellent examples of enterprises found in our village of Llanteg that enable the local population to support local farming families and their businesses. We have seen many films and documentaries on the poor state of our national rivers and seas over the last few years. Would the farming community benefit from an honest gritty documentary in the manner of the popular TV show 'Clarkson's farm' about the real problems of balancing the production of cheap milk alongside caring for the environment?

There are an increasing number of inspiring initiatives supported by farming organisations such as the Nature Friendly Farming Network NFFN (See: https://www.nffn.org.uk/). Again, it is beyond the scope of this report to discuss this in too great a detail, but the vision of the NFFN is a future where farmers are empowered to put nature at the heart of farming, supported by policies that enable and drive this transition.

We copy in Figure 14 a letter we had from a representative of the farming community who has been involved with the dairy farming industry in West Wales for over 30 years and who read a final draft of this report. We think his insights are valuable and warrant inclusion in this section on farming and the community. We have tried to report what we have found as fairly as possible. We reiterate that this is not about pointing fingers, because we are all part of the problem, and, ultimately, we can be part of the solution if we so wish.

Figure 14. Letter to authors of this report from a member of the farming community in Pembrokeshire with 30 years professional experience in the dairy industry across West Wales.

"Dear Principal Authors,

I read the final version of The Keep The Streams Report with interest. Thank you for sending it to me to review and pass comment on.

I note that you have adopted a fair and balanced approach to the issue of water pollution and agriculture, which sadly from the figure you present from the Environment Agency (Figure 12 in your report) does appear to be responsible for the majority of river pollution events in Wales. However, while it is easy to be critical of the farming community, we must understand some of the complexities of producing milk in West Wales.

A few thoughts for you on dairy farming in West Wales, an industry that I was involved with for over 30 years of my professional life.

Going back thirty years in West Wales there were a lot of small dairy herds spread out over a large area, and the average feed per cow was 1.2 tonnes. Expansion of herds in those days was restricted by the cost of purchasing quotas. Over this time l have seen many farmers giving up milk production then renting the land out.

Real expansion of the dairy industry in West Wales came about when milk quotas ended in 2015. Many of the farms that expanded rented extra ground, but were often not allowed to spread slurry on the ground by the land owner, because if a pollution event happens the owner would be liable. One result of this conundrum is that the area of land available for spreading slurry has been reduced. But the slurry has to go somewhere, and it does……, and I think this is contributing to some of the issues of excessive nutrients in our rivers.

Another consequence of so many farmers going out of milk production is an imbalance in land utilisation in West Wales. Some land is intensively farmed, but a lot of land is not utilised effectively. This puts more and more pressure on the intensively farmed land.

An important factor contributing to this problem is how difficult to plan nutrient management it is for active farmers who have short term tenancies on rented ground. From a business perspective, farmers need at least a 6-year tenancy to justify spending money on land improvements. However, much land is rented out on short rentals (6 or 9 months), because if land is rented for more than 365 days the renting farmer would be regarded as a sitting tenant. This would be against the interests of the landowner.

These two issues have contributed to limiting the area of land that is available for slurry to be spread on.

Another issue that I feel needs to be addressed is feed rate per cow that has increased in order to improve milk productivity from 1.2 tonnes per cow 30 odd years ago to 3-4 tonnes per cow per year. This I feel pushes a lot of nutrients through the cow which she cannot utilise, e.g. phosphorus and potassium. I am aware that the potassium index on many farms is too high and this has often caused problems with the metabolic disease, milk fever, in the cows.

Phosphorus in slurry is considerably higher these days than thirty years ago, but there is no legal requirement to restrict phosphorus in dairy diets. This is an area that I feel warrants investigation, perhaps by agricultural colleges.

Many thanks for allowing me to look at this report which I hope contributes to an honest debate within your community, but which also asks some important questions of the way we farm and the impact this has on our beautiful Welsh countryside."

[Name and address withheld on request of the respondent (22/1/2024)]

Deteriorating water quality of the local beaches

During the time this report was being written, we learnt that concerns about the water quality at Amroth and Wisemans Bridge had been raised by members of the local business community with the Amroth Community Council (ACC). Unfortunately, recent data (see: https://environment.data.gov.uk/wales/bathing-waters/profiles/profile.html?lang=en&site=ukl1403-37900) indicates that Amroth only has a 2 star 'good' water quality rating in 2023, whereas in previous years it was deemed as 'excellent' (3 star rating). Recent data for Wiseman's bridge (see: https://environment.data.gov.uk/wales/bathing-waters/profiles/profile.html?_search=Wiseman&site=ukl1403-37940) indicates that water quality has fallen from a 3 star 'excellent' rating in 2021 to the lowest 1 star 'acceptable' rating in 2023. There are concerns that local beaches may be at risk of losing their Blue Flag status if the quality of the water continues to deteriorate in the Bay. In 2023 Amroth, but not Wiseman's Bridge, was listed as having Blue Flag status by the Beach Guide (see: https://www.thebeachguide.co.uk/best-beaches/blue_flag.htm). A public meeting in February 2024 is being organised by ACC including representation and presentations from Welsh Water, Pembrokeshire County Council Environmental Health and NRW to help develop a plan to improve water quality. The current report by LARC on the New Inn Stream is therefore highly relevant to this discussion and a copy will be submitted to ACC.

Recommendations

LARC is now working with the National Trust at Colby to conduct monitoring of the Colby River that runs through Colby Woodland Gardens. The National Trust has funded the purchase of testing kits and a second pH meter for the KTSC Colby project. This project began in October 2023 monitoring 6 sampling locations between Lower Pendeilo Farm and Amroth carpark. Preliminary results indicate that this stream has levels of pollutants lower than the New Inn Stream. Ammonia levels ranged from 0 to 0.04mg/l (4 of 6 sites were 0mg/ml). Phosphate levels ranged from 0 to 0.3mg/l (5 of 6 sites were 0mg/ml). Nitrate levels ranged from 0.9 to 5mg/l. This stream has the advantage of flowing within an area where there is woodland and farmland managed by the National Trust with greater sensitivity to nature, which could explain this difference. However, as has been commented on in the section on visible signs of pollution, in November residents of Amroth observed three pollution events that were not reported to NRW.

There are also ongoing concerns about the condition of Ford's Lake, which is a small river that runs down Pleasant Valley and exits at Wiseman's Bridge. LARC would like to encourage another group of concerned citizens to monitor this stream. As we have found monitoring the New Inn Stream, it is not until you have a group of concerned citizens 'in the field', collecting and analysing samples from multiple locations at monthly intervals, that you can construct a more accurate a picture of where pollution events, both acute and chronic, occur. Again, the process of a team monitoring the stream will start a conversation within the community.

While much of the upper Llanteg valley had been listed as a primary Special Protection Zone (SPZ1) by the Environment Agency '*to protect the Marros-Pendine aquifer in 2016, the whole of Wales has since been designated a Nitrogen Vulnerable Zone by NRW on 1 April 2021*' (Anon., 2021). Although the implementation has been paused, it will be interesting to see if the new restrictions, which (amongst many other measures) will limit the periods when slurry can be applied to the land, will contribute to lowering nitrate and other pollutant levels in the watercourses in Wales generally and our four streams locally, namely Ford Lake (Wiseman's) (Figure 16), Colby River, Castle Stream and the New Inn Stream.

LARC made constructive comments on the planning application for the construction of an earth bank nutrient store (slurry lagoon) at a local farm in April 2023 (Planning reference NP/23/0127/FUL, see https://planning. pembrokeshirecoast.wales/agile_pcnpa/apas/run/wphmakerep.displayURL?ApnID=NP/

23/0127/FUL) and which was approved by the Pembrokeshire Coast National Park on December 4th 2023. Nia Stephens from NRW conducted a Pollution Prevention Assessment review of the farm in 2020 and reported that there was not sufficient slurry storage to satisfy the SSAFO Regulations (Stephens, 2020). The stream running down Factory Lane originates from a single point source of human activity at this farm. This stream (site 7) was noted to be heavily polluted during October-December 2023 during the KTSC study. LARC welcomes the construction of a new slurry lagoon by the local farm with a capacity of 5,400m^3 (1,187835 gallons) because, as NRW noted in their 2020 review of this farm, there was insufficient slurry storage capacity. The construction of this infrastructure has the potential to reduce nutrient pollution of the New Inn Stream. NRW (Stephens, 2020) calculated slurry production for 4 winter months (November-February) to be about 1,683,294 gallons, while the actual slurry-holding capacity at this farm was calculated to be only 1,149,467 gallons. This was identified as a shortfall of 32%, or 533,827 gallons, and was below the 120 days (4 months) storage required under the SSAFO Regulations. It is not unreasonable to ask what happened to this half a million gallons of slurry during the winters from 2020 to 2023 and the years before if there was insufficient storage capacity during this time.

LARC members also met with a representative of the Llanteg Park Community in December 2023 to discuss the KTSC results at site 4 which may be associated with discharges from the community water treatment plant or other sources further upstream on this tributary. These discharges appeared to be causing high nutrient pollution noted at the Goetre stream influx at site 4. LARC was able to advise the community on the purchase of more accurate water monitoring equipment for their water treatment plant and further dialogue will be carried out in 2024. The representative has suggested that further monitoring upstream on this tributary would be helpful to determine the precise source of the excess nutrients. LARC has offered to analyse samples for the community.

It is interesting that there appears to be a seasonal fluctuation of phosphate levels, with poorer readings coinciding with holiday periods (Figure 11, Table 15). Perhaps this is related to the increases in the volume of human waste exceeding the capacity of private and Welsh Water sewage treatment plants? Future river monitoring projects should assess seasonal changes in nutrient pollution to determine the significance of contributing factors, such as tourism. Given the resident population of Pembrokeshire is just 122,000 (Office for National Statistics, 2021) and that an estimated 7 million people visit Pembrokeshire each year (Phillips, 2021), perhaps an impact on sewage treatment plants is hardly surprising. Another observation we have made is that private sewage treatment plants discharge directly into watercourses. This is the case for site 4 and presumably for other private sewage treatment plants throughout the county. It seems strange that these discharge pipes could not empty into watercourses via a natural filtration system such as a reedbed. We are aware that reedbeds can be highly effective in cleaning waste water, indeed one of our LARC members has such a system designed by Jay Abrahams (https://www.permaculture.org.uk/practical-solutions/wetland-sewage-systems). Perhaps this is something that NRW could consider as part of the approval process for private water treatment plants in the future?

The Amroth Wastewater Treatment Works (AWTW) discharges into the New Inn Stream at NGR - SN 17775 07700 (Figure 15a). Two storm overflow (SO) drains are marked on Figure 15b. In 2022, storm drain 1 (WW asset 52108, permit number BP0034003) discharged storm overflow sewage 13 times for a total of 107.75 hours. In 2022, storm drain 2 (WW asset 52107, permit number BP0034002) discharged storm overflow sewage 2 times for a total of 4 hours (https://corporate.dwrcymru.com/en/community/environment/combined-storm-overflows). Storm overflows (SOs) are permitted to discharge when the network is overwhelmed with volume to prevent flooding; this will include wastewater from the sewers as well as a lot of rainwater/surface water. The flow that is discharged from a SO will have some untreated wastewater, although very dilute in permitted conditions (Kelly Jordan, pers. comm., 2023). There are currently plans by Welsh Water, submitted within the Price Review 2024 business plan, to invest in AWTW during the next investment cycle (2025-2030) of the company (Kelly Jordan, pers. comm., 2023). This scheme includes site changes to comply with the introduction of a total phosphorus permit limit of 1.8mg/l and an ammonia (NH_3) permit limit of 4.5mg/l, by end of March 2027 (Kelly Jordan, pers. comm., 2023). All business plans are subject to Ofwat determination which will be finalised during 2024 (Kelly Jordan, pers. comm., 2023). The location of the AWTW discharge pipe into the New Inn Stream was only known after the completion of the project. It is important to state that there is no storm discharge from the AWTW located at SN 17775 07700 (Figure 15a). All flows pumped to AWTW are treated. The discharge through this outflow into the New Inn Stream is the treated effluent (Kelly Jordan, pers. comm., 2023). Any future monitoring of the New Inn Stream should also include a sample point just downstream of this AWTW discharge point in consultation with the owners of the New Inn Caravan Park. If the AWTW are upgraded this will help to improve the water quality of the New Inn Stream and the adjacent sea into which it flows.

Figure 15a. Location of the waste water discharge (NGR - SN 17775 07700), from the Amroth Wastewater Treatment Works into the New inn stream, located upstream of the New Inn caravan park.

Figure 15b. The two Welsh Water storm overflow drains (blue circles) in Amroth (source Welsh Water: https://corporate.dwrcymru.com/en/community/environment/combined-storm-overflows). Storm drain 1 / Red arrowhead – public toilets adjacent to Amroth Castle Caravan Site: this storm overflow discharges into the New Inn Stream just below the New Inn bridge at grid reference SN 17280 07250. Storm overflow 2 / Blue arrowhead – Amroth carpark: this storm overflow discharges into the Colby Stream near to Brookside Villas at grid reference SN 16220 07095. Information courtesy of Kelly Jordan (Kelly Jordan, pers. comm., 2023).

While most media attention is focused on river and sea pollution, areas that people notice, we wonder if contamination of our aquifers has been overlooked and we would encourage relevant organisations or research institutions to start monitoring projects.

Recommendations to reduce nitrates, phosphates and ammonia pollution are complicated and multifaceted. They will require changes to agricultural practises and improvements to waste water treatment plants as well as changes to restrictions on raw sewage discharges by water companies. It is beyond the scope of this report to make recommendations to reduce the levels of these pollutants, but the authors consider that this would make a worthwhile follow-up project for students at a local agricultural college or environmental science program at a regional university. LARC will distribute this report to interested parties including universities and Further Education colleges and will endeavour to encourage meaningful follow-up. Given that the catchments to the streams feeding into Carmarthen Bay at Amroth comprise a relatively small area, it ought to be possible to find solutions. Indeed, we would encourage NRW to consider this catchment as a potential model area for trialling measures to reduce pollution. As of January 2024, it has been reported that NRW are setting up a task team to explore pollution issues with 800 farms across Wales, which is a promising first step in fixing this major issue (Anon, 2024).

Finally, in relation to the current situation, we can do no better than quote from Burt *et al.* (2011) "*No 'quick' fixes' of long-term nutrient excesses should be expected. Ground water moves slowly, and waters of improved quality may take 30 years or more to move from the surface into nearby streams and wells. A long-term view must be taken. Understanding the regional distribution and key scientific factors that affect nutrient concentrations in ground- and surface-waters is critical to implementing and evaluating cost effective programs to manage and protect our water resources*."

It appears to the authors of this current report that water pollution is yet another problem we are leaving for the next generation to fix.

What can 'we' do?

While we cannot change agricultural policy or strongarm water companies, there are things that 'we' the community can do as individuals or households to lessen our domestic impact on water quality. We have copied the following recommendations from Bannau Brycheiniog (Brecon Beacons) National Park Authority that were recently published in the South Wales Argus (Phillips, 2023) and they include:

1. Don't put kitchen waste down the drain.
Food waste ends up down drains regularly, causing numerous blockages and leaks. If you have a small amount of fat, cooking oil or fatty food leftovers to discard, you can recycle them in your food waste caddy.

2. Choose eco-friendly products.
Whether it's from washing up liquid, dishwasher tablets, or cleaning spray, thousands of household chemicals are washed into the rivers every week. From *Ecover* to *Method*, there are plenty of brands that offer products without harmful fragrances, preservatives, and synthetic dyes.

3. Clean your home or business responsibly.
Basic home supplies like soda, lemon juice or vinegar are all brilliant alternatives to standard cleaning products. Other tips include using reusable cloths instead of disposable wipes and toothbrushes for scrubbing around taps or other hard-to-reach places.

4. Think before you flush.
In short, if it's not one of the three Ps (Pee, Poo, and Paper - toilet paper, obviously), then it shouldn't go down the toilet.

5. Empty your septic tank regularly and use septic tank treatment bacteria.
If a septic tank is not cleaned regularly enough, dangerous toxins can build up — eventually causing waste blocks and overflow, and the pollution that seeps into the soil can end up in local rivers. The use of secondary reedbeds to aid soak away from septic tanks and septic tank treatment bacteria may also be beneficial (e.g., *Muckmunchers* ™ or see: https://www.muck-munchers.co.uk/).

6. Be a considerate car-washer.
Many surface-water drains flow straight into rivers and streams.
If possible, take your vehicle off the road or your driveway completely — and wash it on grass or gravel instead, which will filter out contaminants from the water. You could even use an eco-friendly car wash.

7. Make regular visits to the rivers.
Regular visits will arm you with the knowledge to spot when things aren't right, such as milky or oily water. These occurrences should be reported directly to Natural Resources Wales.

8. Report pollution incidents.
As highlighted previously, pollution incidents can be reported to NRW via their 24hr *Incident Hotline*, 0300 065 3000. The West Wales Rivers Trust and the *Wye citizen science water quality monitoring field guide* (2021) includes information on some of the most common, easy-to-spot signs of pollution found in UK rivers and streams (Anon., 2023b, c).

9. Adopt a tributary.
The West Wales Rivers Trust is promoting an initiative for communities to adopt a tributary and this is something that LARC will help promote in our area (see: https://westwalesriverstrust.org/adopt-a-tributary/).

Fig. 16. As with the other three streams in our region (Ford's Lake, Colby River & Castle Stream), the New Inn Stream flows onto beaches which currently have blue flag status (Amroth Beach, Wiseman's Bridge), although there are local concerns that it may lose this status. The offshore coast is now listed as an SAC, while there are two SSSI close to these beaches. Somehow, we need to keep these streams clean.

Figure 17. Photographs of pollution evidence on New Inn Stream.

17a) Factory Lane, December 12th 2022.

17b) Factory Lane, December 12th 2022

17c) Factory Lane, December 12th 2022.

17d) Site 4, example pollution upstream from Goetre, February 19th 2023

17e) Site 4, example pollution upstream from Goetre, February 19th 2023

17f) New Inn bridge, 10th August 2023.

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Tables and Appendices

Appendix 1. Data Tables 3-14

Nitrate results measured as NO_3—N mg/l are reported in Tables 3 (by month) and 4 (by average over project) (original Hanna instrument values).

Table 3 Monthly Nitrate results measured as NO_3—N mg/l levels in the water of the New Inn Stream from 9/8/2022 to 17/7/2023.

NO_3-N Site:-	Date: concentration	09/08/2022	09/09/2022	13/10/2022	25/11/2022	15/12/2022	16/01/2023	19/02/2023	13/03/2023	20/04/2023	11/05/2023	15/06/2023	17/07/2023
1 Furzy Park	mg/l	1	1.30	3.8	3.20	3.60	2.30	3	3	3.7	2.9	2.5	1.7
2 Ely Mill	mg/l	3	1.80	3.4	4.30	3.40	5.00	3.40	2.50	2.6	2.8	3.8	2.4
3 Spiritwood Bridge	mg/l	2.7	n/d	3.4	3	3.2	4	3.4	2	3.8	3.1	3.6	3.4
4 Upstream influx Goetre	mg/l	n/d	13.2	6.3	0	5.4	1.8	1	1.3	1.5	3.9	15.6	5.3
5 Llanteg village influx Goetre	mg/l	n/d	2.10	1.40	1.00	1.10	1.60	1.3	1.1	1.3	1.9	5.3	1.9
6 Goetre riverfly	mg/l	4.2	4.3	2.9	0.9	1.9	1.1	1.1	1.3	2.5	1.4	3.8	4.3
7 Factory Lane	mg/l	n/d	n/d	n/d	n/d	30	6.6	4.6	1.5	5	3.8	1.5	1.3
8 New Inn bridge	mg/l	3.8	1.8	0	2.8	7.1	3.8	3.4	2.1	3.6	2.1	3	4.2

Table 4 Statistical summary of Nitrate measured as NO_3—N mg/l results from the New Inn Stream for 9/8/2022 to 17/7/2023.

$N0_3$-N mg/l	Mean	SD	Max	Min	Count
1 Furzy Park	2.66	0.89	3.8	1	12
2 Ely Mill	3.20	0.85	5	1.8	12
3 Spiritwood Bridge	3.24	0.52	4	2	11
4 Upstream influx Goetre	5.03	4.86	15.6	0	11
5 Llanteg village influx Goetre	1.82	1.16	5.3	1	11
6 Goetre riverfly	2.48	1.31	4.3	0.9	12
7 Factory Lane	6.79	8.96	30	1.3	8
8 New Inn bridge	3.14	1.63	7.1	0	12

Phosphate results measured as PO_4^{3-} mg/l are reported in Tables 5 (by month) and 6 (by average over project) (original Hanna instrument values).

Table 5 Monthly Phosphate results measured as PO_4^{3-} mg/l levels in the water of the New Inn Stream from 9/8/2022 to 17/7/2023.

PO_4^{3-}	Date	09/08/2022	09/09/2022	13/10/2022	25/11/2022	15/12/2022	16/01/2023	19/02/2023	13/03/2023	20/04/2023	11/05/2023	15/06/2023	17/07/2023
Site	concentration												
1 Furzy Park	**mg/l**	0.64	0.84	0.29	0.20	1.62	1.61	0.53	0.52	0.28	0.27	0.2	0.24
2 Ely Mill	**mg/l**	0.43	0.28	0.15	0.29	1.00	0.26	0.36	0.40	0	0.03	0.13	0.06
3 Spiritwood Bridge e	**mg/l**	0.11	n/d	0.08	0.23	1.5	0.12	0.18	0.4	0.29	0.04	0.13	0.2
4 Upstream influx Goetre	**mg/l**	n/d	2.5	2.5	0.28	2.5	0.76	0.52	0.05	1.15	1.85	4.4	5.4
5 Llanteg village influx Goetre	**mg/l**	n/d	0.80	0.40	0.00	0.00	0.14	1.08	0	0.14	0.05	0.39	0.33
6 Goetre riverfly	**mg/l**	2.48	2.5	1.15	0.35	0.87	0	0.22	0.14	0.47	0.19	6.4	0.84
7 Factory Lane	**mg/l**	n/d	n/d	n/d	n/d	0.74	0.23	0.5	0.4	0.17	0.1	0.31	0.36
8 New Inn bridge	**mg/l**	1.79	0.73	0.17	0	0.12	0.03	0.34	0.25	0.29	0.06	0.45	0.64

Table 6 Statistical summary of Phosphate results measured as PO_4^{3-} mg/l levels from the New Inn Stream for 9/8/2022 to 17/7/2023.

PO_4^{3-} mg/l	Mean	SD p	Max	Min	Count
1 Furzy Park	0.60	0.49	1.62	0.2	12
2 Ely Mill	0.28	0.26	1	0	12
3 Spiritwood Bridge	0.29	0.39	1.5	0.04	11
4 Upstream influx Goetre	1.99	1.63	5.4	0.05	11
5 Llanteg village influx Goetre	0.30	0.34	1.08	0	11
6 Goetre riverfly	1.30	1.74	6.4	0	12
7 Factory Lane	0.35	0.19	0.74	0.1	8
8 New Inn bridge	0.41	0.47	1.79	0	12

Phosphate as PO_4^{3-}- mg/l was converted to Phosphate PO_4^{3-}-P mg/l using a conversion factor of dividing by divided by 3.06 and results are reported in Tables 7 (by month) and 8 (by average over project).

Table 7 Monthly Phosphate results calculated as PO_4^{3-}-P mg/l levels in the water of the New Inn Stream from 9/8/2022 to 17/7/2023.

PO_4^{3-}-P	Date	2022	2022	2022	2022	2022	2023	2023	2023	2023	2023	2023	2023
site	concentration	August	September	October	November	December	January	February	March	April	May	June	July
1 Furzy Park	mg/l	0.21	0.28	0.09	0.07	0.53	0.53	0.17	0.17	0.09	0.09	0.07	0.08
2 Ely Mill	mg/l	0.14	0.09	0.05	0.09	0.33	0.09	0.12	0.13	0	0.01	0.04	0.02
3 Spiritwood Bridge	mg/l	0.04	n/d	0.03	0.08	0.49	0.04	0.06	0.13	0.09	0.01	0.04	0.07
4 Upstream influx Goetre	mg/l	n/d	0.82	0.82	0.09	0.82	0.25	0.17	0.02	0.38	0.61	1.44	1.77
5 Llanteg village influx Goetre	mg/l	n/d	0.26	0.13	0	0	0.05	0.35	0	0.05	0.02	0.13	0.11
6 Goetre riverfly	mg/l	0.81	0.82	0.38	0.11	0.28	0	0.07	0.05	0.15	0.06	2.09	0.28
7 Factory Lane	mg/l	n/d	n/d	n/d	n/d	0.24	0.08	0.16	0.13	0.06	0.03	0.10	0.12
8 New Inn bridge	mg/l	0.59	0.24	0.06	0	0.04	0.01	0.11	0.08	0.10	0.02	0.15	0.21

Table 8 Statistical summary of Phosphate results calculated as PO_4^{3-}-P mg/l levels from the New Inn Stream for 9/8/2022 to 17/7/2023.

PO_4^{3-}P mg/l	Mean	SD p	Max	Min	Count
1 Furzy Park	0.20	0.16	0.53	0.07	12
2 Ely Mill	0.09	0.08	0.33	0	12
3 Spiritwood Bridge	0.10	0.13	0.49	0.01	11
4 Upstream influx Goetre	0.65	0.53	1.77	0.02	11
5 Llanteg village influx Goetre	0.10	0.11	0.35	0	11
6 Goetre riverfly	0.43	0.57	2.09	0	12
7 Factory Lane	0.12	0.06	0.24	0.03	8
8 New Inn bridge	0.13	0.16	0.59	0	12

Ammonia results measured as NH_3-N mg/l are reported in Tables 9 (by month) and 10 (by average over project) (original Hanna instrument values).

Table 9 Monthly ammonia NH_3-N (mg/l) levels in the water of the New Inn Stream from 9/8/2022 to 17/7/2023.

NH_3-N / Site	Date / concentration	09/08/2022	09/09/2022	13/10/2022	25/11/2022	15/12/2022	16/01/2023	19/02/2023	13/03/2023	20/04/2023	11/05/2023	15/06/2023	17/07/2023
1 Furzy Park	**ppm**	0.02	0.05	0	0.07	0.03	6.08	0.03	0.14	0.04	0.04	0	0
2 Ely Mill	**ppm**	0.01	0.02	0	0.23	0.00	0.09	0.01	0.08	0.01	0	0	0.05
3 Spiritwood Bridge	**ppm**	0.02	n/d	0	0.19	0.1	0.14	0	0.73	0.19	0.03	0.09	0.07
4 Upstream influx Goetre	**ppm**	n/d	0.22	0.16	0.43	0.19	0.8	0.05	0.58	1.09	0	0.28	0.19
5 Llanteg village influx Goetre	**ppm**	n/d	0.13	0.00	0.16	0.12	0.11	0.08	0.32	0.13	0.05	0.12	0.17
6 Goetre riverfly	**ppm**	0.04	0.08	0.04	0.08	0.11	0.27	0.07	0.38	0.25	0.15	0.21	0
7 Factory lane	**ppm**	n/d	n/d	n/d	1.72	9.99	0.11	0.02	0.8	0.01	0.01	0.06	0.05
8 New Inn bridge	**ppm**	0.06	0.11	0	0.13	0.09	2.84	0.25	0.61	0.02	0.07	0.08	0.02

Table 10 Statistical summary of ammonia NH_3-N (mg/l) results from the New Inn Stream for 9/8/2022 to 17/7/2023.

NH_3-N (mg/l)	Mean	SD p	Max	Min	Count
1 Furzy Park	0.54	1.67	6.08	0	12
2 Ely Mill	0.04	0.06	0.23	0	12
3 Spiritwood Bridge	0.14	0.20	0.73	0	11
4 Upstream influx Goetre	0.36	0.32	1.09	0	11
5 Llanteg village influx Goetre	0.13	0.08	0.32	0	11
6 Goetre riverfly	0.14	0.11	0.38	0	12
7 Factory lane	1.42	3.08	9.99	0.01	9
8 New Inn bridge	0.36	0.77	2.84	0	12

Unionised ammonia as mg/l calculated from ammonia NH_3 using an online calculator and the pH and temperature values are reported in Table 11 (by month) and 12 (by average over project). Values highlighted in yellow exceed the WFD (2015) threshold for unionised ammonia (as N) of 0.021 mg/l.

Table 11 Monthly unionised ammonia (mg/l) levels in the water of the New Inn Stream from 9/8/2022 to 17/7/2023.

unionised ammonia (mg/l)	date	2022	2022	2022	2022	2022	2023	2023	2023	2023	2023	2023	2023
Site	Concentration	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**
1 Furzy Park	mg/l	0.001	0	0	0	0	0.007	0	0	0	0	0	0
2 Ely Mill	mg/l	0.003	0	0	0.001	0	0	0	0	0	0	0	0.001
3 Spiritwood Bridge	mg/l	0.025	n/d	0	0.001	0.001	0	0	0.002	0.003	0.001	0.003	0.002
4 Upstream influx Goetre	mg/l	n/d	0.256	0	n/d	0	0.002	0	0	0.001	0	0.002	0.002
5 Llanteg village influx Goetre	mg/l	n/d	0.001	0	n/d	0	0	0	0	0	0	0.002	0.001
6 Goetre riverfly	mg/l	0.001	0	0	n/d	0	0	0	0	0	0.001	0	0
7 Factory lane	mg/l	n/d	n/d	n/d	n/d	0.024	0	0	0.005	0	0	0.001	0
8 New Inn bridge	mg/l	0.023	0.005	0	0.001	0	0.024	0	0.001	0	0.002	0.001	0.002

Table 12. Statistical summary of unionised ammonia (mg/ml) results from the New Inn Stream for 9/8/2022 to 17/7/2023.

unionised ammonia (mg/ml)	Mean	SD p	Max	Min	Count
1 Furzy Park	0.000667	0.00193	0.007	0	12
2 Ely Mill	0.000417	0.00086	0.003	0	12
3 Spiritwood Bridge	0.003455	0.00689	0.025	0	11
4 Upstream influx Goetre	0.0263	0.07657	0.256	0	10
5 Llanteg village influx Goetre	0.0004	0.00066	0.002	0	10
6 Goetre riverfly	0.000182	0.00039	0.001	0	11
7 Factory lane	0.00375	0.00782	0.024	0	8
8 New Inn bridge	0.004917	0.00842	0.024	0	12

Appendix 2. New Inn Stream Water Quality Monitoring Project Recording sheet for chemical analysis.

Location	**1 Furzy**	**2 Castle Ely Mill**	**3 Spiritwood bridge**	**4 upstream from Goetre**	**5 Llanteg village influx Goetre**	**6 Goetre Riverfly**	**7 Factory Lane**	**8 New Inn bridge**
Date								
Time								
Weather								
Recorder								
Temperature (o c)								
Stream depth (cm)								
Electrical conductivity								
pH								
Nitrate								
Ammonia								
Phosphate								
Comments								

Appendix 3. How to spot river pollution (Courtesy of the West Wales Rivers Trust).