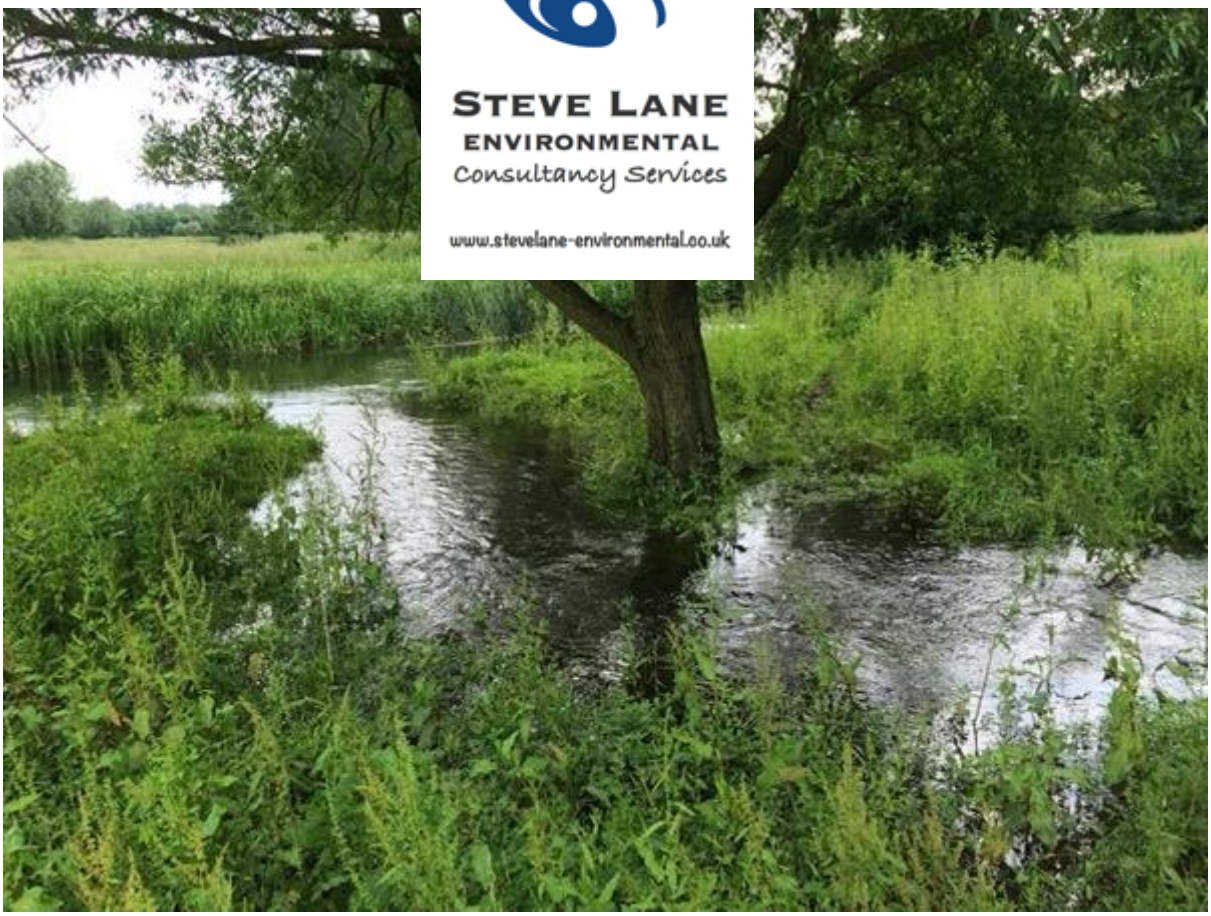
Wensum Water for Tomorrow: Wensum Citizen Science Feasibility Assessment Report – DRAFT V1



Executive Summary

This feasibility assessment has been commissioned to support the Wensum Catchment Partnership (WCP) in plans and feasible locations to scale up a monitoring programme for water quality and water resources across the full Wensum catchment, using citizen science approaches alongside the existing institutional monitoring, fundamentally encouraging cross-stakeholder collaboration across the Wensum catchment and wider Broadland catchment stakeholders. The feasibility assessment seeks to deliver this objective by addressing the following key questions:

- **Why is additional monitoring of the health of the Wensum catchment needed?** Over 90% of UK rivers fail to meet Water Framework Directive targets. Phosphate pollution is one of the main reasons Natura 2000 sites such as the Wensum fail their conservation objectives. More evidence is required at a local scale to better understand catchment water quality and flows and inform future management Citizen science is a key way to deliver increased monitoring across the catchment. **-Pages 13-16**
- **Where?** A desk-based study was undertaken to identify where existing sampling is undertaken and a framework of 84 accessible monitoring locations across the Wensum catchment has been developed. Opportunities to improve collaboration with partners and deliver quality assurance checking of data have also been identified. **-Pages 17-26**
- **What & How?** Suggested parameters, methods & equipment for a Wensum citizen science monitoring programme have been identified, including means to capture and disseminate citizen science data **-Pages 27-35**
- **Field Trials:** A series of field trials of the suggested water quality equipment, methods and sites was undertaken to ground truth the feasibility findings. **-Pages 36-41**
- **How good is our data?** Options for checking data quality are presented, together with comparison of field trial P samples against contemporary EA data. **-Pages 42-44**
- **Develop a pilot scheme:** Recommendations to enable WCP and partners to start a pilot citizen scientist monitoring programme, focussed on the River Tat and Upper Wensum headwaters, providing a framework to scale up and evolve monitoring across the Wensum catchment moving forward. **-Pages 45-53**
- **Options for future development:** Recommendations for future development include the testing and validation of ways to make stream flow measurement more accessible to citizen science and options for developing Wensum citizen science capability moving forward. **-Pages 54-55**

Table of Contents:

Table of Figures:

Tables:

Acknowledgements:

Thanks to Dennis Willis and Roger Gibbons for their help in arranging and taking part in trials at Norfolk Flyfishers Club, Colin Howlett for arranging access, logistical support and taking part in trials at Norfolk Flyfishers Club, Worthing fishery and on the River Tat and Sarah Gelpke of Norfolk Rivers Trust for helping with sampling on the Wendling Beck and feedback on report preparation; Zac Battam of NRT for help with bench trials of water quality equipment; Jessie Leach of the Rivers Trust, Kelvin Allen and John Flowerdew for advice and support.

1. Introduction

1.1 Citizen Science aims and objectives

This feasibility assessment has been commissioned to support the Wensum Catchment Partnership (WCP) in plans and feasible locations to scale up a monitoring programme for water quality and water resources across the full Wensum catchment, using citizen science approaches alongside the existing institutional monitoring, fundamentally encouraging cross-stakeholder collaboration across the Wensum catchment and wider Broadland catchment stakeholders.

The feasibility assessment seeks to deliver this objective by examining the following key questions:

- **Why?** Why is monitoring of the health of the Wensum catchment needed?
- **Where?** Identifying a network of 84 accessible monitoring locations across the Wensum catchment;
- **What & How?** Suggested parameters, methods & equipment for a Wensum citizen science monitoring programme, including means to capture and disseminate citizen science data
- **Field Trials:** Undertaking field trials of suggested equipment and approaches for water quality
- **How good is our data?** Identifying options for checking data quality
- **Develop a pilot scheme:** Making recommendations to enable WCP and partners to start a pilot citizen scientist monitoring programme, providing a framework to scale up and evolve monitoring across the Wensum catchment moving forward

The outputs from this assessment contribute towards the strategic objectives for the Water for Tomorrow project, principally:

T1 work package: *ensure active participation of stakeholders in planning and model design processes, and co-design and implement a programme of further stakeholder participation to ensure transfer and uptake of outputs.*

T2 work package: *contribute to catchment understanding and project implementation and evaluation of innovative management systems that include the development of near real time data collection and data management systems, innovative water allocation processes, and early warning drought systems.*

1.2 Study approach:

1.2.1 Review of case studies, baseline information and literature:

Desk-based work included reference to baseline information and literature including:

- Wensum SSSI Diffuse Water Pollution Plan, Site Improvement Plan
- Anglian River Basin Management Plan
- Nutrient neutrality
- Water for Tomorrow
- Wensum Catchment Management Plan
- Water quality parameters sampled by existing monitoring in the Wensum
- Where existing monitoring is undertaken on the Wensum

A desk-based review of potential citizen science sampling methods, equipment and data recording options was undertaken to inform this assessment, including from citizen science case studies, CaBA Citizen Science resources and literature.

1.2.2 Desk-based trial of smartphone-based data recording

A trial construct of a smartphone app-based data recording and uploading system was developed using the mWater Surveyor app for iPhone and Android devices. This involved designing a mock-user interface within the app platform to enable the user to input and then upload relevant data, observations and photographs. A mock set of data was entered and uploaded to test functionality and demonstrate the feasibility of a potential solution enabling volunteers to upload site data directly from field sites in real time.

1.2.3 Practical feasibility trials of selected equipment, methods and data recording

Additional practical work was undertaken to further inform the potential fitness for purpose of the findings of the desk-based review. A practical trial of the proposed water quality testing equipment, methods and app-based data capture was undertaken in selected Wensum headwater catchments during February and March 2022 to ground truth the findings of desk-based work.

1.2.4 Stakeholder engagement

This work was informed and shaped by regular stakeholder engagement, through presentations and discussions at forums including regular Wensum Catchment Partnership (WCP) meetings. This enabled discussions with partners including the Environment Agency, Natural England, University of East Anglia, Norfolk Rivers Trust, Upper Wensum Cluster Farm Group, Anglian Water, Norfolk County Council, landowners. Regular meetings were also undertaken with the WCP management group and with the wider Water for Tomorrow project. Further engagement was undertaken as part of the practical feasibility trials to ground truth the suitability of the identified water quality sampling equipment and methods. This included working with volunteers to test some of the sampling equipment.

1.3 Context

1.3.1 The River Wensum Catchment

The River Wensum is a low gradient chalk river located in Norfolk, England. Its source rises close to the village of Whissonsett, near Fakenham in North Norfolk at an altitude of 50m above sea level. The river flows 73km in a predominantly south-easterly direction to the tidal limit at New Mills in Norwich, with a catchment area of 685 km^2 (68,493 ha).

The catchment is primarily rural, with the principal land use in its shallow valley being grassland and arable farming. Other than the towns of Fakenham, Taverham, Reepham and Dereham (the latter being on the Wendling Beck), there are few urban areas that influence the river.

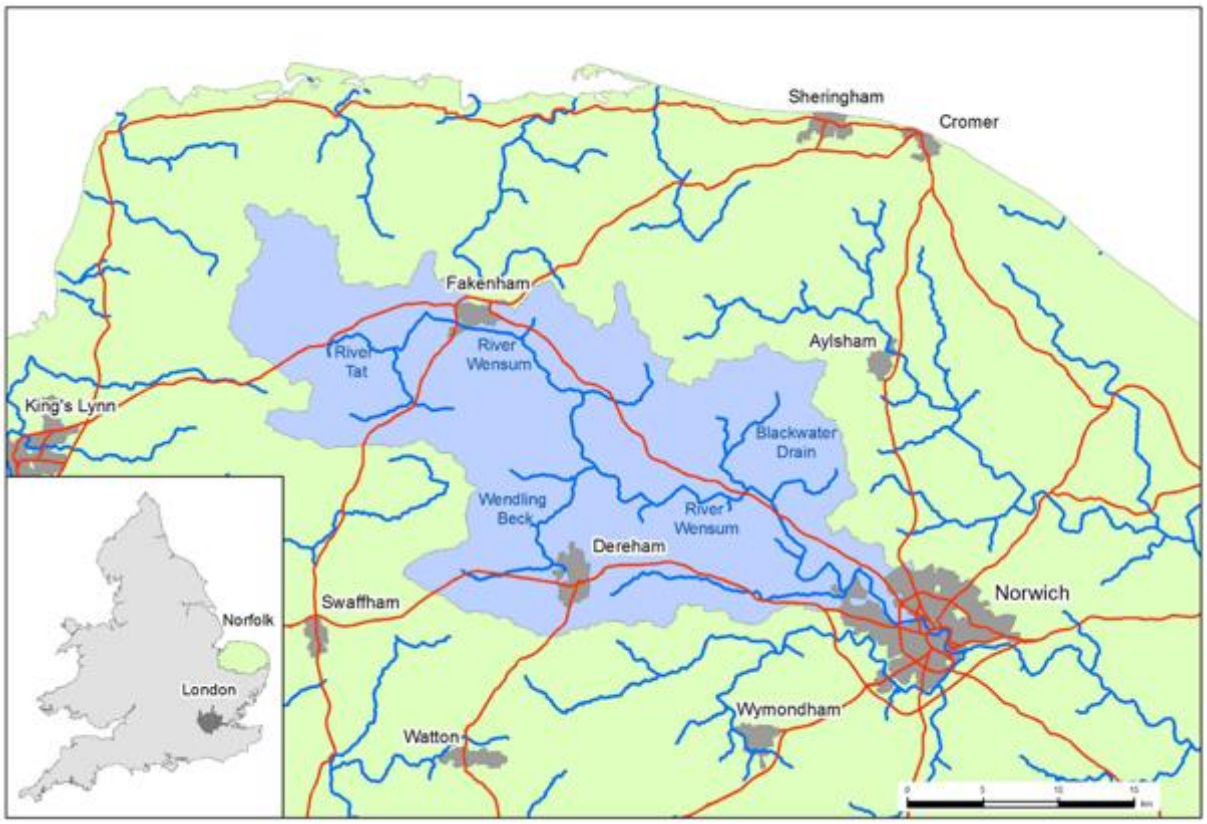


Figure 1: Wensum catchment map (Source: Wensum DTC, UEA)

1.3.2 Geology and hydrology

The Wensum catchment is reasonably flat, with elevations ranging from 0m AOD at the tidal limit of the river, to a maximum of 98m AOD. The upper reaches of the river are fed by chalk springs and drainage from calcareous soils, and support chalk stream vegetation communities. In the downstream reaches the river flows over boulder clay and gravels and the vegetation communities in this reach reflect the change in substrate and slower flow conditions. The catchment is largely covered by boulder clay, which increases runoff during wetter periods and reduces baseflow contribution during drier periods. This makes the Wensum flashier than typical chalk stream catchments such the River Test, River Frome and the Hampshire Avon. Three quarters of the flow in the Wensum at Costessey Mill gauging station comes from baseflow on average. Whilst this means the catchment is baseflow dominant, this is substantially lower than typical chalk streams at >90%. Despite this the river

has limited winterbournes due to a number of secondary aquifers along the river which overlay the drift deposits and keep the river flowing during low flow periods.

The drainage of the Wensum catchment has been substantially altered over time by means of channel modification, floodplain drainage and the presence of mills and their associated structures. This has resulted in sections with slower flowing deeper water above the mills and shallow, faster flowing sections below them. In order to provide a higher flow to power the mills, in some reaches the river has been widened and lined with embankments. In turn the river water level in these sections is elevated above the surrounding floodplain, such that it is no longer possible to drain floodplain land directly into the river. A secondary floodplain drainage system was developed either side of the river in the impounded sections, draining back into the river below the mill structures. The mill structures exert a disproportionate impact on the river, with over two-thirds of the Wensum being impounded behind structures. This has a number of impacts, forcing the river to behave like a series of linear lakes rather than a free flowing river, reducing habitat diversity. This can exacerbate water quality issues, particularly in low flow periods, cause erratic flows due to the operation of sluice structures, increase the impact of sedimentation and causes barriers to the free movement of fish between freshwater habitats, which is increasingly being recognised as important for cyprinid fish as well as migratory salmonids (e.g. Winter, Hindes, Lane & Britton, 2021a; 2021b).

1.3.3 Conservation and Ecology

The Wensum is considered one of the best examples in the UK of a naturally enriched calcareous lowland river. The river and a number of adjacent floodplain land parcels are of national and international importance for wildlife, being designated as a Site of Special Scientific Interest (SSSI) and as a Special Area of Conservation (SAC). The River Wensum SSSI and SAC designation covers 44 miles (71 km) of the Upper Wensum, from its source close to South Raynham down to Hellesdon Mill on the outskirts of Norwich, including its tributaries the River Tat and the Langor Drain. The River Wensum is designated as a Natura 2000 'Protected Area' under the European Union Water Framework Directive and as such is given special consideration within river basin planning. As a chalk river, the Wensum is also recognised as a priority habitat within the UK Biodiversity Action Plan (BAP).

The specific Conservation Objectives for the Wensum SAC features are to:

- maintain in favourable condition, the watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitrichio-Batrachion* vegetation; and
- maintain in favourable condition, the habitats for the populations of:
- white-clawed crayfish (*Austropoitamobius pallipes*);
- bullhead (*Cottis gobio*)
- brook lamprey (*Lampetra planeri*)
- Desmpoulin's Whorl Snail (*Vertigo moulinsiana*)

1.4 The Wensum Catchment Partnership and the Catchment Based Approach

Defra's Catchment Based Approach Policy Framework (May 2013), reinforced by the government's 25 Year Environment Plan, requires a strategic catchment wide approach and to work in collaboration with local partners to manage the water environment. The Anglian River Basin Management Plan 'Water for life and livelihoods' (RBMP) produced by the Environment Agency as required under the EU Water Framework Directive (2006/60/EC) provides a framework for protecting and enhancing the benefits provided by the water environment in the East of England. Local place-based initiatives such as the Catchment Based Approach (CaBA) partnerships are central to water management and supporting wildlife. The catchment-based approach helps to bridge the gap between strategic management planning at river basin level as set out in the RBMP and activity at the local water body scale. It aims to encourage groups to work together more effectively to deal with environmental problems locally.

The Wensum Catchment Partnership (WCP) is part of the Broadland Catchment Partnership, supported by CaBA (Catchment Based Approach). The Wensum Catchment Partnership aims to improve the health and restoration of the Wensum catchment by bringing together national and regional organisational strategies with community engagement and citizen science to undertake extensive catchment monitoring of declining river health. In turn this will inform catchment-scale prioritised and targeted restoration strategies.

The WCP is working to inform the river basin management planning process and help implement measures set out in the Wensum Catchment Management Plan by:

- providing local evidence
- targeting and coordinating action
- identifying and accessing funding for improvements in the catchment
- incorporating river basin management planning into the wider environmental management of the catchment.

Figure 2: Wensum Catchment Management Plan (WCP/Norfolk Rivers Trust)

2. Why is additional monitoring of the health of the Wensum catchment needed?

2.1 Factors affecting the health of the Wensum

Over 90% of UK rivers still fail to meet Water Framework Directive targets. Factors affecting the health of the River Wensum catchment are identified in the Anglian RBMP and examined in detail in the Wensum Diffuse Water Pollution Plan. These include water quality pressures (diffuse pollution, eutrophication, excessive sediment) and water resources (abstraction, drainage, increased population and economic growth, climate change), as well as physical modifications caused by past drainage and river engineering works and the effect of impoundments such as mills on the river.

Diffuse pollution impacts the Wensum through changes to the chemical environment within the water, but also by increasing turbidity, deposition of silt and changes to the physical nature of substrates. Eutrophication causes excessive growth of algae and plants and adversely affects the quality of the water and our uses of it, as well as damaging the ecology of rivers, streams, lakes and freshwater wetland areas. Water quantity is important for the dilution of nutrient inputs and for flushing river channels sufficiently strongly to maintain channel habitats in a silt-free condition. Water velocity and flow regime are an important influence on the health of key Wensum species and habitats. The Wensum also acts as an important water source for public water supply and abstraction for agricultural and other uses. However climate change and growing population mean that water resource shortages are likely to become a pressing issue, with the East of England experiencing a shortfall of 1014 million litres of water per day by 2050 unless action is taken to better understand and manage water resources. Reduced river flows caused by abstraction and climate change can result in reduced dilution of pollution, exacerbating eutrophication and increasing siltation. Siltation can smother river bed substrates, affecting the diversity and abundance of invertebrates and plants, affecting fish spawning and recruitment.

2.1.1 Eutrophication and Phosphate

Phosphate is one of the main reasons that freshwater-dependant Natura2000 sites such as the River Wensum fail their conservation objectives. 55% of all assessed river water bodies in England fail the current WFD phosphorus standards for Good Ecological Status (GES). In extreme cases, excessive nutrient loads can cause rapid and significant deterioration of the river environment. In the River Wye, FOUW estimated that in just 5 years algal blooms caused by P-rich soil run off have resulted in the loss of 90% of the once-extensive water crowfoot communities.

Phosphorus (or phosphate, PO4) is an extremely reactive nutrient with complex behaviours in the environment. The main sources of phosphorus affecting the Wensum catchment are sewage effluent (primarily derived from water industry sewage treatment works) and diffuse pollution such as losses from agricultural land. These are described in detail in the Wensum Diffuse Water Pollution Plan (DWPP).

Despite significant progress in reducing river P over the last 30 years, the level of non-compliance with good ecological status for P remains high. Current and planned measures to control eutrophication will not achieve good ecological status in densely populated areas. Further deterioration is possible through factors such as population growth and demand for agricultural intensification. Climate change is also likely to exacerbate eutrophication impacts, with lower summer flows reducing dilution for effluents and higher temperatures promoting plant and algal growth. Wetter winters are predicted to lead to increased run off and erosion which will increase P losses to water from agricultural land.

The Wensum DWPP sets out Total Reactive Phosphorus targets required to ensure the river moves towards achieving Good Ecological Status:

Location	Total Reactive Phosphorus target (mg/l)
From upstream limits to Sculthorpe	0.04
Sculthorpe to Taverham Bridge (mid-catchment)	0.05
Taverham Bridge to the downstream limit of the SSSI	0.05

Table 1: Wensum phosphate targets from the Wensum DWPP

Figure 3 shows how orthophosphate levels vary seasonally in the Wensum. The data shown cover the period 2010-2012. The figure has been split to show the Blackwater Drain at Great Witchingham (WEN210) in the top chart and all the other sites in the bottom as they show a different pattern and scale of variation. In general the lowest orthophosphate levels are recorded in the spring months (March–May) and thereafter they increase during the summer with peaks in mid to late summer (July–August) and autumn (October– November). This pattern is a useful indication of the sources of phosphate in the Wensum catchment, as elevated phosphate levels in summer, when river flows are lowest, typically represent effects of point sources whereas autumn peaks are commonly associated with the flushing of diffuse phosphate sources. **This variability highlights the need to monitor water quality around the catchment at an increased frequency and intensity in order to better understand contributory sources and inform future management.**

To better understand the health of the catchment and have the evidence needed to work successfully in partnership and drive change, often at a local scale, the Wensum Catchment Partnership needs more evidence. However, one of the key limitations of the existing monitoring carried out by the Environment Agency and others is that only a limited number of sites are regularly monitored across the Wensum catchment.

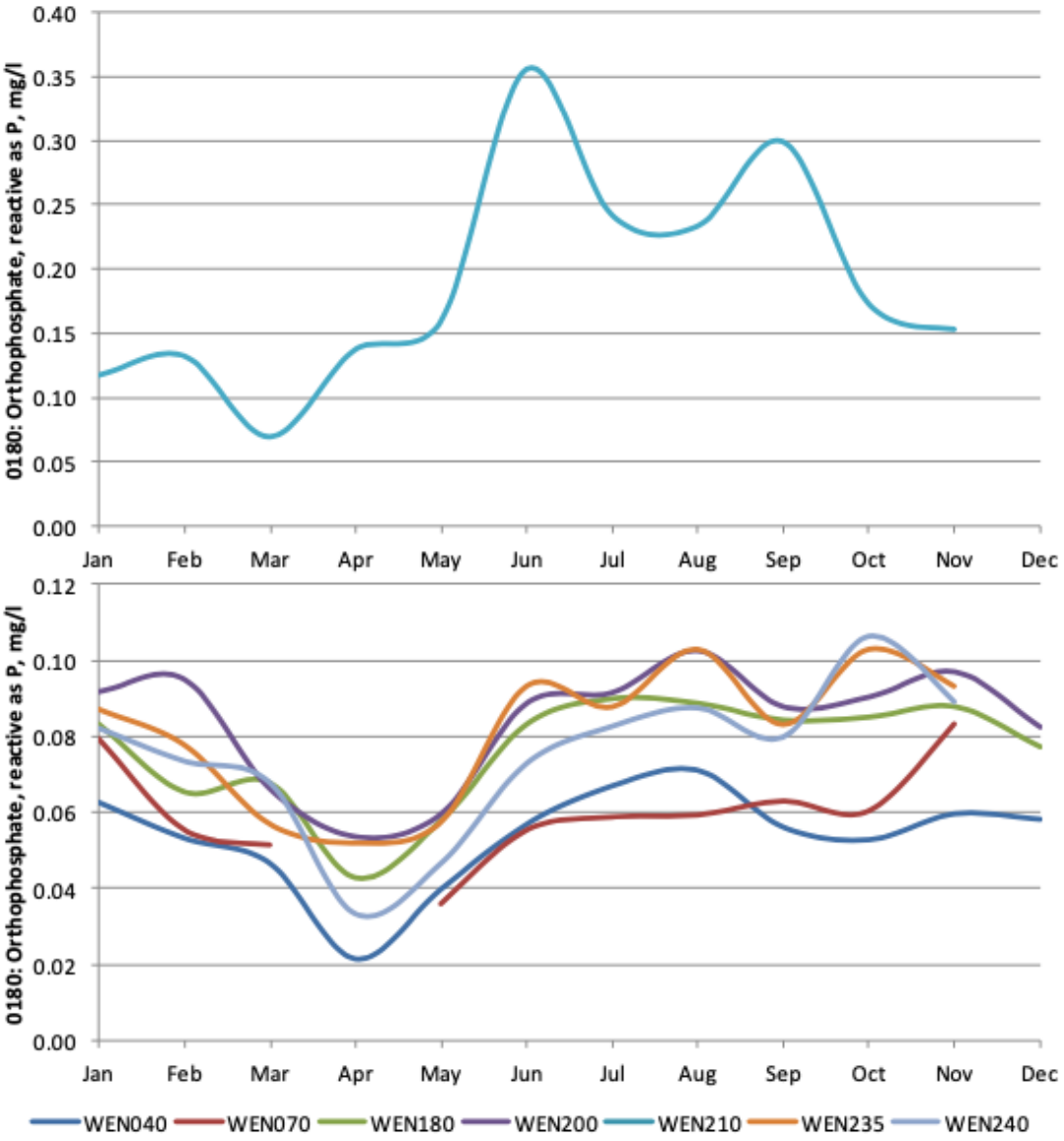


Figure 3: Seasonal variation in orthophosphate levels in the River Wensum. Source: Wensum DWPP

Of the 64 EA water quality sampling sites in the Wensum catchment, only 16 have been sampled within the last 12 months. This presents significant challenges when trying to understand the local influence of pressures such as phosphate levels across such as large catchment area. Of additional note is that Environment Agency sampling programmes may be subject to changes moving forward, through e.g. changing statutory and legislative priorities, resources and budgets.

To overcome resourcing challenges and bridge this evidence gap, the Wensum Catchment Partnership needs to find a way to increase the spatial and temporal scale of Wensum monitoring using citizen science.

2.2 What is Citizen Science?

Citizen science is the involvement of non-professional scientists in scientific research and data gathering. It is increasingly being applied to monitoring of the freshwater environment in the UK. The approach has many benefits, not least it connects people directly with their local environment, raises awareness of the things that can affect it and helps to engage people in working together towards environmental improvement. The spatial and temporal variability of issues across river catchments can be prohibitively difficult to monitor at the level required given cost and resource pressures faced by government agencies and rivers trusts. Moreover, there is increasing concern that the level of funding for environmental monitoring and protection in the UK has been cut to levels that are inadequate, resulting in both environmental harm and increasing public concern. There is an increasing acceptance that citizen science can deliver robust and important additional data and evidence that can be used to inform environmental management decisions, secure funding (e.g. Soar Catchment Partnership) and drive change (e.g. Hegarty *et al*, 2021).

Engaging with citizen science and working with local communities is a key step to scaling up monitoring to help improve our understanding of where and how river health is declining. In the Broadland Catchment Partnership area there are several examples of where this approach has successfully delivered significant environmental outcomes. In 2013 Broads anglers led by the Pike Anglers Club, Norwich and district Pike Club and the Broads Angling Services Group teamed up with the Environment Agency to help monitor salinity levels during tidal surges. The additional monitoring resources generated new data showing the extent of saline incursion on the southern Broads rivers and highlighted areas where fish populations were at risk. This in turn led to a stronger business case for additional fixed telemetry monitoring and a review of future incident response options.

Figure 3a: The Broads Salinity Monitoring project engaged anglers as citizen scientists to improve understanding of salt surges in the Broads

3. Where to sample?

The objective of the Wensum Catchment Partnership and Water for Tomorrow project is to scale up a citizen science project to 80 sites across the Wensum catchment.
To inform this, a desk-based study was undertaken to identify a network of potential monitoring sites across the Wensum catchment. This considered criteria including:

- Where existing monitoring is currently being carried out across the Wensum catchment e.g. Environment Agency, Upper Wensum Cluster Farm Group, Wensum Alliance
- Location of significant point sources e.g. Sewage Treatment Works (STWs)
- Development of a site framework that the Wensum Catchment Partnership can use to establish a citizen science monitoring programme and enable it to scale-up and evolve as needed over time
- Identify opportunities to improve collaborative working e.g. cross-check data quality through identifying existing monitoring sites of strategic importance

3.1 Existing monitoring sites in the Wensum catchment

3.1.1 Environment Agency monitoring sites

The Environment Agency has 64 water quality monitoring in the Wensum catchment, of which 16 have been sampled in the last 12 months (Catchment Data Explorer; EA Analysis & Reporting Team – East Anglia (ENS). These sites are shown in Appendix A (Table A1), with location, site reference number, sampling frequency and whether the site is open (active) or closed (not currently active). There are also fourteen river level, rainfall and flow gauging stations within the catchment. These are listed in Appendix A (Table A2).

3.1.2 Wendling Beck Exemplar Project

This project has installed two autosamplers in the Wendling Beck upstream and downstream of Dereham Sewage Treatment Works. These collect up to 24 x 1 litre samples each at predetermined intervals. At the time of writing this report they are set to sample hourly during rainfall events and every 4 hours to collect daily patterns in water quality. Monthly bed sediment samples are being taken to assess P loads.

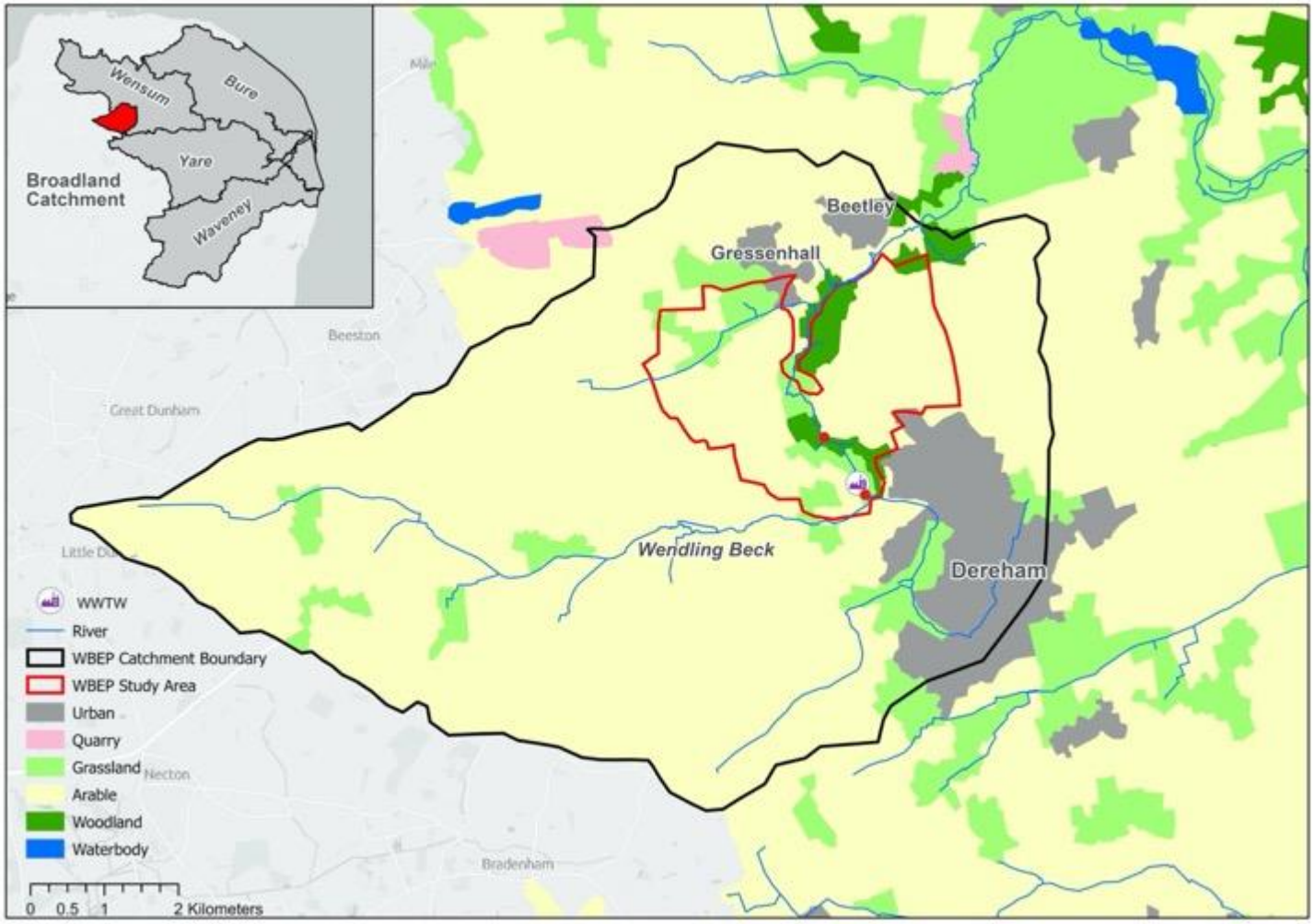


Figure 4: Wendling Beck exemplar project area – autosampler locations shown by the red dots (source: Richard Cooper, UEA)

3.1.3 Upper Wensum Cluster Farm Group (UWCFG)

The Upper Wensum Cluster Farm Group samples 15 sites for PO_4 and NO_3 on a monthly basis and all farms in the group are intensively tested every winter.

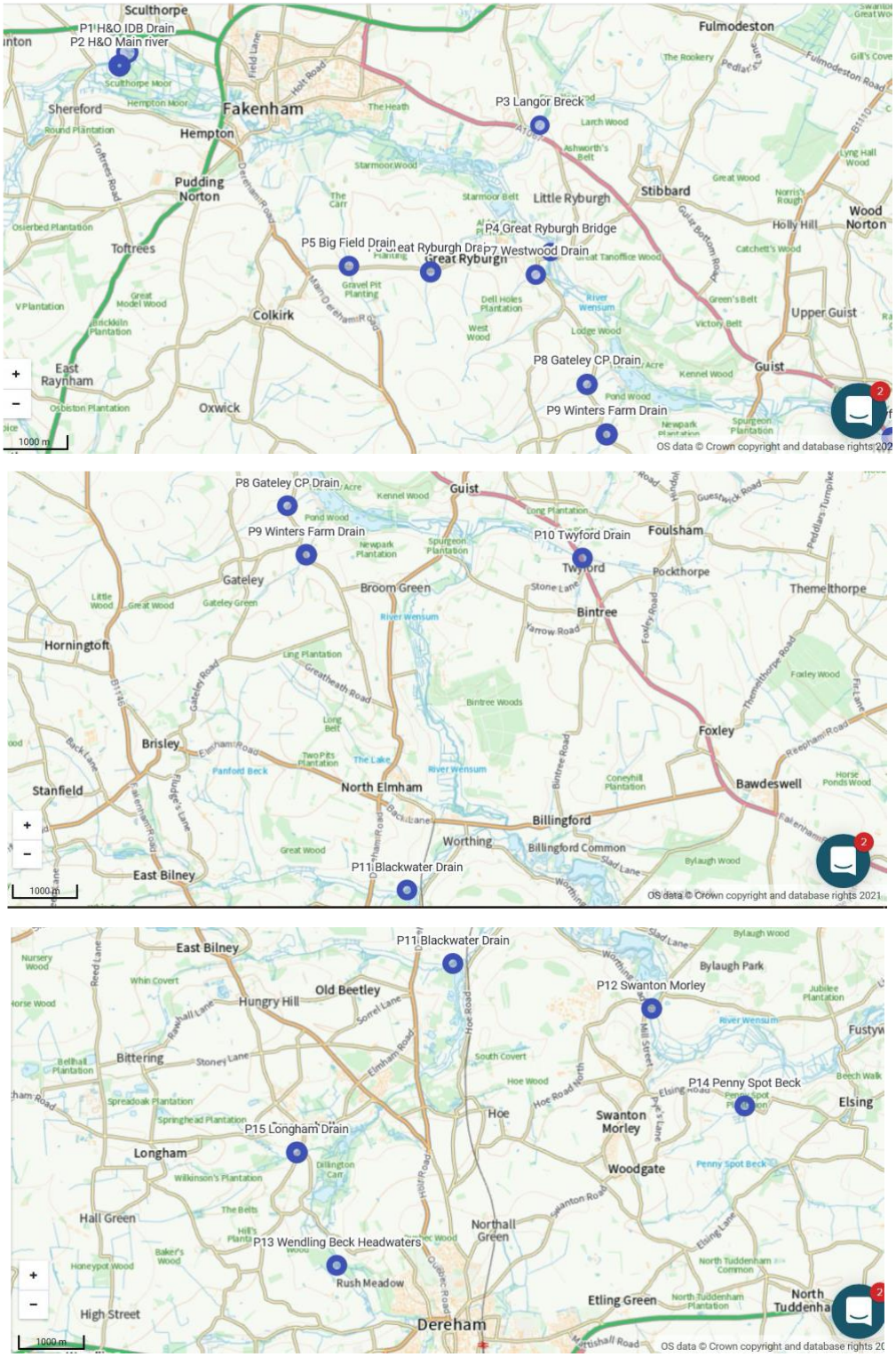


Figure 5: Upper Wensum Cluster Farm Group water quality sampling sites (monthly) – source: Lizzie Emmett UWCFG

3.1.4 Wensum Alliance (Wensum Demonstration Test Catchment)

The Wensum Demonstration Test Catchment project ran from 2010 – 2019 and monitored seven sites in the Blackwater (Reepham Stream) catchment as shown in Figure X below. Monitoring included testing for nitrate and phosphate levels in response to farm-scale measures to reduce diffuse pollution, as well as biological and groundwater sampling.

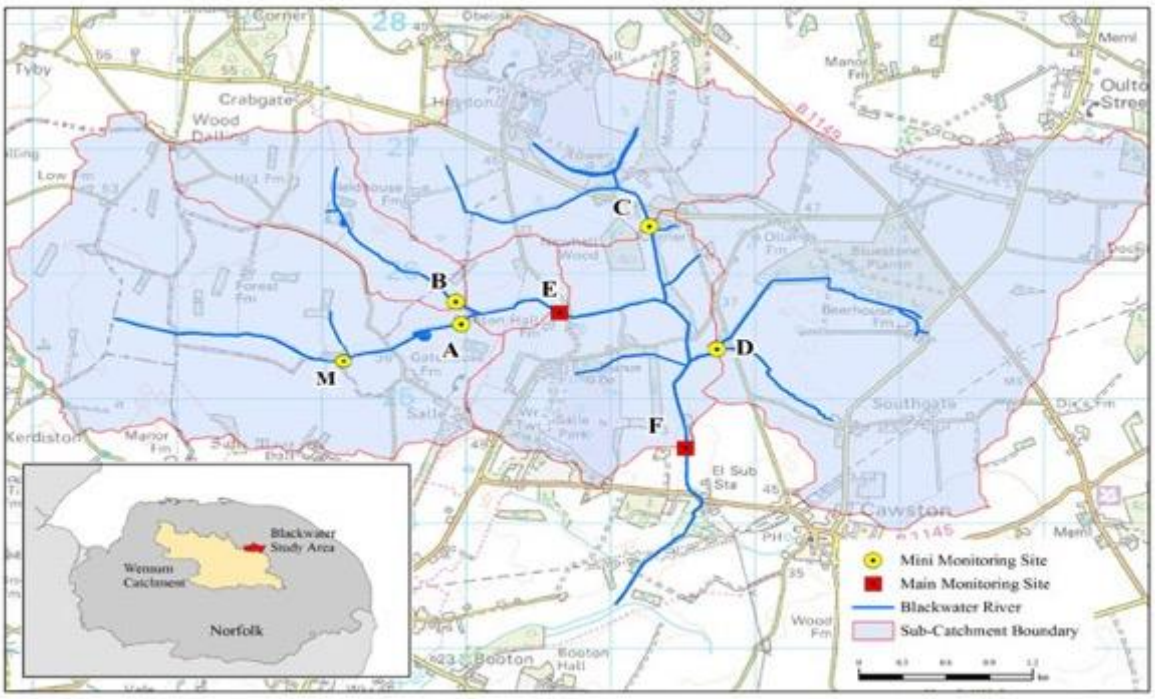


Figure 6: Wensum Demonstration Test Catchment monitoring sites in the Blackwater catchment

3.1.5 Wensum Riverfly Monitoring

The Salmon & Trout Conservation Riverfly Census began in 2015 and monitored five sites for a three year period: Doughton Bridge, Fakenham Common, Pensthorpe Nature Park, Sennowe Bridge and Bintry Mill. Ongoing Riverfly monitoring is being co-ordinated through the WCP Ecology working group, with sites including Bintry Mill, Lenwade, Lyng, Swanton Morley, Raynham Hall, Sculthorpe Moor, Sparham Hall, Tatterford Common and Worthing (Wendling Beck), together with a planned site on the River Tud (Dennis Willis pers. Comm).

3.2 Sampling site selection

It is suggested that citizen science monitoring sites are organised in a framework to enable sampling to be scaled-up around the Wensum catchment in a targeted, resource effective manner. A combination of 84 core 'Sentinel' and discretionary tributary sub-catchment monitoring sites has therefore been identified across the catchment.

3.2.1 Sentinel sites:

A network of core 'Sentinel' sites has been identified on each of the tributary catchments, as close as possible to the confluence with the main River Wensum and at reach boundaries on the River Wensum, River Tud and Wendling Beck. The purpose of these sites is to enable regular, frequent & easily repeatable surveillance monitoring of water quality and river levels within each tributary catchment, which will:

- Provide an improved baseline understanding of river health across the catchment
- Improve detection of any significant issues within each tributary catchment which in turn may be affecting the main River Wensum and provide evidence to inform the WCP
- Enable the WCP to make informed decisions to scale up citizen science monitoring in an effective way where most needed around the catchment as volunteer, budget and equipment resources allow. For example, if monitoring of a tributary Sentinel site detects poor water quality then sampling of additional sub-catchment sites can be instigated to help narrow down the potential location of point and diffuse sources – see Figure 7
- This improved dataset could also be used to justify and/or target additional institutional monitoring resources as required and inform catchment management actions

3.2.2 Sub-catchment sites:

A network of sub-catchment sites has been identified to increase the spatial resolution of sampling on each tributary. Where feasible these include control sites upstream of known point source inputs from Sewage Treatment Works (STWs) and sites downstream of the discharge point to monitor any influence on water quality. **The selection of sites is not intended to constrain future Wensum monitoring, or prevent the consideration of new or alternative sampling sites moving forward, but is intended to provide a baseline to develop a pilot citizen science monitoring programme.** Sub-catchment sites can be prioritised based on sampling results from Sentinel sites and ongoing review of evidence needs, for example through the WCP. Additional sites can then be instigated within each river reach or tributary catchment, so that Citizen Science monitoring effort can be scaled up, or focussed around the catchment as required, for example:

- to enable targeted seasonal 'blitzes' can be undertaken (e.g. to detect any seasonal turbidity problems caused by agricultural or highway run-off during heavy rainfall events)
- to provide additional monitoring evidence for review by the WCP and to support appropriate investigation and measures by statutory agencies as required
- Create a framework of established accessible and sites to enable trained volunteers to undertake 'ad-hoc' sampling e.g. to help report & trace pollution events

The rationale for using this approach to target monitoring resources around the catchment is further illustrated in Figure 7 below.

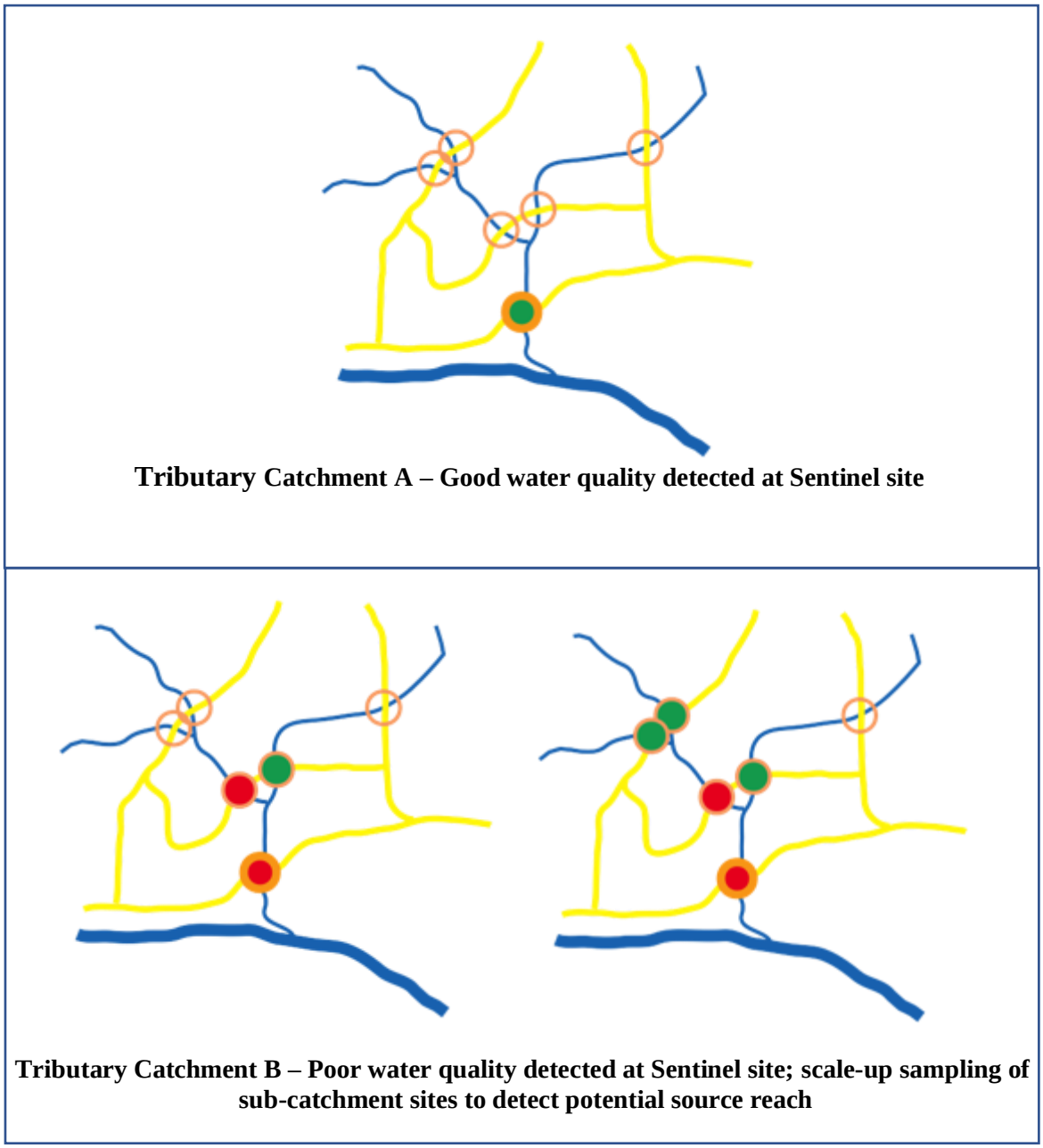
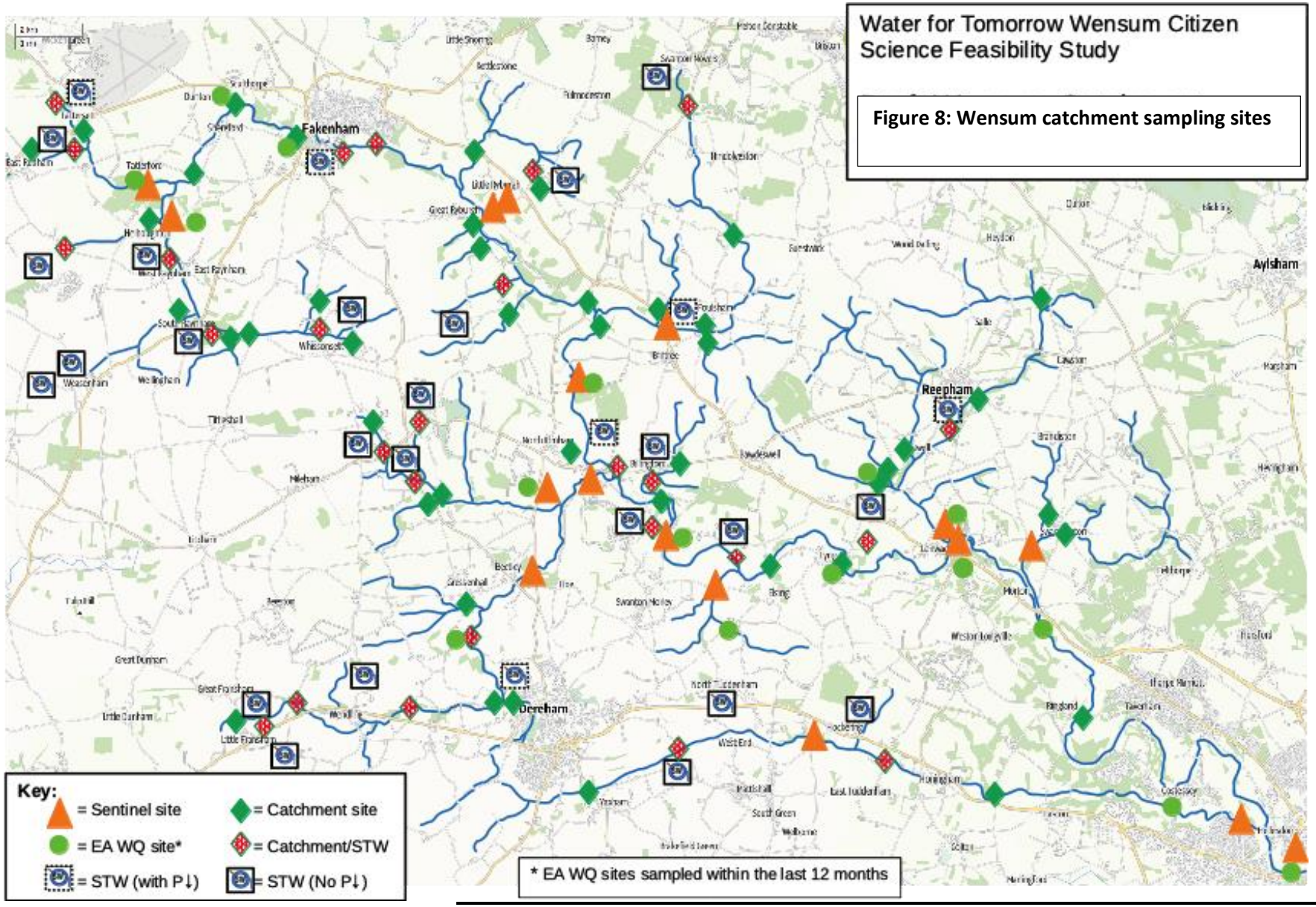


Figure 7: Use of Sentinel sites to monitor headwater catchments and enable sampling effort to be scaled up to monitor sub-catchment sites where poor water quality is detected

A comprehensive network of 84 potential catchment sampling sites has been drafted and mapped as shown in Figure 8. The main rivers Wensum, Tud and Wendling Beck have been split into river reach sections with monitoring sites associated. Site locations and details for each tributary catchment and river reach section are provided in Appendix B.


Water for Tomorrow Wensum Citizen Science Feasibility Study
Figure 8: Wensum catchment sampling sites
Fakenham
Dereham
Reepham
Aylsham
Key:
= Sentinel site
= Catchment site
= EA WQ site*
= Catchment/STW
= STW (with P↓)
= STW (No P↓)
* EA WQ sites sampled within the last 12 months

3.2.3 Practical site selection criteria

This study has adopted the same generic site selection principles as the Environment Agency in targeting road bridges (and footpaths) for taking water samples wherever feasible and safe to do so. This has several distinct advantages where sampling is undertaken by volunteers:

- Significantly reduces the need to obtain and maintain landowner access permissions for a multitude of individual sampling sites
- Easy sampling site identification for volunteers e.g. use of What3Words, Google Street View, use of site and location mapping on data recording apps
- Simplifies access to sampling sites and taking of water samples and river levels using standardised approaches
- Maximises the efficiency and value of volunteer sessions (and also the sampling equipment resource) through the principle of minimising transit or 'down' time between sampling sites, thereby maximising the number of sites achievable within a reasonable volunteer session (2-3 hours)
- Reduce variables or 'unknowns' – unpredictable or inconsistent factors that could reduce sampling time and efficiency e.g. uncertainty over farm access routes, locked gates, muddy conditions, uncertainty over access permissions
- Improves volunteer safety, co-ordination and management in the field e.g.
    - Minimises unknown health & safety risks (e.g. presence of farm animals, off-road driving & variable (e.g. wet and muddy) ground conditions, farm operations, shooting activities, confrontation and challenges by third parties)
    - Ensures volunteers can be easily located in the event of an incident
    - Presents a common suite of generic risk assessment criteria for sampling sites and common associated requirements e.g. high viz PPE for road safety
    - Reduces the risk of conflict and confrontation for volunteers, associated reputational challenges for WCP and risks to ongoing sampling site access e.g. should water quality testing suggest pollution inputs occurring from the landowner's property

Figure 9: Gt. Ryburgh bridge site enables sampling of both the main River Wensum and the Langor Drain Sentinel site

3.3 Improving co-operation and collaboration

It is recommended that the Wensum Catchment Partnership also establishes a framework for co-ordinating and sharing data from all relevant monitoring activities taking place within the Wensum catchment. This would help to ensure that citizen science monitoring is agile and adaptable moving forward and can be utilised to best effect.

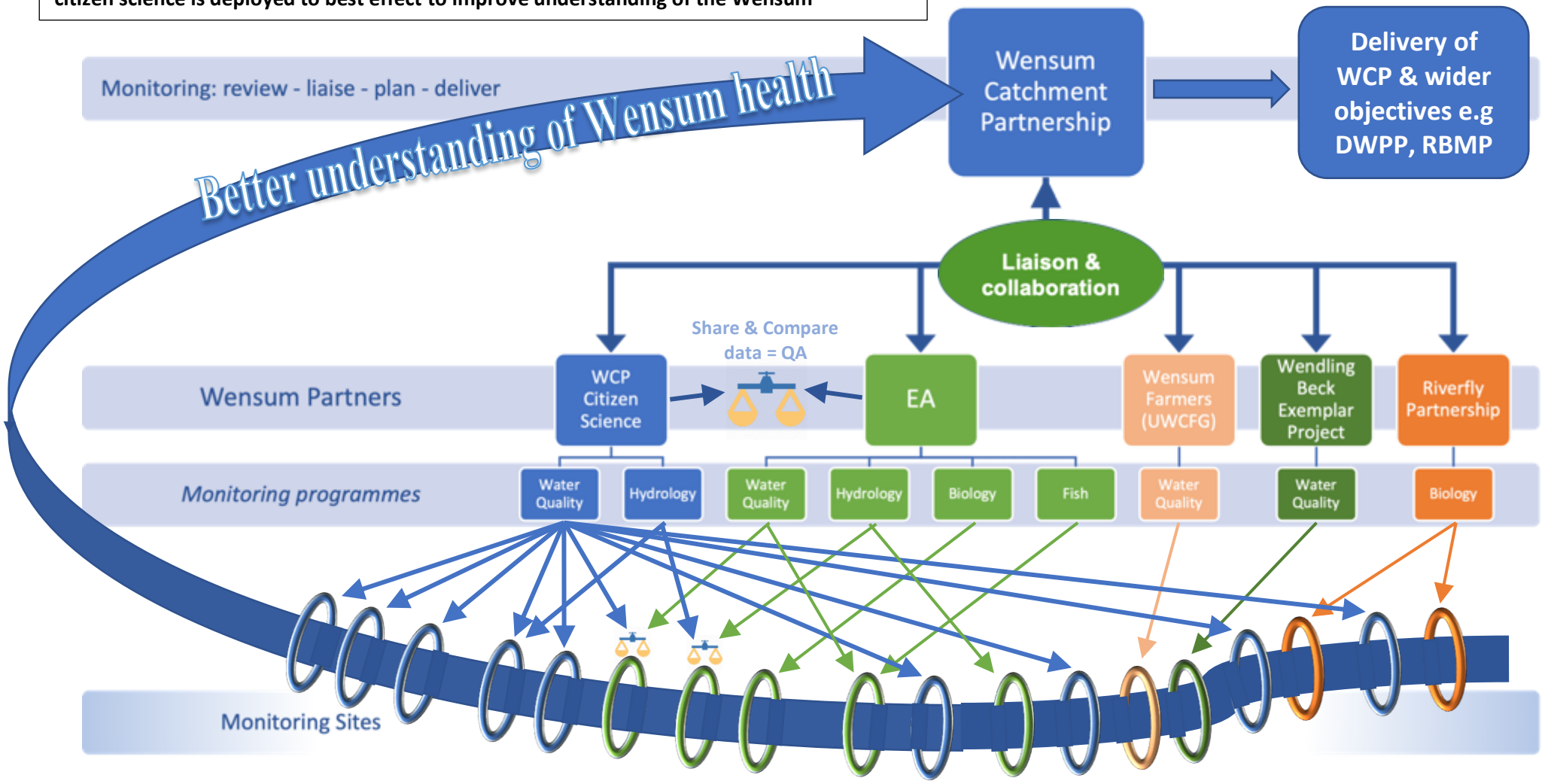
Where proposed sites also align with sampling undertaken by others, such as existing Environment Agency water quality and UWCFG monitoring locations, this has been highlighted to enable the WCP to foster co-ordination and collaboration, for example to:

Increase monitoring frequency – Citizen science resources could enable important monitoring sites to be sampled more frequently than existing institutional priorities and resources allow. For example, through liaison with Environment Agency colleagues in the Analysis and Reporting team and National Sampling and Collection team, the timing of EA monitoring of key sites can be established in advance (most sites are sampled monthly, some weekly). The timing of citizen science sampling events can then be scheduled and organised to best effect.

Avoid duplication of effort – Improving active monitoring liaison with partners through the WCP can avoid duplication of sampling effort and ensure citizen science resources are best utilised. For example, the water quality sampling being undertaken for the Wendling Beck Exemplar Project includes sites upstream and downstream of Dereham STW to monitor P loads. Citizen science resources may therefore be better utilised in assessing both nutrient levels in the catchment further upstream if these are found to be high above Dereham STW and monitoring the influence of the Wendling Beck catchment on the main River Wensum (see field trials below).

Deliver quality assurance checking of data – Whilst avoiding duplication of sampling effort is generally desirable, there are important opportunities for quality assurance of data where citizen science water quality samples can be taken contemporaneously with Environment Agency water quality samples at regular intervals. By developing liaison between the Wensum citizen science programme and the EA's Sampling & Collection and Analysis & Reporting teams, citizen science samples can be undertaken at the same time as the EA samples and the results compared. This would help build confidence in the citizen science dataset amongst partners and ensure it can be incorporated into the relevant institutional processes and used to inform decision making (e.g. Wensum condition assessment, E. Lucas, Natural England, pers. Comm) and drive discussion around solutions rather than 'fair share' apportionment (Wensum Catchment Management Plan). The principle for this quality assurance approach was explored as part of field trials of water quality monitoring equipment – see below.

Figure 10: Improved collaboration across Wensum stakeholders and partners can ensure citizen science is deployed to best effect to improve understanding of the Wensum



4 What and how to sample – Parameters, methods & equipment

4.1 Water quality parameters:

The following water quality parameters are within scope of citizen science monitoring and could therefore be incorporated into a sampling programme for the Wensum catchment:

Water quality parameters	Unit	Wensum targets	**Why monitor?**
Phosphate (PO_4^{-P})	mg/l	Headwaters to Sculthorpe = **0.04mg/l;** Sculthorpe to Hellesdon = **0.05mg/l**	High concentrations can damage aquatic ecosystems speeding up eutrophication and algae blooms; Strict target limits for the Wensum
Ammoniacal nitrogen (NH_3^{-N})	mg/l		Ammonia is toxic to aquatic life and high levels can promote excess algae growth
Dissolved oxygen	mg/l & % saturation	**85% saturation (≅ 7.73mg/l @ 20°C)**	Essential for aquatic life; low levels can cause mortality and stress in fish; excessive levels can indicate problems with algae blooms
Nitrate NO_3	mg/l	**Drinking water standard = 11.3mg/l**	High levels can cause eutrophication and risks to human health in drinking water
Nitrite (NO_{2-})	mg/l		High levels can cause eutrophication and risks to human health in drinking water
Water temperature	°C		Warm water holds less dissolved oxygen than cold water; Controls the rate of many chemical, physical & biological processes; high temperature increases the toxicity of ammonia
Turbidity	NTU		Indicator of the amount of suspended sediments in water; can indicate run-off from agriculture or highways & carry other pollutants
pH			Affects the toxicity of other substances e.g. ammonia in water
Total dissolved solids	ppm		Measure of the combined inorganic and organic substances dissolved in water
Conductivity	µS/cm		Useful general measure of water quality; sudden increase can indicate pollution

Table 2: Key Wensum water quality parameters within scope of citizen science monitoring

4.2 Water quality sampling equipment

The desk-based review of citizen science case studies, resources and literature highlighted the need to identify a basic suite of low-cost equipment with high levels of accuracy and resolution for the key Wensum water quality parameters. This is particularly important when considering the assessment of nutrient pollution in the Wensum, where P target limits range between just 0.04 – 0.05mg/l. Citizen science monitoring must therefore be able to sample at a high resolution to produce high quality, robust data that can be used alongside existing institutional datasets. It is also important to make the most from the time kindly contributed by the volunteers themselves. Examples of water quality monitoring equipment used in citizen science projects can be found on the CaBA website, as well as numerous citizen science case studies (see Appendix C for examples). Key criteria for selecting equipment and methods for the Wensum included consideration of:

- accuracy, resolution, robustness and consistency of selected methods
- ease of use of sampling equipment and techniques – suitability for non-professional citizen scientists
- reducing possible subjectivity and user bias
- cost of equipment, reagents and consumables per test
- options for citizen science data recording and collation
- quality assurance of data

4.2.1 Assessing nutrient pollution – colour comparison kits or digital phtotometers?

Citizen science projects typically use either of two broad types of testing approach when sampling for nutrient pollution (Phosphate, ammonia, nitrate) – low cost chemical colour comparison tests or simple hand held digital photometers.

Low cost chemical test kits or test strips are based on potentially subjective colour chart comparison, giving often only an indicative and often coarse range of values. For example, a number of projects such as Bristol Avon RiverBlitz and The Brecks Fen Edge & Rivers Landscape Partnership Testing the Waters use Kyoritsu chemical tests for phosphate and nitrate sampling. These kits consist of transparent plastic tubes, in which citizen scientists mix unfiltered water samples from sampling cups with pre-measured reagents that produce increasing colour values with increasing nutrient concentration. The Phosphate (PO_4-P) test kit provides nutrient level categories ranging from <0.02 up to >1.0 mg/l. The Nitrate (NO_3) kit ranges from <0.2 up to >10 mg/l. The colour change in the sample is compared visually to a six-point colour chart in both kits and the range value between the closest two colour matches is recorded as the test result. For example, the sample being visually compared to the colour chart in Figure 11 below would be recorded as being somewhere between 5-10mg/l Nitrate.

Low cost digital handheld photometers are being used by citizen science projects such as the Friends of the River Wye. Typical units such as those produced by Hanna and Milwaukee

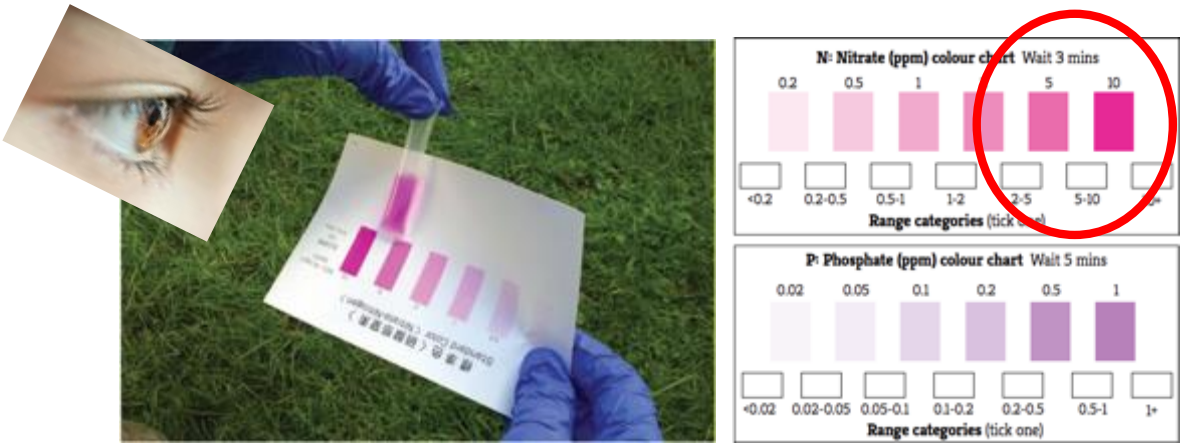


Figure 11: Chemical test kits rely on the user to visually judge the colour of the reacted sample against a range of values – in this example the nitrate sample is between 5- 10mg/l

are capable of digital display of sampling parameters to a high resolution, often +/-0.01 mg/l and the method eliminates any subjectivity and user bias associated with colour comparison techniques. In turn this delivers far more accurate, consistent and comparable data compared with typical chemical test kits. Whilst the initial budget required for digital photometer-based equipment is higher, set against the obvious benefits of accuracy, consistency and compatibility with existing Wensum monitoring, it is considered that this initial investment is worthwhile. Digital photometers were therefore selected for further evaluation over chemical test kits.

Figure 12: Low-cost digital photometers such as the Hanna Phosphate checker HI-713 and the Milwaukee MW12 can give a digital readout of sample test results to +/-0.01 mg/l resolution

4.2.2 Selected water quality equipment options

The following sampling equipment examples were subsequently identified as suitable for use by citizen scientists and capable of delivering the required standards (see Table X below). The suggested equipment for each parameter is detailed further in Appendix D. This does not constrain future Wensum monitoring from considering or using new or alternative sampling options moving forward, but is intended to provide a baseline to develop a pilot citizen

science monitoring programme. The selected equipment was consequently subjected to practical trials in the field to further inform the feasibility assessment.

Figure 13: AZ instruments 8403 digital dissolved oxygen meter

Parameter:	Suggested equipment:	Cost:
Orthophosphate (PO4 - 3) & Orthophosphate as P (PO4-P)	Hanna Low Range Phosphate Checker HI-713 OR Milwaukee MW12 Digital Phosphate Tester	£70 £55
Ammonia-N (NH3-N)	Hanna Low Range Ammonia Checker HI-700 OR Hanna Medium Range Ammonia Checker HI-715	£70 £81
Nitrate (NO3) NB: No low cost 'Checker' for freshwater testing	Hanna HI-97728 Nitrate Portable Photometer OR Horiba LAQUATwin Nitrate Ion meter NO3-11 OR Nitrate test strips/chemical kits e.g. Simplex	£330 – £495 £375 £17.99/50 tests
Dissolved Oxygen (mg/l and % saturation) + water temperature (°C)	AZ Instruments 8403 Dissolved Oxygen Meter OR Similar budget DO meter	£145 £80-100
Turbidity/Suspended Solids	Graduated Turbidity Secchi tube e.g. Camlab or WCRT model	<£50
pH	pH Pen Tester	£5 - £10
TDS & conductivity	TDS & EC Pen Tester	£5 - £10
	Basic Tier 1 set total:	**£280 - 770**

Table 3: Summary of basic water quality equipment examples within scope of a Wensum citizen science monitoring programme (NB: Prices quoted February 2022)

Of note is that at the time of the study no low cost digital photometer or 'checker' was available to test freshwater nitrate samples. An iDip 570 multi-parameter photometer was purchased in order to evaluate potential for citizen science use, however it produced variable results in initial trials and was consequently discounted (see below). In the interim it is recommend that test strips are used, such as the Hach Nitrate & Nitrite test strips.

4.3 Rainfall, river level and river flow monitoring options:

Citizen science river flow and water level case studies appear to be more limited than for water quality. This is likely due to the relative technical difficulty using many stream flow gauging methods (e.g. Dobriyal et al, 2016). However, there are a range of monitoring techniques within scope of citizen science that could be applied in order to gain additional data on rainfall, river levels and flow around the Wensum catchment. These are detailed in Table 4 below and described in Appendix E. Amongst these are examples of emerging smartphone app-based systems that in principle appear well-suited to for use by citizen scientists, subject to validation trials of the system in representative watercourses.

Parameter	Method	Target participation	Cost	Health & safety	Estimated time to complete
Rainfall totals	Rainfall gauge	Trained volunteers	Low (£5-£15)	Low risk	Quick 1-2 minutes
River levels	Fixed point photographs	Trained volunteers & members of the public	Low – Interpretative signs	Low risk	Quick 1 minute
	Fixed gauge board photos	Trained volunteers & members of the public	Low – med (£30-£50 per board + installation)	Low risk	Quick 1-2 minutes
	Virtual staff gauge	Trained volunteers	Low	Low risk	Quick 2 minutes
River levels, flow conditions + wildlife	Time-lapse trail cameras + 4G/LTE	Trained volunteers (monitor data/maintain)	Med £150+ per site	Low risk	Quick (Passive)
Stream flow measurement	Float method	Trained volunteers	Low	Med risk	Slow @1 hour
	Flow meter	Trained volunteers	Moderate (Equipment & PPE)	Med risk	Slow @1-2 hours
	Discharge App (subject to validation trials)	Trained volunteers	Moderate (set up) Low (sampling)	Low	Quick 1-2 minutes

Table 4: Rainfall, river level and flow monitoring options within scope of a Wensum citizen science monitoring project

4.4 Data recording, management and hosting:

Monitoring techniques, data entry and submission methods for use in citizen science programmes need to ensure consistency, standardisation and data quality. This is particularly important when a variety of people (volunteers with differing knowledge, skills and motivations) are involved, when using simple monitoring methods and data formats. Some of the sampling methods proposed here, such as the submission of fixed-point photographs, are straightforward and members of the public already do this, whether or not it is for science. However, there is often a barrier when it comes to physically entering and submitting data to a central system; the observer is not necessarily regarded as a citizen scientist until they share their data with others. Community groups may not be clear about what they can do with their observations once they have them, especially if they do not have the correct skills or infrastructure in place (Starkey, 2018). Data quality problems can be created through incomplete datasets, subjectivity, observer bias and poor discipline when sampling. Bonney *et al.* (2009) claim that carefully designed data forms, clear data collection protocols and participant support are the three most important design aspects that can improve data quality.

A Wensum citizen science project therefore needs to consider how citizen science monitoring data could be recorded in the field, shared/uploaded, checked and managed. Methods can range from traditional paper recording forms, through to use of social media platforms such as Twitter, through to dedicated smartphone apps custom designed for the project. A range of methods is often desirable to make citizen science accessible to different volunteers. However, the selected methods of data entry, sharing and/or upload must be designed to ensure quality, consistency and reliability of the data that is produced.

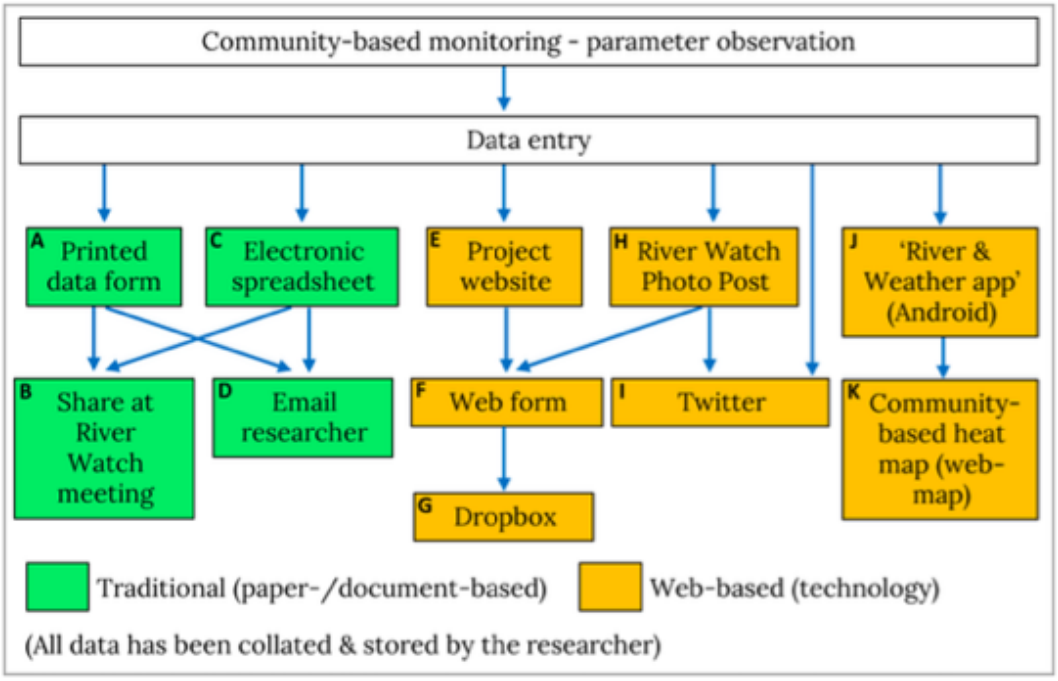
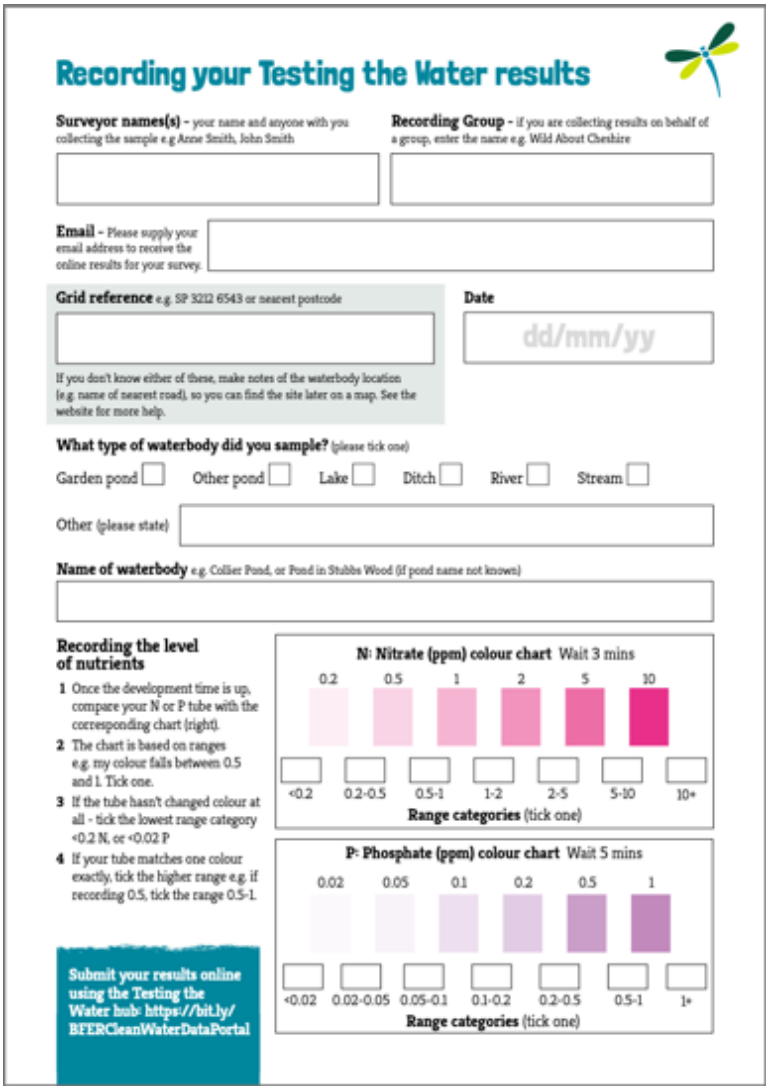


Figure 14: Community-based data entry and submission techniques initially proposed for the Haltwater Burn project. A-D represent 'traditional' techniques, while E-K are 'web-based' tools (From: Starkey, 2018)

4.4.1 Paper-based recording:

Examples of paper-based recording forms for citizen science include Friends of the Upper Wye, BFER Landscape Partnership Scheme Testing the Waters Project. This method may suit certain volunteers, including those with no access to, or limited affinity with, computers and smartphones. Some of the drawbacks with paper-based recording forms include:

- difficulty recording in wet weather conditions
- reliance on the volunteers to accurately, legibly and consistently enter data and key details such as site location, date and time of sampling
- paper-based forms mean 'double-handling' of the data, necessitating the volunteer to spend more time once back at home physically entering the data into a computer, or having to give written records for someone else to complete this task at a later date
- unavoidable time lag between the time of the sampling event and the resulting data being made widely available for review, feedback and wider dissemination



Recording your Testing the Water results

Surveyor names(s) - your name and anyone with you collecting the sample e.g Anne Smith, John Smith

Recording Group - if you are collecting results on behalf of a group, enter the name e.g. Wild About Cheshire

Email - Please supply your email address to receive the online results for your survey.

Grid reference e.g. SP 3212 6543 or nearest postcode

If you don't know either of these, make notes of the waterbody location (e.g. name of nearest road), so you can find the site later on a map. See the website for more help.

Date dd/mm/yy

What type of waterbody did you sample? (please tick one)

Garden pond ☐ Other pond ☐ Lake ☐ Ditch ☐ River ☐ Stream ☐

Other (please state)

Name of waterbody e.g. Collier Pond, or Pond in Stubbs Wood (if pond name not known)

Recording the level of nutrients

1 Once the development time is up, compare your N or P tube with the corresponding chart (right).
2 The chart is based on ranges e.g. my colour falls between 0.5 and 1. Tick one.
3 If the tube hasn't changed colour at all - tick the lowest range category <0.2 N, or <0.02 P
4 If your tube matches one colour exactly, tick the higher range e.g. if recording 0.5, tick the range 0.5-1.

N: Nitrate (ppm) colour chart Wait 3 mins

0.2 0.5 1 2 5 10

☐ <0.2 ☐ 0.2-0.5 ☐ 0.5-1 ☐ 1-2 ☐ 2-5 ☐ 5-10 ☐ 10+

Range categories (tick one)

P: Phosphate (ppm) colour chart Wait 5 mins

0.02 0.05 0.1 0.2 0.5 1

☐ <0.02 ☐ 0.02-0.05 ☐ 0.05-0.1 ☐ 0.1-0.2 ☐ 0.2-0.5 ☐ 0.5-1 ☐ 1+

Range categories (tick one)

Submit your results online using the Testing the Water hub: https://bit.ly/BFERCleanWaterDataPortal

Figure 15: Example of a paper-based recording form (source: BFER Testing the Waters Project)

4.4.2 Electronic data entry forms:

Citizen science projects often feature web-based data entry portals via project websites as a means for volunteers to submit data and observations e.g. BFER LPS Testing the Water Data Portal or the Haltwhistle Burn Project 'Community Hub'. Use of a website-based system may encourage interested passers-by to view other information whilst on the project website and consequently encourage wider engagement with the Wensum citizen science project

4.4.3 Interpretative signs for data submissions by text message or QR-codes:

The use of simple text messages and QR codes is particularly suited to crowd-sourcing data such as river level recrding and observations from members of the public as well as project volunteers e.g. CrowdHydrology.

4.4.4 Social media platforms

Projects such as Haltwhistle Burn project invite public data submission using social media such as Twitter and a QR-coded web form embedded within the project's website. Social media can also connect interested members of the public with others with a shared interest in the citizen science community.

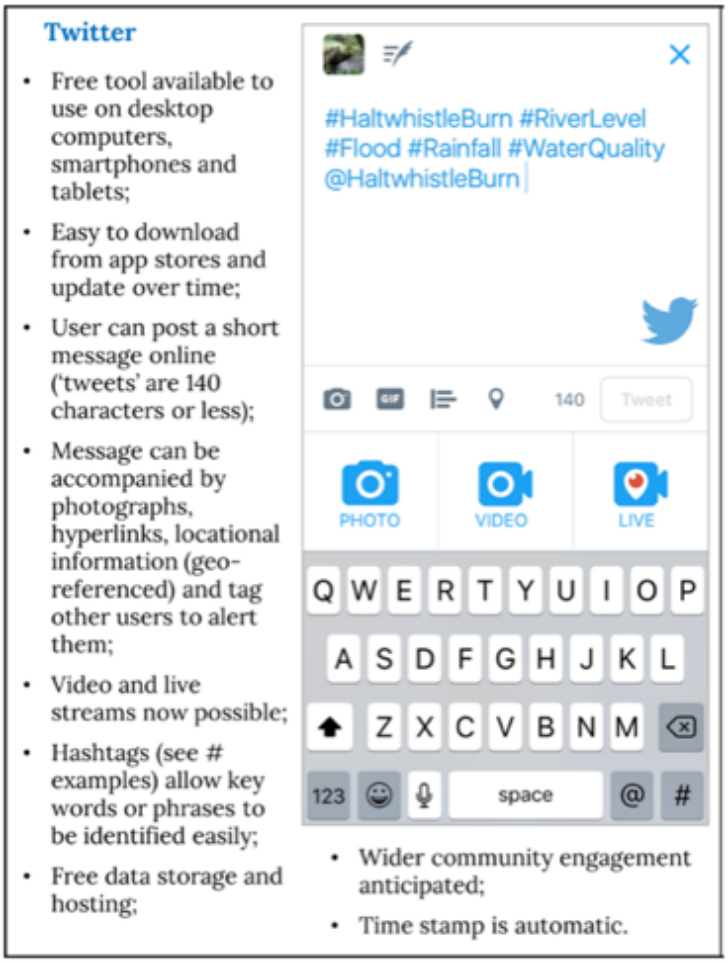


Figure 16: The Haltwhistle Burn citizen science project enables members of the public to contribute river level and flooding observations via social media (source: Starkey, 2020)

4.4.5 Smartphone Apps:

There are a suite of mobile phone apps and data hosting options available that are suitable for use with citizen science applications (e.g. CaBA mobile app review), including apps such as epicollect5 and ArcGIS Survey123. This study developed a custom Wensum citizen science data recording app using a free-to-use app and hosting platform called mWater, which enables custom data entry forms to be created for multiple water quality, level, flow and other parameters, with photo upload and GPS capability. The app provides instant field data upload and access by registered users, which could enable real time data assessment and quality assurance checks. Data can be output as either .CSV or Excel files which can be shared with partners, e.g. Environment Agency (Stansfield, J. pers. Comm.). The mWater platform contains a range of tools for data management and visualisation.

A custom trial data entry user interface was constructed and trialled using the mWater Platform and mWater Surveyor app – see Figure X below and Appendix F. The trial construct was then field tested as part of the assessment of proposed equipment and methodologies.

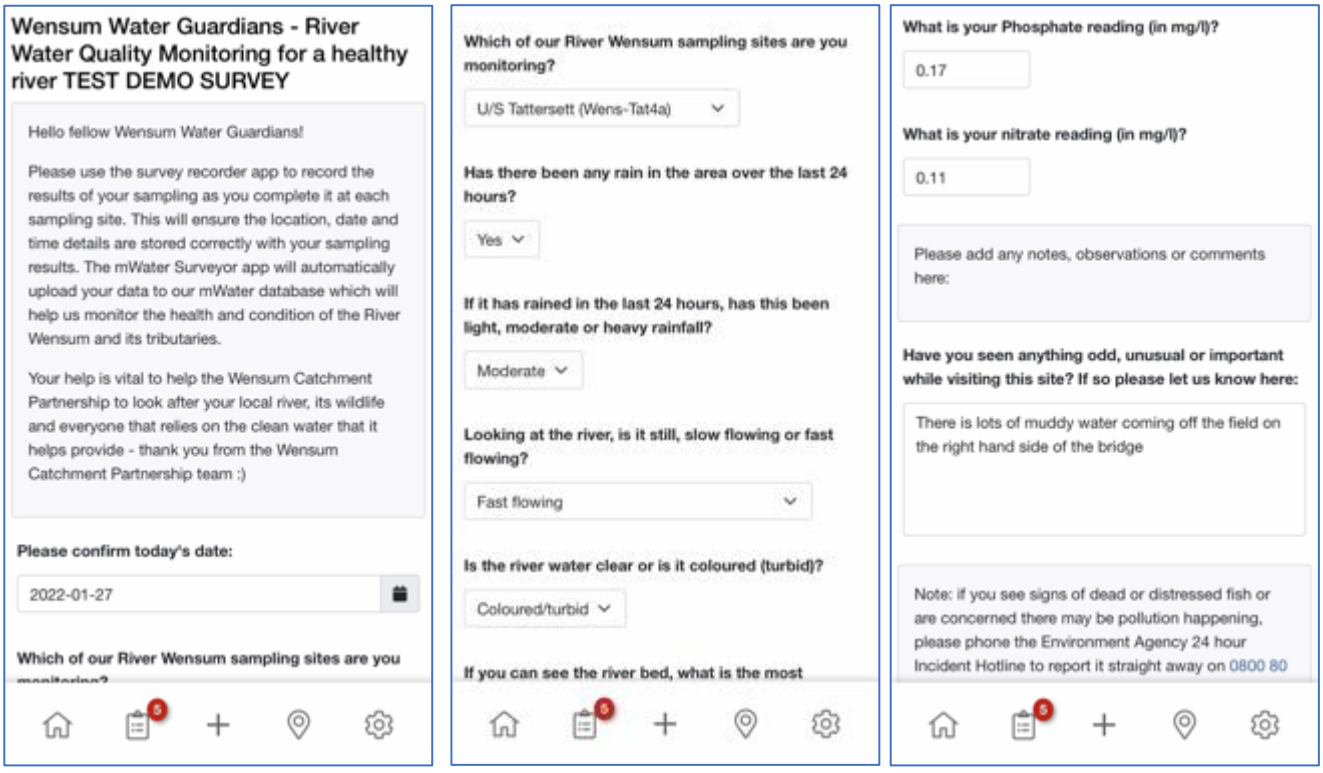


Figure 17: Extracts from a custom trial build of trial data entry user interface for Wensum citizen science monitoring using the mWater platform and mWater Surveyor app

Consideration should also be given to how datasets are held and made more accessible. Tools such as a WCP web-based data dashboard or catchment scorecards (e.g. Westcountry CSI) can be developed which would allow an overview of the current understanding of Wensum health and allow volunteers to see how their data is contributing to this.

5. Practical field trials of basic water quality testing equipment:

In order to ground-truth the selected equipment options identified at the review stage, a set of equipment was purchased in order to conduct practical trials 'on the bench' and in the field. The objective was to assess factors such as ease of use, time taken, accuracy and suitability for purpose. A field-based assessment of app-based data entry and management was undertaken alongside the evaluation of proposed water quality sampling methods discussed above.

5.1 Bench assessment of phosphate testing equipment:

An opportunity arose to undertake a quick practical comparison at Norfolk Rivers Trust office between the Hanna HI-713 and Milwaukee MW-12 phosphate photometers, iDip 570 multi-parameter photometer and a Lovibond MD610. Tests were conducted on a sample of water from the nearby River Glaven. The results are shown in Table 5 below.

	Phosphate Test 1	PhosphateTest 2
Hanna HI-713	0.38 mg/l	0.38 mg/l
Milwaukee MW12	0.39 mg/l	0.40 mg/l
Lovibond MD 610	0.61 mg/l	0.42 mg/l
iDip 570* ***Low-cost multi-parameter photometer purchased to evaluate possible use for Nitrate, phosphate and ammonia**	'Lo' – under range (PO4 test resolution 0.02 – 2.5mg/l) 	'Lo' – under range iDip 570 subsequently discounted due to variable results for P and Nitrate from this water sample: N Test 1: 5 mg/l N Test 2: 9 mg/l N Test 3: 7mg/l

Table 5: Results of bench testing a river water sample using selected photometers

Figure 18: Comparing low-cost digital photometers against the Lovibond MD610

5.2. Field testing of water quality equipment, methods and mWater app:

In order to further inform the feasibility assessment, practical trials of the selected water quality equipment, methods, sites and the mWater app were undertaken during February and March 2022. A series of sites was sampled on the River Tat, Wendling Beck and Langor Drain and data was uploaded via the trial mWater smartphone app. The following example illustrates some results obtained from the Wendling Beck and main River Wensum, including comparison of a series of phosphate testing results against EA water samples. Full details and results from all sites sampled during field tests are provided in Appendix G.

5.2.1 Wendling Beck sampling sites:

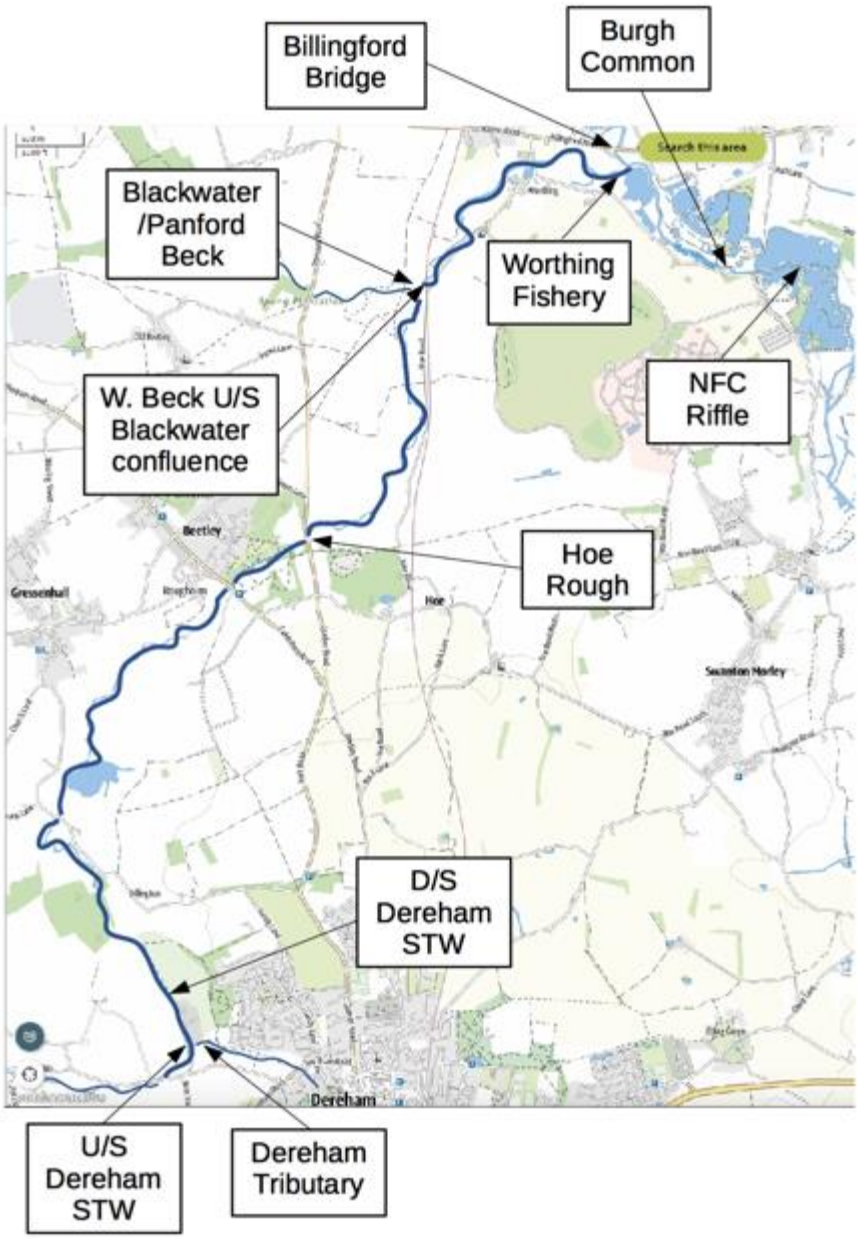


Figure 19: Sites sampled on the Wendling Beck and main River Wensum during field trials February – March 2022

5.2.2 Sampling equipment used:

Phosphate: HI-713 – Hanna Low Range Handheld Phosphate Colorimeter – Checker
Ammonia: HI-715 – Hanna Medium Range Handheld Ammonia Colorimeter – Checker
Nitrate/Nitrite: SimplexHealth Nitrate 0-50ppm & Nitrite 0-10ppm Test Strips (50)
Temperature & Dissolved oxygen: AZ Instruments 8403 Dissolved Oxygen Meter
TDS, EC & pH: Pancellant Water Quality Test Meters pH EC TDS Temperature Set
+ Sampling buckets, sterile gloves, 10ml syringe, stopwatch, hi-viz jacket, glass cleaning cloth, container for disposal of samples.

5.2.3 Sampling methodology:

Samples were taken using a 1 litre bucket and cord from representative free-flowing water on the upstream side of bridges wherever feasible. Areas of stagnant or low flow were avoided. A triple rinse of the sampling container was undertaken before the sample was collected. Care was taken to avoid disturbing either riverbed or bankside sediments and thus risk contaminating the sample. Sites were generally sampled in a downstream direction for biosecurity risk reduction. Where tributaries were subsequently sampled, a different sampling bucket was utilised.

Testing was undertaken at a safe location away from the road. Sample syringes, cuvettes and equipment were rinsed at least twice before carrying out tests. Tests were then undertaken using the above equipment to the manufacturer's guidelines. Used reacted samples were collected for safe disposal and unused river water was disposed to ground well away from the channel. Data was written into notebook form during the testing, then entered onto the mWater Surveyor app and uploaded on completion. A site photo was also taken and uploaded.

Water quality sampling and testing took 25-30 minutes per site including sample collection, analysis, site photo and data entry & upload on mWater app.

Figure 20: (L-R) – Taking a water sample from the Wendling Beck at Worthing Fishery; Colin Howlett undertaking ammonia testing using the Hanna HI-715; uploading site data onto the mWater app

5.2.4 Example results – Wendling Beck & River Wensum sites sampled on 16 February 2022:

Location	P (as $PO4^{-3}$)	P (as $PO4^{-P}$)	$NH3^{-N}$	NO3-N	NO2-N	°C	DO %	TDS	EC	pH
W. Beck U/S Dereham STW	0.21	0.0685	0.00	5	0	10.1	93.5	278	552	7.95
Dereham Trib.	0.09	0.0293	0	2	0		85.1	288	584	7.74
D/S Dereham STW	0.91	0.2968	0.00	5	0	10.3	89.0	270	556	7.89
Hoe Rough	0.28	0.0913	0.01	5	0	10.9	88.4	273	536	7.87
W. Beck U/S Blackwater conf.	0.30	0.0978	0.05	5	0	10.8	87.5	274	544	7.98
Blackwater U/S W. Beck conf.	0.23	0.0750	0.00	2	0	11.9	88.0	272	548	7.95
Worthing Fishery	0.35	0.1141	0.00	-	-	8.6	87.3	248	496	7.83
Billingford Bridge (Wensum U/S conf.)	0.13	0.0424	0.03	2	0	9.9	87.8	252	516	7.86
Burgh Common (Wensum D/S conf.)	0.22	0.0717	0.02	0.5	0	9.1	85.0	248	504	7.85

Table 6: Sampling results from Wendling Beck and River Wensum sites tested on 16 February 2022

Table 6 shows results obtained from sampling sites on the Wendling Beck, Blackwater and main River Wensum on 16th February 2022. Of note is that the main River Wensum was sampled upstream of the confluence with the Wendling Beck at Billingford and downstream at Burgh Common. The results demonstrate the influence of high P levels from the Wendling Beck catchment affecting the River Wensum, which was found to be within target limits for P upstream of the confluence, as can be seen in Figure 21 below.

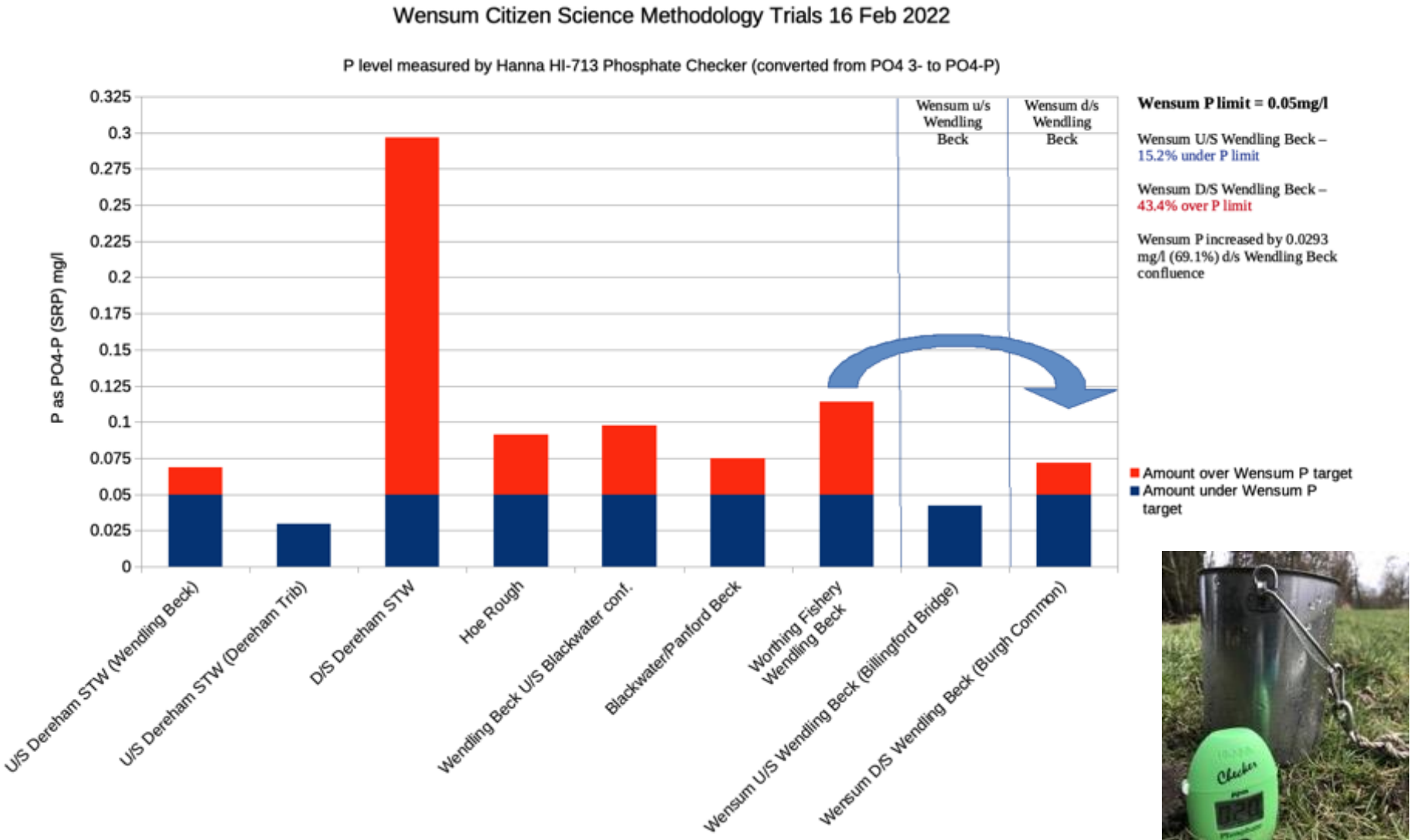


Figure 21: P results from sites sampled using the Hanna HI-713 digital photometer checker (Wensum P target = 0.05 mg/l)

User: **Steve Lane**
Response Id: **Steve Lane-A5SCJJ**
Submitted: **Feb 16, 2022 11:45 AM**
IP Address: **82.132.226.124**
Status: **Final**
Drafted by Steve Lane on Feb 16, 2022 11:39 AM
Submitted by Steve Lane on Feb 16, 2022 11:45 AM

Question	Answer
Please confirm today's date:	February 16, 2022
Which of our River Wensum sampling sites are you monitoring?	WensR4-24a Norfolk Flyfishers Riffle Wed, Feb 16, 2022 11:40 AM 52.73410419508738° 0.9803050964794624°(+/-) 8.001 m
Has there been any rain in the area over the last 24 hours?	Yes
If it has rained in the last 24 hours, has this been light, moderate or heavy rainfall?	Moderate
Looking at the river, is it still, slow, moderate, fast flowing or dry?	Moderate flow
Is the river water clear or is it coloured (turbid)?	Coloured/turbid
If you can see the river bed, what is the most common thing it is made of?	Too coloured to see bed
What is the river water temperature (in degrees C)?	9.1
What is your Dissolved Oxygen reading (in % saturation)?	85
What is your dissolved oxygen reading in mg/l?	9.74
What is your Phosphate reading (in mg/l)?	0.22
What is your nitrate reading (in mg/l)?	2
What is your ammonia reading in mg/l?	0.02
What is your pH reading?	7.85
What is your TDS reading in mg/l?	248
What is your conductivity (EC) reading in uS?	504
Have you seen anything odd, unusual or important while visiting this site? If so please let us know here:	Site at Burghfield common DS fishing platform baking. Highs. Drawn
Please upload a picture of the river channel as you see it looking upstream	 52.733969307692 16° 0.98020009807869°(+/-) 8.001 m
Upload short video (<5 seconds)	

Figure 22: Example mWater data upload from site at Burgh Common (additional ad-hoc site uploaded using an existing site profile)

6. How good is our data?

6.1 Options for checking data quality

Data quality and robustness is a key consideration for citizen science moving forward to ensure all WCP partners can engage with the data. Strategies such as such as ensuring standardised sampling methodologies, volunteer training, effective data recording tools and screening of incoming data can help ensure accuracy and reliability of data. It is recommended that an additional allowance needs to be made to accommodate lab sampling of a proportion of samples (5-10%) to cross-check the citizen science results. Potential options for this on the Wensum include:

6.1.1 Citizen science samples timed to coincide with existing EA monitoring:

Whilst in principle the duplication of monitoring effort should be avoided, if citizen science sampling can be co-ordinated to be undertaken on the same day as the EA sampling it does provide an important opportunity for QA of the citizen science results with the EA lab samples. This principle was demonstrated during the field trials – see below.

6.1.2 Partnership with the UEA labs:

In addition to the importance of co-ordination with EA water quality monitoring for quality assurance benefits, it may be feasible to engage the UEA lab to check 5-10% of samples from citizen science monitoring. This would provide additional quality control assurance of the dataset and align with previous work in the Wensum catchment by the UWCFG and UEA. Whilst desirable, this presents additional cost and logistical considerations. There is a minimum sample batch size threshold of @10 samples to obtain best cost. Samples will need to be co-ordinated (e.g. organised monthly 'Blitz' type approach, collected in appropriate containers (1l plastic bottles), clearly labelled and stored in a cool box with cool blocks before being taken to the UEA lab.

6.1.3 Calibration of citizen science flow data against EA gauging station data:

In order to further develop potential citizen science methods for flow measurement such as Discharge App, it is recommended that field trials are undertaken. These could be sited upstream of an existing Environment Agency gauging station such as at Swanton Morley, or at representative headwater sites and run in conjunction with flow measurement using the float method and a flow meter to compare results. Liaison with Environment Agency Hydrometry and Telemetry colleagues could also enable a trail of methods alongside manual gauging where this is being conducted in suitable watercourses.

6.2 Comparing citizen science field testing samples against EA testing

The field trials provided an opportunity to compare some of the results from the selected equipment against the results of sampling undertaken by the Environment Agency. Moving forward this appears a favourable and cost-efficient way of undertaking cross-checking of citizen science data to build confidence in the adopted approaches. This is particularly important in respect of the methods adopted to test for nutrient pollution, such as P where target limits require sampling at a high resolution. The field trials provide an opportunity to compare results from P samples taken using the Hanna HI-713 during February and March 2022 at sites on the main River Wensum at Swanton Morley. I am grateful to Colin Howlett and Dennis Willis of Norfolk Flyfishers Club and Worthing fishery, who bought equipment to

inform their fisheries management and kindly undertook additional samples of the River Wensum and Wendling Beck. The combined samples provide a combined citizen science dataset extending over a period of a month and a half, which can be compared to results from EA monitoring within the same timeframe. This shows the Hanna units are capable of testing for P at a resolution and accuracy very close to sampling undertaken by the Environment Agency.

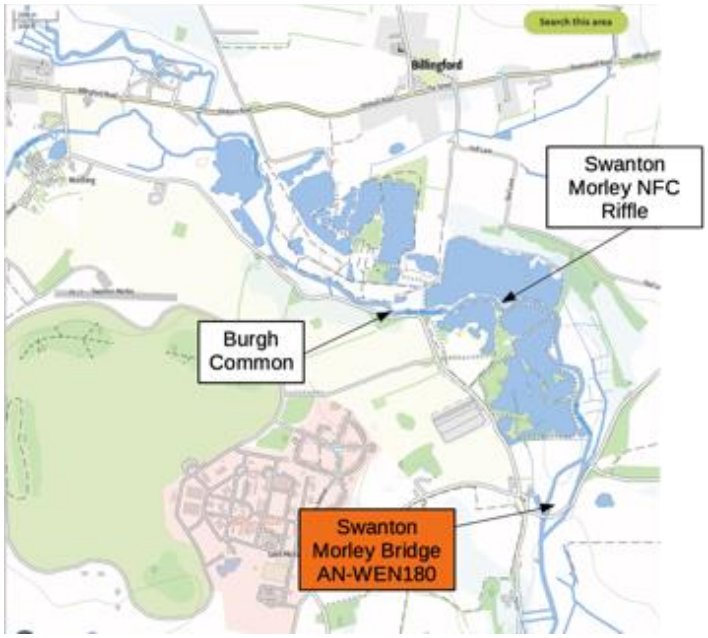


Figure 23: Sampling sites tested during February and March 2022 on the main River Wensum at Swanton Morley and location of the EA monitoring site at Swanton Morley Bridge

	2 Feb 22	8 Feb 22	11 Feb 22	15 Feb 22	16 Feb 22	23 Feb 22	26 Feb 22	2 Mar 22	18 Mar 22
Swanton Morley Bridge AN-WEN180 (EA samples)	0.053		0.065		**0.066**	0.054		0.043	
Swanton Morley NFC riffle		0.055		0.052			0.065		0.068
Burgh Common					**0.072**				

Table 7: Comparison of citizen science phosphate (PO4-P) samples against results from Environment Agency samples taken at Swanton Morley bridge (AN-WEN180)

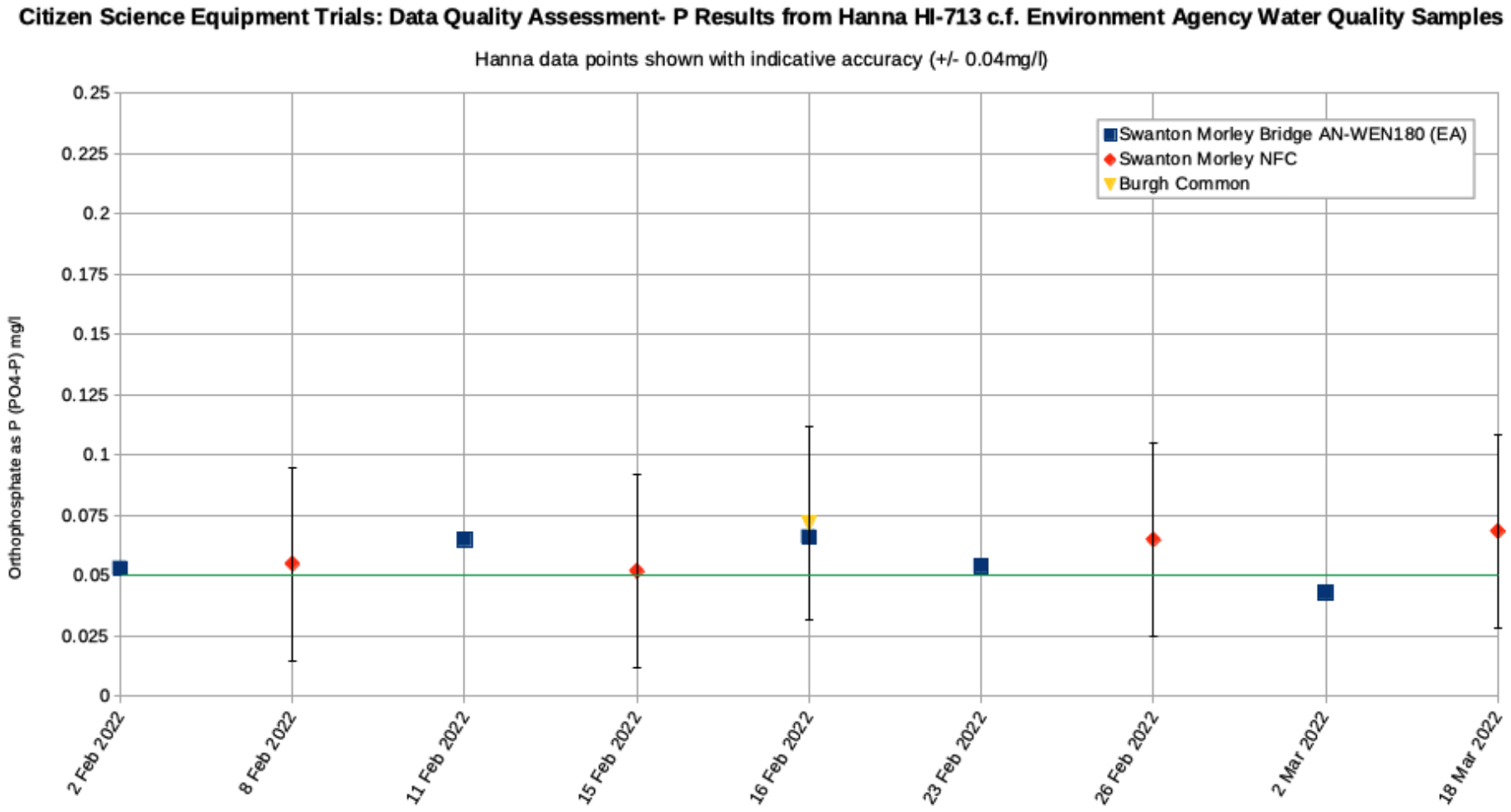


Figure 24: Comparing citizen science P data to Environment Agency water quality samples (February – March 2022)

7. Developing a pilot citizen science monitoring scheme

This study has identified a network of monitoring sites in the Wensum catchment, a suite of suitable water quality testing equipment, a range of suitable rainfall, river level and flow measurement techniques and the means for citizen scientists to record and upload data. As the feasibility assessment progressed, the Wensum Catchment Partnership indicated a desire to develop a pilot citizen science trial focussing on the Upper River Wensum headwater and the River Tat catchment to be run over the summer and early autumn of 2022. The following is intended to provide a framework for conducting a pilot trial using the sites, parameters, equipment and approaches discussed in this report.

7.1 Water quality monitoring site locations:

Currently only two sites are sampled by the Environment Agency on a weekly basis – Tatterford Bridge (AN-WEN010) and Helhoughton Bridge (AN-WEN020). It is proposed that the citizen science pilot should aim to monitor at least 10 sites across the upper Wensum headwaters and Tat catchment, ideally on a weekly basis. This would provide a significantly improved picture of both catchments, given e.g. previously high P records in the Tat during field trials (Appendix X).

7.1.1 River Tat sites:

There are currently 7 proposed citizen science monitoring sites within the Tat, with 2 'control' sites on the main River Wensum which enable monitoring to detect any influence of the Tat catchment on water quality in the main River Wensum:

Figure 25: River Tat sampling sites

It is recommended the pilot aims to monitor a minimum package of 3 core sites on the Tat, along with 2 main River Wensum Sentinel sites (n=5). The rationale for selecting these sites is set out below:

- **Tatterford (W3W = loans.escalates.situation):** Sentinel site to monitor the water quality of the whole Tat catchment and its potential influence on the main River Wensum; existing weekly EA water quality monitoring site (AN-WEN010) for citizen science data QA – see below; potential to develop future river flow sentinel monitoring site subject to landowner agreement (Water for Tomorrow)
- **Coxford Bridge (W3W = baker.revisit.frost):** Core monitoring site to monitor water quality downstream of Sculthorpe STW
- **Abbey Lane (W3W = trappings.flock.stunning):** Core monitoring site to monitor the influence of the Rudham tributary on the main River Tat (given high P levels recorded during equipment trials – see Appendix 1)
- **Helhoughton – River Wensum (W3W = pacemaker.slave.tonal):** Sentinel site to monitor the water quality of the whole upper River Wensum catchment upstream of the River Tat; acts as a control site to enable any influence of the River Tat tributary to be detected in conjunction with the site at Southmill Farm downstream of the Tat confluence; existing weekly EA water quality monitoring site (AN-WEN020) for monthly data QA – see below; potential to develop future river flow monitoring site subject to landowner agreement (Water for Tomorrow)
- **Southmill Farm – River Wensum (W3W = minimums.cube.shad):** Core monitoring site to enable monitoring to assess the influence of the River Tat catchment on water quality in the main River Wensum

The other four sites in the Tat catchment can be monitored as volunteer resources allow/are scaled up, should data indicate possible water quality issues. For example, it is recommended to consider regular monitoring of the other sites on the Rudham tributary if high P levels continue to be recorded at Abbey Lane, in an effort to establish any potential diffuse or point source inputs along the stream.

- **Eye Lane (W3W = slept.tightrope.solutions):** Upstream of East Rudham STW; Intermediate site as required to establish point source or diffuse sources
- **West Rudham (W3W = nylon.haunt.sugars):** Intermediate site as required to establish point source or diffuse sources
- **Grange Road (W3W = lyricist.smelter.only):** Upstream limits of Rudham tributary; sample to assess potential for diffuse or possible point source P loadings (e.g. domestic septic tanks)
- **Broomsthorpe Bridge (W3W = chicken.ballooned.absorb):** Intermediate site as required to establish point source or diffuse sources

Water quality sites should ideally be completed on the same day to deliver the most robust and comparable data. The other sites (Eye Lane, West Rudham, Grange Road, Broomsthorpe) can be undertaken if and whenever feasible, and/or if extremely high/notable readings obtained at the core sites (diffuse/point source investigation). Consider monthly 'Blitz' of multiple sites timed to coincide with day of EA sites/lab sampling to ensure Wensum citizen science uses opportunity for cross-checking/QA of data – see below. Additional ad-hoc

sampling of these sites over and above the weekly target could be undertaken and may add value to the dataset (e.g. reactive additional monitoring during/after rainfall events). Additional or new sites can be be incorporated into the programme as volunteer resources allow.

7.1.2 Upper River Wensum headwater sites:

There are currently 9 proposed citizen science monitoring sites in the upper River Wensum headwaters:

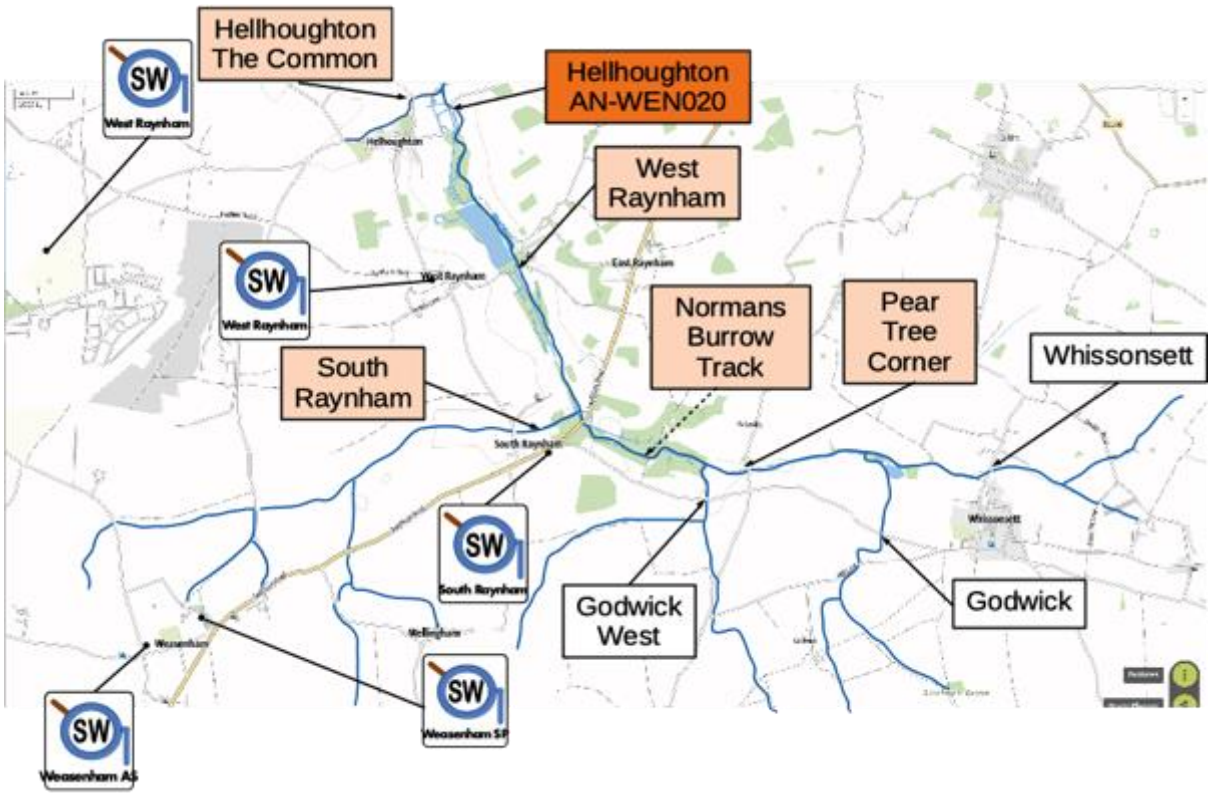


Figure 26: Upper Wensum headwaters sampling sites

It is recommended the pilot aims to monitor a minimum package of 5 core sites on the upper River Wensum headwaters (n=5) at least weekly, along with the main River Wensum Sentinel site at Hellhoughton (see above). The rationale for selecting these sites is set out below:

- **The Common Helhoughton (W3W = diner.seriously.rang):** Monitor any influence of West Raynham airfield STW; tributary control to monitor any other diffuse or point sources before main River Wensum confluence with the River Tat in conjunction with Sentinel site at Hellhoughton (critical to discern what influence River Tat water quality may be having on the River Wensum)
- **West Raynham (W3W = airbase.collapsed.bins):** Excessive macrophyte growth reported in channel upstream by landowner (Raynham Estate pers. comm. 9 March 2022) could indicate elevated nutrient levels; Intermediate site to establish point source or diffuse sources

- **South Raynham Footpath (W3W = says.paler.saying):** Alternative site suggested by landowner due to past water quality concerns in this vicinity (Raynham Estate pers. Comm. 9 March 2022). NB: if poor water quality recorded; consider monitoring additional control site at West Raynham Road Bridge (W3W = twinkling.equality.nerves)
- **Normans Burrow Track (W3W = blockage.dragonfly.blackouts):** Intermediate site to act as control upstream of South Raynham STW; alternative location agreed with landowner (Raynham Estate pers. comm. 9 March 2022) due to roadside health & safety risks on A1065 Swaffham Road bridge
- **Pear Tree Corner (W3W = stocks.conspired.lobster):** Upstream limit of River Wensum SSSI; sentinel site for monitoring upstream headwaters to source

The other three sites in the Wensum headwaters can be monitored as volunteer resources allow/are scaled up, or if additional sites are required to establish possible point source or diffuse impacts (additional new sites can also be added if required):

- **Godwick West (W3W = postings.puff.nags):** Tributary control site to monitor for diffuse or point sources if levels downstream are elevated
- **Godwick (W3W = prospered.dabbling.diplomat):** Tributary control site to monitor for diffuse or point sources if levels downstream are elevated
- **Whissonsett (W3W = punters.post.remotes):** Tributary control site to monitor for diffuse or point sources if levels downstream are elevated

Water quality sites should be completed on the same day to deliver the most robust and comparable data. Additional ad-hoc sampling of these sites over and above the weekly target could be undertaken and may add value to the dataset (e.g. reactive additional monitoring during/after rainfall events). Additional sites can be be incorporated into the programme as volunteer resources allow. Consider monthly 'Blitz' of multiple sites timed to coincide with day of EA sites/lab sampling to ensure Wensum citizen science uses opportunity for cross-checking/QA of data – see below.

7.2 Water quality parameters and equipment:

The table below suggests water quality parameters to be monitored and a suite of basic equipment ('Tier 1), derived from the feasibility assessment e.g. River Wensum conservation objectives, assessment of citizen science case studies, literature and field trials of selected equipment and methods.

Parameter:	Suggested equipment:	Cost:
Orthophosphate (PO4 - 3) & Orthophosphate as P (PO4-P)	Hanna Low Range Phosphate Checker HI-713 OR Milwaukee MW12 Digital Phosphate Tester	£70 £55
Ammonia-N (NH3-N)	Hanna Low Range Ammonia Checker HI-700 OR Hanna Medium Range Ammonia Checker HI-715	£70 £81
Nitrate (NO3) NB: No low cost 'Checker' for freshwater testing	Hanna HI-97728 Nitrate Portable Photometer OR Horiba LAQUATwin Nitrate Ion meter NO3-11 OR Nitrate test strips/chemical kits e.g. Simplex	£330 – £495 £375 £17.99/50 tests
Dissolved Oxygen (mg/l and % saturation) + water temperature (°C)	AZ Instruments 8403 Dissolved Oxygen Meter OR Similar budget DO meter	£145 £80-100
Turbidity/Suspended Solids	Graduated Turbidity Secchi tube e.g. Camlab or WCRT model	<£50
pH	pH Pen Tester	£5 - £10
TDS & conductivity	TDS & EC Pen Tester	£5 - £10
	Basic Tier 1 set total:	**£280 - 770**

Table 8: Water quality parameters and suggested equipment for pilot trial

7.3 Options for monitoring rainfall, river level and flow:

The following rainfall and river level options could be considered as part of an initial pilot trial:

Parameter	Method	Target participation	Cost	Health & safety	Estimated time to complete
Basic (Tier 1) methods					
Rainfall totals	Rainfall gauge	Trained volunteers	Low (£5-£15)	Low risk	Quick 1-2 minutes
River levels	Fixed point photographs	Trained volunteers & public	Low - Interpretative signs	Low risk	Quick 1 minute
	Fixed gauge board photos	Trained volunteers & members of the public	Low - med (£30-£50 per board + installation)	Low risk	Quick 1-2 minutes
Advanced (Tier 2) methods					
Stream flow measurement	Float method	Trained volunteers	Low	Med risk	Slow @1 hour/site
	Flow meter	Trained volunteers	Moderate (Equipment & PPE)	Med risk	Slow @1-2 hours/site
	Discharge app (subject to validation trials)	Trained volunteers	Medium if Android phones required	Low risk	Quick 1-2 minutes

Table 9: Options for measuring rainfall, river levels and flows for pilot trial

7.4 Equipment and other costs:

7.4.1 Water quality

To facilitate field sampling across the two areas it is recommended that at least three sets of basic (Tier 1) sampling equipment are purchased (1 set for the Tat, 1 set for the Wensum headwaters and one set as a spare or 'floating' set):
Three sets of basic Tier 1 water sampling equipment:
Cost = @£350 (excluding nitrate option) per set; Total basic equipment cost = @£1,050
1 Lovibond MD610 unit for Tier 2 SWAT investigation sampling & QA = £1500
Indicative reagent costs are as follows (not including Lovibond reagents):
- **@£2.00 - £3.00 per site** (Ammonia = £0.96 - £1.40 per test; Phosphate = £0.31 - £0.56 per test; NB: Nitrate options = Test strips £0.29 - £0.36 per test; HANNA HI97728 = £0.90 per test; HORIBA LAQUATwin = No reagent required))
- **@£20.00 - £30.00 per week based on 10 sites sampled weekly (5 Tat & 5 upper Wensum)**
- @£80.00 - £120.00 per month based on 10 sites (+allowance for additional sites as needed)

7.4.2 Stream flow & discharge

It is recommended that an allowance is also considered for the purchase of river flow meters for future Wensum flow monitoring. Stream flow assessment using flow meters would provide more robust data than the basic float (e.g. 'orange') method.e.g. GeoPacks Advanced (basic) @£250 or OTT MF Pro electro-magnetic flow meter (advanced, more suitable for very low flows, shallow streams) cost tbc. Examples of volunteer flow measurement methods are provided by e.g. University of Kentucky and Michigan Clean Water Corps.

7.4.3 Additional sampling costs:

Allowance for volunteer expenses (e.g. mileage).
Sampling bucket & cord @£3.00 each – multiple sets desirable to ensure e.g. biosecurity between sites/tributary catchments
10 ml syringes
PPE for volunteers e.g.:

- Disposable latex-free gloves @£10.00 per box of 100
- Hi-Viz jacket or vest (ideally with Wensum Water Quality logo) @£5.00/volunteer
- Safety glasses @£5.00/volunteer
- Protective toe/midsole waders for volunteers undertaking flow monitoring [also consider lifejacket & working in water policy?]

7.5 Quality Assurance/Calibration sampling:

Data quality and robustness is a key consideration for citizen science moving forward to ensure all WCP partners can engage with the data. It is therefore recommended that an additional allowance needs to be made to accommodate lab sampling of a proportion of samples (5-10%) to QA check the citizen science results. Two potential routes for this on the Wensum are:

7.5.1 Weekly sampling timed to coincide with existing Environment Agency monitoring:

The citizen science programme should liaise with the sampling and collection team at the EA to identify the schedule for sampling at the two existing EA sites (Tatterford AN-WEN010 and Helhoughton AN-WEN020). Whilst in principle the duplication of monitoring effort should be avoided, if citizen science sampling can be co-ordinated to be undertaken on the same day as the EA sampling it does provide a strong e.g. monthly opportunity for QA of the citizen science results with the EA lab samples (see Wensum trial example Appendix 2). It may be possible to arrange for additional samples from Tat and Wensum headwater sites to be given to the EA for onward transfer to the EA lab for same analysis (possible cost tbc).

7.5.2 Partnership with the UEA:

Richard Cooper at the UEA is supportive of developing links between the Wensum Citizen science project and the UEA. In addition to the importance of co-ordination with EA water quality monitoring for quality assurance benefits, it may be feasible to engage the UEA lab to check 5-10% of samples from citizen science monitoring. This would provide additional quality control assurance of the dataset and align with previous work in the Wensum catchment by the UWCFG and UEA. Whilst desirable, this presents additional cost and logistical considerations. There is a minimum sample batch size threshold of @10 samples to obtain best cost. Samples will need to be co-ordinated (e.g. organised monthly 'Blitz' type approach, collected in appropriate containers (1l plastic bottles), clearly labelled and stored in a cool box with cool blocks before being taken to the UEA lab. Current indicative UEA lab costs are as follows (R. Cooper, 1 Apr 2022):

- nitrate (NO3), ammonium (NH4) and phosphate (PO4). **£11.82 per sample**
- nitrate (NO3), ammonium (NH4), phosphate (PO4), total phosphorous (TP), suspended sediment (TSS). **£26.18 per sample**

7.6 Management of data:

- Identify and develop field data capture methodology including app and user interface as required (e.g. mWater app used during equipment trials)
- Site data & pictures uploaded by field sampling volunteers onto water survey app – data available to review in 'real time' (see sample screenshots below)
- Data analyst (Project Officer and/or volunteer) review in-coming data, produce monthly report (for example monthly WQ 'scorecard' update sent to WCP partners and volunteers) & liaise with Comms/engagement lead.
- Data assessment & reporting can either be completed in-app (e.g. mWater Portal), or via .csv download and mapping via use of GIS software – e.g. QGIS being developed by the Lark Citizen Science project or ArcGIS Survey123 used by Norfolk Rivers Trust.
- Field Sampling volunteers & Data Analyst identify 'problem' sites (e.g. low DO, high P or NO3) and activate SWAT team Tier 2 sampling as required to track source of pollutants upstream + assess potential for Teir 3 sampling eg WATR deployment
- Report back to Wensum Catchment Partnership, including Environment Agency and Natural England quarterly or as agreed
- Reporting of pollution events (with raised awareness and WQ data/evidence as added value benefit of the citizen science project) to EA Incident Hotline 0800 80 70 60 as required. Obtain incident number to allow follow up etc.

7.7 Suggested Volunteer requirements:

It is envisaged that the pilot trial will need to consider the following roles:

- Field sampling volunteers (basic sampling – Tier 1)
- Field sampling SWAT team volunteers (Advanced investigations – Tier 2)
- Data analysis and management lead
- Volunteer and equipment co-ordinator/liaison
- Public/stakeholder engagement, communications and media lead

7.7.1 Volunteer time required to undertake field sampling role:

Water quality Field trials undertaken by Steve Lane indicate that it takes between 20-30 minutes on site to undertake the suite of basic water quality tests and upload the results using a smartphone app (field tested using mWater). All sites in the trial should ideally be undertaken on the same day to ensure the most robust data.

On this basis, the proposed 5 core sites on the Tat would require the following volunteer resource:

- 5 sites at 30 minutes each **= 2.5 hours site time plus travel time @30 minutes = minimum of 3 hours volunteer field sampling time per week**

- **12 volunteer hours per month based on 4 x sampling events per month**

The proposed 5 core sites on the Wensum headwaters would require the following volunteer resource:

- 5 sites at 30 minutes each **= 2.5 hours site time plus travel time @30 minutes = 3 hours volunteer field sampling time per week**

- **12 volunteer hours per month based on 4 x sampling events per month**

Stream flow and discharge It is recommended that stream flow measurements are considered separately to water quality sampling. Conventional flow sampling time may be between 30 minutes to 1 hour per site. Stream flow sites will need to be identified at suitable locations, which may need to be accessed via private land (subject to landowner permission) if existing sites at road bridges are unsuitable, which would incur additional time per site. For example, the Tat splits into two channels at Tatterford Common bridge, which would necessitate two sites to be completed here to gauge total stream flow (@1-2 hours). It may be more desirable to identify an alternative single channel location – will require further liaison with both major landowners on the Tat (Mr Duckworth-Chad) and Wensum headwaters (Mr Raynham).

7.8 Citizen Science 'Audience' and existing Citizen Science volunteers:

Potential groups to target volunteer recruitment include:

- Anglers and RiverFly monitors
- Local and Parish Councils
- Community groups (water users, wild swimmers, Kayakers, canoeists, Sea Scouts/Scouts & Guides) + e.g. Facebook groups
- Wildlife groups and societies, Norfolk & Norwich Naturalists Society, Norfolk Wildlife Trust
- Universities, Colleges, Schools

- Dog walkers, walkers
- Sculthorpe Moor Nature Reserve

Identification of resource available – Where are volunteers based? What background do they have? How much time can they contribute? Is this a regular commitment (willing to do routine monitoring) or infrequent (e.g. 'Wensum Water Quality Blitz' events; Tier 2 investigations)? Do they have a vehicle? Expenses?

7.9 Volunteer training:

Volunteer recruitment for the pilot trial will need to resource (equipment, venue, budget) and deliver training and accreditation requirements including:

7.9.1 Place-based (e.g. Village hall with nearby stream) training and accreditation workshop covering:

- Theory e.g. - background to the Wensum, WCP & Water for Tomorrow (why?),
    - basic water quality, intro to equipment & sampling methods and reporting results on [mWater] app, how to recognise poor water quality & report pollution incidents (how?);
    - sampling sites (where?)
    - essentials such as PPE requirements, health & safety issues e.g. risk assessment, road safety, chemical handling/disposal and adoption of 'buddy system' or other agreed reporting methods to ensure volunteers can be accounted for whilst undertaking sampling;
    - biosecurity considerations e.g. crayfish plague; Invasive Non-Native Species
    - Dissemination of field guide for sampling
- Practical 'have a go' mentoring session at suitable stream site/s
- Formation of 'River Warden' buddy groups to facilitate:
    - agreed point of contact between volunteers, lead and NRT/WCP citizen science co-ordinator
    - custodianship, maintenance & sharing of sampling equipment as required
    - pairing of volunteers to undertake sampling where required (e.g. mentoring, H&S, building resilience)

7.9.2 Follow up mentoring & feedback

Arrangements put in place to ensure volunteers can be mentored if required to build confidence, resilience and robustness in citizen science. The pilot trial volunteers may also be able to help train and mentor others in future (e.g. developing the volunteer base in neighbouring tributary catchments; 'Blitz' events in other Wensum tributaries or forming links with other catchment partnerships). Arrangements should also be put in place to provide feedback, results and project updates (e.g. Catchment Scorecards, Brecks BFER Testing the Water Report) and future engagement with volunteers. WCP partners could consider wider opportunities to support this, including providing demonstration events (e.g. invertebrate or fish surveys) or work shadowing opportunities for interested volunteers.

8. Options for future development

8.1 Discharge app validation assessment – Water for Tomorrow/CastCo)

There is considerable merit to exploring ways of making stream flow measurement more accessible to citizen science. As discussed, traditional intrusive stream flow gauging methods are technical, time-consuming and present additional challenges when deploying volunteers. Non-intrusive smartphone applications such as Discharge App appear well suited for citizen science flow and discharge monitoring but will require testing and validation in representative local watercourses to ascertain suitability and accuracy before being adopted as part of any monitoring programme.

It is recommended that a trial assessment of the app is considered utilising a suitable section of the Wensum, for example at Swanton Morley just upstream of the Environment Agency flow gauging station. This would enable the outputs of the Discharge app to be compared directly against EA flow gauging station data. Such an exercise could also incorporate a comparison with the other flow gauging methods outlined above. Should the app prove to be effective then a second stage of assessment could be conducted across the range of stream channel sites and typical flow conditions before adopting the method.

8.2 Developing citizen science capability

In order to provide a framework to establish and then scale up citizen science monitoring, a three tier approach is recommended, where Tier 1 represents the baseline monitoring programme set out in this feasibility report, using basic equipment and techniques to suit a large group of volunteers.

- **Tier 2: Targeted reach diffuse/point source assessment:** Pending budget and funding availability, use of higher accuracy but more expensive lab standard equipment such as the Lovibond MD600 (already in use in the Wensum catchment by the UWCFG and Norfolk Rivers Trust, Palintest or Hach photometers (>£800- 1,000) by a small cohort of more experienced/trusted volunteers with additional training. This could enable Wensum citizen science to focus on point source, diffuse pollution or headwater reaches identified through existing datasets, ongoing stakeholder engagement or flagged up through ongoing Tier 1 catchment surveillance monitoring.

- **Tier 3: Targeted continuous remote autonomous sampling/telemetetry:** Continuous sampling for parameters such as river level, flow, turbidity or phosphate may be desirable moving forward to provide the sampling resolution and data accuracy needed to support potentially difficult management or investment decisions by catchment partners moving forward. Whilst there are likely to be constraints around cost, deployment and security, use of such equipment could be feasible thorough either hire e.g. through the Environment Agency National Water Quality Instrumentation Service, or by pooling funding bid/s with other adjacent CS initiatives to provide a shared equipment resource. Telemetry capable remote sensing/sondes are becoming more accessible, with self-contained multi-parameter equipment solutions such as WATR even providing an holistic data hosting capability. Other manufacturers produce sondes capable of autonomous sampling of parameters such as phosphate e.g. ClearWater to lab standards, with potential to link to GSM-capable multi-

parameter hubs e.g. Point Green to enable remote access and monitoring of data. Real-time remote access to data has advantages in enabling citizen science volunteers to help with in-field equipment maintenance and operational validation ('Is our equipment still working and collecting good data?'), plus encouraging better engagement and awareness e.g. pollution reporting.

Monitoring level	Method	Purpose	Equipment	Frequency
Tier One: **Phase 1 - Pilot Trial** **Phase 2 – Roll Out**	Baseline monitoring of a large number of sites across the catchment by a large number of volunteers Accessible for volunteers Water quality & river levels	Evidence water quality, rainfall and river levels in the catchment. Provide on-going, reliable, high quality water quality data to WCP members	Basic suite of Citizen Science equipment – low cost to enable enough kits to be available, high accuracy, digital display, easy to use, consistent – Informed by practical trials and pilot	Weekly (or as resources allow) at identified sites Additional sampling: Events, campaigns, 'bio-blitzes' and seasonal surveys of each sub-catchment
Tier Two	Targeted reach monitoring to assess water quality, identify & monitor specific diffuse or point sources; assessment of river flows More experienced volunteers	To provide higher accuracy sampling effort on point source, diffuse pollution or sampling site and/or validate data at Tier One identified 'hot spots'; river flow data from key catchment sites	Basic Suite of Equipment plus Lovibond MD 610 multi parameter photometer Lab testing of sub-samples (5-10%); Flow meters (& Android phones for use of Discharge App – subject to validation)	Identified through existing datasets, request from WCP or through Tier 1 catchment monitoring
Tier Three	Targeted continuous remote automatic sampling & telemetry – partnerships & equipment share with others?	Provide additional sampling resolution and data accuracy needed to evidence management or investment decisions by catchment partners	WATR, Isco WQT auto sampler or other automatic telemetry monitoring kit.	As determined by the WCP and members

Table 10: Options for developing citizen science capability

References:

A Green Future: Our 25 Year Plan to Improve the Environment. Defra. 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/500583/Impact_assessment_update_to_the_RBMPs_for_England_s_water_environment__2015_.pdf

Acoustic telemetry reveals strong spatial preferences and mixing during successive spawning periods in a partially migratory common bream population; Winter, E.R., Hindes, A.M., Lane, S. and Britton, J.R. (2021). Aquatic Sciences **83**, 52. https://link.springer.com/article/10.1007/s00027-021-00804-9

Blackburn-Lynch, W. C., Agourdis, C. T. and Sanderson, T. M. 2016. Measuring discharge in wadeable streams. University of Kentucky. https://uknowledge.uky.edu/cgi/viewcontent.cgi?article=1086&context=anr_reports

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V. and Shirk, J. 2009. Citizen Science: A developing tool for expanding science knowledge and scientific literacy. BioScience, **59**, 11 977-984. https://academic.oup.com/bioscience/article/59/11/977/251421

Citizen Science and Volunteer Monitoring Resource Pack 2016. The Rivers Trust. https://catchmentbasedapproach.org/wp-content/uploads/2018/07/CaBACitizenScienceVolunteerMonitoringLOWRES.pdf

Citizen Science: crowdsourcing for research. THIS Institute. 2018. https://www.thisinstitute.cam.ac.uk/wp-content/uploads/2018/05/THIS-Institute-Crowdsourcing-for-research-978-1-9996539-0-3.pdf

Dobriyal, P., Badola, R., Tuboi, C. and Hussain, S. A. (2016) A review of methods for monitoring streamflow for sustainable water resource management. Applied Water Science, **7,** 2617-2628 (20127) https://link.springer.com/article/10.1007/s13201-016-0488-y#Tab2

Farming rules for water- getting full value from fertilisers and soil, DEFRA. 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/695598/farming-rules-for-water-policy-paper-v2.pdf

Fieldwork for rivers. Field Studies Council – resources, 14-16 Geography. https://www.field-studies-council.org/resources/14-16-geography/rivers/fieldwork/

Friends of the Upper Wye, Written evidence to Parliamentary Environmental Audit Committee session, 2021. https://committees.parliament.uk/writtenevidence/38743/pdf/

Impact assessment for the updated river basin management plans (2015): evidence base. Environment Agency. 2016. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/500583/Impact_assessment_update_to_the_RBMPs_for_England_s_water_environment__2015_.pdf

Michigan Clean Water Corps. MiCorps Volunteer Stream Flow Monitoring Project Procedures. 2016. Michigan Department of Environmental Quality. https://micorps.net/wp-content/uploads/2017/12/VSMP-StreamFlow-Procedures.pdf

Monitoring Stream Temperatures – A Guide for Non-Specialists. USGS. (2018). https://pubs.usgs.gov/tm/03/a25/tm3a25.pdf

Movements of common bream Abramis brama in a highly connected, lowland wetland reveal sub-populations with diverse migration strategies, Winter, E.R., Hindes, A.M., Lane, S. and Britton, J.R. (2021). Freshwater Biology 00:1-13. https://onlinelibrary.wiley.com/doi/full/10.1111/fwb.13726

Othman, A., Khairudin, W. M., Othman, J., Ghani, M. A. and Saudi, A. S. M. 2017. Water flow measuring methods in small hydropower for streams and rivers – A study. International Journal of Applied Engineering Research. **24.** 14484 – 14489. https://www.ripublication.com/ijaer17/ijaerv12n24_69.pdf

Phosphorus and Freshwater Eutrophication Pressure Narrative, Environment Agency 2019. https://consult.environment-agency.gov.uk/++preview++/environment-and-business/challenges-and-choices/user_uploads/phosphorus-pressure-rbmp-2021.pdf

Protocol Implementation Plan for Monitoring Discharge in Greater Yellowstone Network Parks *Standard Operating Procedures Version 1.0*. National Parks Service, U.S. Department of the Interior 2017. https://irma.nps.gov/DataStore/DownloadFile/588346

Review of phosphorus pollution in Anglian River Basin District. Environment Agency, 2012. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291507/scho0512buwf-e-e.pdf

Riverfly Census Conclusions – River Wensum. Salmon & Trout Conservation (2019). https://salmon-trout.org/wp-content/uploads/2019/03/Wensum-Conclusions-Compressed.pdf

River Wensum: Proposed targets for SAC conservation objectives, Natural England 2014. http://publications.naturalengland.org.uk/publication/5199706858717184

River Wensum SSSI- Exemplar Diffuse Water Pollution Plan and Action Plan IPENS001a. Natural England & Environment Agency 2012. http://publications.naturalengland.org.uk/file/5752380302819328

River Wensum SSSI Notification. Natural England. 1993. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/500583/Impact_assessment_update_to_the_RBMPs_for_England_s_water_environment__2015_.pdf

Roy, S. and Edwards, M., 2019. Citizen Science During the Flint, Michigan Federal Water Emergency: Ethical Dilemmas and Lessons Learned. *Citizen Science: Theory and Practice*, 4(1), p.12. DOI: http://doi.org/10.5334/cstp.154

Seibert, J., Strobl, B., Etter, S., Hummer, P. and Meerveld, H. J. (2019) Virtual staff gauges for crowd-based stream level observations. Frontiers in Earth Science https://doi.org/10.3389/feart.2019.00070

Site Improvement Plan: River Wensum (SIP198). Natural England. 2014. http://publications.naturalengland.org.uk/publication/6720168281505792

Starkey, E., Parkin, G., Quinn, P and Large, A. 2020. Investigating the feasibility and reliability of citizen science for catchment science. Newcastle University. https://www.ukeof.org.uk/documents/conf-2020/poster_eleanor_starkey_2_feasibility_reliability_citizen_science.pdf

Starkey, E. 2020. Using social media to collect flood data and expand the citizen science toolbox. Newcastle University. https://www.ukeof.org.uk/resources/citizen-science-resources/social-media-workshop-2020-12-09/e-starkey-ukeof-social-media-workshop.pdf

Starkey, E. R. 2018. Community-based ('citizen science') monitoring for catchment characterisation, modelling and management. Newcastle University. http://theses.ncl.ac.uk/jspui/handle/10443/4363

Stream flow. US Environmental Protection Agency – Monitoring and assessment>5.1 Stream Flow. https://archive.epa.gov/water/archive/web/html/vms51.html

Terasmaa, J., Vainu, M., Koit, O., Sisak, K., Abreldaal, P. and Puusepp, L. 2020. Spring monitoring manual for volunteers. Allikad.info. https://allikad.info/manuals/discharge_manual_ENG.pdf

The Demonstration Test Catchments Evidence Compendium, DEFRA. 2020. http://www.wensumalliance.org.uk/research_reports/14879_WT15116_DTC_Evidence_Compendium_final.pdf

Tracing the origin of the crayfish plague pathogen, *Aphanomyces* astaci, to the Southeastern United States. Martin-Torrijos, L., Martinez-Rios, M., Casabella-Herrero, G., Adams, S. B., Jackson, C. R. and Dieguez-Uribeondo, J. (2021). Nature – Scientific Reports **11,** 9332. https://www.nature.com/articles/s41598-021-88704-8

Water Action Volunteers. 2010. Streamflow: Flow Speaks Volumes. Volunteer Monitoring Factsheet Series. Unviversity of Wisconsin. https://wateractionvolunteers.org/files/2019/10/StreamFlowMethods_2015.pdf

Water quality in rivers; Fourth Report of Session 2021-22. House of Commons Environmental Audit Committee 2022. https://committees.parliament.uk/publications/8460/documents/88412/default/

Weeser, B., Jacobs, S., Kraft, p., Rufino, M. C. and Breuer, L. 2019. Rainfall-Runoff modelling using crowdsourced water level data. Water Resources Research. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019WR025248

Wensum Catchment Management Plan. 2021. Wensum Catchment Partnership. https://norfolkriverstrust.org/wp-content/uploads/2022/02/Wensum-Catchment-Management-Plan.pdf

West Virginia Department of Environmental Protection 2018. Water Assessment Branch Field Sampling Operating Procedures – Chapter 4. Stream Flow Measurement Protocols. https://dep.wv.gov/WWE/watershed/wqmonitoring/Documents/SOP%20Doc/WABSOP/Ch4-Flow.pdf

APPENDIX A: Environment Agency water quality, rainfall, river level and flow monitoring sites:

Sampling point name	EA site code	Grid ref.	Sampling frequency	Determinands monitored	Status
R.TAT A148 RD.BR.COXFORD	AN-WEN006	TF8480029500	@monthly 26 samples between 2011 and 2014	Standard suite	Closed (last sampled 01-Aug-14)
R.TAT TATTERFORD COMMON	AN-WEN010	TF8670028000	Weekly 819 samples between 2000 and 2022	Standard suite	Open (Last sampled 26-May-22)
EAST RUDHAM STR.EYE RD.BR.	AN-WEN0155	TF8326128410			Last sampled 27-Mar-19
R.WENSUM PEAR TREE CORNER BRIDGE, WHISSONSETT	AN-WEN0175	TF8990023800			Last sampled 29-Jan-13
R.WENSUM HELHOUGHTON BRIDGE	AN-WEN020	TF8730026800	Weekly 719 samples between 2006 and 2022	Standard suite	Open (Last sampled 26-May-22)
BLACKWATER, EADES MILL	AN-WEN025	TG0950221274			Last sampled 17-Jan-17
R.WENSUM SCULTHORPE MILL	AN-WEN040	TF8930030400	Weekly 885 samples between 2000 and 2022	Standard suite	Open (Last sampled 26-May-22)
R. WENSUM GOGGS MILL RD. BR. HEMPTON	AN-WEN045	TF9139629620			Open (Last sampled 11-May-22)
KETTLESTONE STR. LANGER BR.	AN-WEN060	TF9610029300	<monthly 49 samples between 2013 and 2017	Standard suite	Open (last sampled 17-Jul-17)
R.WENSUM GREAT RYBURGH BRIDGE	AN-WEN070	TF9640027400	<monthly 269 samples between 2000 and 2022	Standard suite	Open (Last sampled 31-Jan-20)
FOULSHAM STR.TWYFORD BRIDGE	AN-WEN090	TG0170024500	<monthly	Standard suite	Open (last sampled 26 April 2017)

			52 samples between 2012 and 2017		
R.WENSUM BINTRY MILL	AN-WEN100	TF9980024300			Last sampled 25-Oct-06
R.WENSUM COUNTY SCHOOL BRIDGE	AN-WEN102	TF9923022710			Last sampled 02-Dec-21
BLACK WATER SPONG BR.TRIB.R.WHITEWATER	AN-WEN110	TF9830019100			Last sampled 02-Oct-06
BLACK WATER D/S SPONG BRIDGE TRIB	AN-WEN111	TF9897819188	Monthly 187 samples between 2006 and 2022	Standard suite	Open (last sampled 08-Jun-22)
DRAIN DOWNSTREAM EAST DEREHAM WTW	AN-WEN115	TF9965113969	<monthly 71 samples between 2005 and 2020	WFD Classification	Open (last sampled 10-Jan-20)
TRIB.OF WENDLING BECK U/S OF SCARNING FEN	AN-WEN123	TF9884611752			Last sampled 05-Mar-20
WENDLING BECK D/S WEST BRADENHAM WTW DISCHARGE	AN-WEN126	TF9330610879			Last sampled 10-Jan-20
WENDLING BECK HILL FARM BR.(R.WENSUM)	AN-WEN130	TF9740013400			Last sampled 25-Oct-06
WENDLING BECK GRESSENHALL BRIDGE	AN-WEN140	TF9660015300	Monthly 288 samples between 2000 and 2022	Standard suite	Open (Last sampled 10-May-22)
WENDLING BECK WORTHING MILL (R.WENSUM)	AN-WEN160	TF9980020100			Last sampled 02-Feb-17
R.WENSUM BILLINGFORD BRIDGE	AN-WEN170	TG0040020200			Last sampled 03-Feb-11
R.WENSUM BACK LANE WORTHING	AN-WEN175	TG0110019400			Last sampled 21-Mar-16
R.WENSUM SWANTON MORLEY BRIDGE	AN-WEN180	TG0210018500	Weekly 906 samples between 2000 and 2022	Standard suite	Open (last sampled 26-May-22)
R. WENSUM LYNG ROAD BRIDGE	AN-WEN190	TG0718417810			Open (Last sampled 04-Feb-22)
R WENSUM LENWADE PRE DREDGING SEDIMENT SURVEY	AN-WEN191	TG1008317887			Last sampled 19-Dec-12

R.WENSUM GREAT WITCHINGHAM BRIDGE	AN-WEN200	TG1073518725	Weekly 858 samples between 2000 and 2022	Standard suite	Open (Last sampled 26-May-22)
BLACKWATER DRN.BOOTON BRIDGE NORWICH RD.	AN-WEN203	TG1080022800			Last sampled 02-Dec-21
BLACKWATER DRN.BECK FARM BRIDGE SPARHAM	AN-WEN206	TG0820020200			Last sampled 02-Feb-17
BLACKWATER DRN.GT.WITCHNGHAM	AN-WEN210	TG0820020200	Monthly 286 samples between 2000 and 2022	Standard suite	Open (last sampled 06-Apr-22)
R.WENSUM GREAT WITCHINGHAM WATER QUALITY MONITORING STATION	AN-WEN218	TG1275216944			Last sampled 13-Jun-05
R.WENSUM ALDERFORD OFF MARRIOTT WAY	AN-WEN219	TG1221417773	Monthly 62 samples between 2007 and 2015	Standard suite	Closed (last sampled 01-Oct-15)
R.WENSUM ALDERFORD BRIDGE	AN_WEN220	TG1270018600			Last sampled 12-Dec-12
OLD RAIL BR.ALDERFORD	AN-WEN223	TG1220017800	<monthly 65 samples between 2007 and 2020	Standard suite	Open (last sample 7 Feb 2020)
R.WENSUM RINGLAND BRIDGE	AN-WEN230	TG1420013800			Last sampled 13-Jun-05
COSTESSEY PIT NO.1 (R.WENSUM)	AN-WEN233	TG1622013230			Last sampled 28-Nov-07
R.WENSUM TAVERHAM BRIDGE	AN-WEN235	TG1600013650	<Monthly 242 samples between 2000 and 2022	Standard suite	Open (Last sampled 05-Mar-20)
COSTESSEY PIT NO.2 (R.WENSUM)	AN-WEN235A	TG1630013120			Last sampled 05-Apr-17
COSTESSEY PITS INTAKE	AN-WEN235AA	TG1648013240			Last sampled 14-Dec-18
D/S 1ST CORNER BELOW TAVERHAM BRIDGE (4)	AN-WEN235H	TG1620013600			Last sampled 02-Aug-00
R.WENSUM COSTESSEY MILL	AN-WEN238	TG1760012800			Last sampled 17-Jan-17
R.WENSUM HELLESDON MILL	AN-WEN240	TG1980010400	Monthly	Standard suite	Closed

			199 samples between 2000 and 2014		(Last sampled 01-May-14)
300M D/S HELLESDON BRIDGE (14)	AN-WEN242A	TG1990009800			Last sampled 08-Sep-15
R.WENSUM SWEET BRIAR RD.BR.	AN-WEN250	TG2060009500	Weekly 1550 samples between 2000 and 2022	Standard suite	Open (Last sampled 12-May-22)
R.WENSUM HEIGHAM INTAKE	AN-WEN252	TG2100009700			Last sampled 26-Nov-12
R.WENSUM NEW MILLS	AN-WEN260	TG2263409078	Monthly 266 samples between 2000 and 2020	Standard suite	Open (last sampled 06-Mar-20)
R.WENSUM WHITEFRIARS BRIDGE	AN-WEN275	TG2342509175			Last sampled 12-Mar-20
R.WENSUM CARROW BRIDGE NORWICH	AN-WEN280	TG2390007700	Weekly 248 samples between 2000 and 2020	Standard suite	Open (last sample 18 March 2020)
RIVER WENSUM TROWSE SWING BRIDGE	AN-WEN285	TG2466307649			Last sampled 22-Jan-20
RIVER WENSUM TROWSE SWING BRIDGE	AN-WEN285	TG2466307649			Last sampled 22-Jan-20
WENDLING BECK WENSUM DTC SAMPLE	WENDTC01	TF9327012707			Last sampled 12-Dec-12
LANGOR DRAIN, LANGOR BRIDGE. WENSUM DTC PROJECT	WENDTC07	TF9613229217			Last sampled 02-Feb-17
PENNY SPOT BECK, ELSING. WENSUM DTC	WENDTC09	TG0352516928			Last sampled 12-Dec-12
BLACKWATER, WHITWELL WENSUM DTC	WENDTC10	TG0900021665			Last sampled 02-Feb-17
WENSUM FAKENHAM DTC	WENDTC13	TF9189629315			Last sampled 02-Feb-17
WENDLING BECK, GRESSENHALL FOR DTC	WENDTC2	TF9666816215			Last sampled 12-Dec-12
WENSUM SOUTH RAYNHAM DTC PROJECT	WENDTC20	TF8788124059			Last sampled 12-Dec-12
R.TUD WATERING FM.BR.	AN-TUD010		Monthly	Standard suite	Open (last sample 5 March 2020)

			179 samples between 2000 and 2020		
R.TUD STONE RD.BR.	AN-TUD020		Monthly 87 samples between 2000 and 2007	Standard suite	Closed (2007)
R.TUD HONINGHAM CHURCH FM.BR.	AN-TUD060		Monthly 118 samples between 2000 and 2020	Standard suite	Open (last sample 4 March 2020)
R.TUD COSTESSEY PARK BRIDGE	AN-TUD070		Weekly 779 samples between 2000 and 2022	Standard suite	Open (Last sample 26-May-22)
RSN0049 TRIB.R.WENSUM U/S ELSING HALL	RSN0049	TG0404115893			Last sampled 04-Feb-22
RSN0613 R.WENSUM D/S ATTLEBRIDGE	RSN0613	TG1291816356			Last sample 01-Jun-21
RSN0737 R.WENSUM NIGHT COMMON NEAR HEMPTON	RSN0737	TF9106429608			No info

Table A1: Environment Agency water quality monitoring sites (sources: Catchment Data Explorer, EA Analysis & Reporting Team – East Anglia (ENS))

River	Monitoring station	Environment Agency location ID	OS Grid Reference	Type
Wensum	Fakenham	E25940 34011	TF 91935 29337 (591934,329337)	River level Flow
Wensum	Fakenham Rainfall Gauge	E23392		Rainfall
Wensum	Bintree Mill Sluice Guist	E21726	TF9987224295 (599872,324295)	River level
Wensum	Swanton Morley	E23296 34014	TG 02018 18401 (602021,318399)	River level Flow
Wensum	Salle Gauge	E23420		Rainfall
Wensum	Costessey Mill Sluice	E19862 34004	TG1770012700 (617700,312700)	River level Flow
Wensum	Hellesdon Mill Sluice Norwich	E21581	TG1970010500 (619700,310500)	River level
Wensum	New Mills Sluice	E21621	TG2260009000 (622600,309000)	River level
Wensum	Carrow Bridge TS Norwich	E37212	TG2390007700 (623900,307700)	Tidal level
Wendling Beck	Wendling Beck	E22078	TF 95699 13198 (595702,313199)	River level
Wendling Beck	East Dereham Gauge	E21870		Rainfall
Wendling Beck	Gressenhall Sluice	E22078	TF 95699 13198 (595702,313199)	River level
Tud	Stone Road Farm	6096		River level
Tud	Costessey Park GS	E23081 34005	TG1700011300 (617000,311300)	River level Flow

Table A2: Environment Agency rainfall, river level and river flow monitoring sites

APPENDIX B: Suggested Wensum catchment monitoring sites for the citizen science programme

R. Wensum Reach 1 - Source to Tat Confluence DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
Hellhoughton Bridge	WensR1-7	AN-WEN020	Reach Sentinel Monitoring Site		showcase.guarding.jots	River Reach Surveillance Monitoring/West Raynham & South Raynham STW Monitoring/Monthly EA sampling/EA long term WQ Dataset
Gravel Pit Lane (Horningtoft)	WensR1-1		Catchment Monitoring		suiting.surviving.interest	Verify STW location – AW Lat-Long wrong?
Colkirk Road (Whissonsett)	WensR1-2		Horningtoft STW Discharge Monitoring/Catchment Monitoring		puddings.bedding.royally	
Whissonsett Road	WensR1-3		Catchment Monitoring		crossing.grab.assurance	
Pear Tree Corner	WensR1-4		Catchment Monitoring		stocks.conspired.lobster	

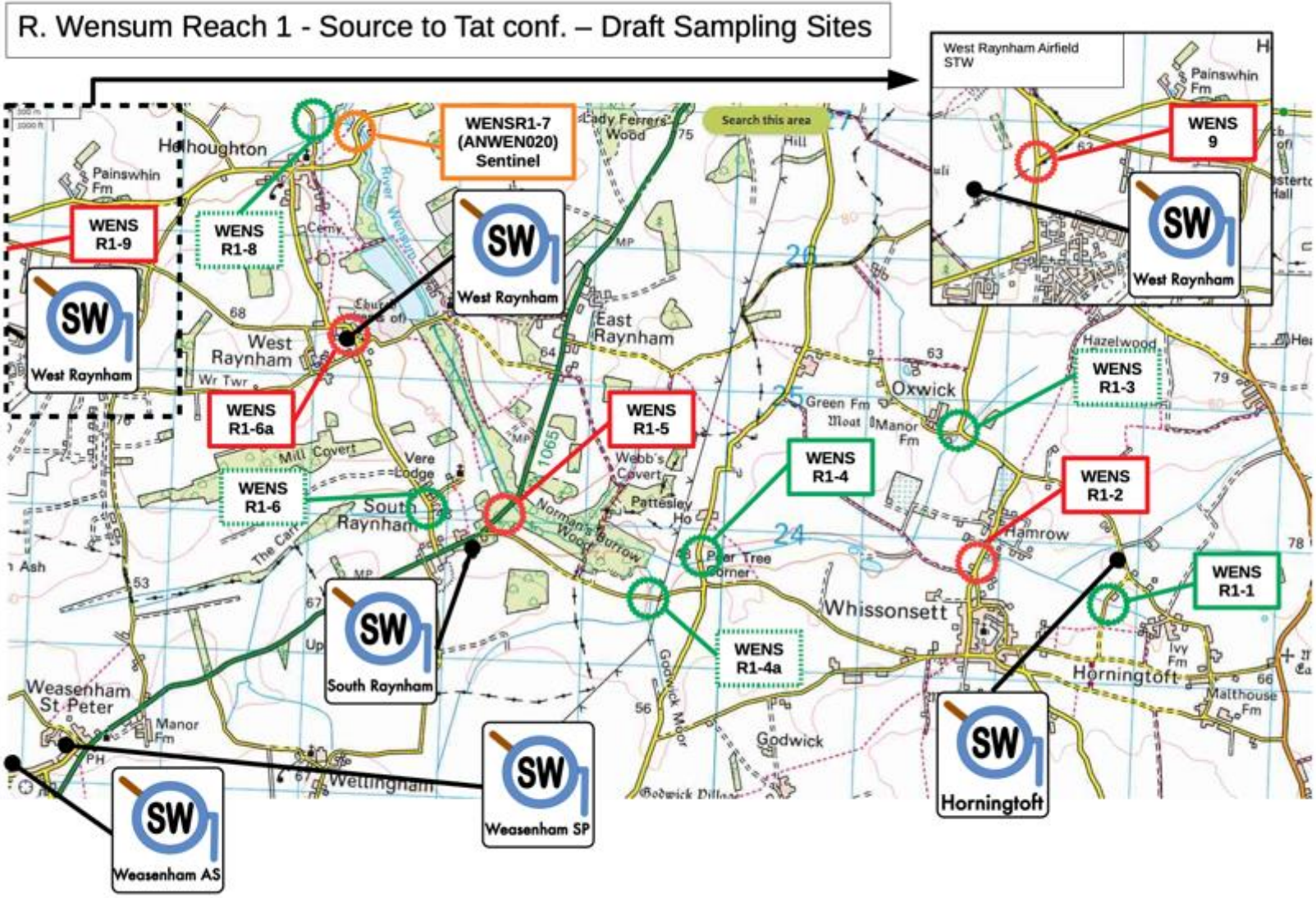
Raynham Road	WensR1-4a		Catchment Monitoring		free.hence.erupted	
Norman's Burrow Wood (A1065)	WensR1-5		South Raynham STW/Catchment Monitoring		deep.overdrive.grading	Locate STW discharge point & confirm
West Raynham Road (South Raynham)	WensR1-6		Catchment Monitoring		twinkling.equality.nerves	
West Raynham HSW	WensR1-6a		West Raynham STW Monitoring		florists.guessing.attending	Locate STW discharge point & confirm
Hellhoughton (The Common)	WensR1-8		West Raynham Airfield STW/Catchment Monitoring		cages.waistcoat.workbench	
West Raynham Road (West Raynham Airfield)	WensR1-9		West Raynham Airfield STW Monitoring		widen.assembles.launch	Locate STW discharge point & confirm

R. Wensum Reach 1 - Source to Tatterford Sewage Treatment Works					
			Location		
Name	**Treatment type:**		**Eastings Northings**	**W3W**	**Notes:**
Horningtoft Council Houses HSW	Secondary Biological Filtration	Works F.E. Outfall	52.779022 0.857997	? Verify location – still operational? printout.basic.shirts	AW – Operational? Verify STW location – AW Lat-Long is wrong F.E. Outfall location from EA WIMS
South Raynham HSW	Secondary Biological Filtration; 21 m3/d max; discharges into an infiltration point on land	Works F.E. Outfall		binder.lecturers.cave	AW; DWF = 21
West Raynham HSW	Secondary Biological Filtration; 9m3/d max	Works F.E. Outfall	52.794432 0.780976	florists.guessing.attending lushly.nosedive.knots	AW asset; F.E. Outfall location from EA WIMS; Descriptive permit; DWF = 9
West Raynham Airfield STW	Not known – SBF?; 96 m3/d max; 2 mg/l P permitted			packing.hoped.otters	Private works; P limit in permit from 2017
Weasenham St Peters HSW	Secondary Biological Filtration	Works	52.766503	however.slides.roughest	AW; DWF = 32

			0.745090		
Weasenham All Saints HSW	Secondary Biological Filtration	Works		drips.discussed.unscathed	AW; DWF = 17

Table B1: Suggested Wensum catchment monitoring sites for the citizen science programme

R. Wensum Reach 1 - Source to Tat conf. – Draft Sampling Sites

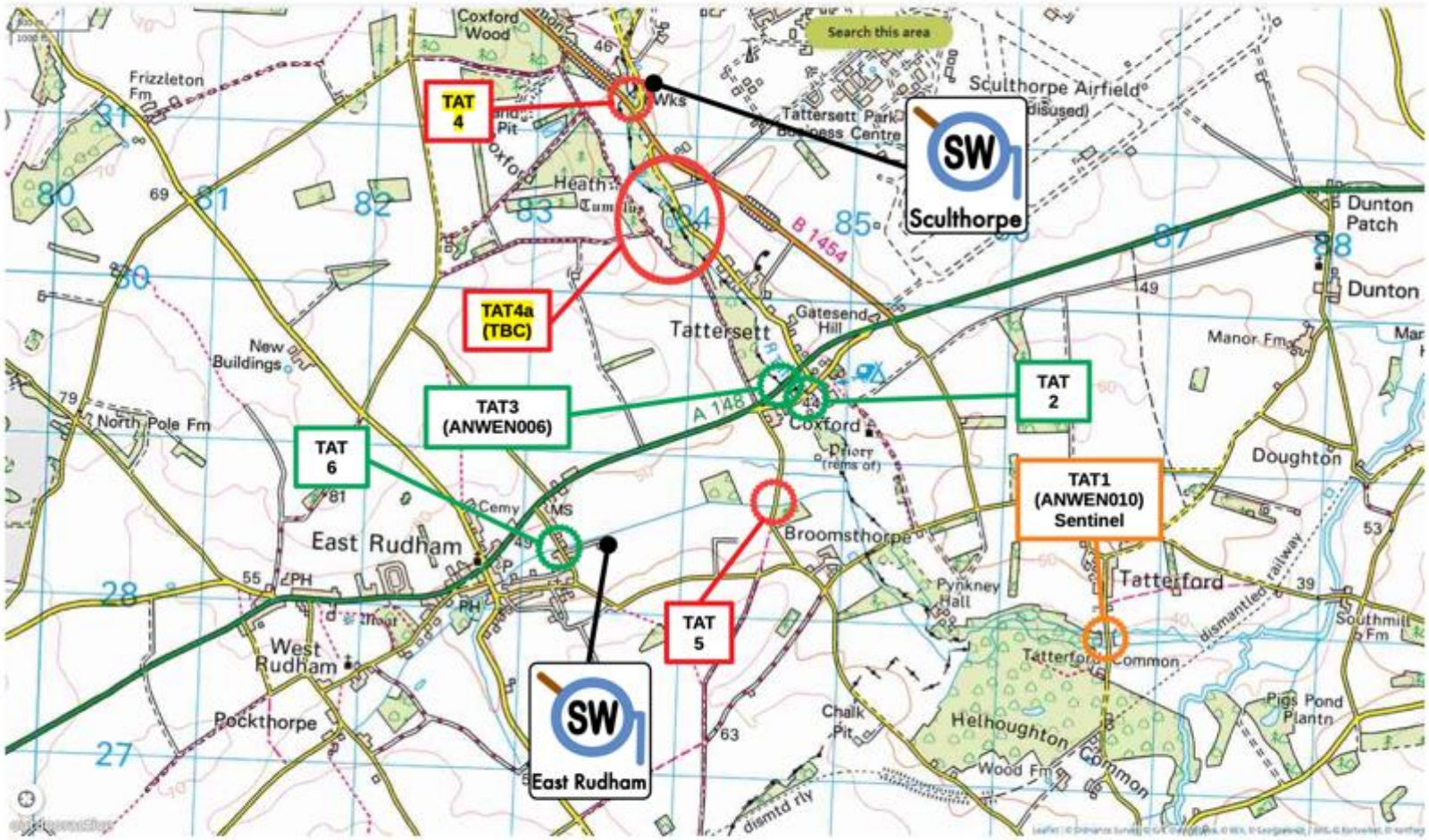


R. Tat Catchment - DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
R. Tat Tatterford Common	Wens-Tat1	AN-WEN010	Tat catchment surveillance site	586700 328000	excavate.vouch.uppermost	River Tat Surveillance monitoring/Monthly EA sampling/Long term EA WQ dataset
Coxford Bridge	Wens-Tat 2		Sculthorpe STW Monitoring/Catchment Monitoring		union.cadet.solar	Consider as replacement monitoring site if road safety an issue at Tat 3
R. Tat A148 Rd Br Coxford	Wens-Tat3	AN-WEN006	Sculthorpe STW Monitoring/Catchment Monitoring	584800 329500	loops.note.economics	No longer sampled by EA; Road safety issues?
Tattersett Business Park B1454	Wens-Tat4		Sculthorpe STW Monitoring Site		butter.squirts.overt	Poss. access/road safety issues? Alternative needed – u/s houses & poss. Septic tank inputs? At/V. close to source – no control site?

U/S Tattersett (Mill Lane (alternative site for Tat4 TBA)	Wens-Tat4a		Sculthorpe STW Monitoring Site			Find safer site u/s Tattersett houses to monitor STW impact (but u/s any possible septic tank inputs?)
Abbey Lane Bridge (Broomsthorpe)	Wens-Tat5		East Rudham STW Monitoring Site		trappings.flock.stunning	
Eye Lane Bridge (East Rudham)	Wens-Tat6		Catchment monitoring/East Rudham STW Control Site		umbrella.bridges.waggled	

R. Tat Catchment - Sewage Treatment Works					
			Location		
Name	**Treatment type:**		**Eastings Northings**	**W3W**	**Notes:**
Sculthorpe RAF Camp STW	Crude Sewage Activated Sludge + Phosphorus removal via Chemical dosing	Works F.E. Outfall	52.847897 0.724974 52.847091 0.720476	entrust.ranged.flagpole sits.generally.sunflower	AW asset F.E. Outfall location from EA WIMS; DWF = 300
East Rudham HSW	Secondary Biological Filtration; closed in 2012 and effluent pumped to other works	Works F.E. Outfall	 52.822779 0.721925	octagonal.saloons.blanks maple.broadcast.stag	AW; Closed in 2012 F.E. Outfall location from EA WIMS

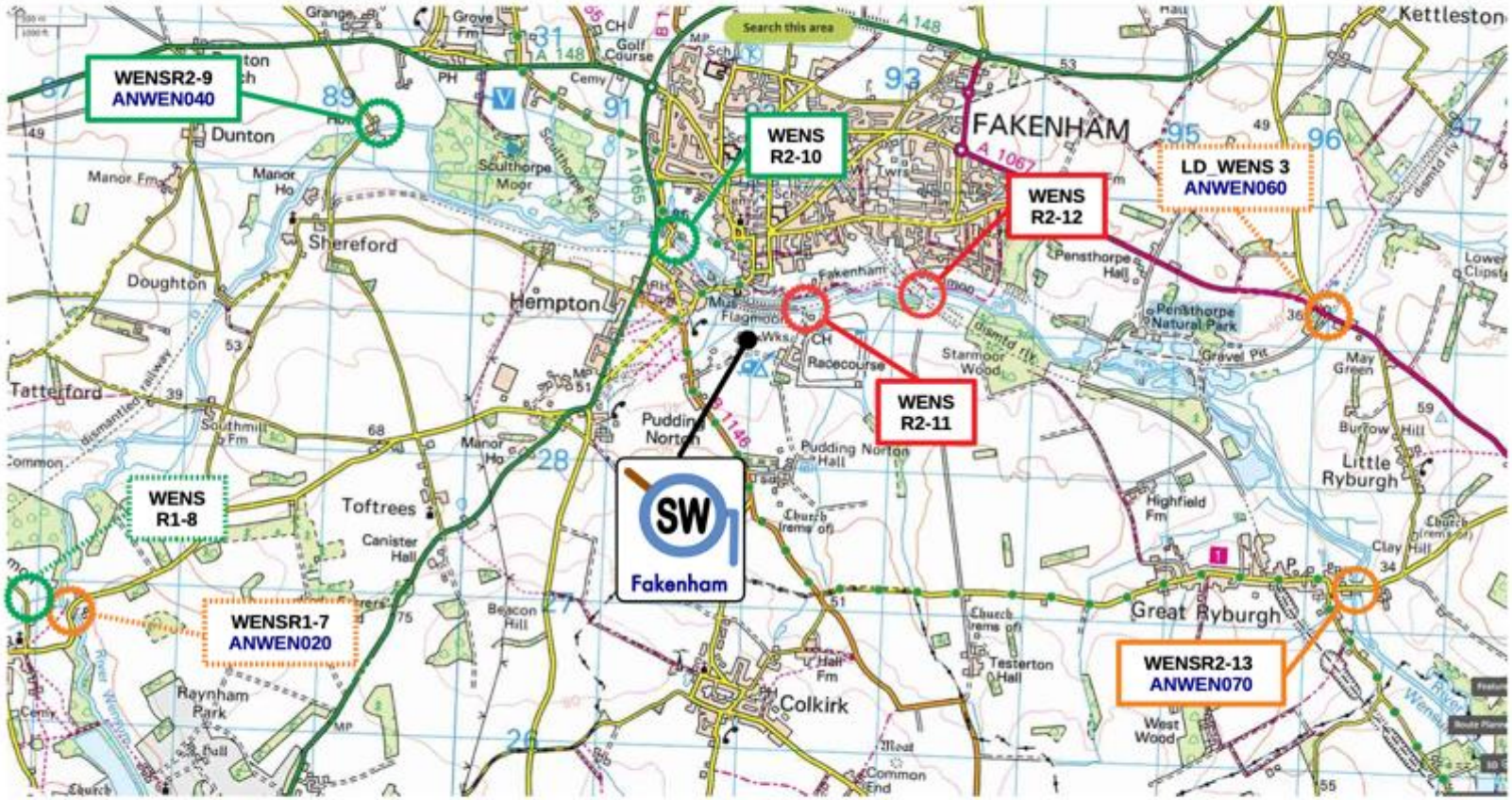
R. Tat Catchment – Draft Sampling Sites



R. Wensum Reach 2 - Tat Confluence to Gt Ryburgh DRAFT Sampling sites			Location			
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
Bridge Road (Great Ryburgh)	WensR2-13	AN-WEN070	Reach Sentinel Monitoring Site	596400 327400	bead.range.marked	River Reach Surveillance Monitoring/Monthly EA sampling/EA long term WQ Dataset
Sculthorpe Mill	WensR2-9	AN-WEN040	Catchment Monitoring	589300 330400	gain.cycle.seriously	Monthly EA sampling/EA long term WQ Dataset/EA fish survey site just U/S
Gogg's Mill Road	WensR2-10		Cathment monitoring/Fakenham STW Control Site		spoiler.clashing.bulbs	Tighter control site for STW monitoring than AN-EA040 Sculthorpe Mill; Limited parking U/S Fakenham Mill/EA fish survey site
Fakenham Racecourse Drain	WensR2-11		Fakenham STW Monitoring Site		replaces.ballpoint.early	Seek access permission if required & verify STW discharge point
Great Eastern Railway Walk	WensR2-12		Fakenham STW Monitoring Site/Catchment Monitoring		pumpkin.hobbyists.workers	Park at Plantation Road to access footpath & shortest walk to site (W3W: dwarf.addicted.packages)

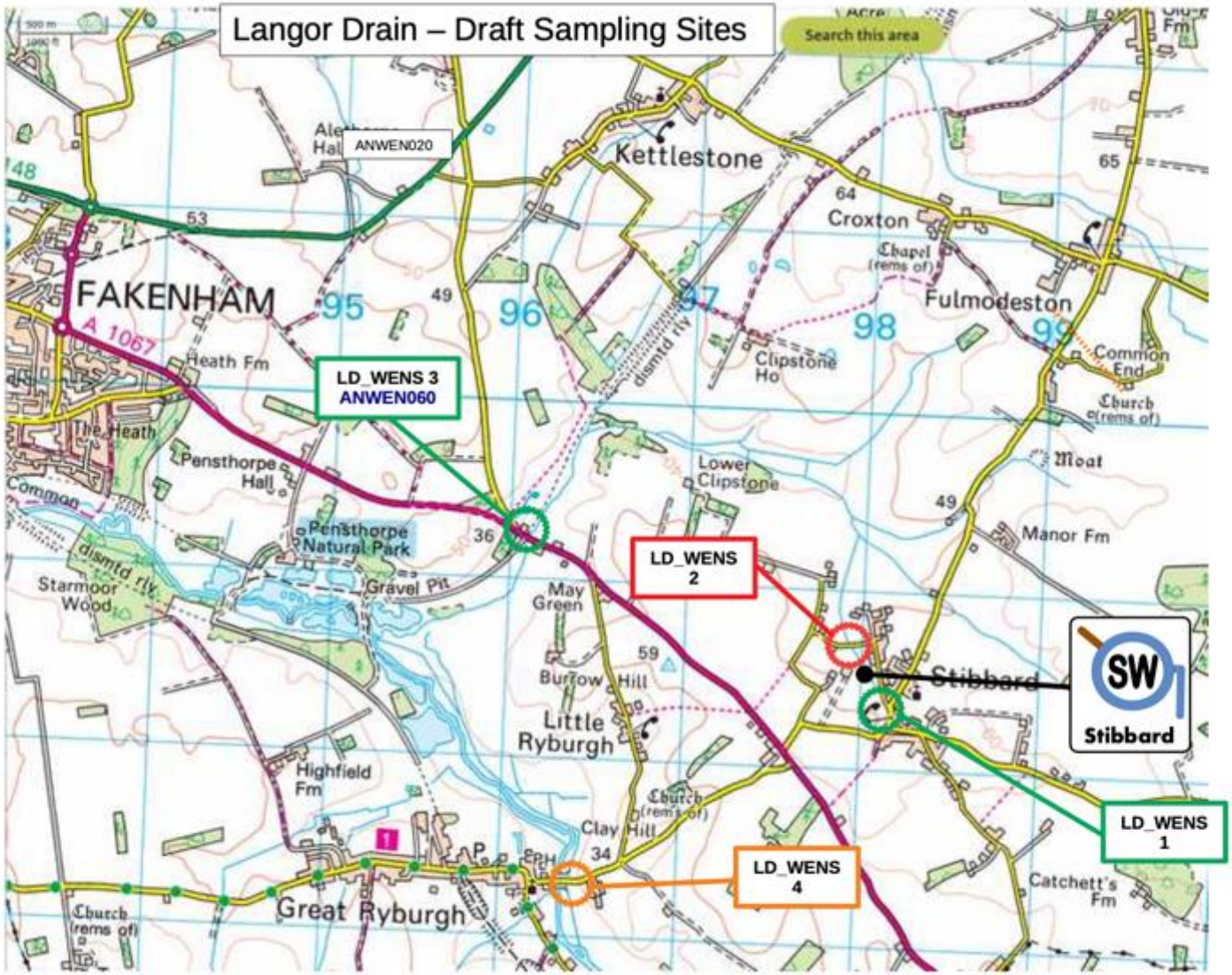
R. Wensum Reach 2 - Tat Confluence to Gt Ryburgh Sewage Treatment Works					
			Location		
Name	**Treatment type:**		**Eastings Northings**	**W3W**	**Notes:**
Fakenham STW (Old and New)	Secondary Biological Filtration; Phosphorus removal via Chemical dosing	Works F.E. Outfall	52.823185 0.847528 52.823377 0.849626	chats.marmalade.navy enrolling.remainder.harvest	AW asset; F.E. Outfall location from EA WIMS; DWF = 3300; FFT Flow band = <8866 m3/d

R. Wensum Reach 2 - Tat to Gt Ryburgh – Draft Sampling Sites



Langor Drain DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
Gt Ryburgh Bridge	LD_Wens4		Sentinel site		storming.nods.investor	Tributary Sentinel site
Langor Bridge, Fakenham Road A1067 (Langor Drain)	LD_Wens3	AN-WEN060	Catchment Monitoring Site		unfilled.targeted.plank	Catchment Monitoring/Monthly EA sampling/EA long term WQ Dataset
Fulmodeston Road, Stibbard (Langor Drain)	LD_Wens1		Catchment monitoring/Stibbard STW Control		providing.lights.conjured	
Moor End Lane, Stibbard (Langor Drain)	LD_Wens2		Stibbard STW Monitoring		unique.sings.decently	

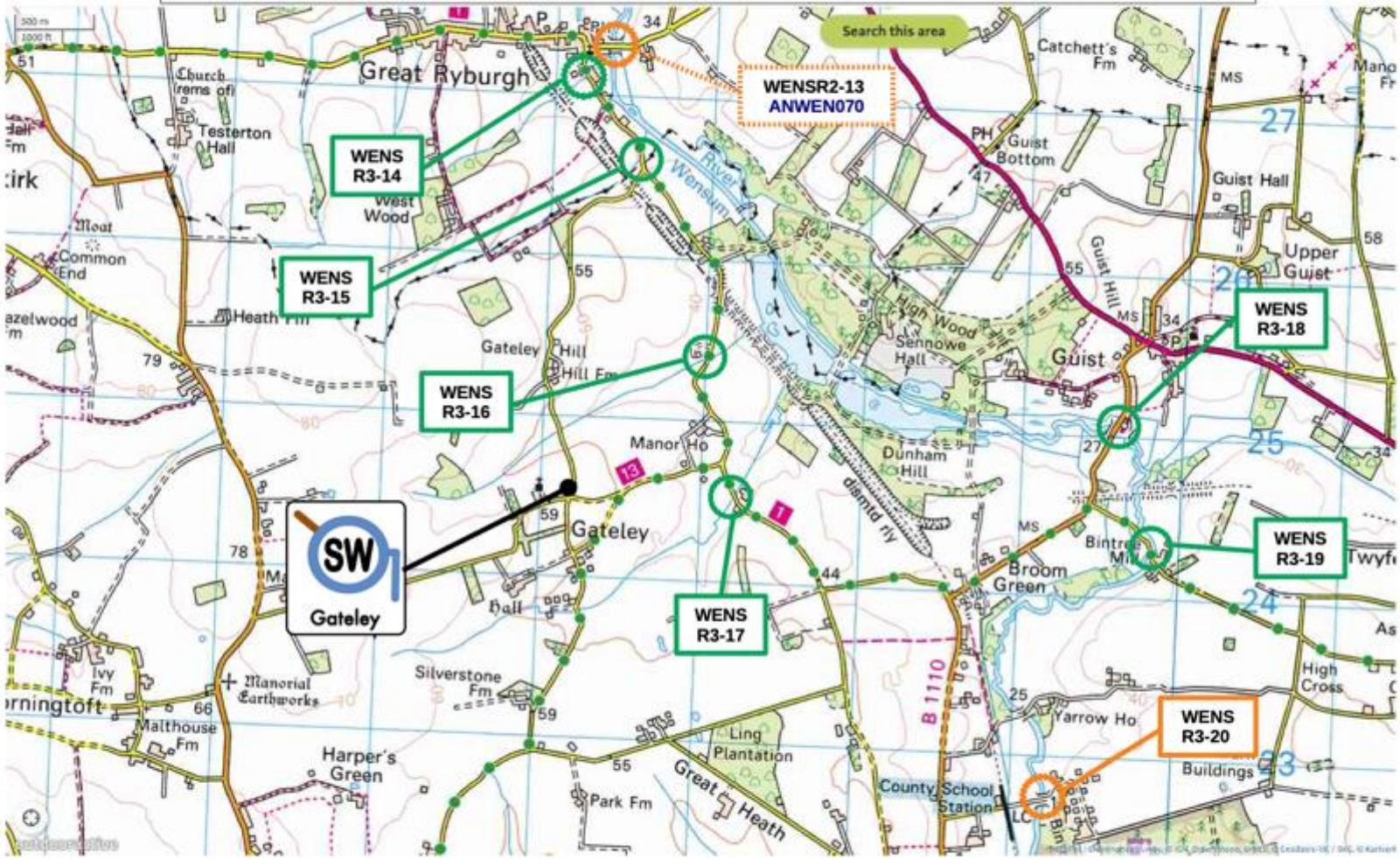
Langor Drain Sewage Treatment Works					
			Location		
Name	**Treatment type:**		**Eastings Northings**	**W3W**	**Notes:**
Stibbard – Moors End Road HSW	CSAS – Crude Sewage Activated Sludge	Works F.E. Outfall	52.817663 0.936819 52.817993 0.93759	half.shudders.wounds supposes.player.critic	AW asset; F.E. Outfall location from EA WIMS; DWF = 80


Langor Drain – Draft Sampling Sites
Search this area
ANWEN020
LD_WENS 3
ANWEN060
LD_WENS
2
LD_WENS
1
LD_WENS
4
SW
Stibbard
FAKENHAM
A 1067
Heath Fm
The Heath
Common
Pensthorpe
Hall
Pensthorpe
Natural Park
Gravel Pit
Starmoor
Wood
dismtd rly
Kettlestone
Croxton
Chapel
(rems of)
Fulmodeston
Clipstone
Ho
dismtd riv
Common
End
Church
(rems of)
Lower
Clipstone
Moat
Manor Fm
May
Green
Burrow
Hill
Little
Ryburgh
Highfield
Fm
Clay
Hill
Church
(rems of)
Great Ryburgh
Church
(rems of)
Stibbard
Catchett's
Fm

R. Wensum Reach 3 - Gt Ryburgh to County School DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
County School Station	WensR3-20	AN-WEN102	River Reach Sentinel Monitoring/North Elmham STW Control Site		homecare.brief.openly	River Reach Surveillance Monitoring/Monthly EA sampling/EA long term WQ Dataset
Mill Road (North)	WensR3-14		Catchment Monitoring		bolsters.typhoon.awesome	
Mill Road (South)	WensR3-15		Catchment Monitoring		essay.last.flattered	
Gateley Hill Trib	WensR3-16		Catchment Monitoring		gathering.intrigued.advantage	Confirm location & discharge point of Gately STW
Gateley Trib	WensR3-17		Catchment Monitoring		delved.boast.batches	Confirm location & discharge point of Gately STW
Guist Bridge B1110	WensR3-18		Catchment Monitoring/Foulsham Trib Control Site		mandates.images.stance	Subject to road safety assessment
U/S Bintree Mill	WensR3-19		Catchment Monitoring/Foulsham Trib Monitoring		decreased.surprised.fewer	

R. Wensum Reach 3 - Gt Ryburgh to County School Sewage Treatment Works					
			Location		
Name	**Treatment type:**		**Eastings Northings**	**W3W**	**Notes:**
Gateley Council Houses HSW	Secondary Biological Filtration	Works	52.782409 0.907747	emptied.scandals.undercuts	AW asset; F.E. Outfall location from EA WIMS; DWF = 4.6
		F.E. Outfall	52.782399 0.907754	leaves.lines.squirts	

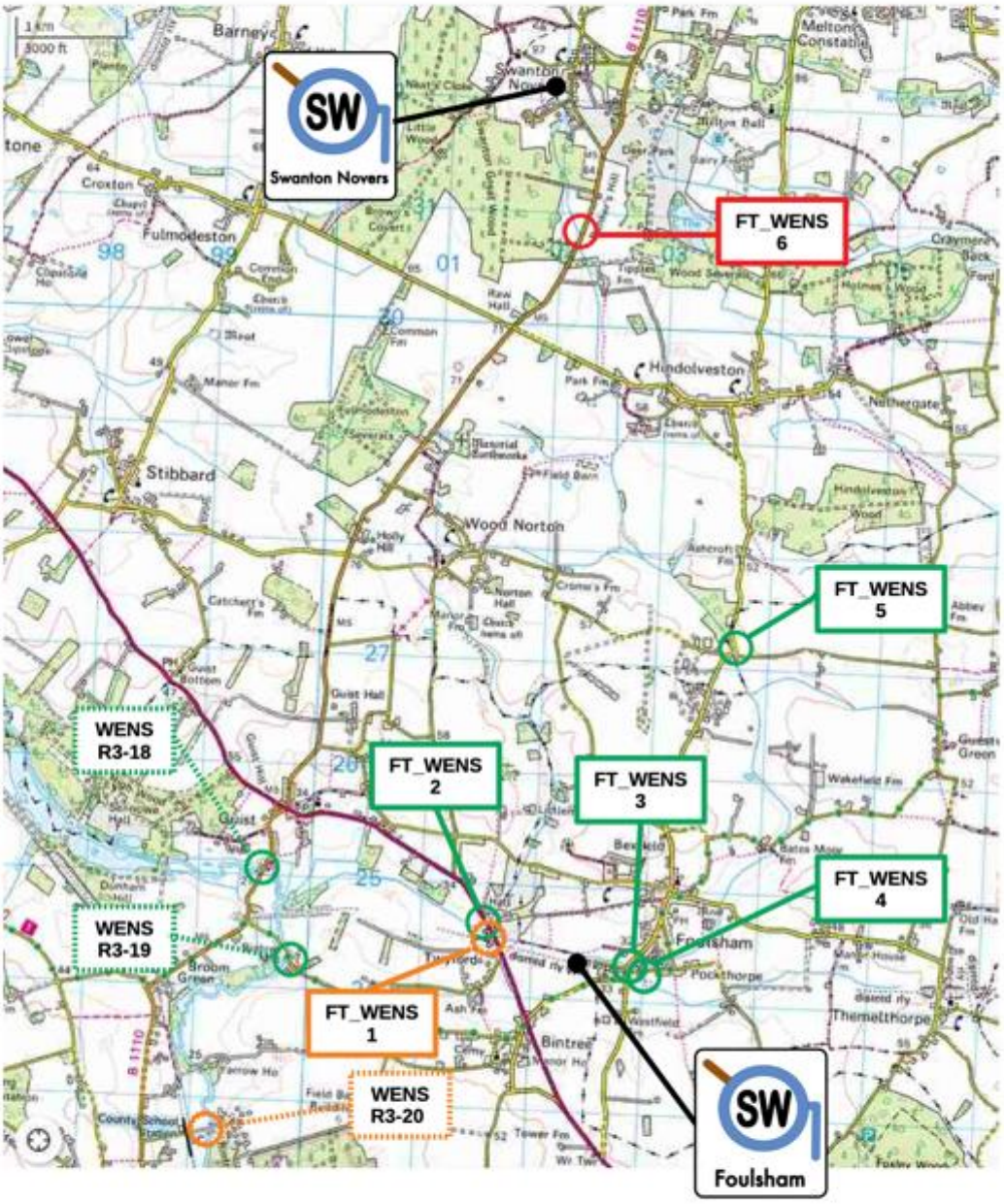
R. Wensum Reach 3 - Gt Ryburgh to County School – Draft Sampling Sites



Foulsham Tributary DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
Twyford Bridge A1067	FT_Wens1		Tributary Sentinel Monitoring Site/Foulsham STW Monitoring		punctuate.item.formally	Access poor between Twyford and Wensum confluence to establish closer site; assess road safety
St Marys Church A1067 (Wood Norton Tributary)	FT_Wens2		Catchment Monitoring		blushed.kiosk.smooth	Assess road safety
Station Road Bridge (Foulsham)	FT_Wens3		Foulsham STW Control Site/Catchment Monitoring		gathers.extremely.brilliant	
Gunn Street Bridge (Foulsham)	FT_Wens4		Catchment Monitoring		tidal.nerve.full	
Guestwick Road Bridge (Foulsham airfield)	FT_Wens5		Catchment Monitoring		narrow.sheepish.increases	
Bunkers Hill B1110	FT_Wens6		Swanton Novers STW Monitoring		lavished.waddle.sway	Assess road Safety

Foulsham Tributary Sewage Treatment Works					
			Location		
Name	**Treatment type:**		**Eastings Northings**	**W3W**	**Notes:**
Foulsham Station Road STW	Secondary Activated Sludge & Phosphorus removal via chemical dosing	Works F.E. Outfall	52.778402 1.000018 52.778242 1.002387	seaside.teaspoons.cheetahs guises.decency.pampered	AW asset; F.E. Outfall location from EA WIMS; DWF = 299; FFT Flow = <769
Swanton Novers HSW	Secondary Biological Filtration	Works F.E. Outfall	52.848988 0.996716 52.848675 0.998038	enchanted.surfed.shorthand bonfires.ordinary.cooked	AW asset; F.E. Outfall location from EA WIMS

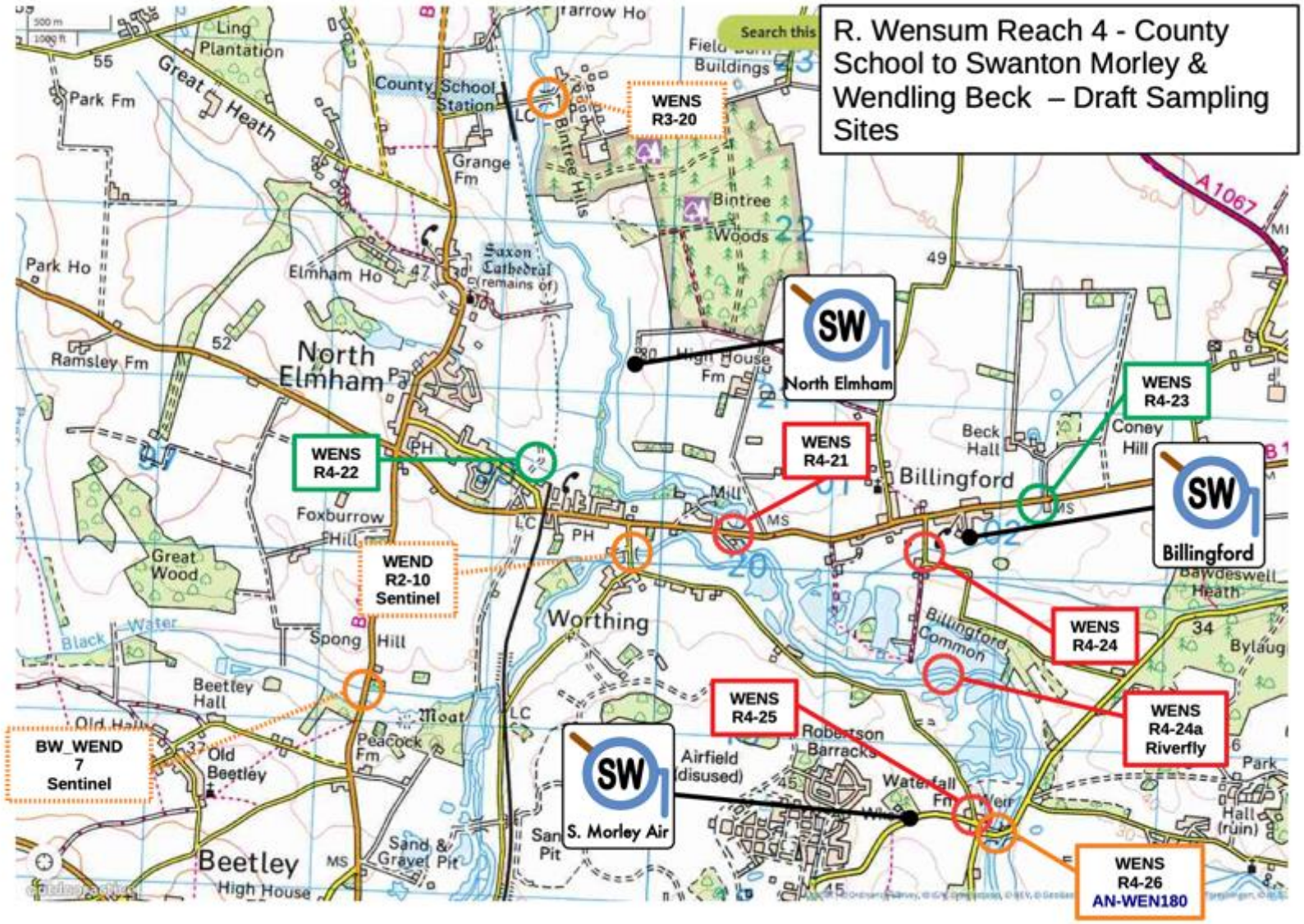
Foulsham Tributary – Draft Sampling Sites



R. Wensum Reach 4 - County School to Swanton Morley DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
Swanton Morley Weirs	WensR4-26	AN-WEN180	River Reach Sentinel Monitoring/Swanton Morley Airfield STW Control Site	52.726361 0.991413	rudder.softest.snacking	River Reach Surveillance Monitoring/Monthly EA sampling/EA long term WQ Dataset
Billingford Bridge B1145	WensR4-21		North Elmham STW Monitoring/Catchment Monitoring		motorist.best.each	Assess road safety – possible to establish site at Mill?
Eastgate Street (North Elmham)	WensR4-22		Catchment Monitoring		commoners.dazzling.rips or scouting.premises.adventure?	Need to establish landowner & access permission to sample this tributary – is this possible at Elmham Mill?
Beck Hall B1145 (Billingford)	WensR4-23		Billingford STW Control Site/Catchment Monitoring		binds.voting.accusing	
Holl Lane (Billingford)	WensR4-24		Billingford STW Monitoring/Catchment Monitoring		breathy.crate.videos	

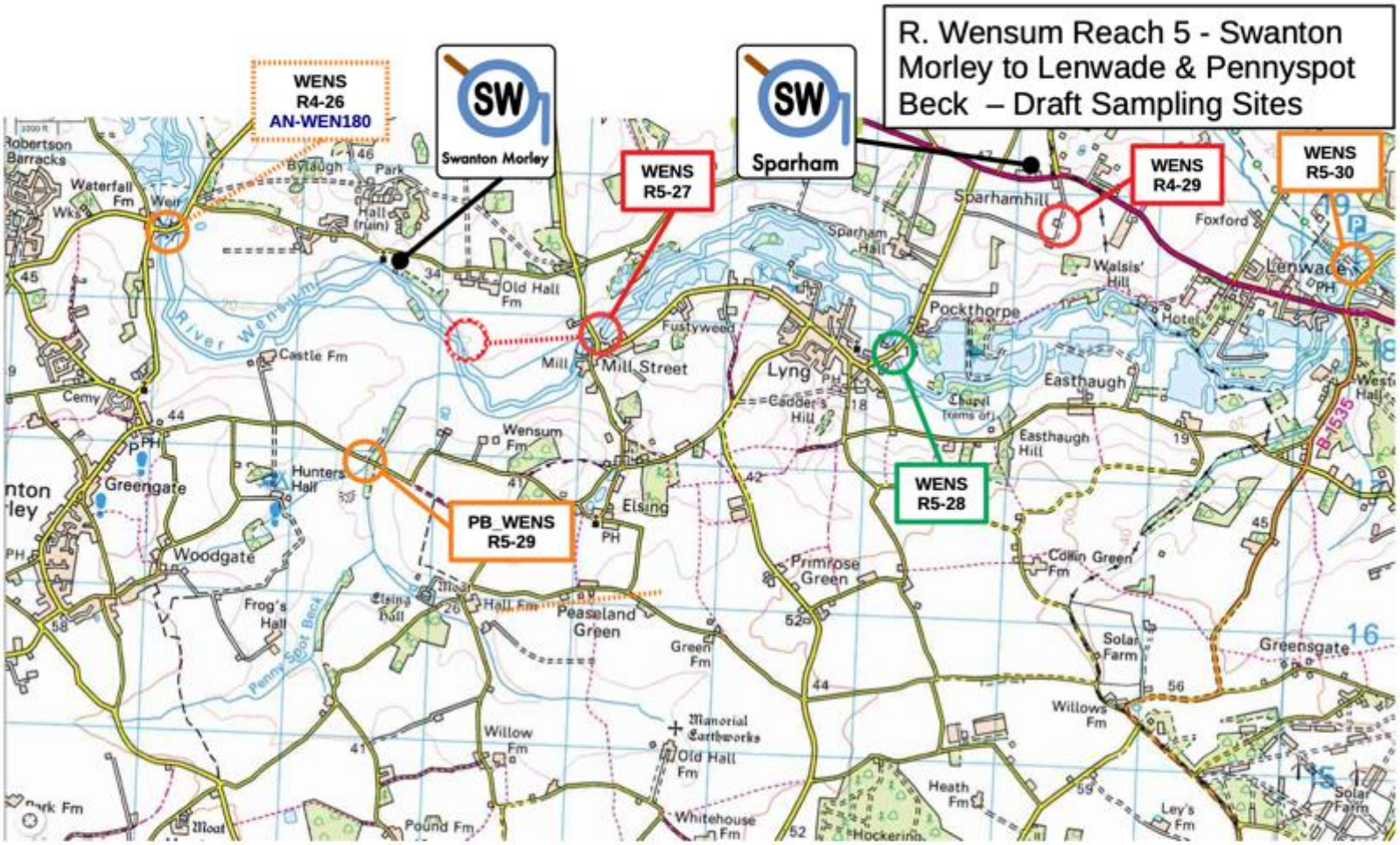
Norfolk Flyfishers Holkham Lake	WensR4-24a		Cathment monitoring/RiverFly site		trimmer.sunbeam.prune	Links to existing Riverfly monitoring site & CS monitoring
Swanton Morley Airfield STW	WensR4-25		Swanton Morley Airfield STW Monitoring		crowned.universal.meaty	Establish STW discharge point & suitable sampling location

R. Wensum Reach 4 - County School to Swanton Morley Sewage Treatment Works		Location		
Name	**Treatment type:**	**Eastings Northings**	**W3W**	**Notes:**
North Elmham STW	Secondary Biological Filtration & Phosphorus removal via chemical dosing	52.752362 0.959100	engage.grips.convinces	AW; DWF = 262; FFT Flow = <682
Billingford HSW	Secondary Biological Filtration	52.742642 0.988076	ruled.haircuts.sheet	AW
Swanton Morley Airfield STW	Secondary Biological Filtration; discharges to lagoon and soakaway on land		nosedive.offhand.known	AW; DWF = 227

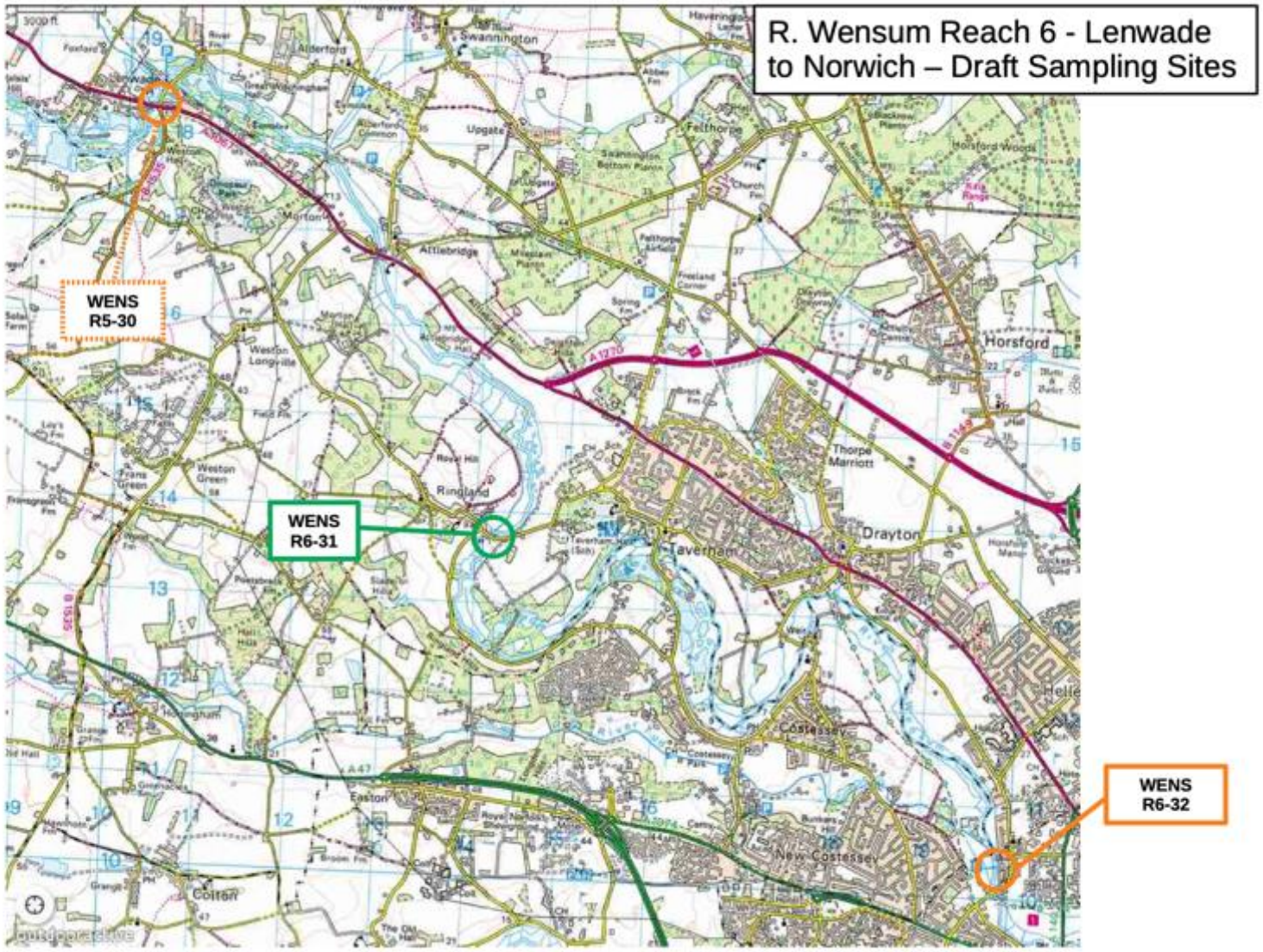

R. Wensum Reach 4 - County School to Swanton Morley & Wendling Beck – Draft Sampling Sites
WENS R3-20
WENS R4-23
WENS R4-21
WENS R4-22
WENS R4-24
WENS R4-25
WENS R4-24a Riverfly
WENS R4-26 AN-WEN180
WEND R2-10 Sentinel
BW_WEND 7 Sentinel
North Elmham
Billingford
S. Morley Air
Ling Plantation
Great Heath
Park Fm
County School Station
Grange Fm
Bintree Hills
Bintree Woods
Park Ho
Elmham Ho
Saxon Cathedral (remains of)
Ramsley Fm
North Elmham
Foxburrow Hill
Great Wood
Black Water
Spong Hill
Beetley Hall
Old Beetley
Peacock Fm
Moat
Beetley
High House
Sand & Gravel Pit
Worthing
Airfield (disused)
Robertson Barracks
Waterfall Fm
Weir
Beck Hall
Coney Hill
Billingford Common
Bawdeswell Heath
Bylaug
Park
Hall (ruin)
A1067

R. Wensum Reach 5 - Swanton Morley to Lenwade DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
Marriott's Way (Porter's Lane, Lenwade)	WensR5-30		River Reach Sentinel Monitoring/Sparham STW Monitoring Site		mills.even.occupy	Adjacent to Blackwater Drain Sentinel site BW_Wens-7; Both rivers easily accessible from Marriot's Way car park
Elsing Lane Bridge (D/S Elsing Mill) or Old Hall Farm (if access possible)	WensR5-27		River Reach Sentinel Monitoring/Swanton Morley STW Monitoring Site		snails.foil.standards or Old Hall Farm at burying.novels.relate	Ideally sampling should be u/s Pennyspot Beck confluence – investigate possibility of access at Old Hall Farm or other
Lyng Road Bridge	WensR5-28		Catchment Monitoring/Sparham STW Control Site		scaffold.hopes.grinning	
Sparham Hill A1067	WensR5-29		Sparham STW Monitoring			
Elsing Road Bridge (Pennyspot Beck)	PB_WensR5-29		Tributary Sentinel Monitoring Site		tucked.rely.scare	

Wensum Reach 5 - Swanton Morley to Lenwade Sewage Treatment Works					
			Location		
Name	**Treatment type:**		**Eastings Northings**	**W3W**	**Notes:**
Bylaugh Near Church STW (Swanton Morley)	Secondary Biological Filtration	Works	52.724873 0.979455	newsstand.starfish.obstruction	AW asset; DWF = 690; FFT Flow = <1900 m3/d
Sparham Norwich Road HSW	Secondary Biological Filtration	Works F.E. Outfall	52.729948 1.079941 52.730112 1.080168	steams.bring.unclaimed cheeks.polka.contemplate	AW asset; DWF = 5


R. Wensum Reach 5 - Swanton Morley to Lenwade & Pennyspot Beck – Draft Sampling Sites
WENS R4-26 AN-WEN180
SW Swanton Morley
WENS R5-27
SW Sparham
WENS R4-29
WENS R5-30
WENS R5-28
PB_WENS R5-29
River Wensum
Penny Spot Beck
Swanton Morley
Sparham
Lenwade
Pockthorpe
Lyng
Mill Street
Old Hall Fm
Castle Fm
Wensum Fm
Hunters Hall
Greengate
Woodgate
Elsing
Primrose Green
Peasaland Green
Green Fm
Willow Fm
Manorial Earthworks
Old Hall Fm
Whitehouse Fm
Pound Fm
Heath Fm
Easthaugh
Easthaugh Hill
Walsis' Hill
Foxford
Sparham Hill
Colkin Green Fm
Solar Farm
Greensgate
Willows Fm
Ley's Fm
Waterfall Fm
Bylaugh Park
Hall (ruin)
Frog's Hall
Elsing Hall
Hall Fm
Cadder's Hill
Chapel (rems of)
Fustyweed
Mill
Cemy
Robertson Barracks

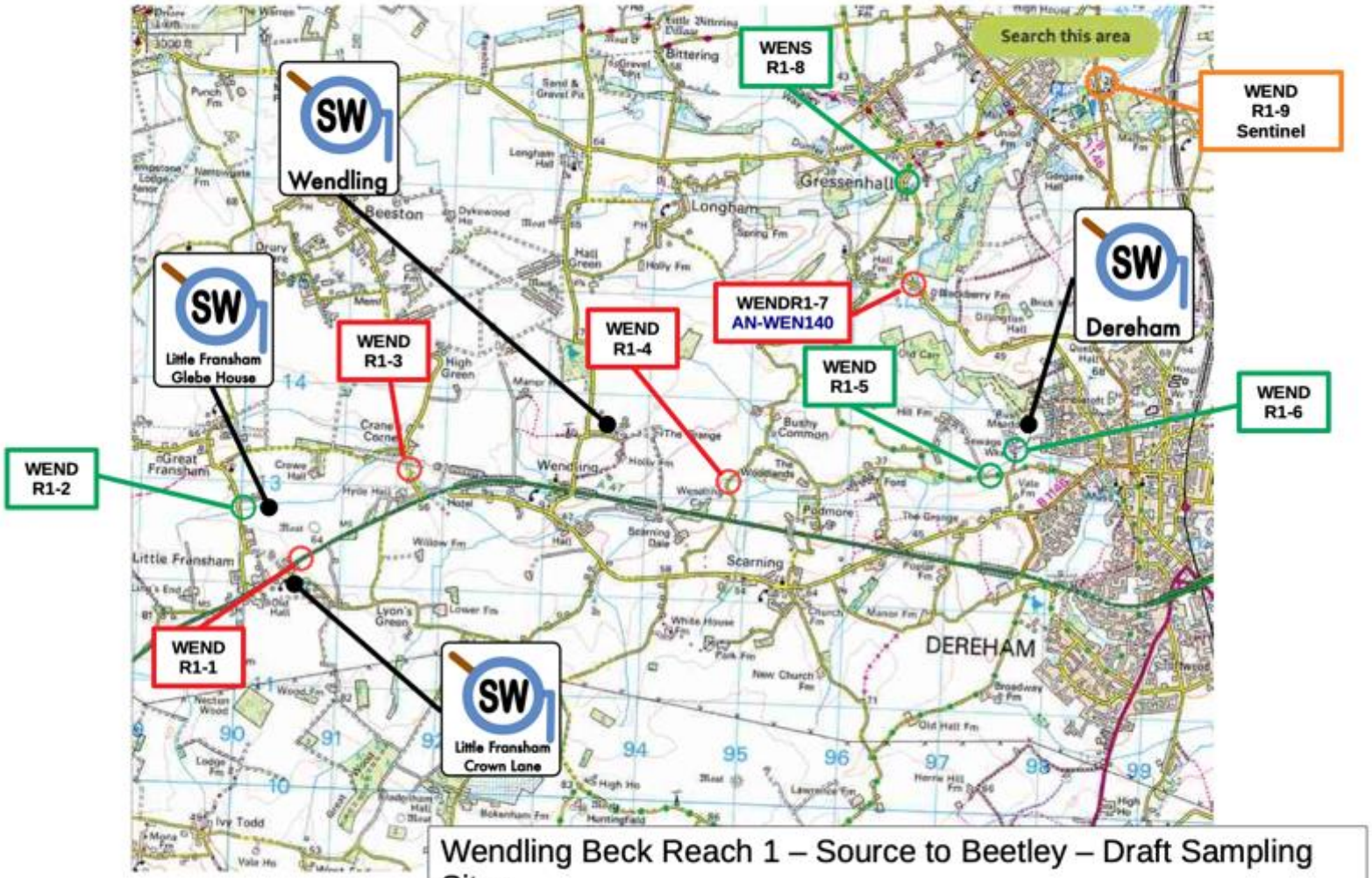
R. Wensum Reach 6 – Lenwade to Norwich DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
Hellesdon Mill Lane	WensR6-32		River Reach Sentinel Monitoring		hung.spice.family	
Ringland River Green	WensR6-31		Catchment Monitoring		departure.crowd.press	


R. Wensum Reach 6 - Lenwade to Norwich – Draft Sampling Sites
WENS R5-30
WENS R6-31
WENS R6-32
Horsford
Drayton
Taverham
Costessey
New Costessey
Attlebridge
Swannington
Ringland
Colton

Wendling Beck Reach 1 - Source to Beetley DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
Holt Road B1110	WendR1-9		River Reach Sentinel Monitoring		combines.tolerates.reaction	Assess road safety; if necessary move upstream to Hoe Rough B1146
A47 near Crown Lane	WendR1-1		Little Fransham Crown Lane STW Control Site		abstracts.renting.smoothly	Confirm discharge point & suitable sampling location inc. road safety
Station Road (Little Fransham)	WendR1-2		Little Fransham Glebe House STW Control Site		into.swinging.haystack	
Beeston Road Bridge	WendR1-3		Catchment Monitoring/Combined Little Fransham STWs Monitoring		judges.engine.contoured	Investigate access further up Little Fransham arm @ Dereham Lane
D/S Wendling Carr	WendR1-4		Catchment Monitoring/Wendling STW Monitoring		exotic.headstone.demand	
Rushmeadow Road Bridge	WendR1-5		Dereham STW Control Site/Catchment Monitoring		oaks.desiring.outlast	

NWT Rushmeadow	WendR1-6		Dereham STW Control Site/Catchment Monitoring		wins.renders.nudge	
Gressenhall Road Bridge	WendR1-7	AN-WEN140	Dereham STW Monitoring Site		formally.drizzly.relief	
Bridge Street (Gressenhall)	WendR1-8		Catchment Monitoring		bypassed.seasonal.flops	

Wendling Beck Reach 1 - Source to Beetley Sewage Treatment Works		Location		
Name	**Treatment type:**	**Eastings Northings**	**W3W**	**Notes:**
Little Fransham Crown Lane HSW	Secondary Biological Filtration	52.672287 0.816842	opposites.dated.sprinting	AW; DWF = 3
Little Fransham Glebe House (Station Road) HSW	Secondary Biological Filtration	52.678820 0.810604	direct.oiled.parsnip	AW
Dereham Rushmeadow Road STW	Secondary Biological Filtration & Phosphorus removal via chemical dosing	52.685448 0.923199	instincts.knees.riverside	AW; DWF = 3769; FFT Flow = <9853 m3/d
Wendling Grange Road HSW	Secondary Biological Filtration	52.685483 0.862825	pricing.boast.awake	AW; DWF = 5.3

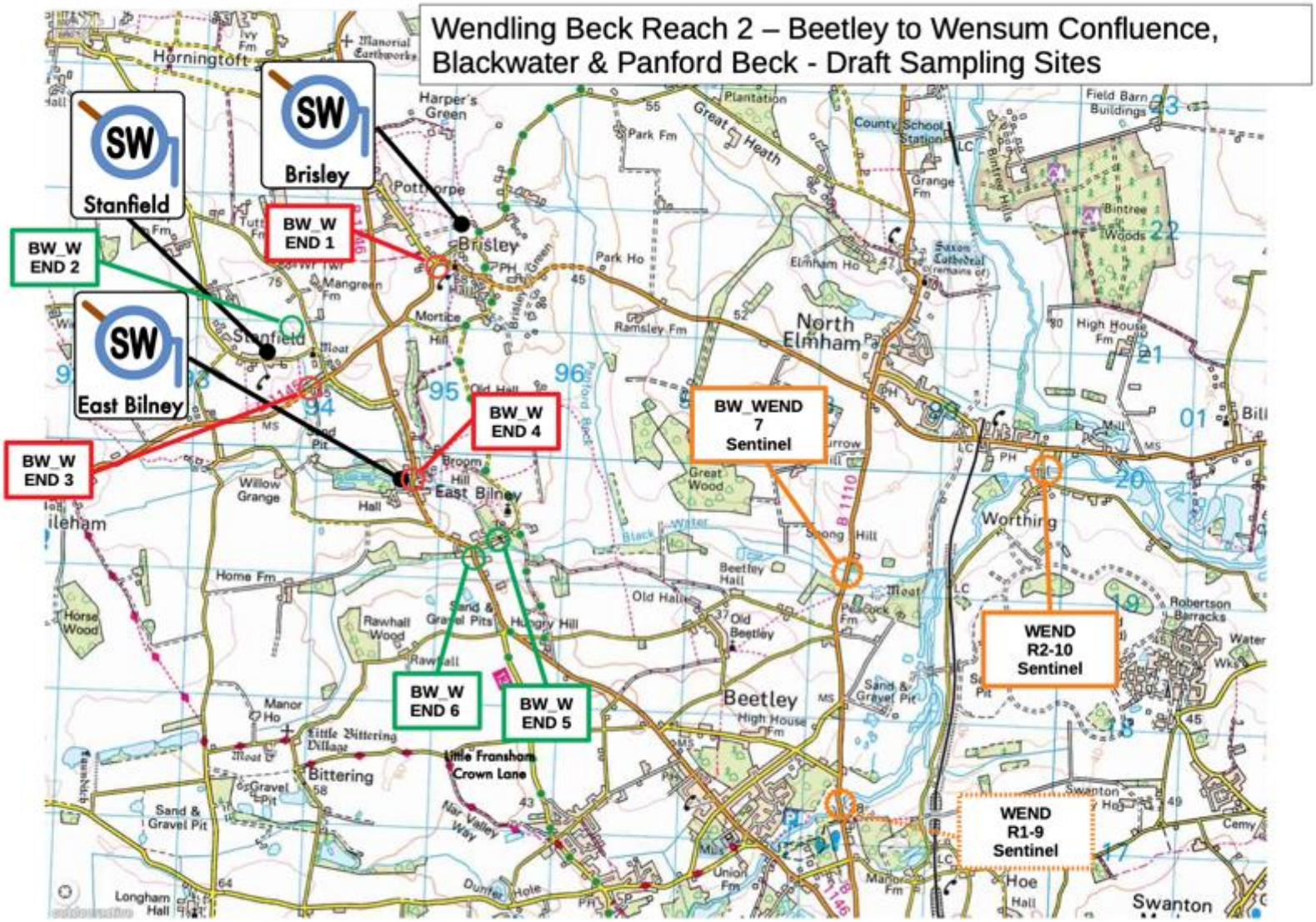


Wendling Beck Reach 1 – Source to Beetley – Draft Sampling Sites

Wendling Beck & Blackwater Reach 2 - Source to Beetley DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
D/S Worthing Mill	WendR2-10		River Reach Sentinel Monitoring		brownish.desktops.cases	
B1145 Brisley	BW_Wend-1		Brisley STW Monitoring		fool.those.inert	Confirm discharge point & suitable sampling location inc. road safety
Off Back Lane (Stanfield)	BW_Wend-2		Stanfield STW Control Site		reservoir.laces.harmonica	Need to contac landowner & obtain access permission for track crossing stream at this point
B1145 Stanfield	BW_Wend-3		Catchment Monitoring/Stanfield STW Monitoring		trudges.backdrop.units	Assess road safety
B1146 Fakenham Road (East Bilney)	BW_Wend-4		Catchment Monitoring/East Bilney STW Monitoring		polices.tune.marine	
Church Road (East Bilney)	BW_Wend-5		Catchment Monitoring		recap.aged.outfitter	

Beck Farm B1146	BW_Wend-6		Catchment Monitoring		apples.storage.regress	Assess road safety
Spong Hill B1110 **Or** **Blackwater u/s Wendling Beck confluence (Old Railway line)**	BW_Wend-7		Tributary Sentinel Monitoring		shampoo.shoulders.wriggled puncture.stuffing.encoder	Assess road safety

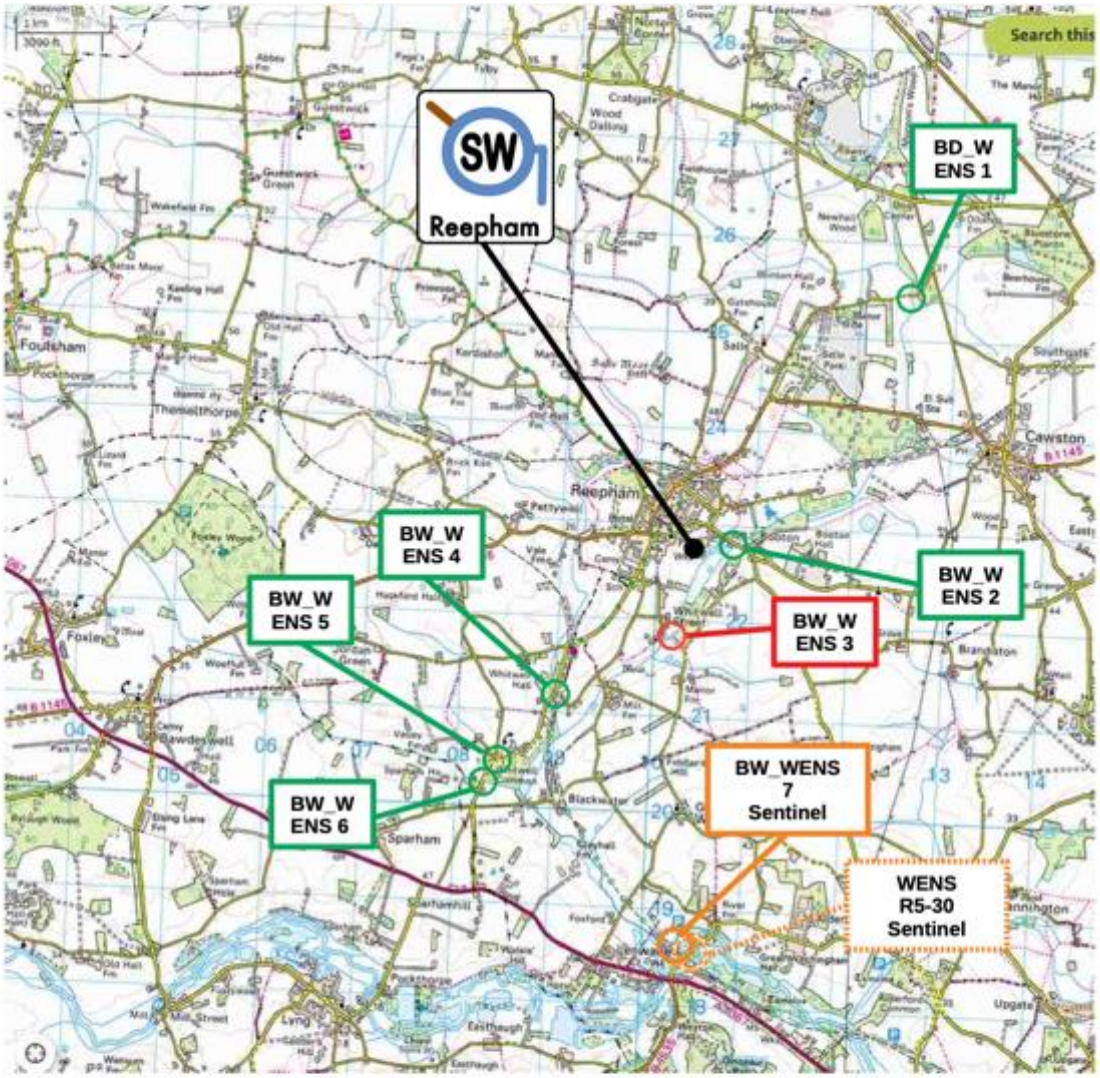
Wendling Beck & Blackwater Reach 2 - Source to Beetley Sewage Treatment Works		Location		
Name	**Treatment type:**	**Eastings Northings**	**W3W**	**Notes:**
Brisley HSW	Secondary Biological Filtration	52.757877 0.888621	wobbling.sculpting.riches	AW; DWF = 3.9
Stanfield Church Lane STW HSW	Secondary Biological Filtration	52.750127 0.867063	worldwide.spinning.sheep	AW; DWF = 4
East Bilney STW	Crude Sewage Activated Sludge	52.740190 0.883746	conspire.bulb.nerve	AW; DWF = 22.4


Wendling Beck Reach 2 – Beetley to Wensum Confluence, Blackwater & Panford Beck - Draft Sampling Sites
SW Stanfield
SW Brisley
SW East Bilney
BW_W END 1
BW_W END 2
BW_W END 3
BW_W END 4
BW_W END 5
BW_W END 6
BW_WEND 7 Sentinel
WEND R2-10 Sentinel
WEND R1-9 Sentinel
Horningtoft
Harper's Green
Brisley
Stanfield
East Bilney
Beetley
North Elmham
Worthing
Swanton
Bittering
Little Fransham
Crown Lane

Blackwater Drain (Reepham Stream) - DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W ///**	**Notes:**
Marriott's Way (Porter's Lane, Lenwade)	BD_Wens-7		Tributary Sentinel Monitoring		scorpions.twinkling.niece	Adjacent to River Wensum Reach 5 Sentinel site WensR5-30; Both rivers accessible from Marriot's Way car park
Salle Park	BD_Wens-1		Catchment Monitoring		golden.column.joggers	
Booton (Norwich Road)	BD_Wens-2		Catchment Monitoring/ReephamSTW Control Site		intrigued.nimbly.crawled	
Whitwell Street Footpath	BD_Wens-3		Catchment Monitoring/Reepham STW Monitoring		///confronts.briefer.fruity	Access via footpath from The Street at W3W: ///hedge.transmit.detonated
Whitwell	BD_Wens-4		Catchment Monitoring		///twinkled.elated.alienated	
Nowhere Lane (North)	BD_Wens-5		Catchment Monitoring		///sprouting.sectors.unsigned	
Nowhere Lane (South)	BW_Wend-6		Catchment Monitoring		///guidebook.evidence.turntable	

Blackwater Drain (Reepham Stream) Sewage Treatment Works		Location		
Name	**Treatment type:**	**Eastings Northings**	**W3W**	**Notes:**
Reepham STW	Secondary Biological Filtration & Phosphorus removal via chemical dosing	52.759895 1.117781	///tequila.sinkhole.handed	AW; DWF = 1000; FFT Flow = <2229 m3/d

Blackwater Drain (Reepham Stream) - Draft Sampling Sites



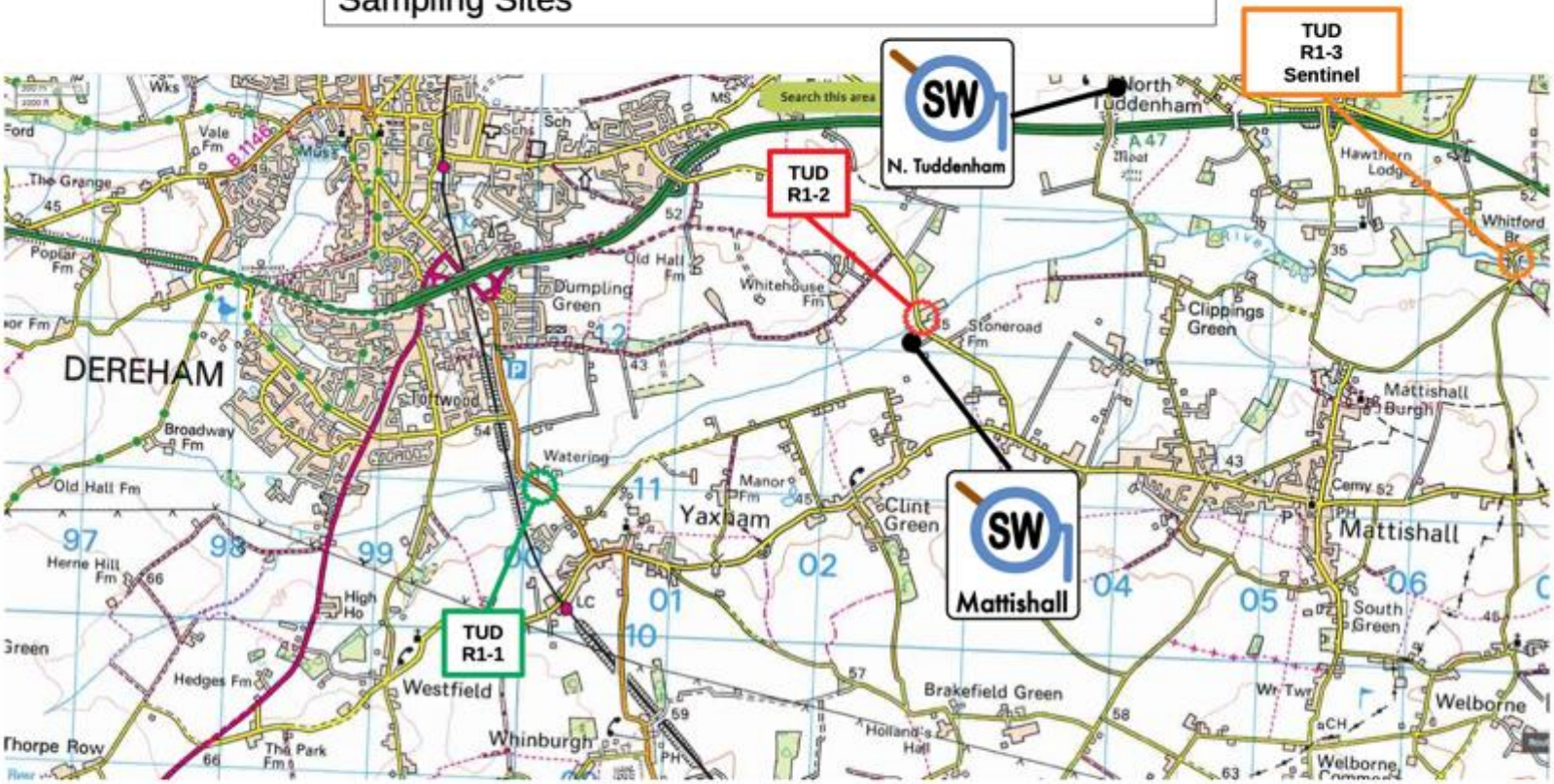
Swannington Beck - DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W ///**	**Notes:**
Reepham Road (Alderford Common)	SB_WensR6-3		Tributary Sentinel Monitoring		spot.winks.branched	Accessible from Alderford Common car park
Swannington (The Street)	SB_Wens-1		Catchment Monitoring		grinning.countries.shredding	
Kett's Lane (Hengrave)	SB_Wens-2		Catchment Monitoring		fuses.harvest.tapers	

Swannington Beck - Draft Sampling Sites

R. Tud Reach 1 – Source to Whitford Bridge - DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
Whitford Bridge	TudR1-3		River reach surveillance site/Hockering STW Control Site		scarves.acoustics.stars	
Watering Farm Bridge (B1135)	TudR1-1		Mattishall STW Control Site/Catchment Monitoring		mascots.sunshine.propelled	Assess road safety
Stone Road Bridge	TudR1-2	AN-TUD020	Mattishall STW Monitoring/Catchment Monitoring	602700 312200	marzipan.daisy.inspected	No longer sampled by EA

R. Tud Reach 1 - Sewage Treatment Works		Location		
Name	**Treatment type:**	**Eastings Northings**	**W3W**	**Notes:**
Mattishall STW	Crude Sewage Activated Sludge	52.667831 0.994801	crusted.thudded.supposing	AW; DWF = 720; FFT Flow = <1872 m3/d

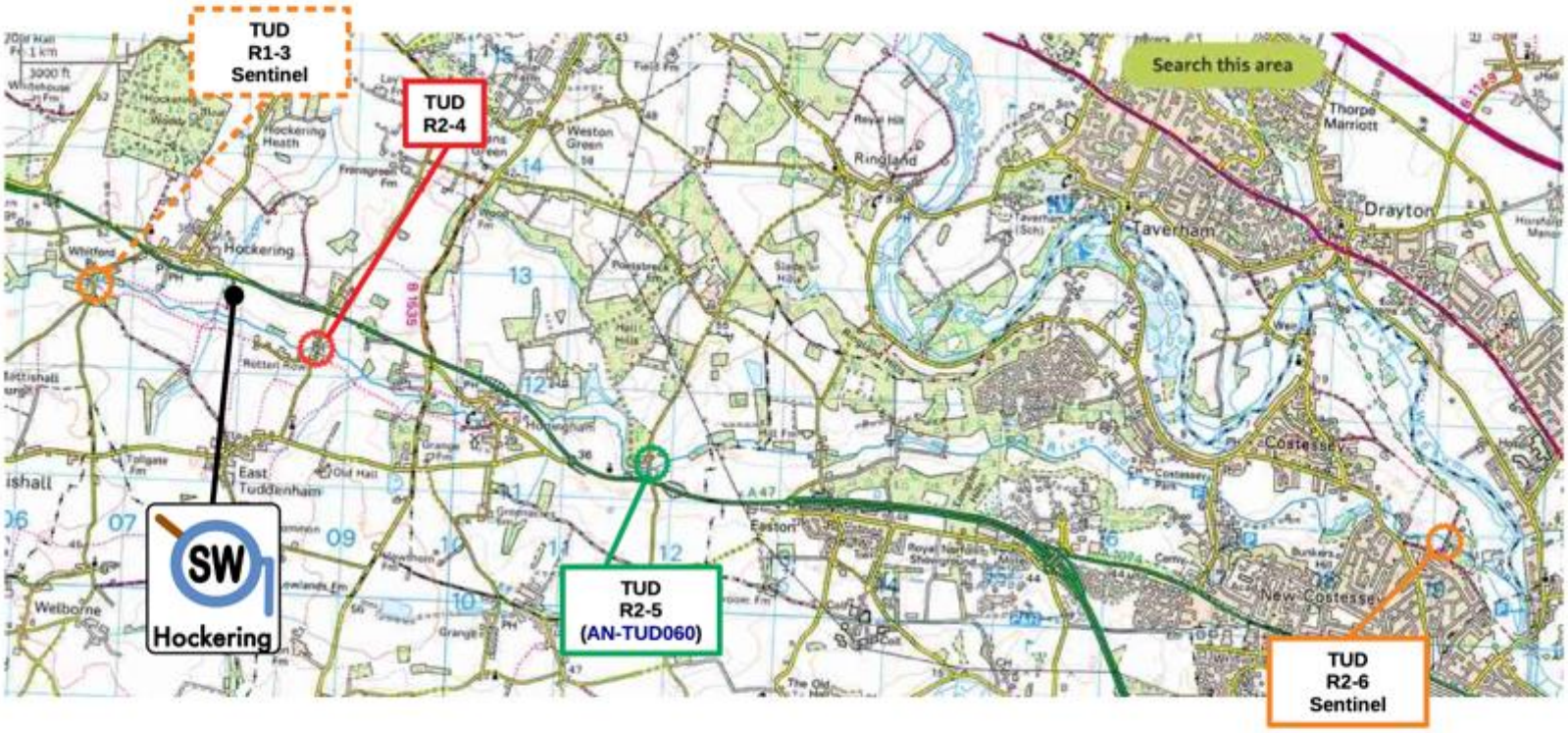
R. Tud Reach 1 - Source to Whitford Bridge – Draft Sampling Sites



R. Tud Reach 2 – Whitford Bridge to Wensum Conf.- DRAFT Sampling sites				Location		
Sampling point name	**Ref no.**	**EA Ref no.**	**Purpose**	**Eastings Northings**	**W3W**	**Notes:**
Red Bridge (Gunton Lane)	TudR2-6		River Reach Sentinel Site		sleep.waddle.foam	
Whitford Bridge	TudR1-3		River reach surveillance site/Hockering STW Control Site		scarves.acoustics.stars	
Church Lane (Rotten Row)	TudR2-4		Hockering STW Monitoring/Catchment Monitoring		storyline.pinch.monument	EA fish survey site
Taverham Road Bridge (Honingham Church Farm Plantation)	TudR2-5	AN-TUD060	Catchment Monitoring/Possible future Western Link Road Building	52.657592 1.130258	fire.hurtles.chimp	

R. Tud Reach 2 - Sewage Treatment Works					
			Location		
Name	**Treatment type:**		**Eastings** **Northings**	**W3W**	**Notes:**
Hockering By A47 STW	Secondary Biological Filtration	Works F.E. Outfall	52.672148 1.072025 52.672139 1.072032	bagpipes.handbags.sprouts legwork.static.screening	AW asset; DWF = 150
North Tuddenham STW	Secondary Biological Filtration	Works	52.684401 1.015173	debate.clinking.pounds	AW; DWF = 6

R. Tud Reach 2 - Whitford Bridge to Wensum Confluence – Draft Sampling Sites



Appendix C: Citizen Science Case Studies:

Across the UK citizen science monitoring programmes have been set up to assess various water quality parameters using a range of methods that could be applicable to developing a similar on the Wensum. The following examples illustrate some of the approaches taken:

River Wye catchment:

The Friends Of the Upper Wye (FOUW) are a grass roots community group formed to champion and protect the River Wye. Nutrient pollution is affecting the river Wye and its tributaries and in the latest assessment Natural Resources Wales found that more than 60% of the Welsh sections of the Wye SAC failed phosphate limits. The Wye and Usk Foundation report that repeated and severe algal blooms in the river have reduced the extent of protected-Ranunculus beds by 90-95% in just three years. FOUW joined with partners including Cardiff University, the Wye & Usk Foundation and the Environment Agency to develop a citizen science water quality monitoring programme and are engaging volunteers to undertake frequent (twice weekly) testing. More recently campaigners and environmental groups including RiverAction and Radnorshire Wildlife Trust launched a campaign for funding to help employ a co-ordinator post and help scale up the sampling to reach more of the River Wye's tributaries.

FOUW have produced a field water quality monitoring guide for their volunteers which runs through each of the basic tests and data recording, as well as providing information on biosecurity, identifying and reporting signs of pollution and health & safety guidelines. This is supplemented by an excellent field guide for citizen scientist river water sampling produced by Cardiff University, which provides more detailed guidance for volunteers. FOUW also host a FOUW YouTube channel providing a series of videos produced by FOUW and Cardiff University explaining how to take samples and use the monitoring equipment. FOUW worked in conjunction with Herefordshire Wildlife Trust and Radnorshire Wildlife Trust to produce a risk assessment for their citizen science monitoring. Volunteers are asked to complete a volunteer registration form which is held by the relevant Wildlife Trust and FOUW to ensure volunteers are covered under insurance.

FOUW and Cardiff University are using the Epicollect5 app to enable volunteers to enter and upload data in the field. For those volunteers without smartphones they have also produced a paper form for field recording and ask volunteers to upload data at home via computer using a link to the Epicollect website.
In February 2022, FOUW had over 100 volunteers regularly testing water quality and links with Cardiff University have proved the data collected by volunteers is valid and comparable to lab testing carried out by agencies such as Natural Resources Wales.

Parameter	Equipment used:
Phosphate	- LaMotte Phosphate test strips - Hanna HI-713 Phosphate Low Range Checker - Hach DR300 Pocket Colorimeter - Phosphate
Nitrate	- Hach Nitrate test strips - Hach DR300 Pocket Colorimeter - Nitrate
Electrical conductivity	- HM Digital EC-3 Electrical Conductivity Tester
Temperature	- HM Digital EC-3 Electrical Conductivity Tester
Turbidity	Secchi tube
Ammonia	Ammonia test strips Ammonia checker Ammonia handheld meter
PH	PH test strips pH meter
Dissolved oxygen	DO test kit DO meter

Table C1: Water quality sampling equipment used by FOUW and Wye citizen science monitoring

River Waveney Trust/RiverEYE

RiverEYE is a collaborative citizen science approach that was developed to use a GPS-enabled smartphone app named RiverEYE, built on the Epicollect+ framework. RiverEYE was trialled in conjunction with volunteers from the River Waveney Trust to collect information on different issues within the Waveney catchment. Volunteers attend a training workshop and used the app to collect photographic evidence of catchment health based on a predetermined set of 12 visual indicators such as bank erosion, fish kills, surface pollution and sediment input from road drains. Data from RiverEYE is stored in a secure online database and can be uploaded for use in other GIS systems e.g. ArcGIS for analysis.

FreshWater Watch projects

FreshWater Watch is a global project launched in 2012 under the HSBC Water Programme, a collaborative partnership with Earthwatch, WaterAid and WWF. FreshWater Watch enables individuals and communities to monitor, protect and restore their local water resources. FreshWater Watch provides volunteers with test kits and training based on the FreshWater Watch Methods Manual to collect core measurements (phosphate, nitrate & turbidity) and observations (e.g. visible signs of pollution, evidence of residential or industrial discharges) and upload them onto a common platform. The data, together with results from the Riverfly partnership, can be accessed on the Earthwatch Freshwater data explorer portal hosted by CEH.

Freshwater Watch uses chemical tests for phosphate and nitrate supplied by Kyoritsu. These kits consist of transparent plastic tubes, in which citizen scientists mix unfiltered water samples from sampling cups with pre-measured reagents that produce increasing colour values with increasing nutrient concentration. The Phosphate (PO_4-P) test kit provides nutrient level categories ranging from <0.02 - >1.0 mg/l. The Nitrate (NO_3) kit ranges from <0.2 - >10 mg/l. The colour change in the sample is compared visually to a six-point colour chart in both kits and the range value between the closest two colour matches is recorded as the test result.

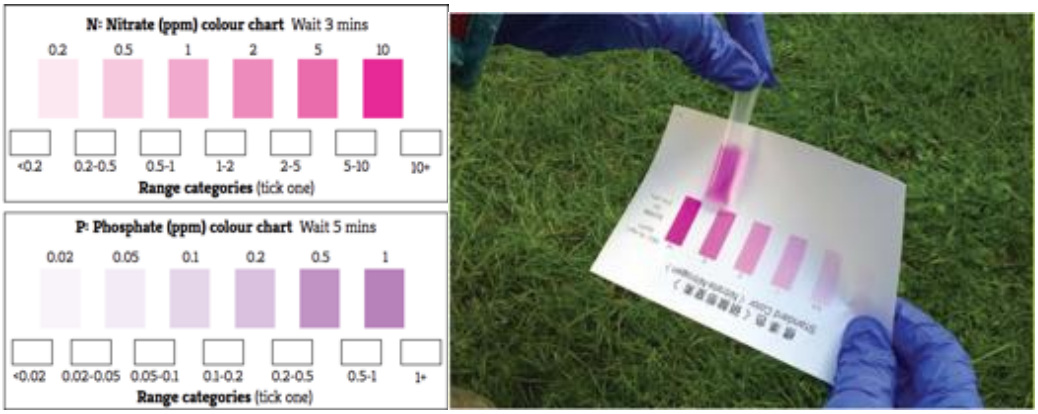


Figure C1: Kyoritsu chemical colour comparison test kits used by Freshwater Watch projects

There are a number of citizen science projects working in partnership with FreshWater Watch, including:

Bristol Avon RiverBlitz Instigated in 2016, the Bristol Avon River Blitz is run by Bristol Avon Rivers Trust (BART) in partnership with FreshWater Watch and is an annual citizen science event that provides a snapshot of water quality in streams, rivers and lakes across the catchment. In the 2021 event 193 citizen scientists took 239 samples across the catchment for the project. Volunteers use Kyoritsu Pack Test kits supplied through FreshWater Watch to test for Nitrate and Phosphate.

For each monitoring site, volunteers are asked to submit the following parameters and observations:

- Test kit key code
- Date & time
- Site name
- Location (Lat/Long)
- Site photograph

Ecological:

- What wildlife have you spotted around you? (free entry field)
- Water body type (Pond, stream, lake, river, wetland or other)
- Immediate surrounding land use
- Bank vegetation

Characteristics:
- What course does the river/stream take? (Straight, meandering, braided, N/A or other)
- What are the flow conditions? (Very low level (a light film of water), shallow but flowing steadily, a mix of deep pools and shallow fast flowing riffles, deep water filling the channel, other)
- Are the river/stream banks natural? (Yes (banks formed of natural materials including soil and vegetation), No (banks made of stone/brick/masonry), N/A
- What is the bed made up of? Select all that apply: (Silt or heavy sediment, Algae, sewage fungus, large stones/rocks, small stones, small gravels)

Plantlife:
- Is there any in-stream vegetation? (*Ranunculus*, bur-reed, bulrush, marsh marigold, water mint, other)
- Are there any invasive plants in the channel or banks? Select all that apply: (Himalayan balsam, Japanese knotweed, floating pennywort, giant hogweed, other)

Litter & potential contaminants:
- Is there any of the following on the water surface? Select all that apply: (foam, floating algae, litter, oily sheen)
- If you can see any litter please list what kind e.g. plastic bottles, tin cans, food wrapping: (free entry field)

Chemical: Enter the readings from your chemical test kits:
- Nitrate in ppm (0, 1, 2, 5, 10, 20, 50)
- Phosphate in ppm (0, 5, 10, 30, 50)

Optical:
- Estimate the water colour (colourless, yellow, brown, green, other)

Additional notes:
- Is there anything else of interest that you have discovered about your test site? (Free entry field)

In 2021the project developed a new interactive GIS data visualisation platform in conjunction with Riskaware called the River Blitz Explorer Tool which enables people to view the health of watercourses in the catchment and for volunteers taking part to enter their data.

Lincolnshire Rivers Trust

Lincolnshire River Trust is working with the Environment Agency and FreshWater Watch to enable Grantham RiverCare volunteers to monitor seven testing sites on the River Witham around Grantham on a monthly basis.

River Liffey citizen science study

This project recruited volunteers from corporate funders and local interest groups such as paddle boarders, kayakers and rowers through social media and engagement with local clubs. Volunteers were trained in phosphate and nitrate sampling and identifying potential sources of pollution in workshops including field-based activities under the FreshWater Watch programme. The study sampled 19 locations across the River Liffey over a nine month period to fill in the data gaps in environmental monitoring commensurate with UN sustainable development goal indicator 6.3.2 (phosphate and electrical conductivity). Qualitative, observational data recorded by citizen scientists also detected significant detrimental

nutrient inputs to the river that may have come from storm drains and residential discharges. The study concluded that observational data recorded by citizen scientists suggested that urban discharges, especially domestic misconnections due to urban expansion, may have been more important factors influencing detrimental water quality than rainfall events. The study concluded that the range of data from the project spatially and temporally enhanced national agency monitoring and that an expansion of the programme would strengthen the case for use of the data by the appropriate national agencies.

West Country Citizen Science Investigations

As part of the Tamar Catchment Partnership, Westcountry Rivers Trust (WRT) received National Lottery Funding to launch a pilot citizen science trial to engage people with the health of their local rivers and create an accessible platform was created for members of the public to report minor pollution events. This allowed WRT to collate the information and pass it on when required to the Environment Agency and South West Water.

Initially WRT teamed up with FreshWater Watch (see above), who provide phosphate and nitrate testing kits and an online recording system and smartphone app. This was piloted with volunteers for a year, with WRT using the opportunity to work with volunteers to gain feedback. The platform was found to be popular with volunteers and the online system of training and reporting allowed a wide audience to be engaged without the need for face to face meetings. However, WRT found that some volunteers struggled with the online training. Project leaders also found that a proportion of interested volunteers dropped out at each stage of the online system.

Parameter	Equipment used:
Phosphate	- LaMotte Phosphate test strips
Turbidity	Secchi turbidity tube
Total Dissolved Solids	- TDS pen
Water temperature	- TDS pen

Table C2: Water quality monitoring equipment used for Westcountry CSI

WRT used the pilot trial with FreshWater Watch to inform further development of citizen science monitoring called Tamar CSI (Citizen Science Investigations), which was extended to become Westcountry CSI.

CSI volunteers recorded water quality parameters and signs of pollution, as well as river channel characteristics and land use. Other features of interest are also recorded, such as wildlife sightings and signs of invasive species. Data is entered onto recording sheets and is designed to be flexible so that volunteers can choose to record only parameters that they are confident and/or interested in identifying. Surveys are undertaken as regularly as volunteers wish.

Westcountry CSI data is upload by volunteers onto an online platform called 'Cartographer'. This places a point at each sample location which shows each parameter, often using a colour scale. When the region is viewed, it is possible to see areas with high or low results. Volunteers

can also supplement the data with photographs. The CSI Cartographer database is openly accessible to citizen scientists, providing volunteers with the facility to view other results and photos, see graphs of results over time and even undertake their own data analysis. WRT produces a series of annual scorecards for each waterbody which summaries all the data that has been collected over the last 12 months.

Key findings of the Wescountry CSI project:

- ensure the system is flexible, as this helps to keep each volunteer interested and excited about the project linked to their own interests;
- WRT found that although less frequent monitoring appears to be less demanding on the volunteer, encouraging more regular monitoring helps to keep people engaged;
- Westcountry CSI is improving and adjusting the type of monitoring equipment, provision of information and ways of communicating with volunteers as the project grows.

iWharfe project – a 'Blitz'-type approach:
The iWHARFE citizen science project was initiated following a campaign by the Ilkley Clean River Group (ICRG) to highlight problems of untreated sewage discharges from Ashlands sewage treatment works. The project is a partnership between ICRG, Addingham Civic Society and the Yorkshire Dales Trust. It engaged local communities along the Wharfe valley, working with the Environment Agency, Yorkshire Water and other Agencies and was funded by donations and grants in 2020.
iWharfe undertook the 'Big Health Check' on 24th August 2020, involving five teams of citizen scientists who took water samples from 60 sites at approximately the same time on the same day. The samples were stored in cool boxes and delivered to a central laboratory that undertook testing for *E. coli* and Intestinal *Enterococci* (IE) within 24 hours of sampling. On the day of sampling, many of the popular sites used for bathing and recreation were found to be contaminated by high concentrations of faecal bacteria. The iWharfe data indicated that in most situations treated effluent discharge from sewage treatment works were the dominant source of faecal bacteria in the river on the day of sampling.
The results were felt to be valuable in raising awareness about river water quality and in highlighting some of the principal sources of faecal bacteria affecting the river. The iWharfe project plan to prioritise further surveys in low flow conditions, identification of unknown point sources and more focused sampling upstream and downstream of both STW outfall and tributary inflows. In December 2020 ICRG succeeded in getting the Wharfe at Ilkley formally designated as the first bathing river in the UK under the Bathing Water Regulations 2013.

Wild Oxfordshire: Wychwood Water Watchers

The Brecks Fen Edge & Rivers Landscape Partnership Testing the Waters The BFERLP Testing the Waters project is led by the Freshwater Habitats Trust and has four broad aims:

Aims of BFER LPS Citizen Science – Testing the Water

- To create monitoring networks for endangered freshwater species and the extent of clean unpolluted water using simple but sophisticated citizen science methods, providing a baseline for the long-term monitoring of water quality and the distribution of key red list freshwater species` in the project area;

- To increase awareness in a range of audiences of the distribution of protected freshwater species and priority freshwater habitats, facilitating better conservation management practices;

- To increase people's engagement with and understanding of the exceptional freshwater heritage of the Brecks, apparently one of Britain's driest landscapes but also one of the most important areas for freshwater biodiversity

- To inform the delivery of river restoration activities and guide future landscape conservation activity in the scheme area

The project webpage contains training information and videos, health & safety and biosecurity guidance, as well as links to reports and video presentations generated from the data collected and an excellent Testing the Waters project leaflet. The project is using environmental DNA testing and FreshWater Watch Kyoritsu test kits to collect biological and environmental data in rivers, streams, ponds and drains across the 1019 sq. kilometre Brecks area. Volunteers use a standard form to record information and test results in the field and are asked to upload it to a central Testing the Waters data portal hosted on the Freshwater Habitats Trust website.

The project ran 3 online training sessions over February, March and April 2021, attended by 66 volunteers. Each volunteer was issued 10 test kits and asked to sample 10 waterbodies within a given allocated area. In the first round of water quality testing between 2nd March and 7th July 2021, volunteers collected 483 water samples across a range of freshwater habitats. 40% of sites sampled showed no evidence of nutrient pollution. Only 6% of the streams and 1% of river and cut-off channels sampled were found to be unaffected by nutrient pollution. Of the ditch networks sampled, 55% were found the be unaffected by nutrient pollution.

Project contact: bfer.admin@suffolk.gov.uk

Appendix D: Details of suggested water quality sampling equipment:

Orthophosphate (as PO_4^{-3} and PO_4-P) – (Wensum PO_4-P target = 0.04-0.05 mg/l):

Examples of suitable testing equipment:

HI-713 - Hanna Low Range Handheld Phosphate Colorimeter - Checker
– Range: Phosphate as PO4 -3 from 0.00 – 2.50 ppm (mg/l);
- Readings can be multiplied by 0.3261 to convert to orthophosphate as P (PO4-P)
- Resolution: 0.01 ppm (mg/l)
- Accuracy @ 25^{0}C: ± 0.04 ppm (mg/l) ±4% of reading
- Price: £58.00 (exc. VAT), £69.60 inc. VAT; reagents for 25 tests = £14.10 inc. VAT (£0.56 per test)

HI-717 - Hanna High Range Handheld Phosphate Colorimeter - Checker
- Range: Phosphate as PO4 -3 from 0.0 – 30.0 ppm (mg/l);
- Readings can be multiplied by 0.3261 to convert to orthophosphate as P (PO4-P)
- Resolution: 0.1 ppm (mg/l)
- Accuracy @ 25°C: ± 1.0 ppm (mg/l) ±5% of reading
- Price: £58.00 (exc. VAT), £69.60 inc. VAT; Reagents for 40 tests = £12.24 inc. VAT (£0.31 per test)

Milwaukee MW12 Digital Phosphate Tester
- Range: Phosphate as PO4 -3 from 0.0 – 2.50 ppm (mg/l);
- Readings can be multiplied by 0.3261 to convert to orthophosphate as P (PO4-P)
- Resolution: 0.01 ppm (mg/l)
- Accuracy @ 25°C: ± 0.04 ppm (mg/l) or ±4% of reading
- Price: £45.56 (exc. VAT), **£56.95 inc. VAT**; Reagents for 25 tests = £23.08 inc. VAT **(£0.92 per test**)

Unionised Ammonia (NH_3-N) – (Wensum NH_3-N target 0.21mg/l):

Examples of suitable testing equipment:
HI-715 – Hanna Medium Range Handheld Ammonia Colorimeter - Checker
– Range: Ammonia as NH_3-N from 0.00 – 9.99 ppm (mg/l);
- Resolution: 0.01 ppm (mg/l)
- Accuracy @ 25^{0}C: ± 0.05 ppm (mg/l) ±5% of reading
- Price: £67.50 (exc. VAT), **£81.00 inc. VAT**; Reagent 25 tests = £35.04 inc. VAT (**£1.40 per test**)

HI-700 – Hanna Low Range Handheld Ammonia Colorimieter - Checker
– Range: Ammonia as NH_3-N from 0.00 – 3.00 ppm (mg/l);
- Resolution: 0.01 ppm (mg/l)
- Accuracy @ 25^{0}C: ± 0.05 ppm (mg/l) ±5% of reading

- Price: £58.00 (exc. VAT), **£69.60 inc. VAT;** Reagents for 25 tests = £23.88 inc. VAT (**£0.96 per test**)

Figure D1: Hanna HI-715 Medium Range Ammonia and HI-713 Low Range Phosphate Checkers

Dissolved oxygen (mg/l and % saturation + water temperature °C/°F) – (Wensum DO% target = 85%):

Example tested: **AZ Instruments 8403 Dissolved Oxygen Meter**
- Range: Dissolved Oxygen 0-199.9 %;
0-19.99 mg/l
- Resolution: 0.1%
0.01 mg/l
- Accuracy: ±1.5% F.S. (%)
±1.5% F.S. (mg/l)
- Price: £137.84 (exc. VAT), **£165.41 inc. VAT**

Nitrate (NO_3):

When reviewing potential options for nitrate, it became evident that both Hanna and Milwaukee did not market a low cost digital colorimeter for use with freshwater samples similar to those identified for phosphate and ammonia. The Exact iDip 570 Multi-Parameter Photometer (£189.00 +@ one-off £5.00/test set up + reagent cost) was identified as a possible low cost digital photometer option that could be used to test multiple water quality parameters, including, crucially, freshwater nitrate samples. A unit was subsequently

purchased and assessed as part of equipment trials carried out for this project. Comparative tests were undertaken with the iDip 570, testing against Hanna phosphate and ammonia Checkers, the Milwaukee Phosphate checker and the Lovibond MD610. However, results from the iDip were found to be inconsistent and it was discounted as a viable option.

No suitable equipment from other manufacturers was found at a similar budget price point. Until such equipment becomes available, Nitrate sampling would need to be undertaken using standard Nitrate test strips or chemical test kits in line with other citizen science projects. If more accurate nitrate results are desirable, digital nitrate photometers for freshwater samples are available at a higher price point such as the Hanna HI97728 Nitrate Portable Photometer (£330 - £495) or the Horiba LAQUATwin Nitrate Ion Meter NO3-11 (£375).

Example Test strips e.g. **SimplexHealth Nitrate 0-50ppm & Nitrite 0-10ppm Test Strips (50)**
- Range: Nitrate as N: 0, 0.5, 2, 5, 10, 20, 50 ppm (mg/l N); Nitrite as N: 0, 0.15, 0.3, 1, 1.5, 3, 10 ppm (mg/l N)
- For conversion of levels to NO_2 (Nitrite) and NO_3 (Nitrate), multiply Nitrate value by 4.4268 to get NO_3 mg/l; and multiply Nitrite value by 3.3 to get NO_2 mg/l.
- Price: £14.99 (exc. VAT), **£17.99 inc. VAT (£0.36 per test)**

Hach Nitrate Test Strips Nitrate 0-50 mg/l & Nitrite 0-3 mg/l (25)
- Range: Nitrate as NO3-N mg/l: 0, 1, 2, 5, 10, 20, 50 mg/l; Nitrite as NO2-N mg/l: 0-3.0 mg/l
- Price: £14.69 (exc. VAT), **£18.37 inc. VAT (£0.74 per test)**

Total Dissolved Solids (TDS), Conductivity (uS) and pH:

Examples tested: **Pancellant Water Quality Test Meters pH EC TDS Temperature Set**
- Range: pH: 0.00 – 14.00
  TDS: 0 – 9990 ppm
  EC – 0 – 9990 µS/cm
  °C – 0.1 – 80.0°C ; °F – 32.0 – 176.0 °F
- Resolution: pH: 0.01 pH
  TDS: 1ppm
  EC - 1µS/cm
  °C/ °F: 0.1
- Accuracy: pH: ±0.01 pH
  TDS: ±2%
  EC: ±2%
  °C/ °F: ±2%
- Price: £16.22 (exc. VAT), **£19.46 inc. VAT**

Turbidity:

Most citizen science projects use simple graduated Secchi tubes with a Secchi disk at the bottom or graduated dots on the base to measure turbidity. The tubes have a graduated scale on the side. Measurements are based on the depth of the water at which the Secchi disc is no longer visible to the observer peering into the top of the tube. The higher the concentration

of sediment or phytoplankton in the water sample, the higher the NTU, and the less water is needed for the disc to disappear. **Cost: <£50.**

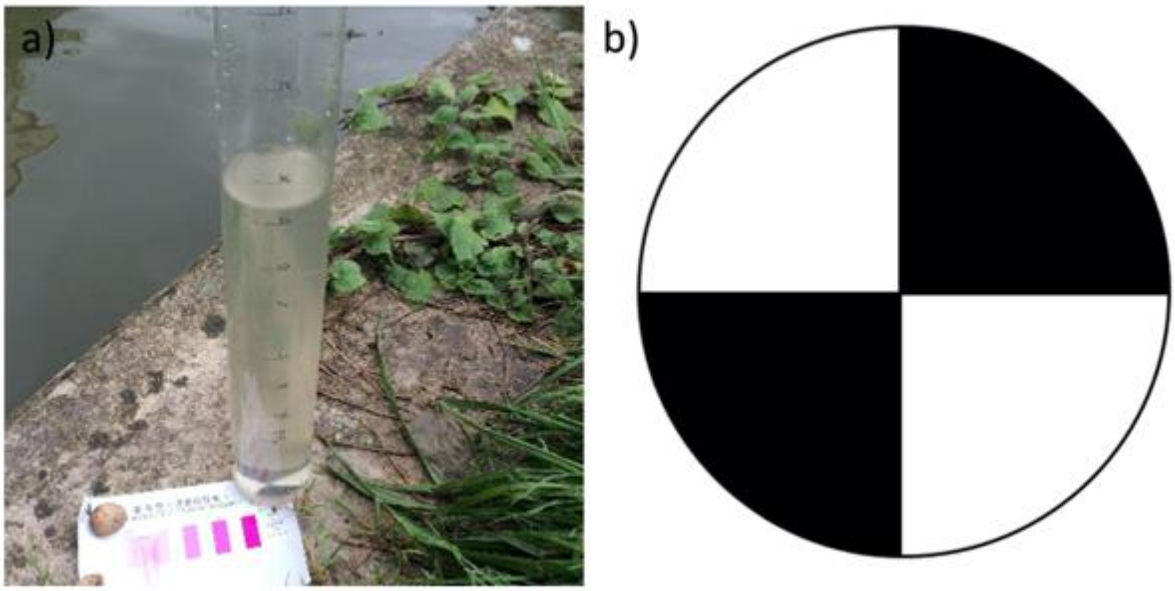


Figure D2: a) Graduated Secchi tube and b) Secchi disk. (source: FWW methods manual)

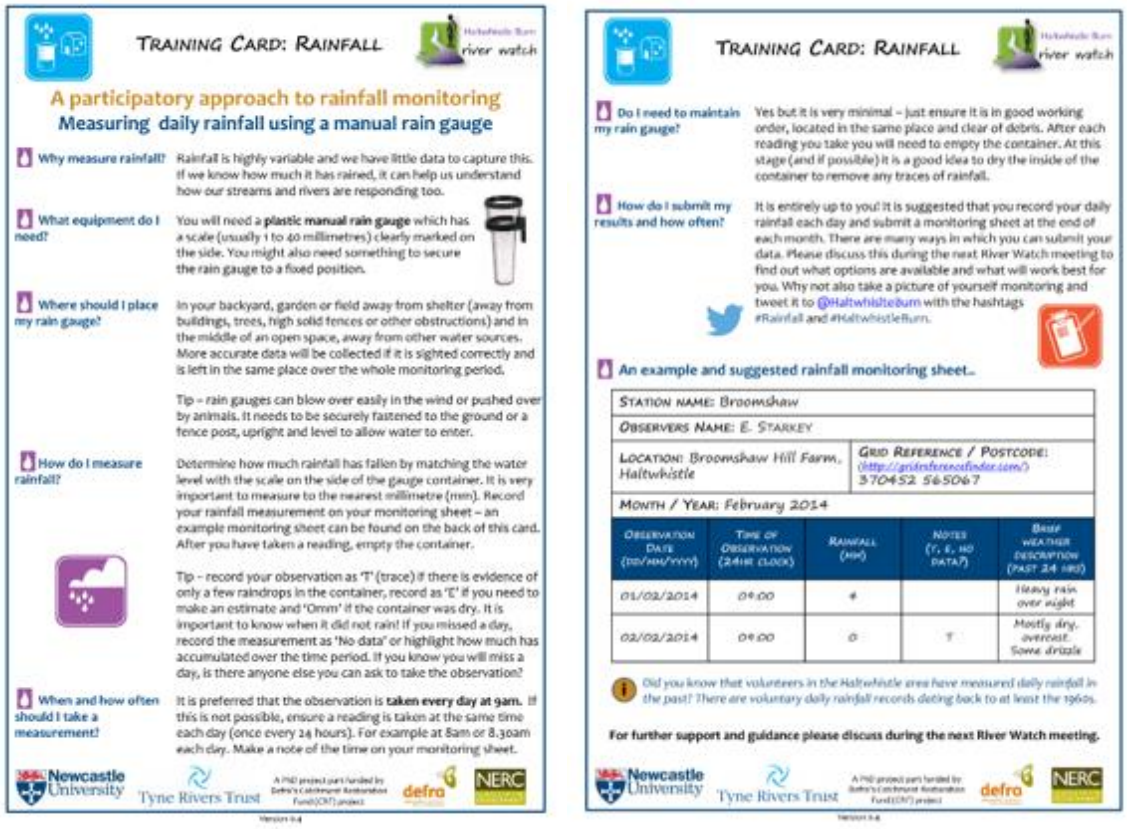
Appendix E: Rainfall, river level and flow options:

Rainfall totals - Rainfall gauging:

Rainfall observations are fundamental to catchment hydrology, quantifying inputs to the catchment system. A plastic rain gauge or graduated measuring cylinder is used to collect and store rainfall over a fixed observation period (usually daily). Daily rainfall totals are manually observed, the gauge emptied and reset for the next period.

Figure E1: Example of a simple rainfall gauge for monitoring precipitation

The collection of rainfall data is well suited to a citizen science approach, requiring simple, low cost equipment (typically £5 - £15), taking only a short time to complete (1-2 minutes) and can be undertaken wherever volunteers are able to install and regularly monitor one. Where volunteers live within the target catchment area and can install a gauge at home then this encourages regular observations to be recorded (ideally on a daily basis at a fixed time). Projects such as Haltwhistle Burn River Watch have developed a comprehensive set of volunteer resources including a volunteer training card for undertaking rainfall and other monitoring techniques.



TRAINING CARD: RAINFALL

A participatory approach to rainfall monitoring

Measuring daily rainfall using a manual rain gauge

Why measure rainfall? Rainfall is highly variable and we have little data to capture this. If we know how much it has rained, it can help us understand how our streams and rivers are responding too.

What equipment do I need? You will need a **plastic manual rain gauge** which has a scale (usually 1 to 40 millimetres) clearly marked on the side. You might also need something to secure the rain gauge to a fixed position.

Where should I place my rain gauge? In your backyard, garden or field away from shelter (away from buildings, trees, high solid fences or other obstructions) and in the middle of an open space, away from other water sources. More accurate data will be collected if it is sighted correctly and is left in the same place over the whole monitoring period.

Tip – rain gauges can blow over easily in the wind or pushed over by animals. It needs to be securely fastened to the ground or a fence post, upright and level to allow water to enter.

How do I measure rainfall? Determine how much rainfall has fallen by matching the water level with the scale on the side of the gauge container. It is very important to measure to the nearest millimetre (mm). Record your rainfall measurement on your monitoring sheet – an example monitoring sheet can be found on the back of this card. After you have taken a reading, empty the container.

Tip – record your observation as 'T' (trace) if there is evidence of only a few raindrops in the container, record as 'E' if you need to make an estimate and '0mm' if the container was dry. It is important to know when it did not rain! If you missed a day, record the measurement as 'No data' or highlight how much has accumulated over the time period. If you know you will miss a day, is there anyone else you can ask to take the observation?

When and how often should I take a measurement? It is preferred that the observation is **taken every day at 9am.** If this is not possible, ensure a reading is taken at the same time each day (once every 24 hours). For example at 8am or 8.30am each day. Make a note of the time on your monitoring sheet.

Newcastle University · Tyne Rivers Trust · defra · NERC

TRAINING CARD: RAINFALL

Do I need to maintain my rain gauge? Yes but it is very minimal – just ensure it is in good working order, located in the same place and clear of debris. After each reading you take you will need to empty the container. At this stage (and if possible) it is a good idea to dry the inside of the container to remove any traces of rainfall.

How do I submit my results and how often? It is entirely up to you! It is suggested that you record your daily rainfall each day and submit a monitoring sheet at the end of each month. There are many ways in which you can submit your data. Please discuss this during the next River Watch meeting to find out what options are available and what will work best for you. Why not also take a picture of yourself monitoring and tweet it to @HaltwhistleBurn with the hashtags #Rainfall and #HaltwhistleBurn.

An example and suggested rainfall monitoring sheet..

STATION NAME: Broomshaw

OBSERVERS NAME: E. STARKEY

LOCATION: Broomshaw Hill Farm, Haltwhistle

GRID REFERENCE / POSTCODE: (http://gridreferencefinder.com/) 370452 565067

MONTH / YEAR: February 2014

OBSERVATION DATE (DD/MM/YYYY)	TIME OF OBSERVATION (24HR CLOCK)	RAINFALL (MM)	NOTES (T, E, NO DATA?)	BRIEF WEATHER DESCRIPTION (PAST 24 HR)
01/02/2014	09:00	4		Heavy rain over night
02/02/2014	09:00	0	T	Mostly dry, overcast. Some drizzle

Did you know that volunteers in the Haltwhistle area have measured daily rainfall in the past? There are voluntary daily rainfall records dating back to at least the 1960s.

For further support and guidance please discuss during the next River Watch meeting.

Newcastle University · Tyne Rivers Trust · defra · NERC

Figure E2: Example of a volunteer training card for rainfall monitoring (Source: Haltwhistle Burn River Watch)

River levels and fixed gauge board river level photography

River level (also known as 'Stage') recording can be easily captured using fixed point photography, where Citizen Science volunteers can take and upload a picture of the river or stream channel with their smartphone at a fixed pre-determined location to allow comparison over time (for example looking immediately upstream from a bridge). This is enhanced where a fixed feature can be included as standard in the photo frame to aid comparison of actual river level (stage) between data over time e.g. an easily identifiable permanent bank feature.

Figure E3: Example of a fixed stream gauge to record river levels (Credit: USGS)

A reference photo could also be produced for each site to help volunteers frame the image to ensure the same points/river features are included in shot at the same scale every time. Of note is that photo surveys can also provide additional data and observations. For example, comparison of submitted photos over time may indicate the sudden appearance of the sand deposition on the stream bed in the lower right corner in Figure X. This may indicate heavy sediment run off occurring further upstream e.g. during intense rainfall events and can be used as evidence to drive diffuse pollution reduction measures, either with Highways or through e.g. Catchment Sensitive Farming (CSF) initiatives.

Figure E4: Fixed point photographs can capture river levels and also evidence other impacts such as sediment-rich run off smothering river beds after intense rainfall events (bottom right of picture)

Fixed gauge board photos

Where a fixed river gauge board is installed this enables accurate data on river levels to be recorded. The main advantage of this approach is that river level data can be collected easily, quickly (1-2 minutes) and consistently, either whilst volunteers are undertaking water quality monitoring, or as a standalone task or opportunity to engage passers-by (see 'crowdsourcing' below). e.g. onto a paper form, or sent electronically, e.g. via text message or Twitter. Photos are easily upload in real time from smartphones and can also provide invaluable evidence of impacts on watercourses e,g. during high rainfall or flooding events. Uploading a photo of the gauge board also enables the data to be quality checked. The concept has been successfully demonstrated for this project using a citizen science data input form created using the mWater platform and Surveyor app.

Gauge board materials would typically cost between £30 - £50 per installation. It is worth considering that manufacturers can produce a variety of different types of gauge board to make them easier to read in different conditions – photoluminescent or 'glow in the dark', retroreflective finish like standard road signs that are easier to read in low light or with a torch, infra-red camera gauge boards e.g. ShelleySigns. When installing a gauge board, it is important to consider location relative to the observer, location in the channel – typically

along the edge to avoid catching flood debris or causing a flood risk and ideally referencing to datum (e.g. AOD) so the position of the gauge board is known and can be replicated e.g. if it needs to be replaced. At bridges or culverts it is easier to link the gauge board height and position to a fixed permanent feature of known height, as well as a channel of fixed dimensions to aid in future calculation of a stage-discharge relationship. If gauge boards are installed in watercourses it is likely a consent or permit may be required first. For main rivers this would be a Flood Risk Activity permit or Exemption obtained from the Environment Agency. In non-main river watercourses this would be a Land Drainage Consent obtained from the Water Management Alliance or relevant Internal Drainage Board, or Norfolk County Council for work on ordinary watercourses. There may be a charge of typically £50 per structure as part of a permit application. If gauge boards, interpretative signs or other equipment are to be fixed to bridges then permission should also be sought from County Council Highways and/or landowners first.

Figure E5: Gauge board positioned under a road bridge to enable observations and photos to be taken by an observer at a fixed location (Source: Starkey, 2020)

Gauge boards will require some maintenance, though the need for this can easily be assessed from uploaded photographs, which can be checked for a) damage; b) overgrowth of vegetation and c) need for cleaning e.g. due to algae or other fouling.

Crowd-Sourcing fixed point river level photography – To further extend this potential source of extra data, the project could consider encouraging members of the public to upload photos of the river at accessible locations. QR-coded information sign boards could be designed and installed at desired locations enabling wider members of the public to contribute 'crowd sourced' photographic images or video of current river levels and gauge boards. This approach has been used by projects eg. WEF Stormwater CS monitoring and the Haltwhistle Burn Citizen Science Project. Time-variable river level data obtained from crowdsourcing has also been used to calibrate a conceptual rainfall-runoff model and converted into a continuous discharge model (Weeser *et al*, 2019).

Figure E6: Crowd sourcing river level observations via interpretative signage inviting interested members of the public to text or upload data (Source: CrowdHydrology 'How high is your river?)

This approach can help to extend engagement into the wider community which could encourage more volunteers to get involved in Wensum citizen science. This is particularly relevant where public engagement can be actively canvassed e.g. press releases in advance of or during drought status.

Fixed point river level via smartphone app (virtual staff gauge)

Where fixed gauge boards are absent, or cost, health & safety considerations and/or permitting restrictions prevent installation, it may be possible to use a GPS-enable smartphone app based system for river level recording. Volunteers can also use a 'Virtual Staff Gauge' to record river levels via the CrowdWater application developed by the University of Zurich (Seibert et al, 2019). The app enables submission of data from fixed physical gauge boards as described above. Where fixed gauge boards are absent, the 'virtual staff gauge' function also enables an observer to use to overlay a virtual gauge board onto an image of the stream bank, aligned with the water surface. Observers can then use this reference photo to record observed changes in stream level over time and upload via the app in a consistent way.

App-based approaches such as Crowdwater present additional distinct advantages in that they eliminate health and safety risks and PPE requirements associated with having to expect volunteers to enter the water to take measurements.

This also eliminates other possible sampling impacts, such as disturbance, repeated trampling of often sensitive river-bed habitats and bio-security risks.

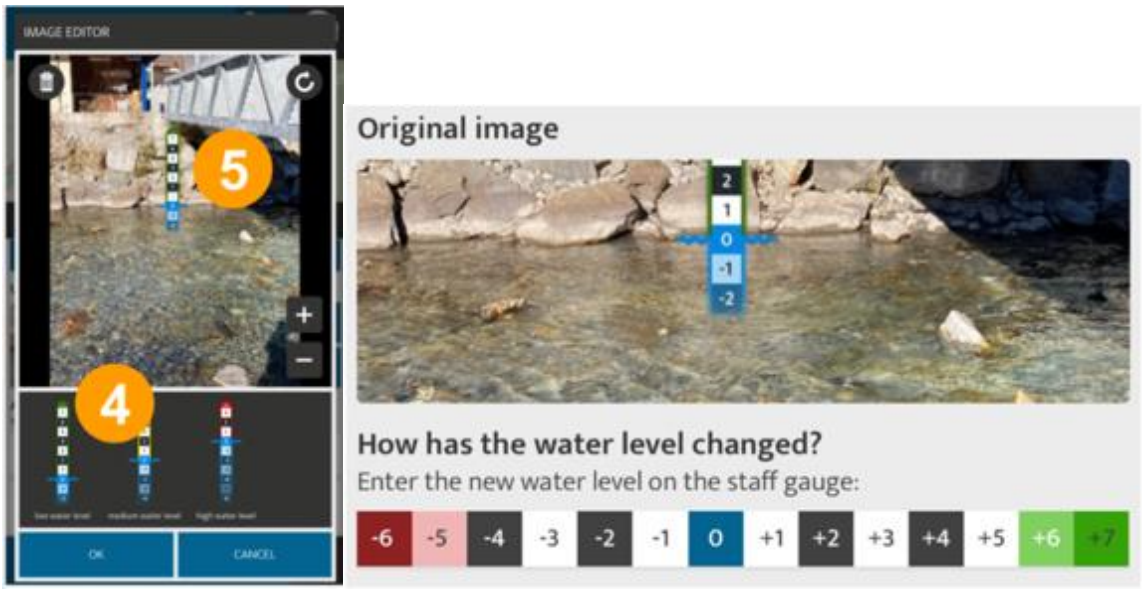


Figure E7: The Crowdwater App allows users to measure river water levels over time using a 'virtual staff gauge' and comparison against an original reference image (Source: Crowdwater)

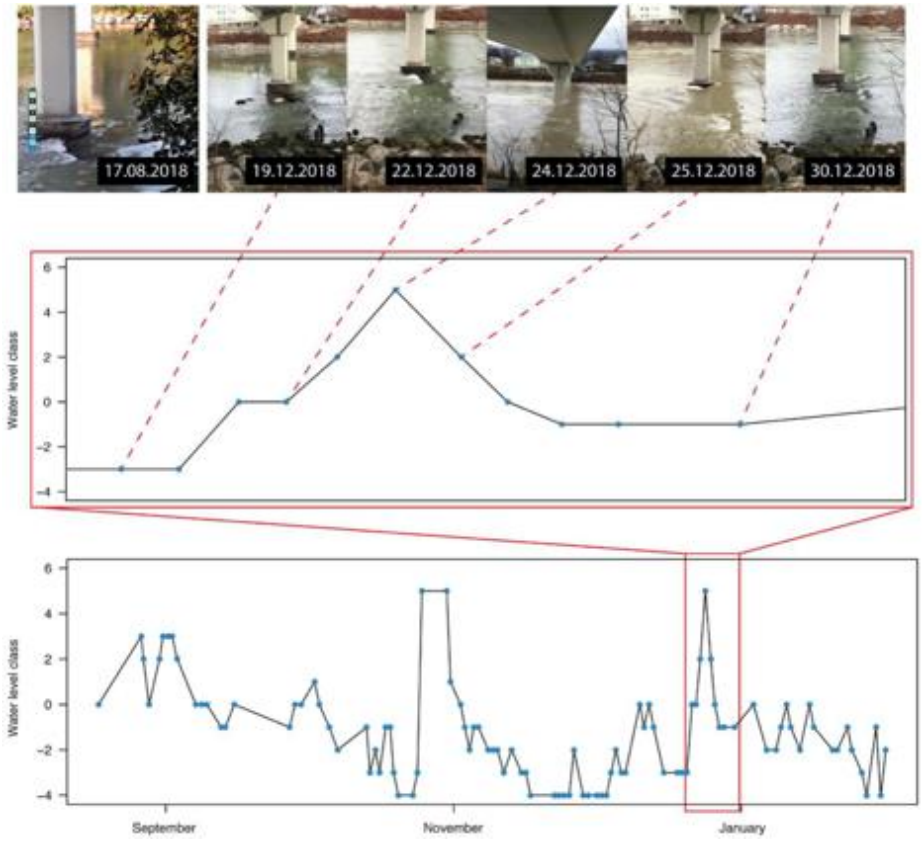


Figure E8: Example of a water level time series obtained using the CrowdWater app (River Salzach, Austria). The pictures for one runoff event (and the reference picture) are shown as an example in the top row (Source: Seibert et al, 2019)

Time Lapse Fixed Point River Levels and flows

Time lapse photography or video of fixed river gauge boards using installed automatic trail cameras at key river sites e.g. at 'Sentinel' site locations to help build an improved understanding of river level and flows of sub-catchments that are not currently monitored. Where river level (stage) and discharge measurements can be obtained and consequently the stage-discharge relationship & Flow Duration Curve can be calculated at a location, this method can subsequently enable river discharge and flows to be determined over long time periods from the river level data. (NB: Fixed point photography has added value as it can also be used to track obvious changes in river flows and turbidity or changes in bed sediment composition over time (e.g. in response to heavy rainfall events mobilising sediments from roads and/or farmland).

Trail cams with night vision and GSM modem capability are desirable if within budget (e.g. HuntPassion 4G Smart Wildlife Camera), or standard wildlife cameras fitted with an additional 3G, 4G or LTE low cost modem such as SpyPoint CellLink can enable real time uploading of data. As well as real time monitoring, telemetry-linked systems have a distinct advantage, in that it is possible to confirm the system is operating correctly and collecting data remotely in real time. Any faults or issues can therefore be investigated and corrected quickly, minimising down time and unnecessary site visits can be avoided. It may also be feasible to integrate other activities of interest to local citizen scientists to increase engagement, e.g. logging wildlife sightings recorded using the cameras such as water vole or otters. Moving forward, should initial trials of the Dishcarge app for stream flow prove successful, then there is much scope to use trail cams as a means of intensively monitoring river flows over long periods.

Figure E9: HuntPassion 4G-capable Wildlife Camera

Stream flow measurement

The measurement of stream flow over time and across varied river stage conditions (i.e. capturing all river flow conditions from high flow events to periods of low flow) enables the stage-discharge relationship and Flow Duration Curve to be calculated (e.g. Othman et al, 2017). This information is important in terms of water resource assessment (e.g. Water for Tomorrow), enabling a better understanding of:

- water resource availability
- impacts of abstraction or the influence of rainfall on catchments
- the influence of river flows on diluting and thereby reducing the impact of both diffuse and point source pollution
- stream and river flows during extreme events, such as drought and floods
- the potential impacts of climate change on the freshwater environment

Where citizen science capacity is sufficiently developed then stream flow monitoring could be considered at e.g. Sentinel sites around the Wensum catchment to improve our understanding of hydrology and water availability in the headwaters. Site selection is important as there are a number of key requirements to ensure flow measurements are as representative and accurate as possible (e.g. West Virginia Department of Environmental Protection 2018).

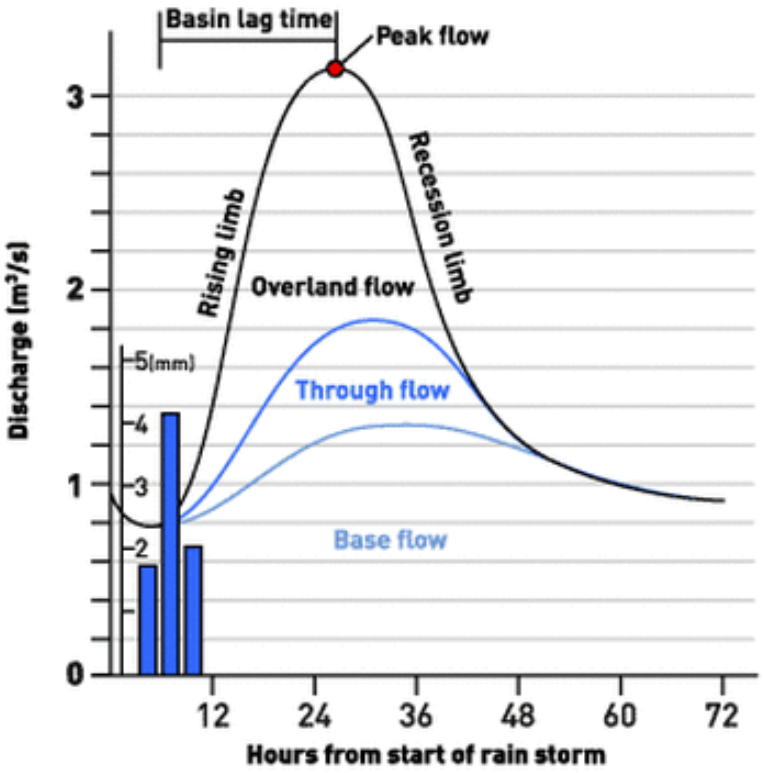


Figure E10: Theoretical storm hydrograph showing the effects of rainfall on river discharge (Source: BBC education)

Stream gauging generally involves 3 steps:

1. Measuring stream stage — obtaining a continuous record of stage—the height of the water surface at a location along a stream or river
2. The discharge measurement — obtaining periodic measurements of discharge (the quantity of water passing a location along a stream)
3. The stage-discharge relation or rating curve —defining the natural but often changing relation between the stage and discharge at that location; using the stage-discharge relation to convert the continuously measured stage into estimates of streamflow or discharge

The development of an accurate stage-discharge relation requires numerous discharge measurements at all ranges of stage and streamflow and once established it is specific to that site. In addition, these relations must be continually checked against on-going discharge measurements because stream channels are constantly changing. Changes in stream channels are often caused by erosion or deposition of streambed materials, seasonal vegetation growth, debris, or ice. New discharge measurements plotted on an existing stage-discharge relation graph would show this, and the rating could be adjusted to allow the correct discharge to be estimated for the measured stage. It follows that if river level and flow gauging is undertaken at sites like bridges or culverts, the fixed channel geometry can enable a more accurate stage-discharge relationship to be derived.

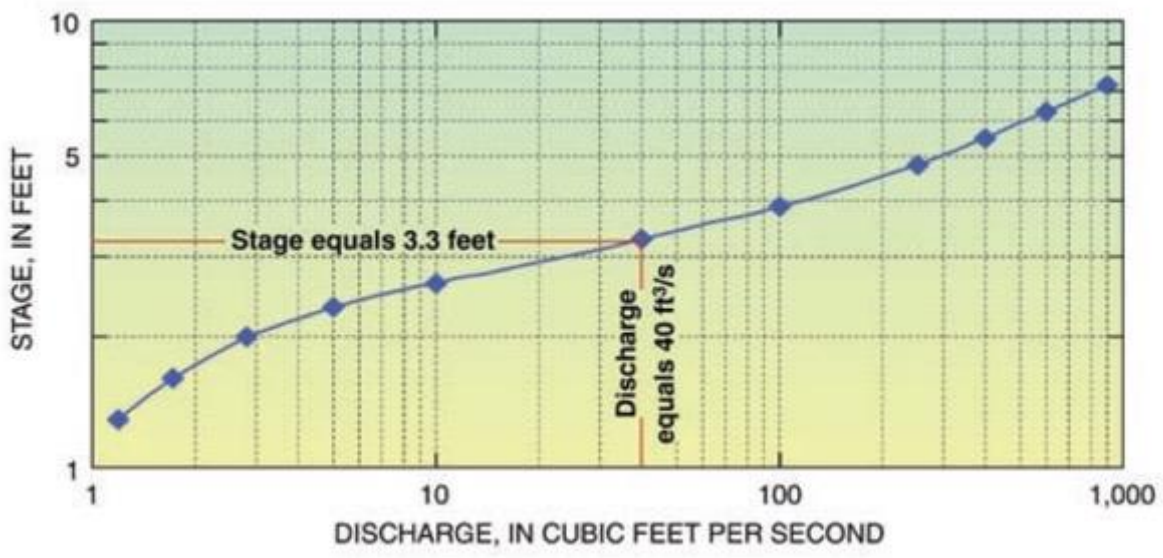


Figure E11: Example of a stage-discharge relationship, where river level can be used to estimate stream flow and discharge at a fixed location (source: USGS)

Method		Operational ease	Cost effectiveness	Accuracy	Time Effectiveness	Ecological significance	References	Remarks
Direct measurement method	Timed volume method	Easy	Inexpensive	High	Efficient	Non-polluting	Najafi et al. (2012) and Shope et al. (2013)	The method can be used only for streams with less flow rate and with a fall
Velocity-area methods	Float method	Easy	Inexpensive	Low	Efficient	Non-polluting; Physical disturbance e.g. trampling stream bed, biosecurity	Hilgersom and Luxemburg (2012), Watson et al. (2013) and Kitlasten and Fogg (2015	The method can be used only for small streams
	Dilution gauging method	Difficult	Inexpensive	Low	Efficient		Moore (2004) and Comina et al. (2014)	Difficult to operate and tracer or dye can damage the environment
	Trajectory method	Difficult	Inexpensive	High	Inefficient	Non-polluting	Boman and Shukla (2009) and Liu et al. (2014)	The method can be applied only to streams where flow can be diverted into a pipe
	Current meters method	Difficult – requires specialist training	Expensive	High	Efficient	Non-polluting; Physical disturbance e.g. trampling stream bed, biosecurity	Chauhan et al. (2014) and Boldt and Oberg (2015)	Current meter can be used only for short term study
	Acoustic doppler profiler method	Difficult	Expensive	High	Efficient	Non-polluting	Herschy (2008) and Flener et al. (2015)	The method can only be used where all the flow can be diverted into a pipe
	Electromagnetic method	Difficult	Expensive	High	Efficient	Non-polluting	Herschy (2008)	Accuracy of the estimates get affected by the size of the stream
Formed construction methods	Weirs method	Difficult	Expensive	High	Inefficient	Non-polluting; Physical impact to stream ecology e.g. barrier to fish passage	Hudson (2004), Martin (2006) and Bonacci et al. (2015)	Construction of the weir on natural streams may alter the local habitat
	Flume method	Difficult	Expensive	High	Inefficient	Non-polluting; Physical impact to stream ecology e.g. barrier to fish passage	Shieh et al. (1996), Baffaut et al. (2015) and Bonacci et al. (2015)	Construction of the structure on natural streams may alter the local habitat
Non-contact measurement methods	Remote sensing method	Difficult	Expensive	Low	Efficient	Non-polluting	Ward et al. (2013) and Birk and Ecke (2014)	It covers larger areas in less time but results need ground truthing
	Particle image velocimetry	Difficult	Expensive	High	Efficient	Non-polluting	Hauet et al. (2008) and Adrian and Westerweel (2011)	This method covers larger areas and yield accurate results but estimates need to be validated and cannot be used in hilly terrain

Table D1: Comparison of different methods used for streamflow estimation (Adapted from Dobriyal et al, 2016)

There are two basic 'traditional' stream flow measurement techniques, based on the velocity-area method that are applicable to the typical lowland streams found in the Wensum catchment (highlighted in Table X above):

River level and flow – floating object method:

The float method is a basic way of measuring stream flow and discharge and is well-suited to citizen science applications, being low cost, easy to undertake and well suited to small lowland streams (e.g. Dobriyal et al, 2016) such as those found in the Wensum catchment. It requires only low cost equipment (measuring tape, ruler or similar for measuring stream depth, marker posts or string to delineate the measured section, a floating object e.g. orange, a stopwatch or timer and a long handled net to retrieve the float at the end of each run) and follows a basic methodology (e.g. Terasmaa *et al*; Field Studies Council; US Environmental Protection Agency, Water Action Volunteers). It is however time-consuming to undertake, both in terms of setting out the site and necessitating several repeat measurements in order to produce a more accurate estimation of stream flow. Measurements using this method cannot be undertaken in very shallow streams (<10cm).

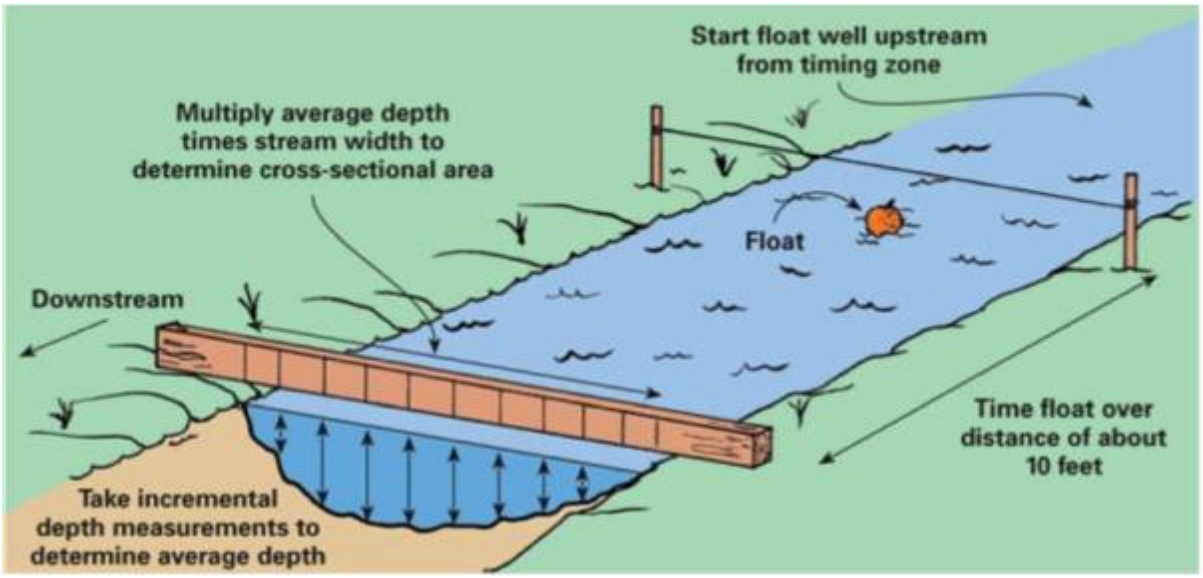


Figure E12: Stream flow estimation using the float method (source: Othman et al, 2017)

4.2.8 River level and flow – flow meter method

In-stream flow measurements can be undertaken at selected sites, for example using low cost flowmeters such as the Geopacks Advanced Flowmeter, Global Water YSI Flow Probe, or more advanced equipment such as the OTT MF Pro. Flow measurement over a range of river levels is essential to help establish a stage-discharge relationship for the river at that location and to generate a Flow Duration Curve. Where the site already has a river level dataset these historic levels can be referenced to the stage-discharge relationship and the flows estimated. Landowner permission may need to be sought in order to locate a suitable river section and access for sampling. Ideally flow measurement sites need to be located on a straight section, with no significant impediments to flow such as branches, weed beds etc for at least 10m

upstream and downstream of the flow transect location. Flow measurement methodology involves splitting the channel width into sub-sections, measuring the depth and flow at each sub-section to calculate flow and discharge (e.g. Michigan Clean Water Corps, US EPA, US National Parks Service)

Figure E13: Measuring stream flow with the OTT MF Pro flow meter (Source: OTT)

There are additional considerations if deploying this method:

- **health & safety:** volunteers need to enter the stream to undertake measurements – PPE? River conditions? Risk assessment? (e.g. Friends of the River Wye)
- **site access:** Suitable sites need to be identified and landowner access permission obtained
- **time/resources:** Both flow measurement methods take a significant time to complete at each site (@0.75 - 2 hours) – unlikely to be feasible alongside water quality monitoring
- **Ecology and bio-security**: What are the impacts of regular disturbance on the site e.g. trampling of the stream bed? Bio-security e.g. crayfish plague (Martin-Torrijos et al, 2021)?

Non-intrusive smartphone-based optical stream flow measurement

Other emerging smartphone based solutions may be applicable to generating more robust CS river flow and discharge data in a quick and non-intrusive way, for example DischargeApp. Discharge App is a smartphone app based om the Android platform which allows the user to undertake non-intrusive, optical flow measurements and provides a portal for uploading and managing data. Use of this app would require an initial preliminary survey of candidate sites to set up four fixed markers (two on each bank) and either use a suite of standard channel forms, or for irregular channels undertake detailed measurements of the stream bed and bank geometry. However, once sites are set up, subsequent citizen science surveys can then be undertaken quickly (<2 minutes) and easily by volunteers using the smartphone app (Discharge demo video). This means it should be possible for volunteers to obtain flow and

discharge data alongside water quality sampling, rather than as a standalone sampling programme due to the time taken to complete stream flow measurements using traditional intrusive methods. A further benefit of this efficiency would be the potential to deliver more frequent flow sampling data. It may also be possible to extend this through the use of automated trail cams or good quality web cams as above. It is recommended that validation trials of Discharge app are undertaken before use.

Non-intrusive app-based approaches such as Discharge App present additional distinct advantages in that they eliminate health and safety risks and PPE requirements associated with having to expect volunteers to enter the water to take measurements.

This also eliminates other possible sampling impacts, such as site disturbance, repeated trampling of often sensitive river-bed habitats and bio-security risks.

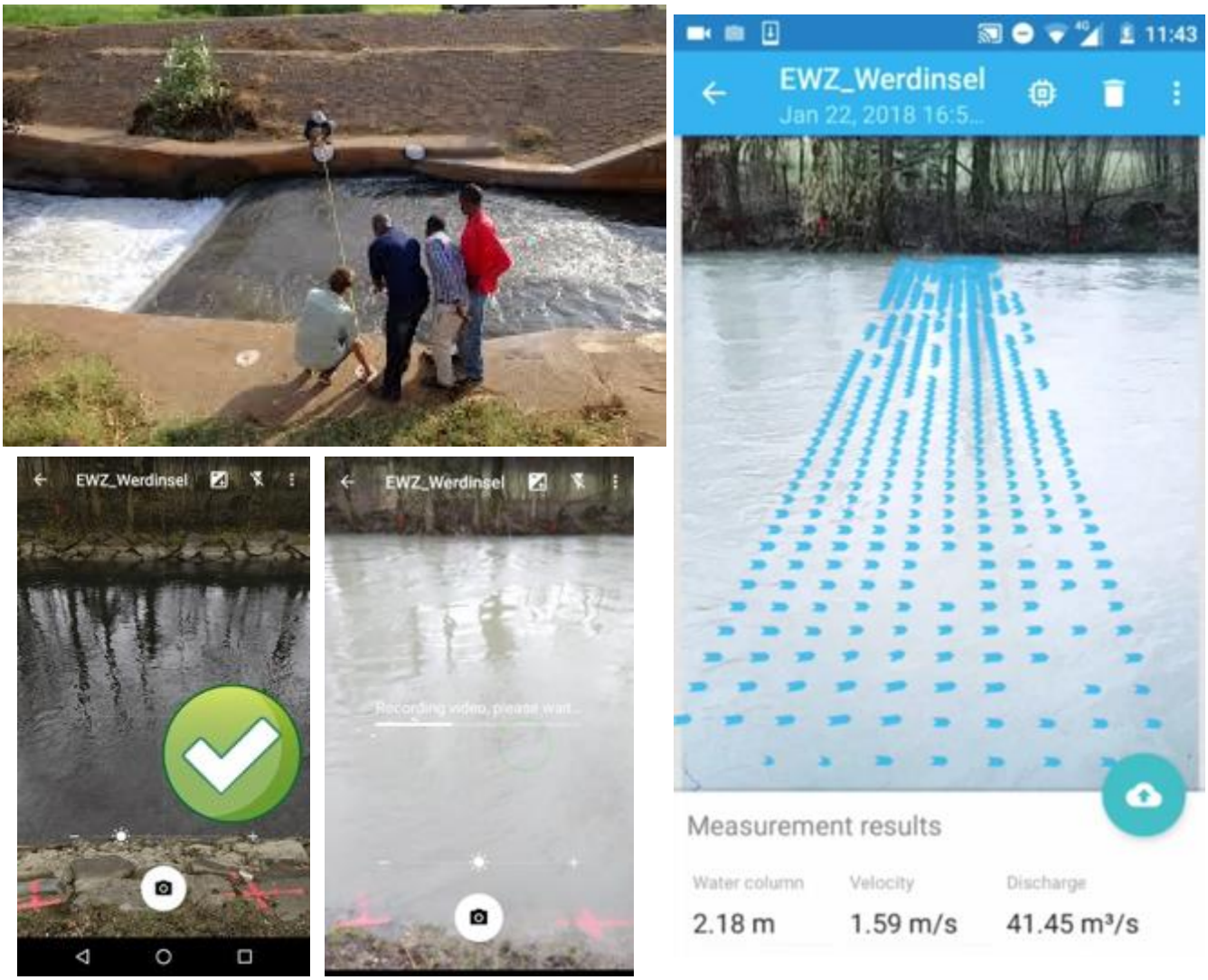
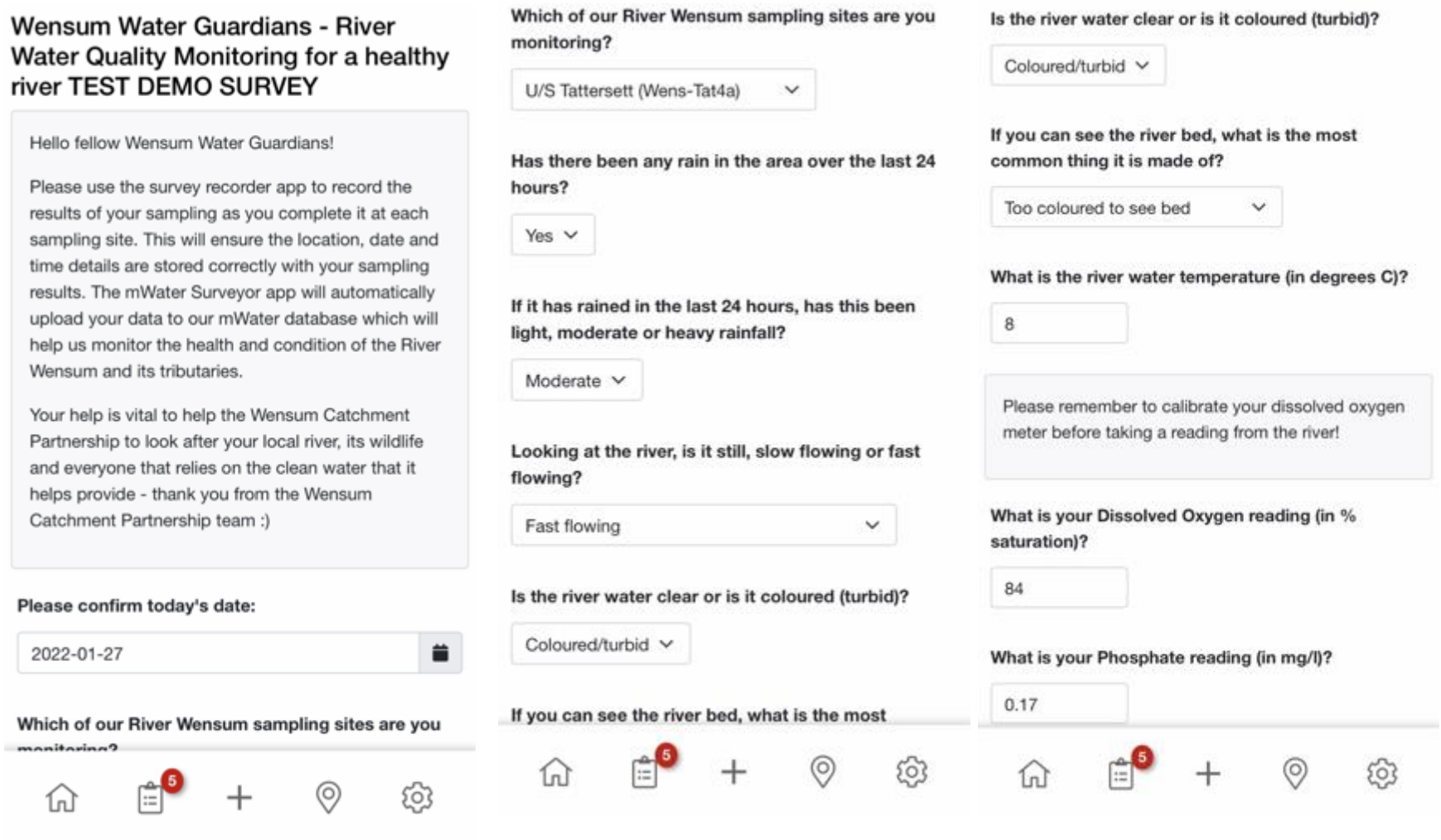
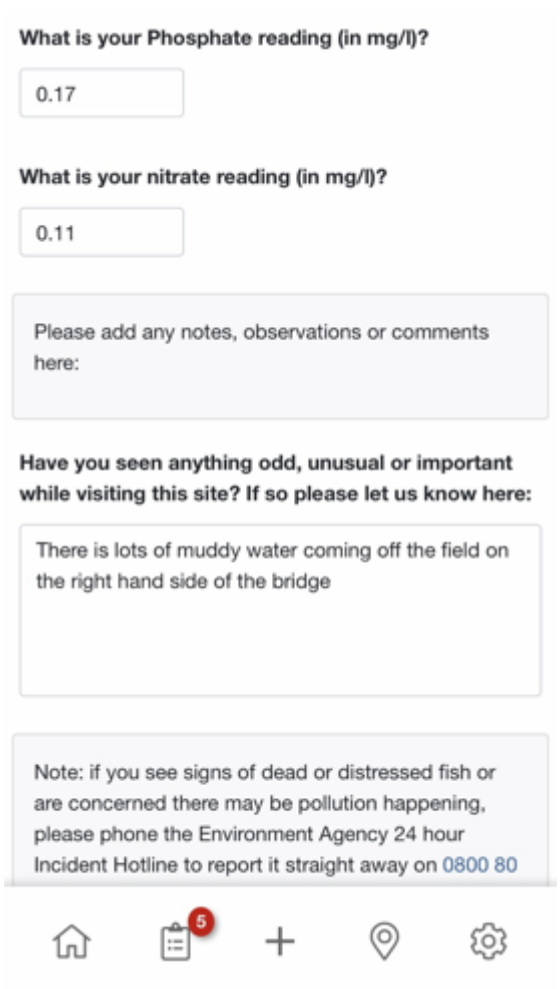


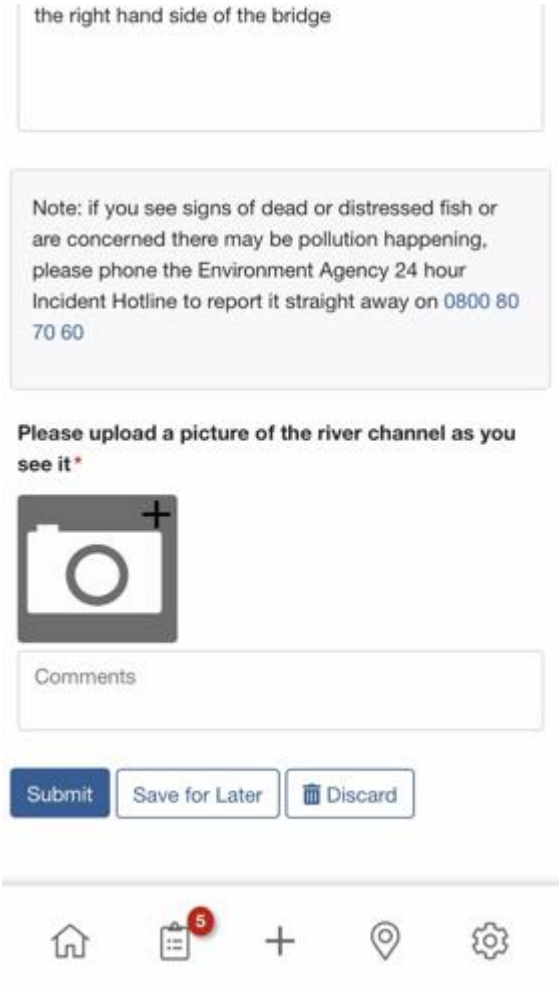
Figure E14: Discharge App uses smartphone-based optical flow measurement which could enable volunteers to rapidly and efficiently undertake stream flow and discharge measurement (source: Phototrack AG

Appendix F: mWater Surveyor app trial construct for data entry

Figure F1: Screenshots of citizen science data entry app constructed using mWater Surveyor and the mWater Portal.




What is your Phosphate reading (in mg/l)?
0.17
What is your nitrate reading (in mg/l)?
0.11
Please add any notes, observations or comments here:
Have you seen anything odd, unusual or important while visiting this site? If so please let us know here:
There is lots of muddy water coming off the field on the right hand side of the bridge
Note: if you see signs of dead or distressed fish or are concerned there may be pollution happening, please phone the Environment Agency 24 hour Incident Hotline to report it straight away on 0800 80

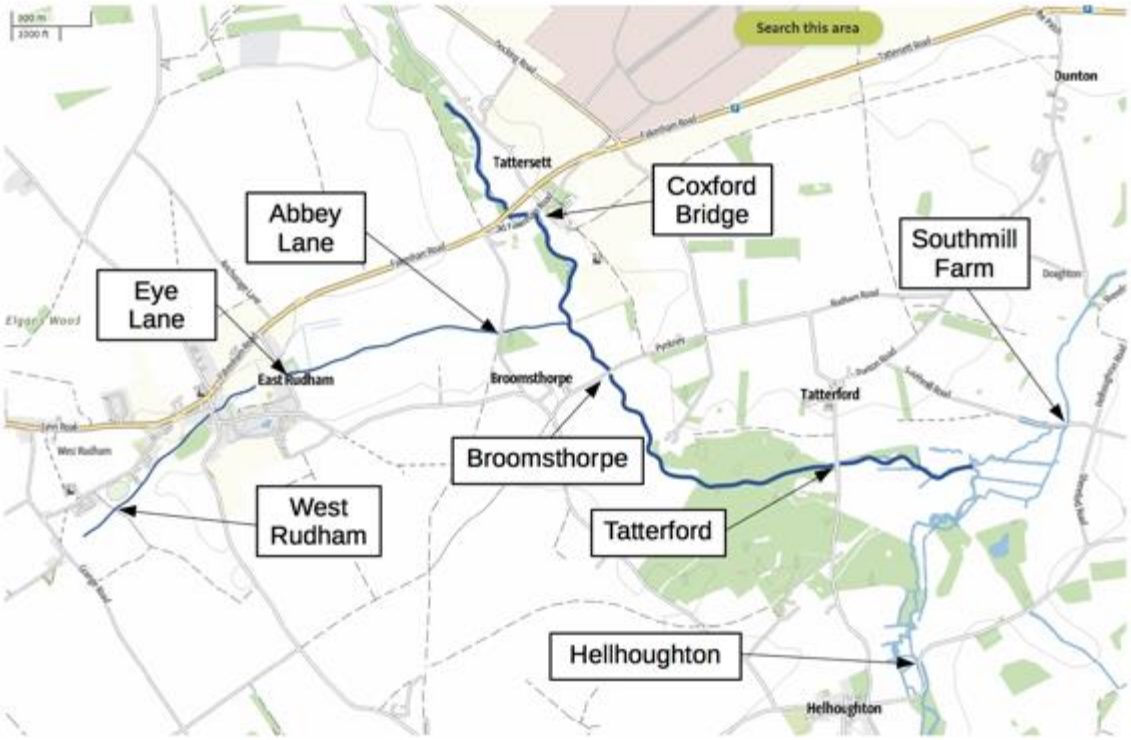

the right hand side of the bridge
Note: if you see signs of dead or distressed fish or are concerned there may be pollution happening, please phone the Environment Agency 24 hour Incident Hotline to report it straight away on 0800 80 70 60
Please upload a picture of the river channel as you see it *
Comments
Submit
Save for Later
Discard

Appendix G: Water quality results from practical equipment trials

The following data were obtained during field visits to various upper Wensum tributary catchments in February 2022.

River Tat:

Sampling sites on the River Tat are shown below.



River Tat sites sampled on 9 February 2022:

Location	P (as PO4 $^{-3}$)	P (as PO4^{-P})	NH3^{-N}	NO3-N	NO2-N	°C	DO %	TDS	EC	pH
Coxford Bridge	0.30	0.0978	0.00	5	0	8.0	82.5	252	462	7.35
Eye Lane	0.26	0.0848	0.00	5	0	9.5	92.1	264	556	7.65
Abbey Lane	0.30	0.0978	0.04	5	0	8.9	90.1	272	532	7.60
Broomsthorpe	0.15	0.0489	0.00	10	0	8.6	88.0	262	506	7.55
Tatterford	0.28	0.0913	0.01	5	0	8.4	87.6	252	512	7.65

Readings in red fail to meet Wensum water quality targets (PO4-P = <0.04mg/l u/s Sculthorpe; DO=>85%)

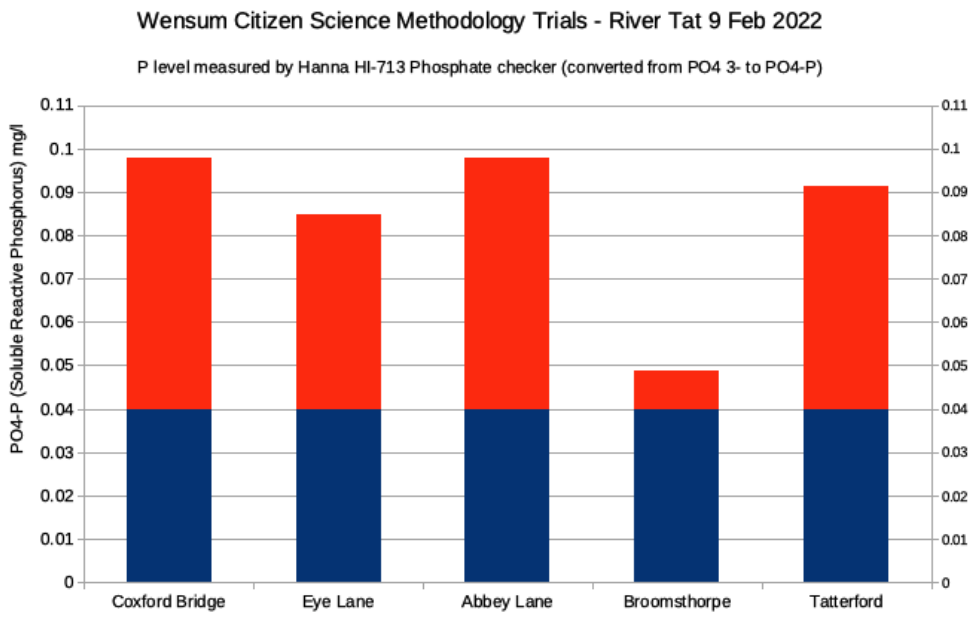
Equipment used:

Phosphate: HI-713 - Hanna Low Range Handheld Phosphate Colorimeter - Checker
Ammonnia: HI-715 – Hanna Medium Range Handheld Ammonia Colorimeter – Checker

Nitrate/Nitrite: SimplexHealth Nitrate 0-50ppm & Nitrite 0-10ppm Test Strips (50)

Temperature & Dissolved oxygen: VWR DO210TDS, EC & pH: Pancellant Water Quality Test Meters pH EC TDS Temperature Set

Time taken: 25-30 minutes per site including photo and data entry/upload on mWater app.



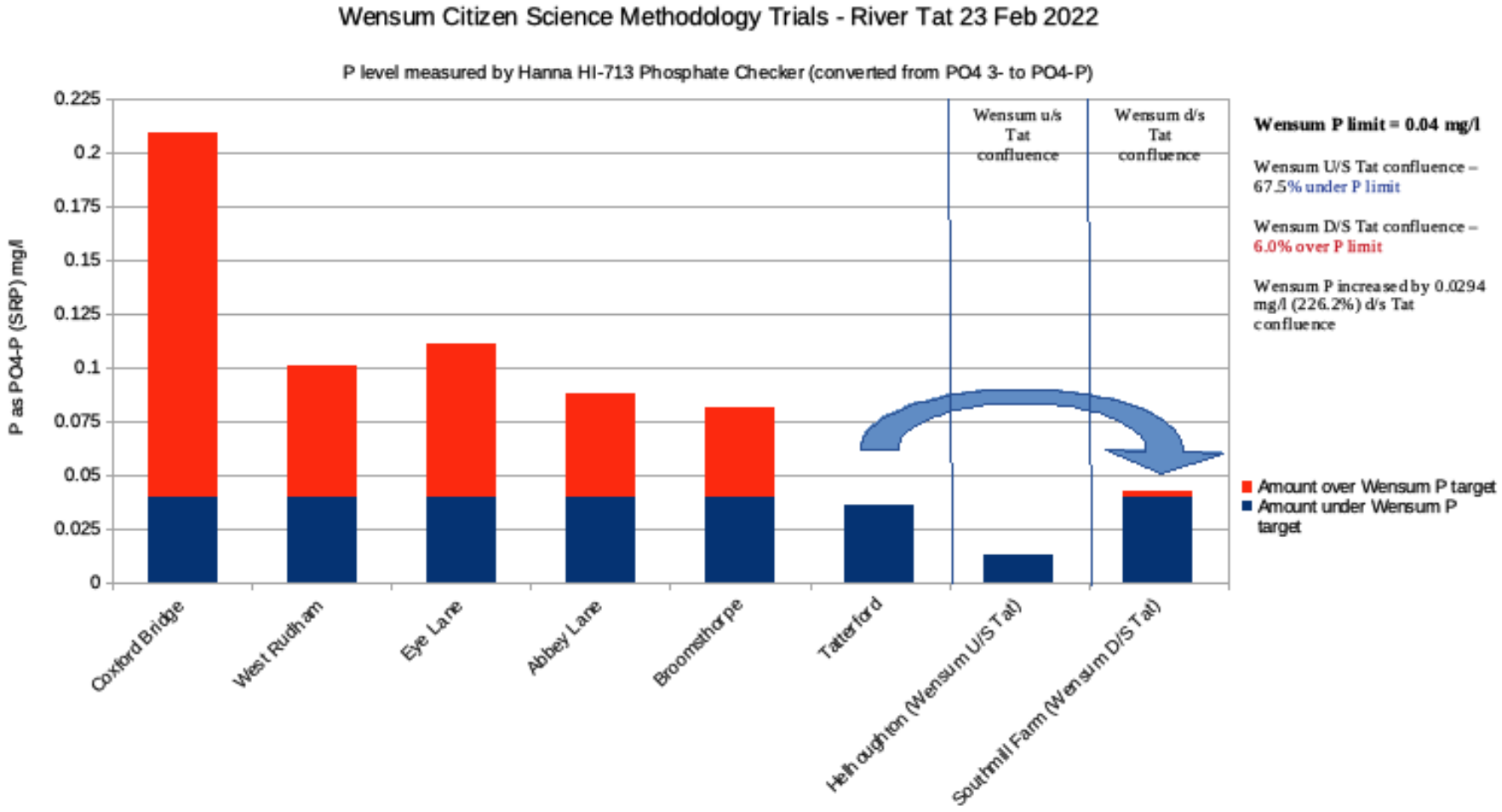
River Tat sampled on 23 February 2022:

The following sites were sampled in the Tat catchment, together with two sites on the main River Wensum upstream and downstream of the confluence with the Tat.

Location	P (as $PO4^{-3}$)	P (as $PO4^{-P}$)	$NH3^{-}N$	NO3-N	NO2-N	°C	DO %	TDS	EC	pH
Coxford Bridge	0.64	0.2087	0.00	5	0	6.3	74.0	237	454	7.60
W. Rudham	0.31	0.1011	0.00	5	0	9.6	81.4	-	-	-
Eye Lane	0.34	0.1109	0.00	5	0	10.1	95.9	282	570	7.70
Abbey Lane	0.27	0.0880	0.00	5	0	7.2	85.9	256	510	7.60
Broomsthorpe	0.25	0.0815	0.00	5	0	8.5	81.0	247	512	7.73
Tatterford	0.11	0.0359	0.00	5	0	8.1	81.8	241	496	7.9
Helhoughton (Wens U/S)	0.04	0.0130	0.00	5	0	8.1	85.8	272	548	7.99
Southmill Farm (Wens D/S)	0.13	0.0424	0.00	5	0	7.9	83.6	264	512	7.89

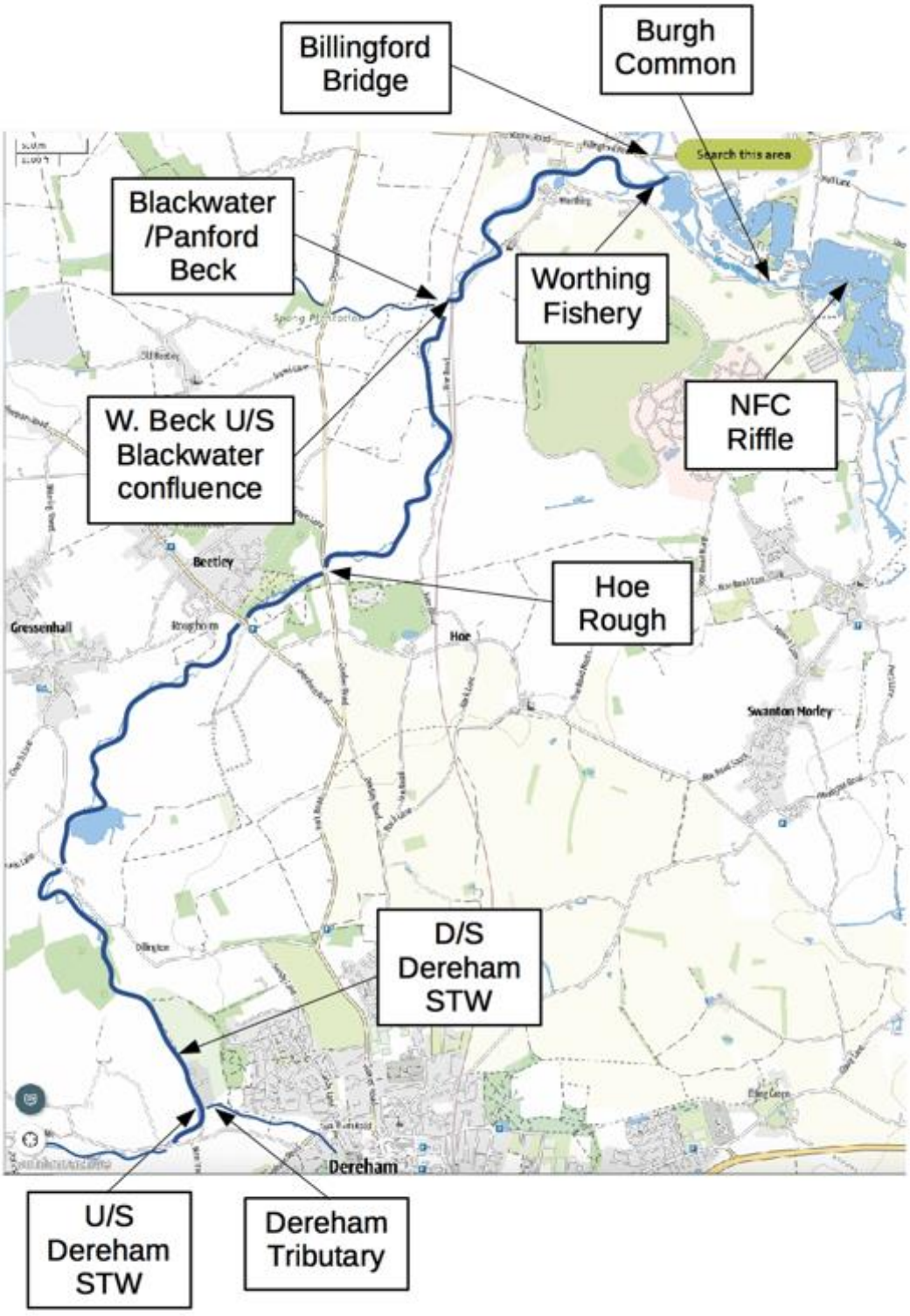
Readings in red fail to meet Wensum water quality targets (PO4-P = <0.04mg/l u/s Sculthorpe; DO=>85%)

Equipment used:
Phosphate: HI-713 - Hanna Low Range Handheld Phosphate Colorimeter - Checker
Ammonnia: HI-715 – Hanna Medium Range Handheld Ammonia Colorimeter – Checker
Nitrate/Nitrite: SimplexHealth Nitrate 0-50ppm & Nitrite 0-10ppm Test Strips (50)
Temperature & Dissolved oxygen: AZ Instruments 8403 Dissolved Oxygen Meter
TDS, EC & pH: Pancellant Water Quality Test Meters pH EC TDS Temperature Set
25-30 minutes per site including photo and data entry/upload on mWater app.


Wensum Citizen Science Methodology Trials - River Tat 23 Feb 2022
P level measured by Hanna HI-713 Phosphate Checker (converted from PO4 3- to PO4-P)
P as PO4-P (SRP) mg/l
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
Coxford Bridge
West Rudham
Eye Lane
Abbey Lane
Broomsthorpe
Tatterford
Helhaughton (Wensum U/S Tat)
Southmill Farm (Wensum D/S Tat)
Wensum u/s Tat confluence
Wensum d/s Tat confluence
Wensum P limit = 0.04 mg/l
Wensum U/S Tat confluence – 67.5% under P limit
Wensum D/S Tat confluence – 6.0% over P limit
Wensum P increased by 0.0294 mg/l (226.2%) d/s Tat confluence
Amount over Wensum P target
Amount under Wensum P target

Wendling Beck:

Sampling sites visited on the Wendling Beck are shown below.



Wendling Beck sites sampled on 8 February 2022:

The following sites were sampled in the Wendling Beck catchment, together with two sites on the main River Wensum upstream and downstream of the confluence with the Wendling Beck.

Location	P (as PO4 $^{-3}$)	P (as PO4^{-P})	NH3^{-N}	NO3-N	NO2-N	°C	DO %	TDS	EC	pH
U/S Dereham STW	0.15	0.0489	0.00	2	0	8.9	104.3	296	586	7.84
D/S Dereham STW	0.46	0.1500	0.00	5	0	9.0	102.9	314	636	7.83
Worthing Fishery	0.20	0.0652	0.04	2	0	8.3	110.2	279	542	7.93
Billingford Bridge (Wens U/S conf.)	0.04	0.0130	0.00	5	0	8.5	103.9	276	564	7.72
NFC Riffle (Wens D/S conf.)	0.17	0.0554	0.05	2	0	7.3	105.0	251	524	7.63
Billingford Drain (NFC culvert)	0.14	0.0457	0.00	2	0	8.0	105.1	240	486	7.38

Readings in red fail to meet Wensum water quality targets (PO4-P = <0.05mg/l d/s Sculthorpe; DO=>85%)

Equipment used:

Phosphate: HI-713 - Hanna Low Range Handheld Phosphate Colorimeter - Checker

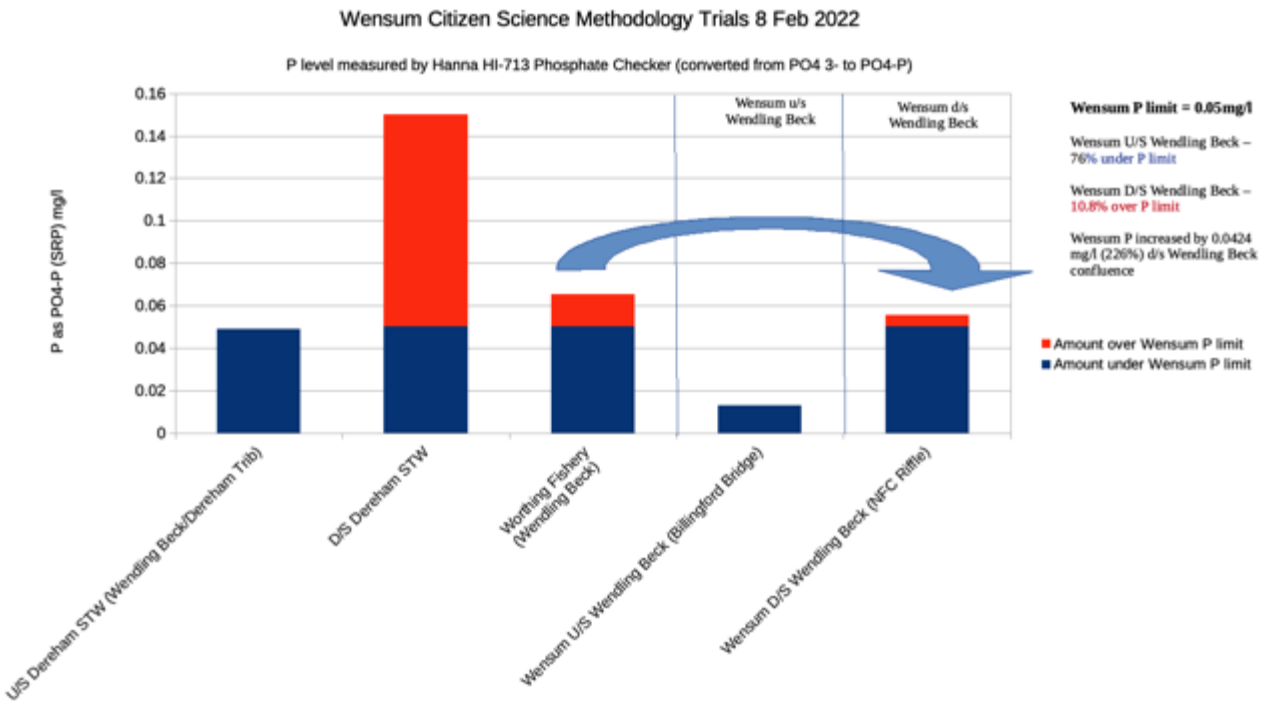
Ammonnia: HI-715 – Hanna Medium Range Handheld Ammonia Colorimeter – Checker

Nitrate/Nitrite: SimplexHealth Nitrate 0-50ppm & Nitrite 0-10ppm Test Strips (50)

Temperature & Dissolved oxygen: VWR DO210

TDS, EC & pH: Pancellant Water Quality Test Meters pH EC TDS Temperature Set

Time taken: 25-30 minutes per site including photo and data entry/upload on mWater app.



Dereham tributary before its confluence with the Wendling Beck at Rushmeadow

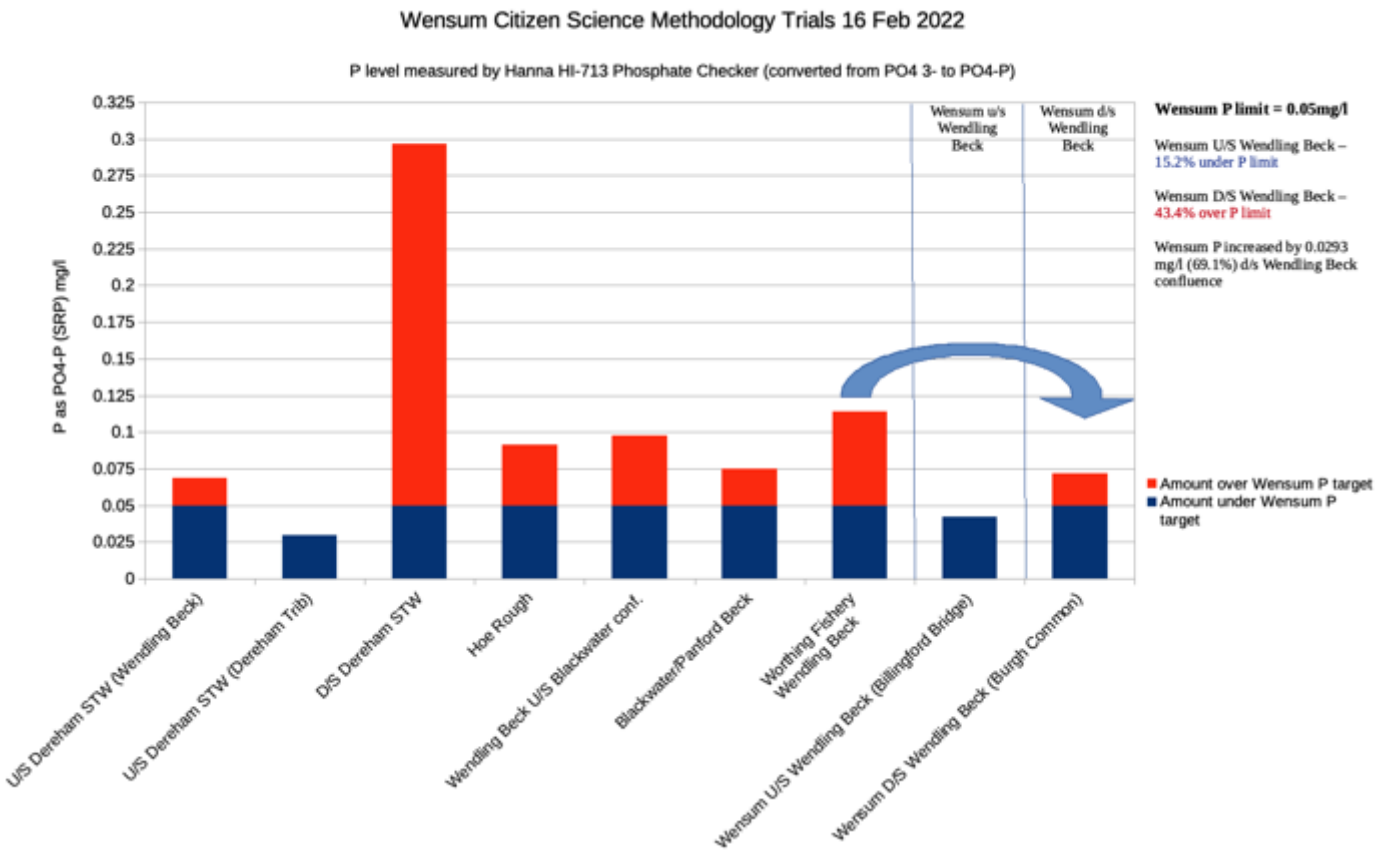
Wendling Beck & River Wensum sites sampled on 16 February 2022:

Location	P (as $PO4^{-3}$)	P (as $PO4^{-P}$)	$NH3^{-N}$	NO3-N	NO2-N	°C	DO %	TDS	EC	pH
W. Beck U/S Dereham STW	0.21	0.0685	0.00	5	0	10.1	93.5	278	552	7.95
Dereham Trib.	0.09	0.0293	0	2	0		85.1	288	584	7.74
D/S Dereham STW	0.91	0.2968	0.00	5	0	10.3	89.0	270	556	7.89
Hoe Rough	0.28	0.0913	0.01	5	0	10.9	88.4	273	536	7.87
W. Beck U/S Blackwater conf.	0.30	0.0978	0.05	5	0	10.8	87.5	274	544	7.98
Blackwater U/S W. Beck conf.	0.23	0.0750	0.00	2	0	11.9	88.0	272	548	7.95
Worthing Fishery	0.35	0.1141	0.00	-	-	8.6	87.3	248	496	7.83
Billingford Bridge (Wensum U/S conf.)	0.13	0.0424	0.03	2	0	9.9	87.8	252	516	7.86
Burgh Common (Wensum D/S conf.)	0.22	0.0717	0.02	0.5	0	9.1	85.0	248	504	7.85

Readings in red fail to meet Wensum water quality targets (PO4-P = <0.05mg/l d/s Sculthorpe; DO=>85%)

Equipment used:

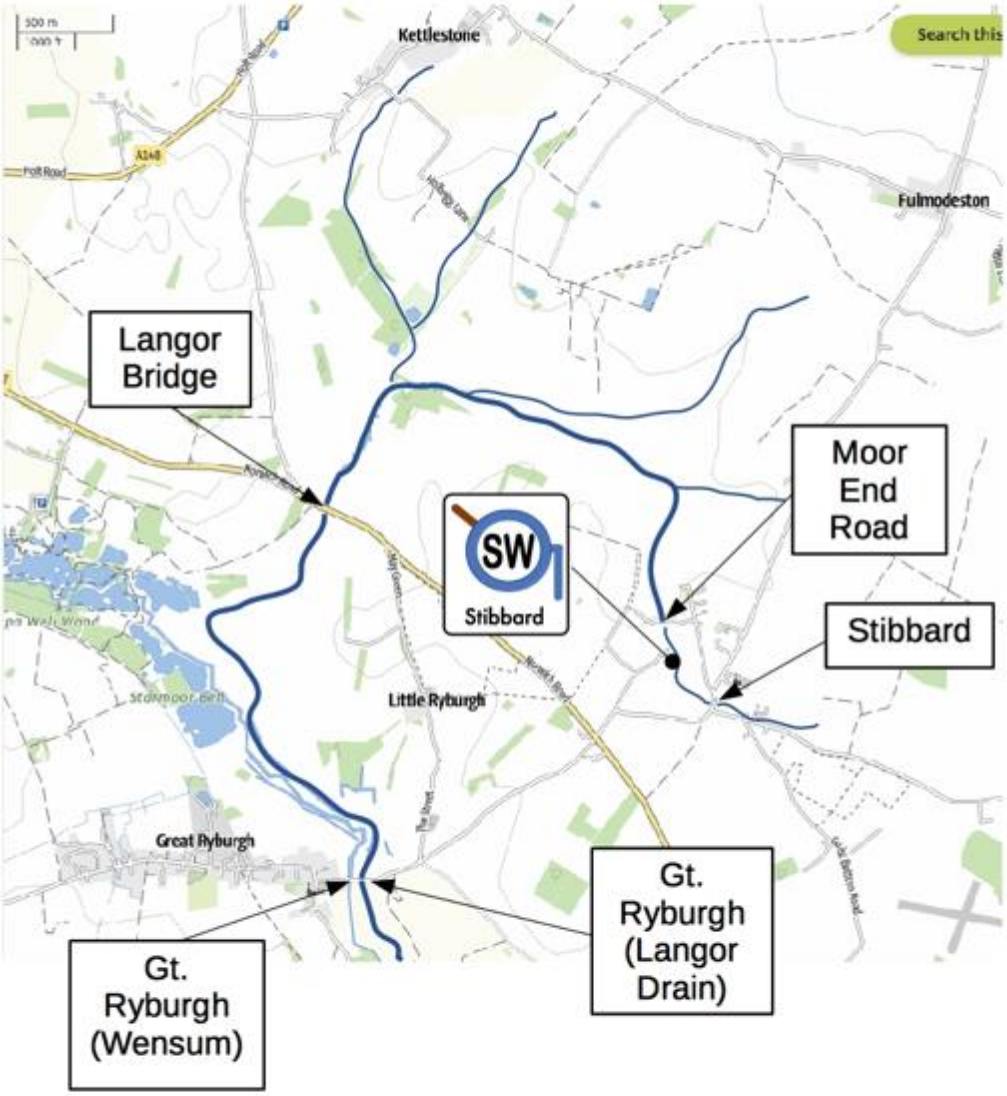
Phosphate: HI-713 - Hanna Low Range Handheld Phosphate Colorimeter - Checker
Ammonnia: HI-715 – Hanna Medium Range Handheld Ammonia Colorimeter – Checker
Nitrate/Nitrite: SimplexHealth Nitrate 0-50ppm & Nitrite 0-10ppm Test Strips (50)
Temperature & Dissolved oxygen: AZ Instruments 8403 Dissolved Oxygen Meter
TDS, EC & pH: Pancellant Water Quality Test Meters pH EC TDS Temperature Set
25-30 minutes per site including photo and data entry/upload on mWater app.



Sarah Gelpke of Norfolk Rivers Trust sampling the Wendling Beck at Rushmeadow

Langor Drain:

Sampling sites visited on the Langor Drain are shown below.



Langor Drain 22 February 2022:

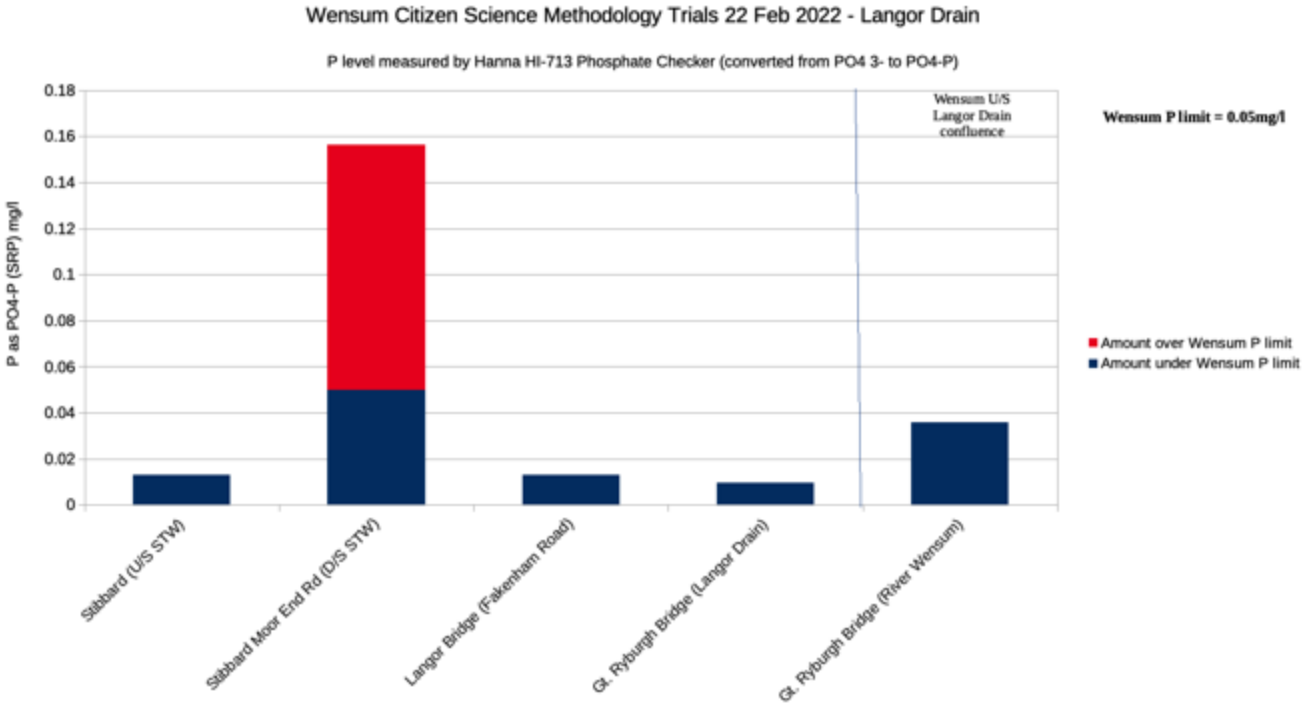
The following sites were sampled in the Langor Drain tributary, together with the main River Wensum just upstream of the confluence with the Langor Drain.

Location	P (as $PO4^{-3}$)	P (as $PO4^{-P}$)	$NH3^{-N}$	NO3-N	NO2-N	°C	DO %	TDS	EC	pH
Stibbard	0.04	0.0130	0	2	0	10.3	80.4	260	518	7.85
Moor End Road	0.48	0.1565	0.05	2	0	8.3	81.2	278	556	7.82
Langor Bridge	0.04	0.0130	0	2	0	8.7	83.3	271	546	7.79
Gt. Ryburgh (Langor Drain)	0.03	0.0098	0	2	0	7.4	83.6	257	516	7.69
Gt. Ryburgh (Wensum)	0.11	0.0359	0.04	5	0	7.1	82.9	240		7.81

Readings in red fail to meet Wensum water quality targets (PO4-P = <0.05mg/l d/s Sculthorpe; DO=>85%)

Equipment used:
Phosphate: HI-713 - Hanna Low Range Handheld Phosphate Colorimeter - Checker
Ammonnia: HI-715 – Hanna Medium Range Handheld Ammonia Colorimeter – Checker
Nitrate/Nitrite: SimplexHealth Nitrate 0-50ppm & Nitrite 0-10ppm Test Strips (50)
Temperature & Dissolved oxygen: AZ Instruments 8403 Dissolved Oxygen Meter
TDS, EC & pH: Pancellant Water Quality Test Meters pH EC TDS Temperature Set
25-30 minutes per site including photo and data entry/upload on mWater app.

Phosphate sample from the Wendling Beck at Worthing Fishery


Wensum Citizen Science Methodology Trials 22 Feb 2022 - Langor Drain
P level measured by Hanna HI-713 Phosphate Checker (converted from PO4 3- to PO4-P)
P as PO4-P (SRP) mg/l
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Wensum U/S Langor Drain confluence
Wensum P limit = 0.05mg/l
Amount over Wensum P limit
Amount under Wensum P limit
Stibbard (U/S STW)
Stibbard Moor End Rd (D/S STW)
Langor Bridge (Fakenham Road)
Gt. Ryburgh Bridge (Langor Drain)
Gt. Ryburgh Bridge (River Wensum)

STEVE LANE
ENVIRONMENTAL
Consultancy Services

www.stevelane-environmental.co.uk