

The Cleddau Project: C- CAP Phase 2 Report



Paul JA Withers
Lancaster University



Ariennir gan
Lywodraeth Cymru
Funded by
Welsh Government



Contents

Executive Summary	3
Crynodeb Gweithredol.....	6
Glossary	9
1. Introduction	10
2. Methodology	11
2.1 The Cleddau catchment study area.....	11
2.2 Sampling programme.....	12
2.3 SAC compliance and nutrient targets	13
2.4 Data analysis	14
3. Results	15
3.1 Phosphate	15
3.2 Nitrate	20
3.3 Ammonia	22
3.4 Turbidity	23
3.5 Temperature.....	23
3.6 pH.....	24
3.7 River flow	24
3.8 Comparison with NRW monitoring.....	26
3.9 Comparison with CEH monitoring.....	28
3.10 Comparison to other citizen science data	32
3.11 Dominant source signals.....	33
4. Overall Conclusions and Recommendations	37
4.1 Conclusions.....	37
4.2 Recommendations	39
5. Acknowledgements	39
6. References.....	40

Appendices 1-5

Executive Summary

The Cleddau Catchment Assessment Project (C-CAP) is a 'citizen science' community initiative formed in 2024 committed to resolving the persistent pollution that threatens the health and biodiversity of the Cleddau waterways. The current focus of the project is on monitoring nutrient pollution with nitrogen (N) and phosphorus (P) due to the poor ecological condition of the freshwater and marine Special Areas of Conservation (SAC). Continued N and P enrichment of water leads to increased abundance and reduced diversity of aquatic plants and organisms, and can periodically result in nuisance growth of algae (e.g blooms), which are detrimental to both river and human health when environmental conditions are right.

This report summarises the results of an analysis of Phase 2 of a nutrient monitoring programme across the Cleddau catchment from July 2024 to June 2025. River water from a total of 46 sites largely representing Cleddau tributaries were monitored every two weeks for orthophosphate-P, nitrate-N, ammonia-N and turbidity concentrations alongside river flow, pH and temperature. There were more monitoring sites in the Western Cleddau catchment than in the Eastern Cleddau catchment and those feeding into the Estuary. Most of the monitoring sites were on tributaries.

The C-CAP project provided a greater frequency and consistency of monitoring across the catchment than is currently resourced by Natural Resources Wales (NRW) and therefore makes a valuable addition to the evidence base needed to promote better management of river pollution and restore favourable condition to the SAC. Beyond the data benefit, the volunteer run project also generated considerable community awareness and engagement.

Orthophosphate-P concentrations were very variable with annual mean P values of 0.02-0.05 mg/L at ca. 55% of sites and around or over 0.1 mg/L at other sites. Upstream sites on monitored tributaries tended to have lower P concentrations than downstream sites but not always. The time series of concentration data showed a general pattern of a very variable background P signal (<0.01 to >0.1 mg/L) interspersed with episodic spikes of much higher concentrations ranging up to 1.6 mg/L in both winter and summer, and indicates widespread P pollution across the catchment. Preliminary concentration (C)-flow (Q) analysis suggested a mixture of wastewater and agricultural sources was contributing to the river P flux or load (kg/ha) across most sites, but with agriculture the major source. Further CQ analysis on a longer time series of data is required to verify this initial source apportionment.

Comparison of C-CAP and NRW P concentrations at common locations showed good agreement at some sites with lower annual mean P values, but C-CAP concentrations

were notably much greater than those measured by NRW at many other sites. Discrepancies were most apparent for sites in the Eastern Cleddau catchment. Preliminary comparison of C-CAP P concentrations with more detailed but limited P fractionation of river samples by the UK Centre for Ecology & Hydrology (CEH) also showed some similar discrepancies, and suggests the accuracy (or consistency) of C-CAP monitoring of orthophosphate-P may need to be improved.

Nitrate concentrations showed much less intra-annual variation and mean and median annual values were largely in the range from 2.0-4.5 mg/L at 85% of sites, and again indicates endemic N pollution sufficient to compromise good ecological status. Concentrations as low as 1.1 mg/L and as high as 5.7 mg/L were recorded at other sites. As with orthophosphate-P, upstream sites on monitored tributaries tended to have lower N concentrations than downstream sites but not always. C-CAP concentrations compared well (r^2 0.84) with NRW nitrate-N values at common locations. There was no correlation between orthophosphate-P and nitrate-N concentrations across sites. Dilution of N concentrations at high flows, increased concentrations in spring and decreased concentrations in summer were all seasonal trends that require a longer time series to verify.

Ammonia-N concentrations were not always measured, not detectable (i.e. zero values) on many of the sampling dates and highly variable. Annual mean concentrations (including zero values) never exceeded 0.3 mg/L, although peak concentrations of up to 4 mg/L occurred on individual sampling days. Comparison with CEH data suggests measurement of ammonia may need to be improved. There was no overall correlation between orthophosphate-P and ammonia-N concentrations. Turbidity measurements were too insensitive to detect differences in suspended sediment concentrations, although clear increases in turbidity up to 240 BTU were observed during high flow storm events.

Annual mean temperature and pH measurements typically averaged between 10.0 and 13.5°C and between 7.0 and 8.5, respectively and showed wide seasonal variability with lowest values in winter and highest values in summer, as expected. Limited comparison between site recorded river flow and daily mean river flows at the two current gauging stations showed generally good agreement providing some confidence in C-CAP measurements, but further calibration of site measured flows is needed once more gauged flow data becomes available.

To enhance the value of the C-CAP project, it is therefore recommended to both continue the monitoring programme and improve the accuracy of sampling and measurements:

- (a) complete calibration of C-CAP river flow measurements once the National Flow Archive has been updated with daily flow rates for the two gauging stations in the catchment.
- (b) increase the scope of future sampling to include measurement of dissolved oxygen and to investigate the apparent discrepancies between C-CAP measurements and NRW monitoring data for common monitoring sites using paired sampling and especially for the Eastern Cleddau catchment sites.
- (c) cross check C-CAP P protocols and results with those of other Citizen Science groups on other rivers using the same apparatus
- (d) expand comparisons of C-CAP monitoring results with more detailed assessment of the dissolved and particulate P forms in the water column as recently carried out by CEH
- (e) enhance quality control of P measurements by repeating very high and very low measurements and routinely calibrating the Hanna instruments against standard water samples of known orthophosphate-P content
- (f) continue the C-CAP monitoring programme beyond Phase 3 to extend the time series of measurements to allow enhanced evaluation of sources of nutrient pollution and their seasonal variation across the catchment.
- (g) Undertake a review of N concentrations in groundwater across the catchment to inform source attribution of river N concentrations.

Crynodeb Gweithredol

Mae dalgylch y Cleddau yn ardal bwysig ar gyfer amaethyddiaeth, pysgodfeydd, hamdden a thwristiaeth yng Nghymru. Mae'r rhan fwyaf o'r dalgylch, a'r aber y mae dwy brif afon y dalgylch yn llifo iddo, sef y Cleddau Wen a'r Cleddau Ddu, yn Ardal Cadwraeth Arbennig (ACA) o bwys. Nid yw cyflwr yr ACA yn ffafriol ar hyn o bryd, gan fod gweithgaredd dynol (anthropogenig) yn golygu fod ffosfforws (P) a nitrogen (N) yn cyfoethogi maetholion. Nid yw 70% o'r cyrff dŵr yn y dalgylch yn cyrraedd y targed o ran crynodiadau orthoffosffad-P, sy'n ofynnol ar gyfer cyflwr ffafriol yn yr ACA. Er mwyn cyrraedd y targedau hyn ac er mwyn darparu amgylchedd dŵr glân ac iach i bobl a bywyd gwylt, mae angen gweithredu i leihau'r llwyth P sy'n mynd i mewn i'r rhwydwaith afonydd yn dalgylch y Cleddau.

Mae'r adroddiad gweithredol hwn yn crynhoi'r ymchwil er mwyn sicrhau gwell dealltwriaeth o bwysau'r mewnbwn ffosfforws o fewn y sector perthnasol, sy'n effeithio ar ansawdd y dŵr o fewn dalgylch y Cleddau. Mae'r adroddiad hefyd yn gefnogol i sicrhau Cynllun Rheoli Maetholion (NMP) i liniaru llygredd oherwydd presenoldeb P yn nyfrffyrdd y Cleddau, gan sicrhau fod cyflwr yr ACA yn ffafriol drachefn. O fewn yr astudiaeth, ceir dadansoddiad manwl o ddefnydd ffosfforws o fewn y sector yn dalgylchoedd y Cleddau Wen a'r Cleddau Ddu, hyd at y man lle maent yn ymuno ym Mhwynt Picton. Hefyd, mae'r astudiaeth yn adrodd ar yr effaith posibl gan bwysau mewnbwn P o fewn y sector ar y crynodiadau P a'r fflwcs P sydd yng ngwahanol is-ddalgylchoedd yr afonydd, a'r goblygiadau ar gyfer rheoli P o fewn y sector.

Yn 2021, dangosodd Dadansoddiad Llif Sylweddau (P-SFA) yn dalgylchoedd y Cleddau Wen a'r Cleddau Ddu, mai <50% oedd effeithlonrwydd cyfredol y defnydd o P yn systemau bwyd y dalgylch o fewn y sectorau amaethyddol a dŵr gwastraff. Roedd aneffeithlonrwydd yn y defnydd o P yn y sector amaethyddol sy'n gysylltiedig â ffermio da byw, yn cynhyrchu gormodedd o P amaethyddol bob blwyddyn. Roedd y swm uchel hwn o P nas defnyddiwyd tua 8.5 kg/ha ar gyfartaledd o fewn yr ardal ffermio (ac eithrio pori tir garw) yn y ddau ddalgylch. Roedd aneffeithlonrwydd o ran adfer y P yn y sector dŵr gwastraff yn arwain at ollyngiadau P mewn carthion sy'n cyfateb i tua 0.23 kg/ha ar gyfartaledd yn dalgylch y Cleddau Wen (Gorllewinol) ac i tua 0.09 kg/ha ar gyfartaledd yn dalgylch y Cleddau Ddu (Dwyreiniol).

Mae dosbarthiad y ffosfforws amaethyddol dros ben a gollyngiadau dŵr gwastraff yn cynrychioli'r pwysau mewnbwn P ar gyrrff dŵr y dalgylch bob blwyddyn. Amrywia'r dosbarthiad hwn yn fawr yn yr is-ddalgylchoedd, yn dibynnu ar y math o fferm, mewnbynnau P, a lleoliad y Gwaith Trin Dŵr Gwastraff (WwTW). Roedd y pwysau mewnbwn P cyfunol blynyddol o'r ddau sector, ar rwydwaith afonydd y Cleddau, yn cyfateb i tua 385 tonnell o P, ac roedd y mwyafrif (>95%) yn deillio o amaethyddiaeth. Roedd pwysau'r mewnbwn P dros ben o amaethyddiaeth yn gymharol gyson ar draws yr is-ddalgylchoedd yn dalgylch y Cleddau Wen (Gorllewinol), sef 8-10 kg P/ha, ond roedd mwy o amrywiaeth yn is-ddalgylchoedd y Cleddau Ddu (Dwyreiniol), sef 6-17 kg P/ha. Mae'r pwysau sydd yn y mewnbwn P amaethyddol hwn yn cael ei glustogi gan briddoedd y dalgylch.

Roedd dadansoddiad o grynodiadau orthoffosffad-P mewn afonydd (y tybir eu bod yn gyfystyr â ffosfforws hydawdd adweithiol (SRP)) a fflwcs, yn cynnwys y monitro arferol gan Cyfoeth Naturiol Cymru (CNC) ers 2000, a monitro mwy cyson gan y Prosiect Gwyddoniaeth Dinasyddion (C-CAP) ers 2024. Canfu dadansoddiad manwl o grynodiad P yn yr afonydd (C) a llif (Q) dros gyfnod monitro sefydlog rhwng 2010 a 2023, fod y rhan fwyaf (>80%) o ffosfforws adweithiol hydawdd yr afon a welwyd yn y rhan fwyaf o orsafoedd monitro yn gysylltiedig â mewnbynnau P amaethyddol gwasgaredig yn ystod cyfnodau o lif dŵr uwch. Dim ond mewn tair gorsaf fonitro y gwelwyd mai mewnbynnau P dŵr gwastraff oedd y nodwedd amlycaf yn y ffosfforws adweithiol hydawdd. Ar sail y monitro C-CAP, nodwyd fod amrywiad amserol mwy sylweddol yn y crynodiadau ffosfforws adweithiol hydawdd mewn llednentydd, o'i gymharu â monitro gan Cyfoedd Naturiol Cymru mewn safleoedd sy'n gyffredin i'r ddwy raglen.

Mewn gorsafoedd monitro lle mae arwyddion bod ffosfforws amaethyddol gwasgaredig yn dominyddu, roedd y crynodiadau ffosfforws adweithiol hydawdd ar gyfartaledd bob blwyddyn yn yr afonydd yn amrywio o 0.04 -0.07 mg/L yn is-ddalgylchoedd y Cleddau Wen (Gorllewinol) ac yn amrywio o 0.004 -0.04 mg/L yn is-ddalgylchoedd y Cleddau Ddu (Dwyreiniol). Roedd fflwcs y ffosfforws adweithiol hydawdd ar gyfartaledd bob blwyddyn mewn gorsafoedd gwasgaredig yn amrywio o 0.3-0.6 kg P/ha ar y Cleddau Wen (Gorllewinol) ac o 0.05-0.5 kg/ha ar y Cleddau Ddu (Dwyreiniol). Mae'r amrywiad llawer mwy sydd yn y fflwcs ffosfforws gwasgaredig yn rhwydwaith afonydd y Cleddau Ddu (Dwyreiniol) yn adlewyrchiad o gyfraniad y dyfroedd mwy pur sy'n llifo o amgylcheddau amaethu llai dwys ar yr ucheldir, a lle mae llif uwch yn yr afonydd. Roedd hyn yn gyfrifol am ddyblu'r gwahaniaeth yn y crynodiadau ffosfforws adweithiol hydawdd cymedrig rhwng prif afon y Cleddau Wen (Gorllewinol) (0.04 mg/L) a'r Cleddau Ddu (Dwyreiniol) (0.02 mg/L). Mewn gorsafoedd monitro, lle mae mewnbynnau P yn dominyddu yn y dŵr gwastraff, roedd cyfartaledd y crynodiadau ffosfforws adweithiol hydawdd bob blwyddyn yn amrywio hyd at 0.11 mg/L ac roedd cofnodion fflwcs y ffosfforws adweithiol hydawdd bob blwyddyn yn amrywio hyd at 1.0 kg/ha, ac felly mae eu pwysigrwydd fel ffynonellau llygredd ar gynnydd yn lleol.

Yn gyffredinol, ni chafodd crynodiadau o gyfanswm y ffosfforws (TP) eu monitro'n rheolaidd ac eithrio yn y ddwy orsaf fedryddu ym Melin Prendergast a Phont Canaston. Yn dilyn cyfuno data ar gyfer y ddwy orsaf hyn â data hŷn (e.e. 2004-2010), canfuwyd fod cyfraniadau P sylweddol ar ffurf gronynnau a ffosfforws tawdd organig yn y ddau ddalgylch (cymhareb TP:SRP o 1.6-4.1), ac yn enwedig yn afon y Cleddau Ddu (Dwyreiniol). Roedd y fflwcs yng nghyfanswm y ffosfforws yn yr afon yn amrywio o 0.52-1.25 ledled llednentydd a phrif afon y Cleddau Wen (Gorllewinol), ac roedd yn amrywio o 0.12-1.26 ledled rhwydwaith afon y Cleddau Ddu (Dwyreiniol).

Pan gânt eu cyfuno â'r ffosfforws hydawdd adweithiol yn yr afonydd a'r fflwcs yng nghyfanswm y ffosfforws o ddalgylchoedd eraill a ddominyddir gan dda byw, roedd perthynas gadarnhaol arwyddocaol ($P < 0.001$) rhwng y P amaethyddol oedd dros ben bob blwyddyn a fflwcs y ffosfforws hydawdd adweithiol yn yr afonydd (r^2 0.55 ar gyfer y Cleddau Wen ac r^2 0.73 ar gyfer y Cleddau Ddu) â fflwcs cyfanswm y ffosfforws (r^2 0.59) ledled yr is-ddalgylchoedd. Mae'r berthynas hon yn awgrymu fod hyd at 5% o'r P

amaethyddol oedd dros ben bob blwyddyn yn cael ei golli'n uniongyrchol mewn dŵr ffo stormydd, a bod hyd at 60% o fflwcs y ffosforws hydawdd adweithiol a chyfanswm y ffosforws o ffynonellau gwasgaredig yn deillio o gronfeydd P mewn pridd etifeddol, a bod hyn yn dibynnu ar swm y P oedd dros ben. Pe ystyrir fod y swm dros ben ar gyfartaledd yn nalgylch y Cleddau yn 8.5 kg P/ha, roedd y P etifeddol yn cyfrif am 0.4 kg P/ha o'r fflwcs yng nghyfanswm y ffosforws, sef 0.77 kg P/ha.

Mae amcangyfrifon o ddosraniad ffynhonnell y sector, gan ddefnyddio'r model SEPERATE o fewn prif ardaloedd ACA'r dalgylchoedd hefyd yn nodi cyfraniad amlwg gan amaethyddiaeth, sef 83% yn nalgylch y Cleddau Wen (Gorllewinol) a 91% yn nalgylch y Cleddau Ddu (Dwyreiniol). Mae'r canlyniadau hyn yn tynnu sylw at yr angen i leihau'r P amaethyddol sydd dros ben, yn ogystal â'r rhaglen gyfredol o gael gwared â P yn well yn y Gwaith Trin Dŵr Gwastraff (WwTW).

Bydd y mewnbynnau P dros ben parhaus sy'n deillio o amaethyddiaeth bob blwyddyn, nid yn unig yn arwain at golledion P uniongyrchol a chynyddol yn y dŵr ffo bob blwyddyn, ond hefyd bydd swm y P yn y pridd a dirlawnder y P yn cynyddu, a hefyd bydd P yn dianc yn y dŵr ffo. Mae'n debygol y bydd newid yn yr hinsawdd yn gwaethygu'r colledion hyn ac mae'r ymchwil hwn yn awgrymu bod angen gostyngiadau yn y P amaethyddol sydd dros ben, i alluogi cyrraedd y targedau er mwyn sicrhau cyflwr ffafriol o fewn yr ACA. Amcangyfrifir y bod cael gwared ar y P amaethyddol cyfartalog bob blwyddyn, sef tua 8.5 kg P/ha ar hyn o bryd, wedi arwain at leihau'r fflwcs yn y ffosforws hydawdd adweithiol a'r fflwcs sydd yng nghyfanswm y P ar gyfran fyddai rhwng 40 a 60% yn afonydd y Cleddau Wen a'r Cleddau Ddu. Roedd y gostyngiadau canrannol hyn yn cyfateb i ostyngiad yng nghrynodiad y ffosforws hydawdd adweithiol yn swm y ffosforws amaethyddol dros gyfnod o amser o tua 0.02 mg/L yn nalgylch y Cleddau Wen (Gorllewinol) a gostyngiad o 0.01 mg/L yn nalgylch y Cleddau Ddu (Dwyreiniol).

Argymhellir ymchwil pellach er mwyn gwneud y canlynol:

- a. Cynnal Dadansoddiad Llif Sylweddau ar gyfer nitrogen (N) ac ailadrodd pellach o'r P-SFA yn seiliedig ar adborth rhanddeiliaid yn y dalgylch.
- b. Gwella rhaglenni monitro maetholion ledled y dalgylch, er mwyn cael gwell cofnodion o'r amrywiad amserol a ffurf yr N a'r P sydd yn yr afonydd.
- c. Asesu'r symiau a dosbarthiad y P etifeddol ym mhriddoedd y dalgylch a'u cyfraddau rhyddhau posibl mewn dŵr ffo o'r tir yn ystod stormydd.
- d. Ehangu cymariaethau o ganlyniadau monitro C-CAP gyda gwerthusiad mwy manwl o'r ffurfiau ffosforws (P) hydawdd a gronynnol yn y golofn ddŵr, fel y cynhaliwyd yn ddiweddar gan CEH
- e. Gwella rheolaeth ansawdd mesuriadau P drwy ailadrodd mesuriadau sy'n uchel iawn ac yn isel iawn, a thrwy galibro'r offerynnau Hanna yn rheolaidd yn erbyn samplau dŵr safonol â chynnwys orthoffosffad-P hysbys
- f. Parhau â rhaglen fonitro C-CAP y tu hwnt i Gam 3 er mwyn ymestyn y gyfres amser o fesuriadau i ganiatáu gwerthusiad gwell o ffynonellau llygredd maetholion a'u hamrywiad tymhorol ar draws y dalgylch
- g. Cynnal adolygiad o grynodiadau N mewn dŵr daear ar draws y dalgylch i lywio priodoli ffynonellau crynodiadau N mewn afonydd

Glossary

Baseflow Index (BFI) – a measure of the proportion of the annual river flow that derives from groundwater stores and assessed on a scale of 0-1. Low values represent impermeable landscapes and high values represent permeable landscapes.

CQ analysis – a form of analysis which looks at the relationship between measured nutrient concentrations (C) and the rates of river flow (Q) to help describe nutrient behaviour and potential source attributions within a waterbody.

CSOs – Combined Storm Overflows. This term encompasses P discharge from combined sewer overflows (CSOs), pumping stations and storm tanks.

GES – Good Ecological Status.

Nutrient Neutrality - the term used to refer to a requirement that additional development (e.g. housebuilding) does not increase the net nutrient loading to water (i.e. has a neutral impact).

River P flux – the amount of P export from the river calculated as the product of the mean annual flow over a given area (usually the catchment outlet), and the annual average flow-weighted P concentration.

SRP – Soluble Reactive Phosphorus – the soluble fraction of inorganic P in the water column measured by colorimetry on a 0.45 µm filtered water sample. Assumed here to be synonymous with ‘orthophosphate’ as routinely measured in water by Natural Resources Wales (NRW), and the form of P used in target setting for ‘Good Ecological Status’ under the Water Framework Directive (WFD), Sites of Special Scientific Interest (SSSIs) and Special Areas of Conservation (SACs).

TDP – Total Dissolved Phosphorus – the sum of SRP and a soluble organic P fraction and measured after an acid digestion and colorimetry on a 0.45 µm filtered water sample.

TP – Total Phosphorus – all inorganic and organic fractions of P in the water column measured by acid digestion and colorimetry. This is the form of P used in target setting for favourable condition of the Ramsar by Natural England.

WFD – Water Framework Directive.

WwTW – Wastewater Treatment Works (also known as Water Recycling Centres).

1. Introduction

The Cleddau Catchment Assessment Project (C-CAP) is a major "citizen science" water testing sub-project that covers the Cleddau catchment and is carried out in partnership with the West Wales Rivers Trust (WWRT). The Cleddau Project is a grassroots community initiative formed in 2024, committed to resolving the persistent pollution that threatens the health and biodiversity of the Cleddau waterways while highlighting their ecological significance and natural beauty. The key objectives are to enhance the existing knowledge base, raise awareness amongst the Cleddau stakeholders of water quality issues, engage the public, and promote better management of river pollution through education, advocacy, and data collection by volunteers (<https://thecleddauproject.org.uk>). The current focus of the project is on nutrient pollution with nitrogen (N) and phosphorus (P) due to the poor ecological condition of the freshwater and estuary Special Areas of Conservation (SAC) as evidenced by the high rate of failure to achieve the P targets required for their favourable condition.

There have been 3 phases of monitoring at a number of strategic sites across the Western Cleddau, Eastern Cleddau and Estuary catchments, some of which are common with the the monitoring programme carried out by National Resources Wales (NRW). Phase 1 of C-CAP was designed as a three-month period for volunteers to gain experience and evaluate analytical methods and techniques in the field. Over 50 volunteers were trained and carried out water sample testing, and data entry across 23 sites. The key findings from Phase 1 highlighted that nitrate results were almost all higher than surface water pollution thresholds, consistent with historical NRW data, while phosphate results were more variable. Ammonia levels were generally low, and turbidity scores were low due to minimal rainfall. Phase 2 of C-CAP marked a significant upscaling of the project, with the number of sites increased to 46 and the volunteer team expanding to 90 surveyors where they conducted twice a month over a 12-month period (July 2024 – June 2025). Phase 3 of C-CAP has continued the monitoring programme at 25 sites from July 2025.

To augment and improve the current water quality monitoring program run by NRW in the Cleddau catchment, an analysis of the C-CAP Phase 2 monitoring data was undertaken. The specific objectives of the Phase 2 analysis were to:

- (a) Assess the distribution of N and P pollution across the Cleddau catchment and identify potential pollution hotspots
- (b) Compare C-CAP results with those of the NRW monitoring programme across the catchment
- (c) Identify any seasonal trends and source signals in N and P pollution across monitoring sites
- (d) Summarise recommendations for future work in the catchment and the need for continued citizen science monitoring

2. Methodology

2.1 The Cleddau catchment study area

The Western Cleddau (313 km²) and Eastern Cleddau (230 km²) catchments in Pembrokeshire, south-West Wales flow into the Daugleddau estuary. The Western Cleddau river has its source at Llangloffan Fen and flows for 30 km to the estuary, whilst the Eastern Cleddau river flows for 26 km from its source in the Preseli Hills. Annual rainfall is high ranging from ca. 1700 mm in the Preseli Hills to ca. 1100mm in the lowlands. The Baseflow Index (BFI) of river flow is ca. 0.6, which signifies that ca. 60% of the river flow is derived from water infiltrating the landscape to groundwaters rather than in surface runoff (Marsh and Hannaford, 2008).

The catchments of both rivers are largely underlain by Cambrian and Ordovician sandstones, siltstones and shales. Soil types are largely well drained or seasonally waterlogged clay-rich brown earths of fine loamy and fine silty textures and variable depth to rock (Manod, Denbigh and Moorgate Associations). Smaller pockets of more impermeable soils occur locally, peaty soils in the Preseli Hills and heavy alluvial soils bordering the rivers. The landscape is a one of low rolling hills except in the headwaters of the Eastern Cleddau where the river is more turbulent as its flows through narrow wooded valleys (NRW, 2016).

The Eastern Cleddau and Western Cleddau rivers form part of the Cleddau Rivers Special Area of Conservation (SAC), which covers an area of 752 ha ending near the Haverfordwest town weir (Western Cleddau) and Blackpool Bridge (Eastern Cleddau). At these points the freshwater Cleddau Rivers SAC meets the estuarine portion of the Pembrokeshire Marine SAC, a large marine designation covering 138,069 ha. Whilst the SACs do not overlap they do share some conservation features (river and sea lamprey and otter). In addition to the SAC designations, the foreshore within the SACs is also a Special Site of Scientific Interest (SSSI) and much of the land area surrounding the estuary is within the Pembrokeshire Coast National Park.

Approximately 75% of the land use is permanent and temporary grassland supporting mostly dairy and to a lesser extent sheep farming. Dairy farming accounts for over 40% of the farmed area in both catchments according to the June agricultural census (Welsh Government, 2025), although this proportion may be as high as 55% including all rented land on dairy farms. Smaller pockets of arable crops (potatoes, maize and cereals) are grown on the more permeable soils largely in the south and West of the catchments. Agriculture in the Cleddau catchment makes a major contribution to Welsh food production, especially milk (Pembrokeshire produces 25% of all Welsh milk) and potatoes (50% of Welsh potatoes), (NRW, 2022b). A relatively small rural population is

boosted by large numbers of tourists in summer. Haverfordwest in the Western Cleddau catchment is the main urban centre with smaller populations at Narberth, Clynderwen, Letterston, Keeton, and Wolfscastle.

2.2 Sampling programme

The sampling programme was designed to monitor the concentrations of orthophosphate-P ($\text{PO}_4\text{-P}$), nitrate-N (NO_3N) and ammonia-N (NH_3N) alongside field measurements of temperature, pH, turbidity, and flow, biological indicators and environmental conditions at a number of sites within the Cleddau catchment. A list of all sites is given in Appendix 1 and their locations in the catchment are shown in Figure 1, and in relation to point wastewater discharges is shown in Appendix 5.

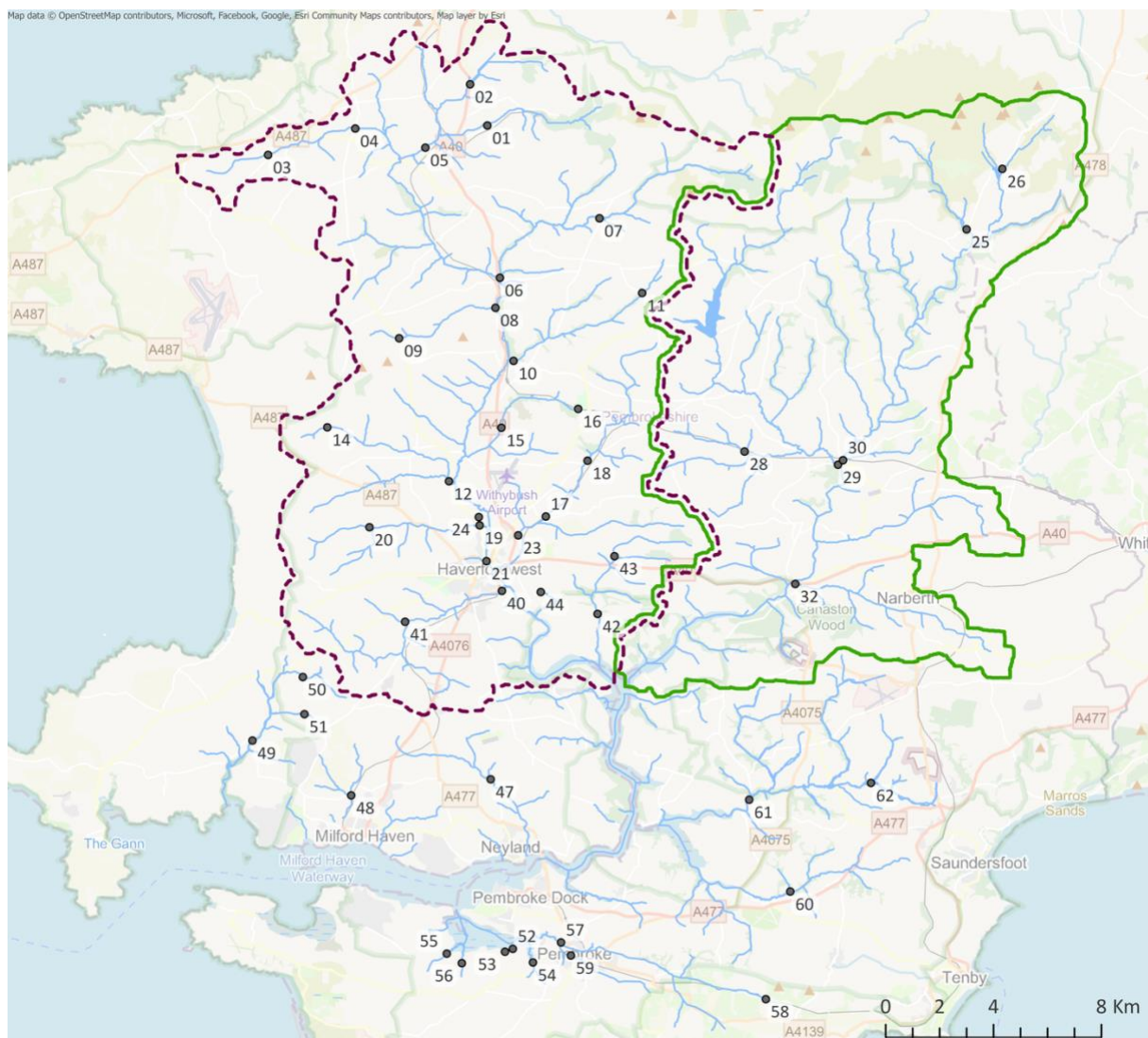


Figure 1. Locations of the Citizen Science monitoring sites in the Cleddau catchment as separated by the Eastern and Western boundaries. Note: boundaries have been offset for display purposes only. Additional monitoring sites feeding into the estuary are also shown.

Site selection was primarily strategic, aiming to capture a comprehensive overview of the catchment area, while also incorporating locations identified through local knowledge as potential pollution hotspots, proximity to volunteer location and ease and safety of access. Volunteers for Phase 2 were recruited, trained and assigned to one or more sites. Protocols for field measurements and sample collection were carefully designed to achieve a balance between scientific rigour and volunteer citizen scientists' practical feasibility. To maximise site comparability and decrease weather-related error, field measurements and samples were conducted twice a month in the morning. The parameters recorded at each site are:

- Date, time and weather in the previous 24 hours.
- Water flow rate and stream cross-sectional area to calculate total flow (m^3/s).
- Water temperature (using Hanna Instruments HI98107 pH Meter).
- pH (using Hanna Instruments HI98107 pH Meter).
- Phosphate: (Orthophosphate, PO_4 ; Hanna Instruments HI-713 low range Phosphate Photometer). Resolution 0.01 mg/L and accuracy 0.04 mg/L. Converted to orthophosphate-P ($\text{PO}_4\text{-P}$) for reporting.
- Nitrate: (Nitrate-N, NO_3N ; Hanna Instruments HI-97728 Nitrate Photometer). Resolution 0.1 mg/L and accuracy 0.5 mg/L.
- Ammonia: (Ammonia-N, $\text{NH}_3\text{-N}$; Hanna Instruments HI-715 Medium Range Ammonia Photometer). Resolution 0.01 mg/L and accuracy 0.05 mg/L.
- Water turbidity (using a Secchi tube).
- Presence/absence of algae, Ranunculus (water crowfoot), or migratory/other fish.
- Whether a pollution event was reported.

2.3 SAC compliance and nutrient targets

The freshwater SAC is currently in an unfavourable condition and all monitored areas of the Western Cleddau and two areas of the Eastern Cleddau within the SAC are failing to achieve P targets for compliance (Hatton-Ellis and Jones, 2021; NRW, 2022). Annual average target orthophosphate-P concentrations range from 0.010 - 0.015 mg/L in headwaters to 0.040 mg/L downstream. Recent monitoring since 2021 suggest further deterioration with only 28% of assessed waterbodies achieving their P targets (NRW, 2024; Arcadis, 2025). Nutrient neutrality rulings are currently in place prohibiting any development in the catchment area that increases net P loads entering the river SAC, and net N loads entering the estuarine SAC (NRW, 2026a).

There is no statutory target nitrate-N concentration for Good Ecological Status (GES) in freshwaters in the UK but concentrations above 1 mg/L, and especially above 2 mg/L),

are considered to indicate pollution (Nikolaidis et al., 2022). The maximum acceptable ammonia-N concentration (90th percentile) for GES in freshwaters is 1.1mg/L, with concentrations over 2.5 mg/L indicative of severe pollution (WFD-UKTAG, 2013).

2.4 Data analysis

2.4.1 Statistical analysis

Descriptive statistics were applied to measured parameters across all sampling sites to establish mean, median and range values with standard errors after data cleaning to remove clear outlier and suspect values. Orthophosphate concentrations were converted to orthophosphate-P before analysis and zero values were assumed to represent the limit of detection (0.003 mg PO₄P/L). Eight zero values for nitrate-N were excluded as suspect. Zero values were recorded for ammonia-N on the majority of sampling dates at 25% of sampling sites and were recorded as such. Pearson correlation coefficients were calculated to assess associations between determinands.

Outliers were kept to a minimum and identified as *single* high or low values that were more than twofold higher or lower than the nearest value and provided:

- (a) they could not be explained by a high flow event or present in Phase 1 and Phase 3 sampling data
- (b) they did not coincide with an elevated spike in other determinands

Only 4 outlier values were recorded for orthophosphate-P and 9 values for nitrate-N (See Appendix 2). Their omission does not mean that they necessarily did not occur but had a disproportionate influence on the overall annual mean value. Orthophosphate data for two upstream sites (Nant y Bugail and Upper Spittal) were abandoned due to sampler observations of difficulties with instrument recording and an unusually high proportion of very high readings.

2.4.2 Source attribution analysis

Concentration (C) and river flow (Q) analysis can provide information on the relative strength of point source (i.e. wastewater and industry) and diffuse source (i.e. agriculture and urban) signals contributing to the flux of P and N in the river (Bowes et al., 2008; Moatar et al., 2017). This CQ analysis is based on the log-log relationship of nutrient concentration and river flow whose gradient is designated as *b*. A strong negative relationship represents dilution of a near continuously discharged *point P source* such as the discharge from wastewater treatment centres, industrial units, septic tanks and farmyard drains. A strong positive relationship represents the increasing mobilisation of dissolved and particulate P from pollution sources in surface or subsurface runoff or within the river channel. This pattern of P delivery is controlled by hydrological

connectivity pathways rather than the abundance of a source and is associated with *diffuse P sources* in agricultural and urban runoff during storm events, or river bank or bed erosion. A third type of behaviour is when there is no relationship between C and Q which implies a homogenous distribution of a diffuse P source which may be small as in upland catchments or large as in intensively farmed catchments. In this type of P behaviour, changes in hydrological connectivity do not affect nutrient concentrations in the river.

Since CQ analysis requires a sufficient number of data points to adequately establish patterns of CQ behaviour over the year, phase 2 monitoring data was combined with Phase 1 and Phase 3 (up to January 2026) data to help identify dominant source signals. As gauged flow for the full monitoring period is not yet available, uncalibrated C-CAP flow data was used. The CQ analysis is hence currently limited to those sites with both C-CAP flow and nutrient concentration data over all three phases of monitoring. This analysis must therefore be considered as preliminary until (a) Phase 3 has been completed and (b) gauged river flow data becomes available over the monitoring period to calibrate C-CAP flow data. However, such preliminary analysis is useful to provide an indication of the value of CQ analysis to the C-CAP monitoring programme and the development of a better understanding of sector contributions to river P and N flux.

3. Results

3.1 Phosphate

Orthophosphate-P concentrations were very variable at the majority of the Phase 2 sampling sites, ranging up to 1.63 mg/L across 24 sites in the Western Cleddau catchment, up to 0.82 mg/L across 6 sites in the Eastern Cleddau catchment and up to 1.63 mg/L across 15 Estuary sites. Mean, median and range values for each site excluding single outlier values are given in Appendix 3 and the distribution of mean annual P concentrations is shown in Figure 2. The pattern of the temporal variation in orthophosphate-P concentrations is broadly similar across many of the sites, with lower background concentrations interspersed with variable occurrence of spikes in concentrations at different times of the year. Spikes in P concentration are commonly observed in a time series chemograph and can be an indication of nutrient transport during an episodic storm event, direct deposition by livestock with direct access, or a discharge of more concentrated wastewater effluent (Edwards and Withers, 2008; Jarvie et al. 2010). This spikiness is reflected in the almost ubiquitous trend for median annual P concentrations to be lower than annual mean values (Appendix 3). The background (median) signal typically varied from ca. < 0.01 mg/L in upstream sites to values of over 0.1 mg/L at more downstream and estuary sites. Further analysis of the magnitude of mean and median concentrations is summarised under the three catchment areas.

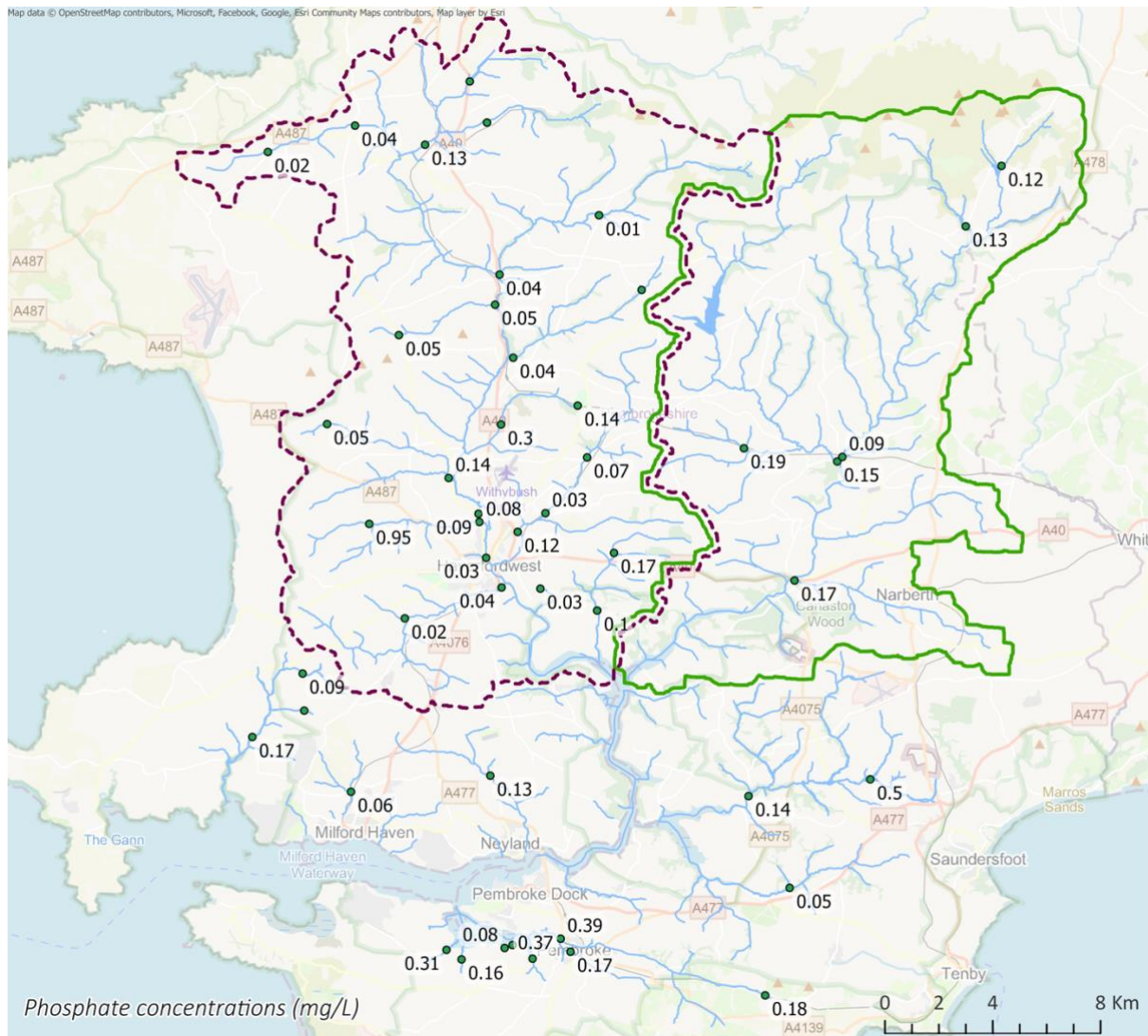


Figure 2. The distribution of mean annual orthophosphate-P concentrations at individual sampling sites across the Cleddau catchment.

3.1.1 Western Cleddau sites

Overall annual mean orthophosphate concentrations ranged from 0.01 mg/L in the upper Anghof river to 0.95 mg/L in the upstream site on the Cartlett Brook (Appendix 3). Upstream sites tended to have lower mean P concentrations than downstream sites on the same river but not always (e.g. Cresswell Brook). Mean annual P concentrations of 0.02-0.05 mg/L were recorded at the majority of sites above Treffgarne, at Nant-y-Coy Brook, Spittal Brook, Pelcombe Brook, Merlins Brook, Hanton Brook and in the main river at Haverfordwest. Peak P concentrations of up to 0.4 mg/L were recorded at these sites, but were often <0.2 mg/L (Figure 3a and b).

Higher mean annual P concentrations above 0.1 mg/L were recorded at N. Cleddau, Rudbaxton, Lower Camrose, Cartlett and Millin Pill tributary sites (Appendix 3). Elevated

mean P concentrations at these sites were associated with variable spikes in P concentrations in both summer and winter of generally up to 0.8 mg/L (Figure 3 c, d and e), although repeated concentration spikes of 1.6 mg/L were recorded at the Upper Cartlett site (Figure 3f).

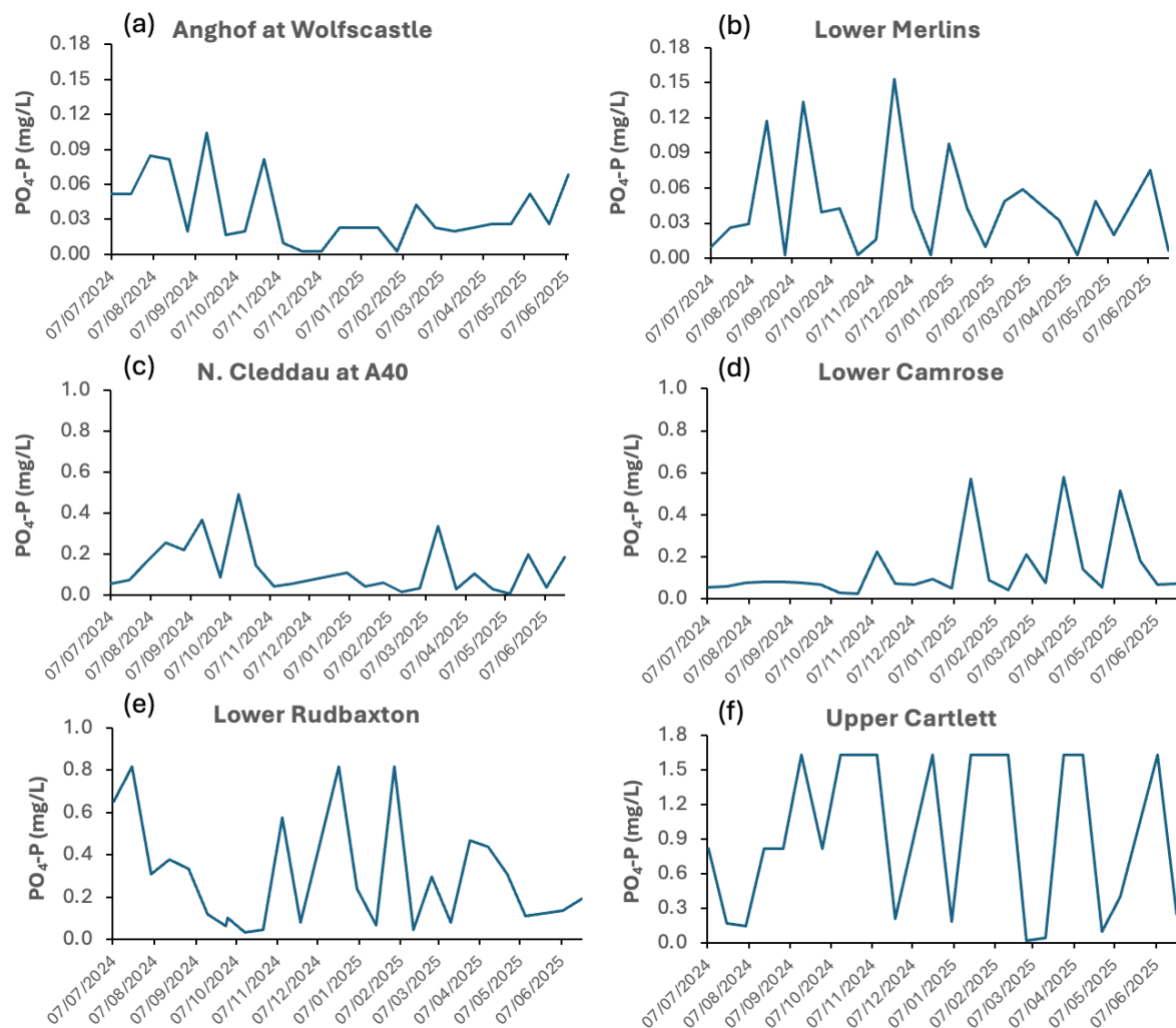


Figure 3. Time series of orthophosphate-P (PO₄-P) concentrations at six of the sites monitored in the Western Cleddau catchment under the C-CAP Phase 2 monitoring programme from July 2024 to June 2025. Note the differences in scale.

High P concentrations in winter at these sites often coincided with either high flow events, increased ammonia-N concentrations and or increased turbidity levels: for example a major storm event on the 24 November 2024 and to a lesser extent on 5 January 2025 generated higher concentrations of both orthophosphate-P and ammonia-N at a number of sites. Interestingly, these ammonia spikes occurred during the closed period for slurry spreading. Increased P concentrations in summer were most noticeable at sites on the Rudbaxton tributary and at Northern Cleddau and Cartlett monitoring

stations, but smaller increases in P concentrations in summer were also noted at Llangloffan station and in the Anghoff river above Treffgarne (Figure 3a).

3.1.2 Eastern Cleddau sites

There were fewer monitored sites in the Eastern Cleddau catchment but annual mean orthophosphate-P concentrations were notably high at around or over 0.1 mg/L. Background (median) P concentrations were overall also higher than those in the Western Cleddau catchment and varied from 0.03-0.11 mg/L. High variability in P concentrations at both upstream and downstream sampling sites was reflected in the relatively high standard errors around the means (Appendix 3), although the number of concentration spikes appeared less than at hotspots on the Western Cleddau monitoring stations (Figure 4).

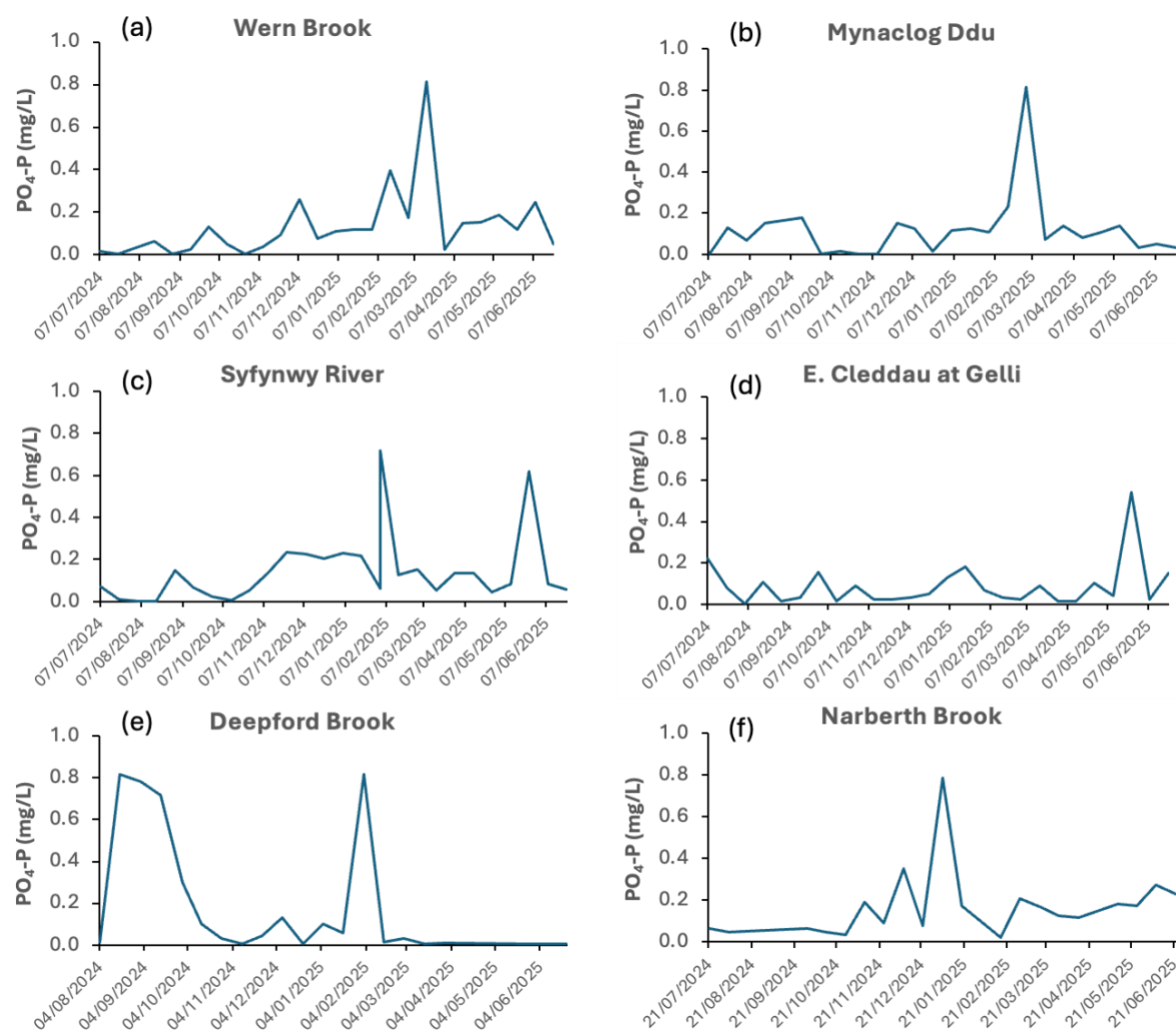


Figure 4. Time series of orthophosphate-P (PO₄-P) concentrations at six sites monitored in the Eastern Cleddau catchment under the C-CAP Phase 2 monitoring programme from July 2024 to June 2025. Scales are the same at all sites.

Increased concentration spikes occurred at all sites most often in February/March and May (Figure 4), either under higher flow rates and/or coinciding with increased ammonia-N concentrations. The site at Deepford Brook also had a large number of consecutively high P concentrations in August/September 2024, but preliminary results from Phase 3 do not suggest any similar increase in autumn 2025.

3.1.3 Estuary sites

The sampled sites feeding into the estuary had the largest overall mean orthophosphate-P concentrations with values between 0.2 and 0.5 mg/L at 8 of the 15 sites monitored. Background (median) P concentrations were also relatively high, typically ranging from 0.06 -0.2 mg/L (Appendix 3). Sites at Lower Sandy Haven, on the Pembroke river, Upper Cresswell, Lambeeth and to a lesser extent Goldborough Pill all exhibited a large number of high concentration spikes (Figure 5).

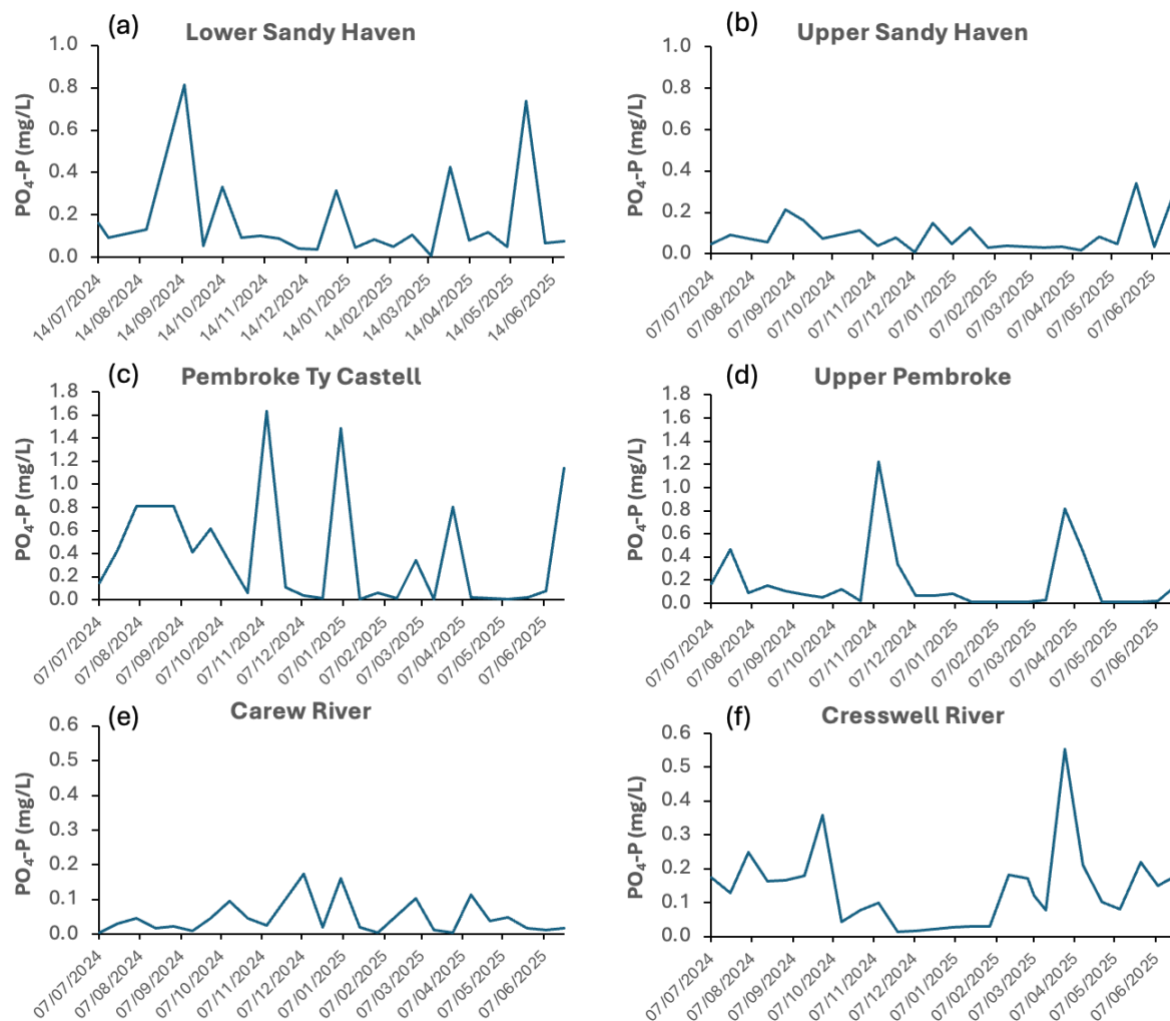


Figure 5. Time series of orthophosphate-P (PO₄-P) concentrations at six of the Estuary sites monitored under the C-CAP Phase 2 monitoring programme from July 2024 to June 2025. Note the difference in scales.

These spikes occurred in both autumn and spring and were not always related to high flow rates or increased ammonia-N concentrations. In contrast, upstream sites at Sandy Haven, the Carew River, Lower Cresswell, Bentlass West and Hubberston Pill showed a much smaller range in P concentrations with mean values of between 0.05 – 0.14 mg/L (Figure 5b, e and f and Appendix 3).

3.2 Nitrate

In contrast to orthophosphate-P concentrations, nitrate-N concentrations were much less variable both between sites and also generally within sites (Figure 6). The datasets lacked the concentration spikes associated with P, and median N concentrations were very similar to mean N concentrations at all sites (Appendix 3).

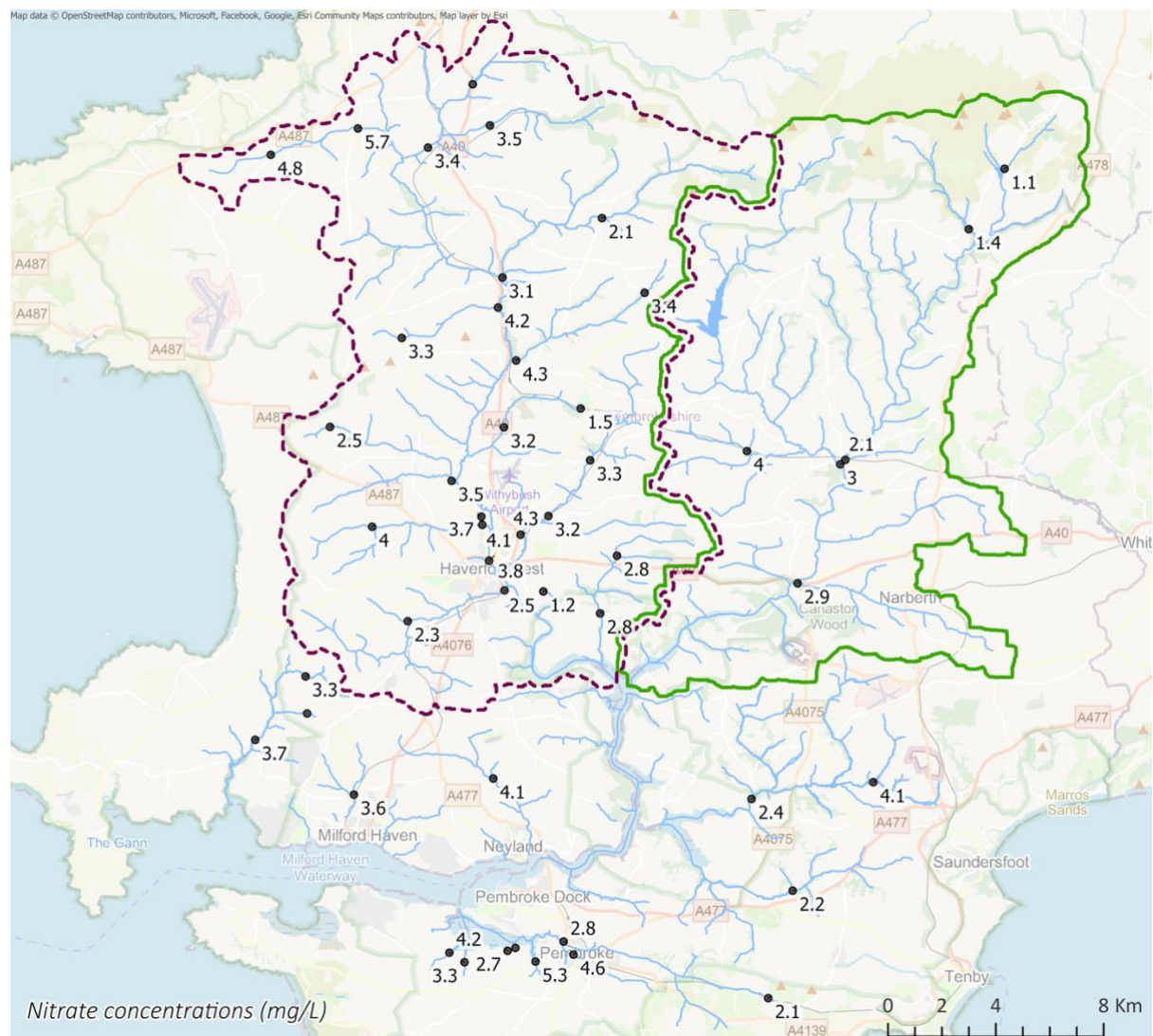


Figure 6. The distribution of mean nitrate-N concentrations at individual sampling sites across the Cleddau catchment for the year July 2024 to June 2025.

Annual mean N concentrations were between 2 and 4.5 mg/L at 85% of the sites, and were noticeably lower in upstream sites compared to downstream sites on the same river; for example compare the Anghof river sites at Puncheston (annual mean 2.1 mg NO₃N/L) and at Wolfscastle (annual mean 3.1 mg NO₃N/L) in Figure 7c and d. Highest annual mean nitrate-N concentrations were observed in the headwaters of the Western Cleddau at Llangloffan (5.7 mg/L) and at the Estuary site at Quoits Mill (5.3 mg/L), whilst lowest mean N concentrations were observed in the headwaters of the Eastern Cleddau at Mynaclog Ddu (1.1 mg/L), and at Hanton Brook (1.2 mg/L) in the Western Cleddau catchment (E.g. Figure 7, a,b and e). There was no correlation between orthophosphate-P concentrations and nitrate-N concentrations across sites.

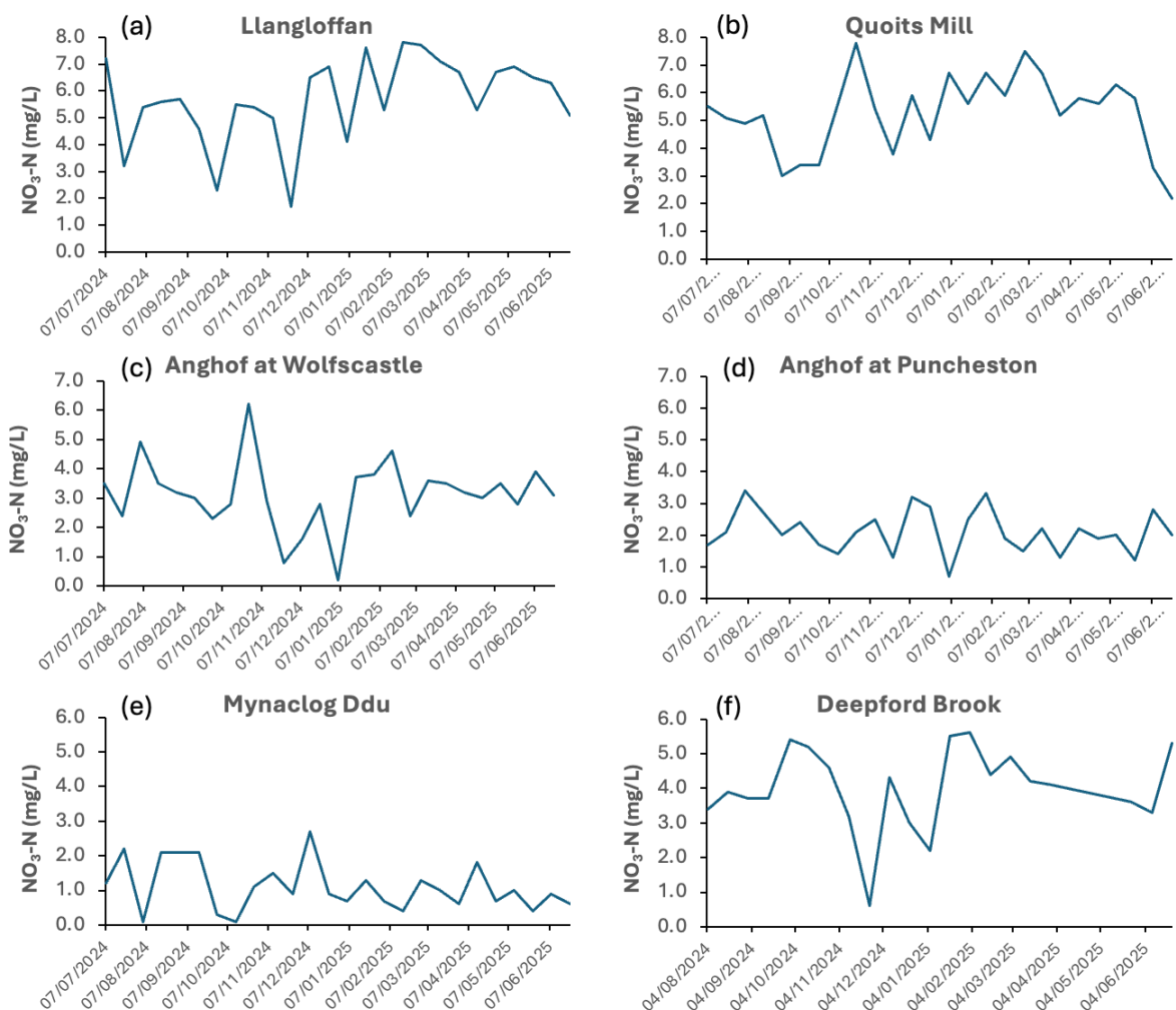


Figure 7. Time series of nitrate-N (NO₃N) concentrations at six sites monitored under the C-CAP Phase 2 monitoring programme from July 2024 to June 2025. Note the difference in scales.

At the majority of the sites, nitrate-N concentrations were relatively stable over time except for noticeable drops in concentrations under high river flows; for example after

storm events on 24 November 2024 and 5 January 2025 (e.g. the Deepford site in Figure 5f). Dilution of N concentrations at high flow was a notable feature at many sites. At some sites (e.g. Llangloffan and Quoits Mill in Figure 7), N concentrations increased during spring and then started to fall away again during summer. Declines in N concentrations during summer were also observed at Carew river and Bentlass West stream sites feeding into the estuary. A longer time series of data is required to verify the occurrence and significance of these potential trends.

3.3 Ammonia

Ammonia measurements were not always recorded and at many sites was detectable on only a few sampling occasions (Appendix 3). Sites which more consistently recorded ammonia-N levels included Northern Cleddau, Camrose Brook, Rudbaxton Brook and Millin Pill in the Western Cleddau catchment, the headwater sampling sites at Wern and Mynaclog Ddu in the Eastern Cleddau catchment, and at Sandy Haven, Carew river, Cresswell river, Westfield Pill and Lambeeth sites feeding into the estuary. However, annual mean ammonia-N concentrations never exceeded 0.3 mg/L, although peak concentrations on individual sampling days ranged up to and over 2 mg/L (Figure 8d, Appendix 3).

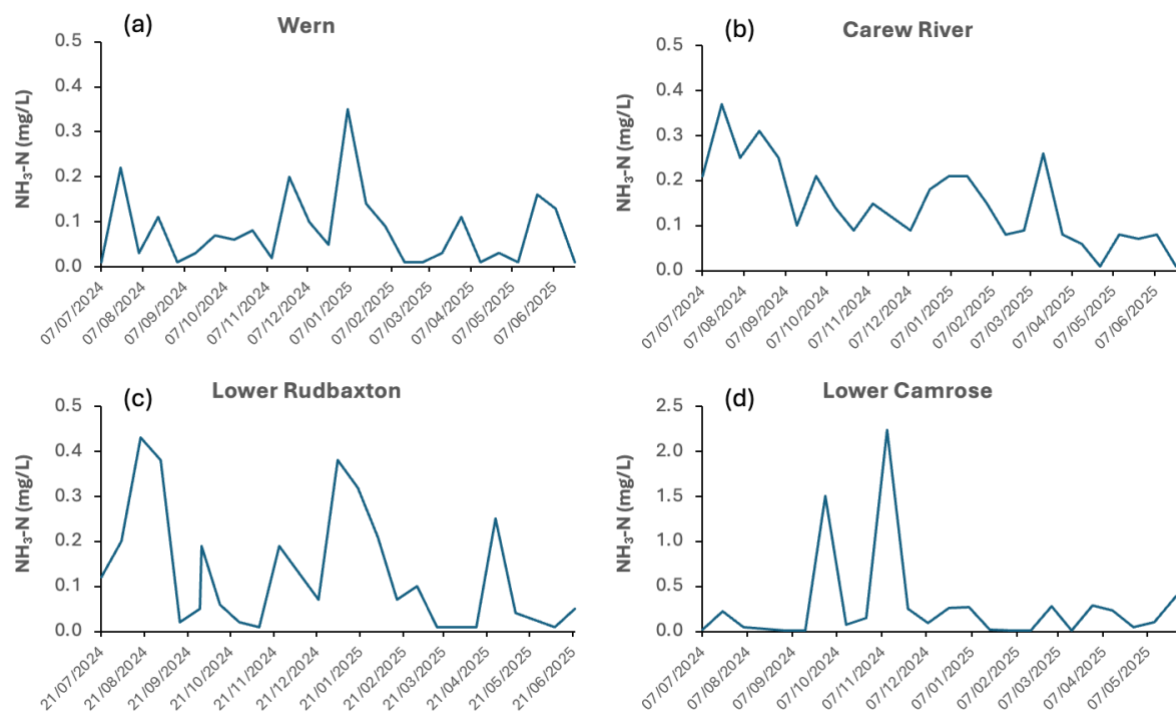


Figure 8. Contrasting temporal patterns of ammonia-N (NH₃N) concentrations at four sites monitored under the C-CAP Phase 2 monitoring programme from July 2024 to June 2025. Note the difference in scale at Lower Camrose.

High ammonia-N concentrations often (but not always) coincided with elevated orthophosphate-P concentrations at individual sites, although there was no overall correlation between these two determinands across sites. Increased concentrations of ammonia-N were recorded in both summer (e.g. Lower Rudbaxton and Carew River sites) and winter (e.g. Wern and Lower Camrose sites) as shown in Figure 8.

3.4 Turbidity

Turbidity levels remained at 12 NTU on most sampling dates at all stations where it was recorded, and therefore proved an insensitive method of estimating concentrations of suspended sediment. However consistently higher turbidity was recorded at many of the sites on two sampling dates coinciding with more intense storm events: on 24/11/2024 turbidity levels ranged from 40 – 240 NTU, and on 05/01/2025 ranged up to 50 NTU. On these dates turbidity values were generally greater at estuary sites reflecting more turbulent mixing of transported sediments.

3.5 Temperature

Average river temperatures across sampling sites in the Phase 2 sampling programme varied within the narrow range of 10.0 – 13.5°C (Appendix 4). Average values were generally lower at Eastern Cleddau sampling stations and higher at Estuary sites compared to sites in the Western Cleddau catchment. In contrast the seasonal range in temperatures was quite marked at all sites with a two to three-fold difference in values between winter and summer (Figure 9). However, maximum temperatures did not exceed the 20°C threshold associated with deaths in the salmon populations in the R. Wye in 2022 when temperatures in June reached 24°C (Environment Agency, 2024). The summer of 2024 was generally cooler than the long-term average in Pembrokeshire.

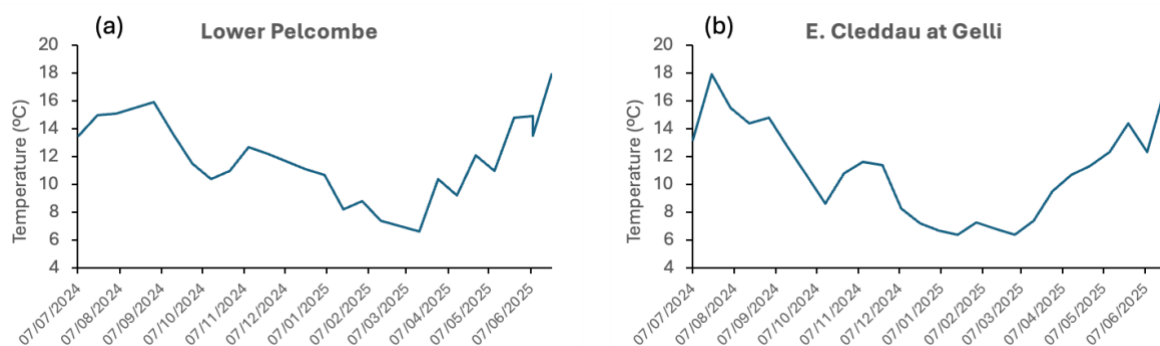


Figure 9. Seasonal variation in river temperature at (a) Lower Pelcombe Brook station in the Western Cleddau and (b) Eastern Cleddau river at Gelli station in Eastern Cleddau.

3.6 pH

River pH values across the year typically averaged between 7.0 and 8.5 at the majority of sampling stations, but was ca. pH 6.3 at the two stations on the Anghof tributary in the Western Cleddau catchment (Appendix 4). Eastern Cleddau stations were nearer pH 7 and estuary stations closer to pH 8 compared to the wider range found at Western Cleddau stations. Seasonal variation throughout the year was relatively large and variable with pH values changing by up to nearly 4 units at some stations. At most stations, the seasonal pattern was very consistent with declines in pH during winter months and increasing again in spring and summer as biological activity increased (Wang et al., 2025). Two typical examples are shown in Figure 10. pH values as low as 3 to 5 were recorded at some stations in October or November 2024 (Appendix 4), which is considered too acidic for fish spawning and egg survival as optimal pH values for fish are between 5 and 9 (European Inland Fisheries Advisory Commission, 1969). However, pH measurements can be very sensitive to operating conditions and many surveyors had issues with their pH meters. Very low or very high pH values should therefore be treated with some caution.

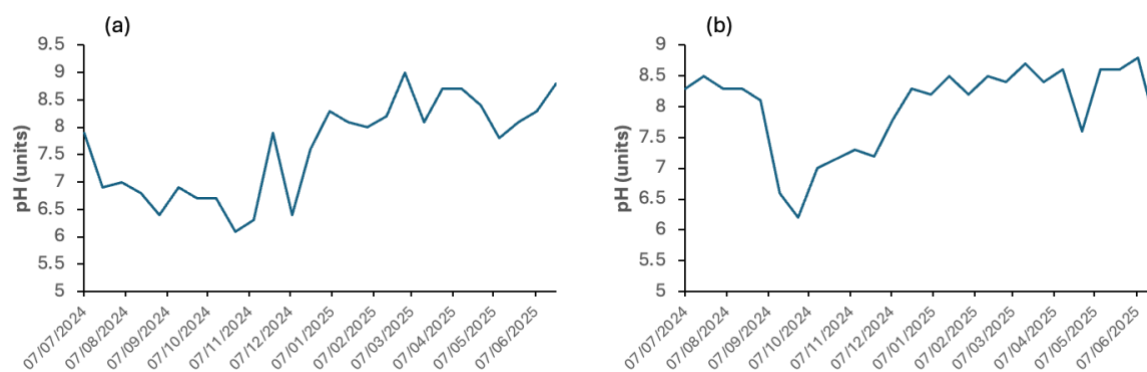


Figure 10. Seasonal variation in river pH at (a) Llangloffan station in Western Cleddau and (b) an estuary station at Bentlass West.

3.7 River flow

River flow is a critical factor affecting the ultimate concentration of P and N in the water column and therefore needs to be measured simultaneously with nutrient concentrations. For a similar nutrient loading (kg/ha) entering the river, the higher the amount of flow the lower the nutrient concentration in the water column. The Cleddau catchments have only two flow gauging stations currently operating: Treffgarne gauging station on the Western Cleddau river and Canaston Bridge in the Eastern Cleddau river. These stations provide data on mean daily flow (m^3/s) available from the National River Flow Archive (Centre for Ecology and Hydrology, 2026). Generally, flow across individual tributaries is not measured except as river height, and the C-CAP measurements at the

time of sampling therefore provide a very important additional source of flow data. The measurements are only approximate but nevertheless potentially adequate for assessing the relationships between flow and nutrient concentration. C-CAP flow measurements for the Eastern Cleddau are notably much more limited than for the Western Cleddau.

The National River Flow Archive only provide flow data retrospectively so a comparison between C-CAP measurements and gauged flow is only possible for the period up to January 2025. Most sampled sites showed a positive relationship between C-CAP measurements and gauged flow: some examples are given in Figure 11 and suggest that C-CAP measurements are generally reliable estimates which indicates very good process and diligence by volunteers. Rainfall data for the previous 24-hours is correlated to gauged daily mean flow and this may provide an additional level of C-CAP flow calibration. The measured C-CAP mean flows across the tributary sampling stations in the Phase 2 monitoring programme ranged from 0.15 to 1.75 m³/s (see Appendix 4), except for the Syfynwy tributary in the Eastern Cleddau catchment which was 4 m³/s presumably due to influx of water from the Llys-y-Fran reservoir.

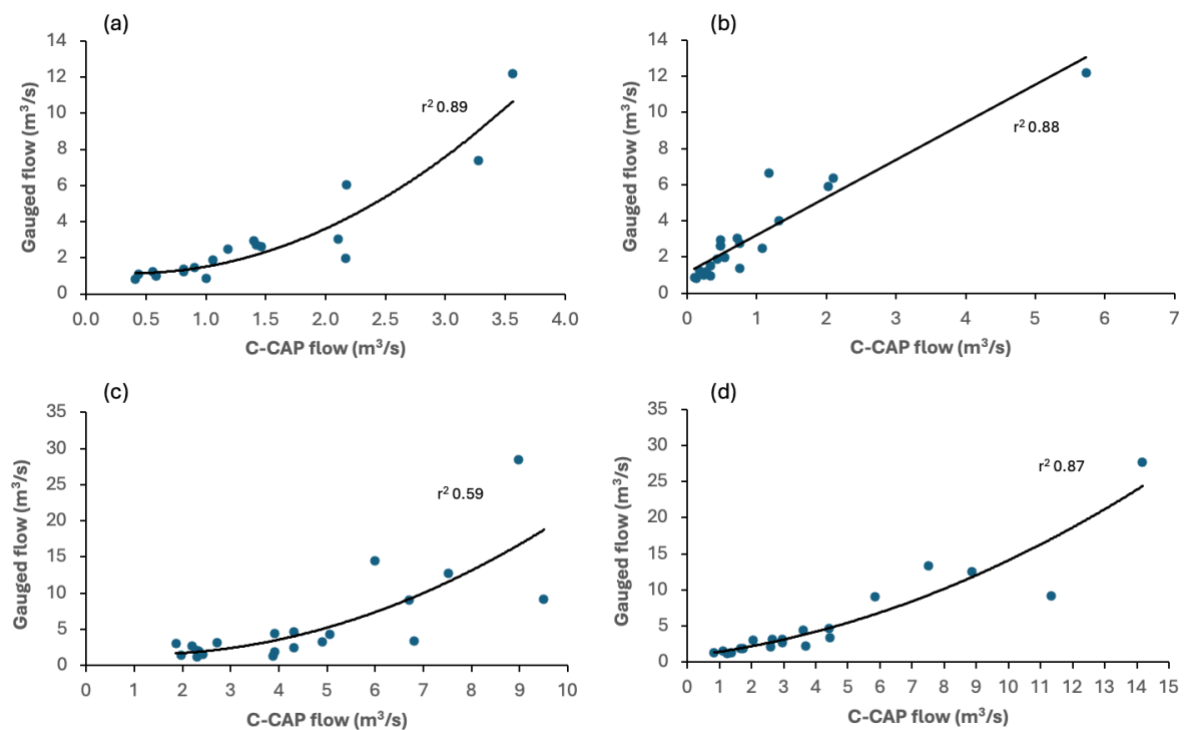


Figure 11. The relationships between C-CAP measured river flow at sampling (a) North Cleddau station and (b) Carlett brook at Dingle Lane station with 15-minute gauged flow at Treffgarne, and at (c) Syfynwy river at Gelli station and (d) Eastern Cleddau river at Gelli station with 15-minute gauged flow at Canaston Bridge.

A further comparison can be made between C-CAP measurements of mean flow covering Phase 1, Phase 2 and Phase 3 (up to September 2025) with catchment area-adjusted gauged flow for individual tributaries (Table 1). Again, there was generally very good agreement between the two flow estimates ($P < 0.001$, r^2 0.88), except for Merlins Brook on the Western Cleddau and Narberth Brook and Syfynwy river on the Eastern Cleddau. The higher C-CAP flows on the Syfynwy river may well represent additional regulated flows from the Llys-y-Fran reservoir to support water abstraction at Canaston Bridge. The reason for the discrepancy at the other two tributaries remains unclear, but the C-CAP measured data were more limited and variable at these two stations. Further calibration of C-CAP flows with gauged flow and rainfall is recommended once gauged flow data is updated to cover the Phase 2 monitoring period.

Table 1. Comparison of river flows for sites monitored by the C-CAP project with catchment area-adjusted gauged flows at monitoring sites common to both C-CAP and NRW monitoring programmes.

C-CAP site	Site name	Area km ²	River flow (m ³ /s)		
			C-CAP	Gauged	Ratio
4	W. Cleddau river at Llangloffan	10.3	0.36	0.33	1.09
6	Anghof river	38.9	1.69	1.25	1.35
10	Spittal Brook	17.2	0.46	0.41	1.12
12	Camrose Brook	21.9	0.60	0.60	1.00
15	Rudbaxton Brook	12.7	0.30	0.35	0.86
19	Pelcombe Brook	16.2	0.62	0.45	1.38
23	Cartletts Brook	35.4	0.80	0.97	0.82
28	Deepford Brook	18.4	0.77	0.61	1.26
29	Syfynwy river at Gelli	70.7	3.97	2.33	1.70
30	E. Cleddau river at Gelli	87.7	3.30	2.97	1.11
32	Narberth Brook	17.6	1.18	0.58	2.03
40	Merlins Brook	27.8	1.43	0.76	1.88
42	Millin Pill	15.5	0.31	0.43	0.72

3.8 Comparison with NRW monitoring

A comparison between C-CAP measured data and NRW measured data for sites common to both monitoring programmes can be made for annual mean orthophosphate-P concentrations over broadly the same 2024/2025 monitoring period (Table 2). Due to the much smaller numbers of samples taken under the NRW monitoring programme, the C-CAP data are also compared to the annual mean orthophosphate-P concentrations for the 2010-2023 period used to estimate river P flux in the RePhoKUs study on the Cleddau rivers (Withers et al., 2026a).

There is agreement for some sites (e.g. upstream of Treffgarne in the Western Cleddau), but P concentrations measured by C-CAP for many of the tributary sites are notably higher than those measured by NRW. There was no overall statistically significant correlation between the two sets of data. At Camrose Brook, Deepford Brook and Syfynwy river at Gelli the difference is due to the greater number and/or magnitude of the concentration spikes in the C-CAP chemical record, while at other sites (Wern Brook, Rudbaxton Brook, Narberth Brook and Millin Pill) the difference is due to a consistent increase across the majority of flows. Some of the discrepancy may also be explained by the poorer frequency of monitoring by NRW, although a similar lack of correlation was present when taking the longer time series of data under the RePhoKUs study (Table 2).

Table 2. Comparison of river orthophosphate-P concentrations monitored by C-CAP with those measured by NRW at monitoring sites common to both programmes.

Site	Site name	C-CAP (Phase 2)		NRW (2024/2025)		NRW (2011/2023)	
		n	PO4-P	n	PO4-P	n	PO4-P
3	Mathry	25	0.020	5	0.033	77	0.026
4	Llangloffan	26	0.044	12	0.049 ¹	30	0.044
5	N Cleddau	24	0.131	12	0.058 ²	-	-
6	Anghof River	26	0.038	7	0.037	97	0.046
10	Spittal Brook	23	0.040	5	0.022	111	0.040
12	Camrose Brook	26	0.139	8	0.046	56	0.052
15	Rudbaxton Brook	25	0.300	9	0.074	95	0.080
19	Pelcombe Brook	23	0.030	5	0.045	96	0.074
21	HaverfordWest	16	0.027	12	0.036	110	0.045
23	Cartletts Brook	22	0.118 ³	12	0.069	93	0.072
25	Wern Brook	26	0.134	10	0.006	66	0.004
26	Mynaclog Ddu	25	0.115	19	0.005 ⁴	-	-
28	Deepford Brook	21	0.189	9	0.036	120	0.043
29	Syfynwy River at Gelli	27	0.145	6	0.013 ⁵	48	0.023
32	Narberth Brook	21	0.165	12	0.038 ¹	77	0.040
40	Merlins Brook	18	0.044	3	0.029 ⁶	46	0.057
42	Millin Pill	26	0.102	5	0.036	58	0.051
47	Westfield Pill	24	0.131	7	0.057 ⁷	no data	
50	Sandy Haven	24	0.091	5	0.059	no data	
58	Pembroke River	26	0.176	8	0.133 ⁷	no data	
61	Cresswell River	27	0.141	8	0.215 ⁷	no data	

¹2023 data only; ²2025 only; ³0.075 mg/L at initial site 17 on the Cartlett Brook; ⁴2023-2024; ⁵July-Nov 2024 only; ⁶2020 data only; ⁷2020-2022.

In contrast to orthophosphate-P data, there was good agreement (r^2 0.84) between C-CAP and NRW monitoring programmes for nitrate-N concentrations (Table 3). This is despite the much poorer frequency of NRW measurements. No RePhoKUs data for nitrate-N is available.

Table 3. Comparison of river nitrate-N ($\text{NO}_3\text{-N}$) concentrations monitored by C-CAP with those measured by NRW at monitoring sites common to both programmes.

Site	Site name	C-CAP (Phase 2)		NRW (2024/2025)	
		n	$\text{NO}_3\text{-N}$	n	$\text{NO}_3\text{-N}$
3	Mathry	25	4.8	5	4.0
4	Llangloffan	26	5.7	12	6.1 ¹
5	N. Cleddau	23	3.4	12	3.1 ²
6	Anghof River	26	3.1	8	2.7
10	Spittal Brook	23	4.3	5	4.4
12	Camrose Brook	26	3.5	8	3.1
15	Rudbaxton Brook	25	3.2	9	4.0
19	Pelcombe Brook	23	3.3	5	3.0
21	HaverfordWest	16	3.8	12	3.6
23	Cartletts Brook	22	4.3	12	4.1
25	Wern Brook	26	1.4	10	0.6
28	Deepford Brook	21	4.0	9	3.6
29	Syfynwy River at Gelli	27	3.0	6	2.2 ³
32	Narberth Brook	21	2.9	12	2.7 ¹
40	Merlins Brook	18	2.3	3	2.1 ⁴
42	Millin Pill	26	2.8	5	2.5
47	Westfield Pill	24	3.7	7	4.1 ⁵
50	Sandy Haven	24	3.7	5	4.2
58	Pembroke River	26	2.8	8	3.5 ⁵
61	Cresswell River	27	2.5	8	2.2 ⁵

¹ 2023 data only; ²2025 only; ³July-Nov 2024 only; ⁴2020 data only, ⁵ 2020-2022

3.9 Comparison with CEH monitoring

Some preliminary data on the fractionation of river P into soluble reactive P (SRP), total dissolved P (TDP) and total P (TP) was undertaken by CEH at 5 sampling locations to provide some information on the forms of P in the river which are not measured by the C-CAP project or indeed routinely measured by NRW. In addition to the highly bioavailable SRP form which is generally synonymous with orthophosphate-P, this analysis suite

enables separation of a dissolved organic P (DOP) fraction defined as TDP minus SRP and a particulate (PP) fraction defined as TP minus TDP. In reality, such fractionation is a simplification of a spectrum of P forms of variable bioavailability but is nevertheless useful to identify P forms contributing to the river P signal (Jarvie et al., 2002). The analysis of the river samples by CEH also included nitrate and ammonia to allow some comparison with C-CAP data for the same locations. Additionally chloride, silica and sulphate were also measured to provide background geochemical information.

The five sampling stations were Western Cleddau river at Llangloffan, Anghoff River at Wolfscastle, Lower Rudbaxton Brook and Lower Cartlett Brook in the Western Cleddau catchment and the Eastern Cleddau river at Gelli station in the Eastern Cleddau catchment. The samples were taken on the 6 January 2026 under very wet conditions and again on the 4 March 2026 under much drier and warmer conditions. The relevant results are shown in Table 4. Total P concentrations ranged up to 0.3 mg/L under the wetter conditions of the 6 January sampling date, but were consistently lower at all five sites under the drier conditions of the 4 March sampling date.

On the 6 January sampling date, the SRP fraction represented from 32 - 65% of TP being highest at the Eastern Cleddau site and lowest in the Cartlett Brook. However on the 4 March sampling date, SRP concentrations were very low or not detectable at all sites, which is most likely due to active uptake by stream biota in the warmer weather (Pearce et al., 2023). The concentrations of DOP on the 6 January were also significant representing between 7% and 37% of TP, but they were the most dominant fraction (up to 87% of TP) on the 4 March at all but one site (Cartlett Brook). Particulate P concentrations were variable on both sampling dates, ranging up to 40 or 50% of TP (Table 4). The particulate fraction is therefore also a significant form of P being transported in land runoff, and although less bioavailable than SRP, can still be important forms of P contributing to aquatic growth, including in the estuary. The greater transport of P forms other than SRP in land runoff is also supported by the high TP:SRP ratios of 1.5-3.3 suggested by the NRW monitoring programme, and used in the recent assessment of river P flux across the Eastern and Western Cleddau catchments (Withers et al., 2026a).

Table 4. Concentrations of soluble reactive P (SRP), total dissolved P (TDP), total P (TP), nitrate-N (NO₃N) and ammonium-N (NH₄N) measured by CEH at 5 sampling sites on two sampling dates in comparison to orthophosphate-P (PO₄-P), NO₃N and NH₄N concentrations measured by the C-CAP project on paired samples. The corresponding fractionation of TP (% of total) into SRP, dissolved organic P (DOP) and particulate P (PP) and Chloride (Cl) concentrations measured by CEH are also given.

Site	CEH data									C-CAP data		
	Concentration (mg/L)			% of total			Concentration (mg/L)			Concentration (mg/L)		
	SRP	TDP	TP	SRP	DOP	PP	NO ₃ N	NH ₄ N	Cl	PO ₄ -P	NO ₃ N	NH ₄ N
6 January 2026												
Llangloffan	0.035	0.062	0.073	48	37	15	6.43	0.03	25.7	0.036	8.5	0.05
Anghof	0.105	0.118	0.180	58	7	34	2.99	0.05	15.9	0.100	2.9	0.05
Rudbaxton	0.037	0.069	0.114	32	28	39	4.84	0.26	26.5	0.390	5.2	0.12
Cartlett	0.032	0.066	0.105	30	32	37	4.42	0.44	33.5	0.050	4.6	0.12
Eastern Cleddau	0.200	0.241	0.308	65	13	22	4.32	0.70	85.2	0.490	3.7	0.46
4 March 2026												
Llangloffan	0.000	0.025	0.035	0	71	29	5.63	0.09	24.2	0.020	6.6	0
Anghof	0.000	0.031	0.047	0	66	34	2.95	0.01	14.8	0.070	4.4	0.01
Rudbaxton	0.004	0.057	0.061	7	87	4	4.61	0.01	20.1	0.070	5.2	0.12
Cartlett	0.000	0.046	0.092	0	50	50	3.59	0.15	17.9	0.060	3.7	0.12
Eastern Cleddau	0.008	0.091	0.095	8	87	4	3.14	0.09	18.9	0.220	2.8	0.24

Nitrate-N concentrations ranged from 3 – 6 mg/L on both sampling dates (Table 4), but ammonium-N concentrations were much lower on 4 March (0.01 – 0.15 mg/L) than on the 6 January (0.04-0.9 mg/L). The largest nitrate-N concentration was found at Llangloffan and the largest ammonium-N concentration was found at the Eastern Cleddau site on 6 January sampling date and in the Cartlett Brook on 4 March. The CEH analysis also found much greater concentrations of Cl at the Eastern Cleddau site on the 6 January, which may suggest a wastewater signal is more dominant at this location (Jarvie et al., 2012). This is also consistent with the greater SRP fraction at this site (Table 4). However, an elevated Cl concentration was not found at this site on the 4 March.

A comparison of C-CAP data with CEH data for phosphate, nitrate and ammonia using paired samples at each sampling location is also shown in Table 4. There is a very good correlation between the two sampling programmes for nitrate-N across both sampling dates (r^2 0.84), but there was less agreement for ammonium-N and SRP concentrations relative to the 1:1 line (Figure 12).

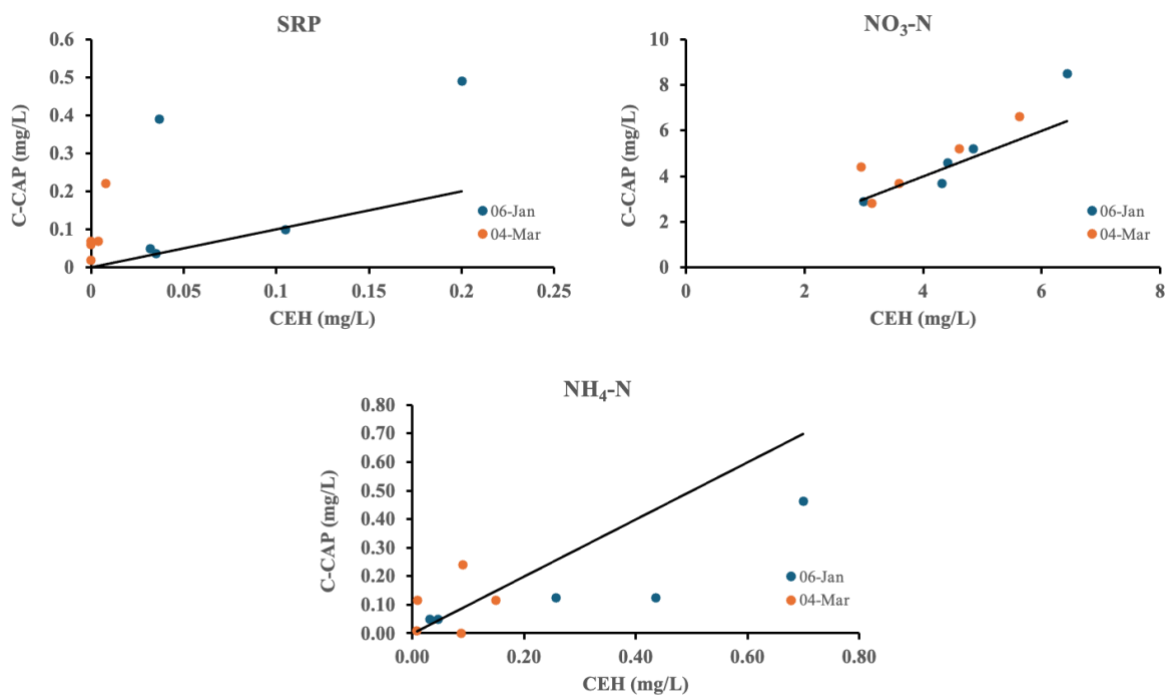


Figure 12. Comparisons between C-CAP and CEH analysis of soluble reactive P (SRP), nitrate-N (NO₃N) and ammonium N (NH₄N) on paired water samples at five sites on two sampling occasions in 2026 relative to a 1:1 line.

C-CAP values for SRP at Rudbaxton and Eastern Cleddau sites were considerably greater than CEH values on 6 January, whilst C-CAP values for NH₄N were lower for three of the sites (Rudbaxton, Cartlett and Eastern Cleddau). There was however some apparent correlation between the two sets of SRP and NH₄N data on individual sampling dates. This is only a very limited dataset and further comparisons are recommended, but these

results along with the comparisons to NRW monitoring data suggest the accuracy (or consistency) of C-CAP monitoring may need to be improved, especially for orthophosphate-P.

3.10 Comparison to other citizen science data

A full comparison of C-CAP results with the results of other citizen science monitoring programmes is beyond the scope of this report, but some general comments can be made regarding published summary reports of a similar monitoring programme in the Wye catchment. In their integrated analysis report for the R. Wye (Environment Agency, 2024), NRW found that citizen science monitoring data for orthophosphate using Hanna meters generally gave higher results than those analysed by NRW for the same site or area, although both sets of data identified similar hotspots of P pollution.

Orthophosphate-P concentrations in the R. Wye and its tributaries in Wales measured by the citizen science monitoring programmes between 2022 and 2025 ranged from <0.04 mg/L in upland areas in Wales to values of up to 0.3 mg/L in the majority of the English Wye catchment (Ricardo, 2025). NRW monitoring data compiled for RePhoKUs research in the Wye catchment over the 2010 – 2023 period similarly showed much lower mean orthophosphate-P concentrations in upland Wales (<0.01-0.03mg/L) than in lowland areas (0.02-0.12 mg/L), (Withers, unpublished data). Mean SRP concentrations of between 0.04 and 0.11 mg/L were also observed for the rivers in livestock dominated catchments of the Somerset Levels and Moors with limited influence of wastewater P discharges (Withers et al., 2026b). The C-CAP results for the Cleddau catchments therefore show broadly similar results to sampling programmes undertaken by volunteers and regulatory agencies in other areas.

Von Benzon et al. (2025) compared orthophosphate-P measured on three large sampling campaigns on the rivers in the Wye catchment using Hanna meters with laboratory analyses on paired samples, and found that 62% were in good agreement. Hanna meters performed most accurately between temperatures of 5-11°C in laboratory tests and these authors suggested leaving samples to react longer before reading at low temperatures improved accuracy. They concluded that volunteers can produce high-quality datasets that enhance understanding of water quality issues across river catchments and could reliably support statutory monitoring.

One difference between the C-CAP monitoring programme and the Wye monitoring programme is the inclusion of dissolved oxygen measurement, which is useful for detecting oxygen sufficiency and depletion and before the onset of algal blooms.

3.11 Dominant source signals

Phosphorus and nitrogen behave fundamentally differently in the landscape which affects the forms that are transported in land runoff to waterways, the mode and seasonal distribution of their transport to water and their bioavailability to aquatic biota (Heathwaite and Johnes, 1996; Withers and Lord, 2002). The inorganic phosphate (PO_4) ion is highly reactive and becomes readily bound to iron (Fe), aluminium (Al) and calcium (Ca) and to a lesser extent organic matter in the soil. Organic compounds of P also form complexes with soil minerals, and soluble organic forms become weakly bound to soil surfaces. Consequently applied phosphate is readily retained within the topsoil of farmed land (typically 30cm) and does not readily leach through the soil into groundwater on most soil types (Syers et al., 2008; Withers et al., 2001). There is also no gaseous form of P lost from farmed soils. Consequently, inorganic and organic P is variably mobilised and transported in surface runoff and drainflow in both soluble and particulate forms depending on rainfall duration and intensity, land vulnerability to erosion and P input management (Brownlie et al., 2022). Particulate forms of P are considered less directly bioavailable to aquatic biota but can become bioavailable when they become deposited in anaerobic conditions in river sediments (Reynolds et al. 2001; Withers and Jarvie, 2008).

In contrast to the P in land runoff, the majority (80-90%) of P in wastewater effluent directly discharged into water from WWTW is in a soluble form and highly bioavailable once in the water column (Jarvie et al., 2006; Naden et al., 2016). The patterns of P transport from wastewater and agricultural sources are therefore also fundamentally different. Whilst wastewater discharges are almost continuous from points in the landscape and in a highly bioavailable form, diffuse agricultural P loss is highly episodic and occurs from variable locations in the landscape and in forms of variable bioavailability (Edwards and Withers, 2016).

In contrast, the inorganic nitrate (NO_3) ion does not bind to soil but migrates down through the soil and is readily mobilised in surface runoff, leached to groundwater or denitrified to gaseous forms of N (NO , N_2O and N_2) and released to the atmosphere when not taken up by crops (Cameron et al., 2013). The inorganic ammonium (NH_4) ion is readily converted to nitrate by microorganisms through nitrification or becomes adsorbed onto clays in the soil when not taken up by crops. Organic forms of N are mineralised to ammonia in soils. As N is so mobile it is readily transported in both surface runoff and groundwater to waterways and is highly bioavailable to aquatic biota (Sutton et al., 2011). Transport of ammonium-N is more pronounced following application of organic manures to land since most N in manures is in the ammonium form (Smith et al., 2001). Wastewater effluent contains both nitrate and ammonium N depending on the level of treatment (Naden et al., 2016). Soluble and particulate organic N may also be lost in

smaller amounts in both wastewater and diffuse agricultural and urban sources, but there is no inorganic particulate form.

A summary of the output of CQ analysis of orthophosphate-P concentrations is given in Table 5 and examples of the CQ behaviour for the Western Cleddau, Eastern Cleddau and Estuary monitoring sites are shown in Figure 13. Four contrasting patterns of CQ behaviour are evident. A strong positive b value indicative of a dominant diffuse (i.e. agriculture) P source was present at the Carew river estuary site (Figure 13a). A strong negative b value indicative of a dominant point (i.e. wastewater) source was present at the Cresswell river site (Figure 13b). Smaller positive or negative b values such as at Nant y Coy (Figure 13c) indicates that diffuse sources are still dominant and more homogeneous in nature. This type of CQ behaviour was also found at Pelcombe Brook and Sandy Haven sampling sites.

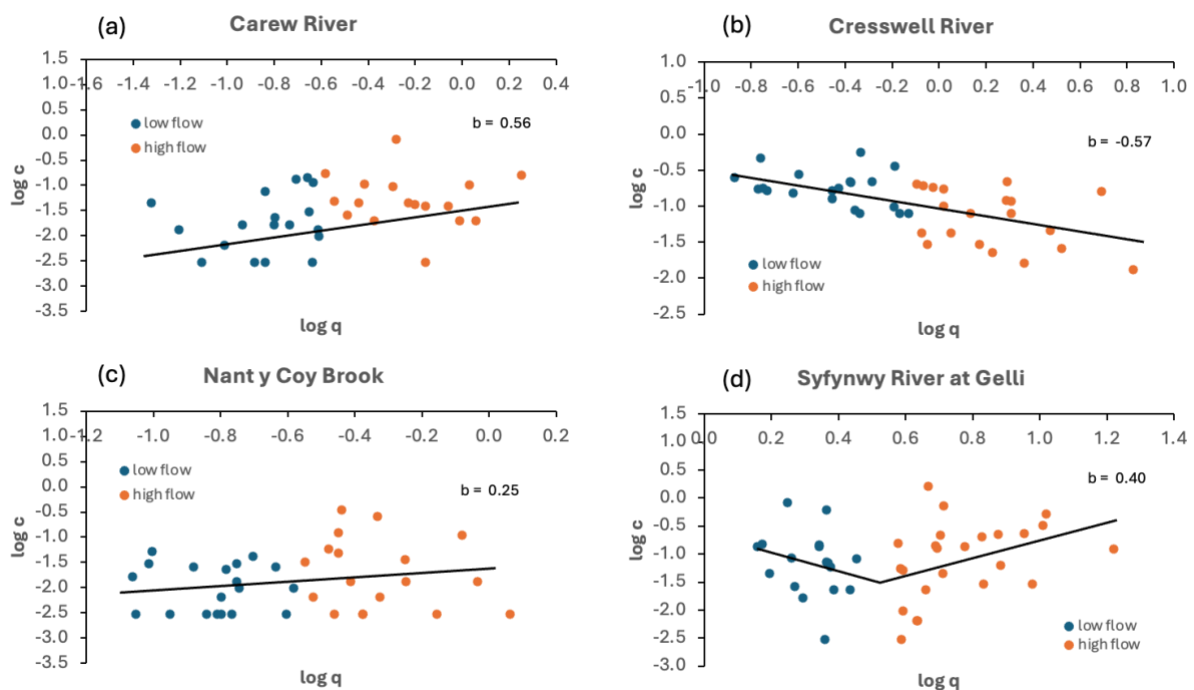


Figure 13. Contrasting patterns of CQ behaviour for orthophosphate-P concentrations at four sites monitored under the C-CAP Phase 2 monitoring programme from July 2024 to June 2025.

The magnitude of the flow-weighted orthophosphate-P concentrations helps determine the strength of the diffuse P signal, with notably higher values at Sandy Haven than at Pelcome Brook or Nant y Coy (Table 5). Finally, hybrid CQ patterns with a clear break in slope as at the Syfynwy at Gelli site (Figure 13d) indicates the presence of both point and diffuse sources, with the relative proportions of each source determined by the position of the break in slope.

Table 5. Flow-weighted concentrations and annual flux of orthophosphate-P (PO₄-P) at selected sites with varying area and flow and the proportions of the annual flux attributed to point and diffuse sources according to CQ analysis. The CQ b values are also given.

Site	Site name	Area	Flow	b		PO ₄ -P conc.	PO ₄ -P flux		(% of total)	
									(km ²)	(m ³ /s)
4	Llangloffan*	10.3	0.43	-0.068		0.048	0.64		14	86
5	N. Cleddau at A40*	29.0	1.59	-0.796		0.096	1.67		75	25
6	Anghof River at Wolfcastle*	38.9	2.13	-0.593		0.026	0.44		66	34
8	Nant-y-Coy	8.41	0.33	0.248		0.042	0.53		0	100
10	Spittal Brook*	17.2	0.95	0.250		0.187	3.25		20	80
12	Camrose Brook*	21.9	0.60	-0.198		0.092	0.79		Too variable	
15	Rudbaxton Brook*	12.7	0.49	0.028		0.481	5.88		Too variable	
19	Pelcombe Brook	16.2	0.66	-0.271		0.036	0.46		0	100
40	Merlins Brook	27.8	2.25	0.153		0.061	1.57		13	87
42	Millin Pill	15.5	0.48	-0.178		0.085	0.83		38	62
29	Syfywny river at Gelli	70.7	4.60	0.400		0.200	4.10		13	87
30	E. Cleddau at Gelli	87.7	4.16	-0.271		0.067	1.00		10	90
49	Sandyhaven	-	0.43	-0.134		0.158	-		0	100
57	Pembroke River	-	3.55	-0.034		0.346	-		5	95
60	Carew River	-	0.41	0.557		0.089	-		0	100
61	Cresswell River	-	1.20	-0.573		0.099	-		100	0

*Sites with an asterisk signify there is a WWTW or CSO directly upstream of the C-CAP monitoring site (See Appendix 5).

These hybrid patterns of CQ behaviour were present at all other sites, with diffuse sources contributing the majority of the river P flux at 7 sites (Llangloffan, Spittal Brook, Merlins Brook, Millin Pill, Syfynwy at Gelli, E. Cleddau at Gelli and Pembroke river) and point sources contributing the majority of the river P flux at two sites (Anghof at Wolfcastle and the N. Cleddau), (Table 5). A CQ pattern of behaviour could not be determined at two sites (Rudbaxton and Camrose Brook) due to the large variability in the data (Table 5).

Contrasting CQ patterns of behaviour are also evident for nitrate-N (Figure 14). At Pelcombe Brook, nitrate-N concentrations increased steadily with flow (Figure 14a), whilst at Camrose Brook concentrations remained relatively constant throughout the year (Figure 14b). This latter CQ behaviour was observed at the majority (ca. 60%) of sites with measured flow and suggests a well distributed source of diffuse (agricultural) N loss in the landscape. On the main Eastern Cleddau river at Gelli, nitrate-N increased at lower flows but became diluted at higher flows suggesting the source was becoming exhausted at high flow (Figure 14c). At the Carew river feeding into the estuary, nitrate concentrations increased across the majority of flows but flattened off at high flow, again suggesting the source of the N was becoming depleted under high flow (Figure 14d).

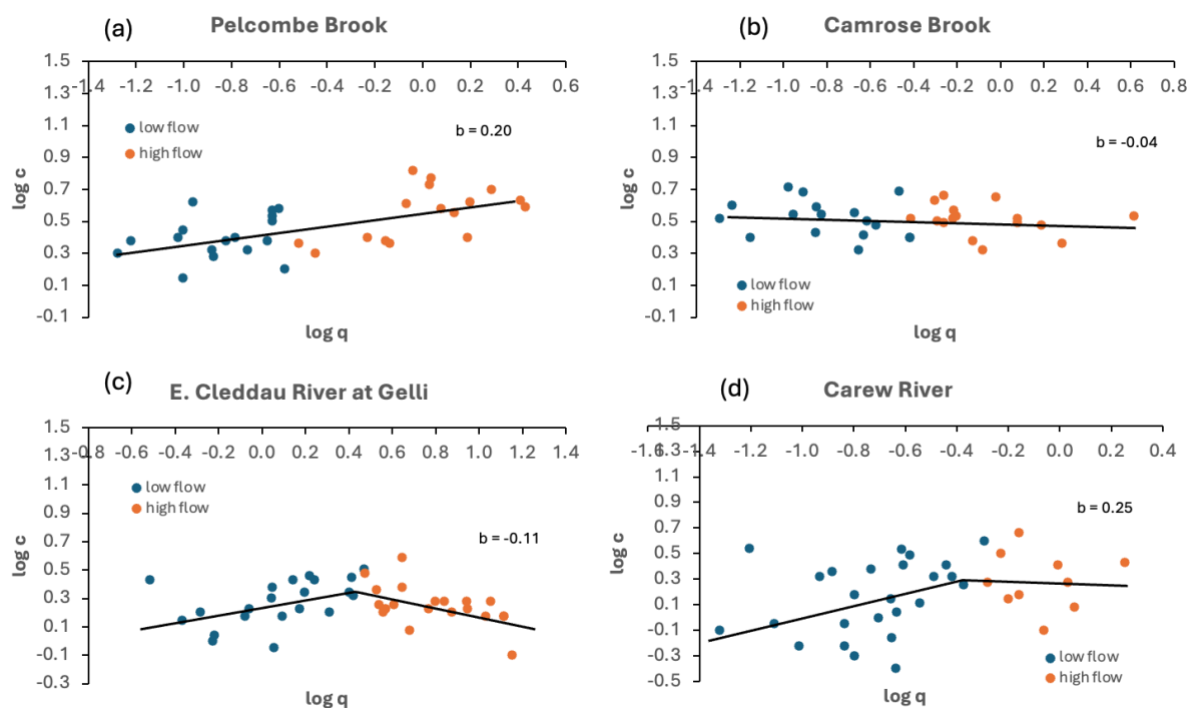


Figure 14. Contrasting patterns of CQ behaviour for nitrate-N concentrations at four sites monitored under the C-CAP Phase 2 monitoring programme from July 2024 to June 2025.

Depletion and dilution of N concentrations at high flow was observed to varying degrees at Rudbaxton, Millin Pill, Syfwyny river, Deepford, Narberth, Cresswell River, Bentlass Western and Lambeeth. More extensive time series are required to verify these different trends in CQ behaviour.

4. Overall Conclusions and Recommendations

4.1 Conclusions

The C-CAP Phase 2 monitoring programme has provided a valuable dataset of nutrient (N and P) concentrations and associated river flow over a 1-year period across a number of tributaries in the Cleddau catchment. Analysis of concentration time series for 46 sites shows widespread and variable nutrient pollution across the catchment.

For orthophosphate-P, the time series showed a general pattern of a background P signal interspersed with spikes of much higher concentration ranging up to 1.6 mg/L. The background (median) signal varied from ca. < 0.01 mg/L in upstream sites to values of over 0.1 mg/L at more downstream and estuary sites. Annual mean orthophosphate-P concentrations including nutrient spikes typically ranged from 0.02 – 0.05 mg/L at 55% of the sites in the Western Cleddau catchment, but were more consistently around or above 0.1 mg/L at other sites in the Western Cleddau, all sites on the Eastern Cleddau and the majority of sites feeding into the estuary. In the Western Cleddau catchment, sites at Rudbaxton, Camrose, Northern Cleddau and Millin Pill were notable hotspots with high annual mean P concentrations > 0.1 mg/L, as were upstream sites on the Spittal and Cartlett tributaries.

Spikes in orthophosphate-P concentrations occurred under both lower flows in summer and higher flows in winter with some values linked to higher ammonia-N concentrations and turbidity on individual sampling days. Preliminary concentration (C)-flow (Q) analysis suggested a mixture of wastewater and agricultural sources was contributing to the river P flux across most sites, but with agriculture the major source. Further CQ analysis on a longer time series of data is required to verify these initial findings.

Nitrate concentrations were much less variable with mean and median values typically in the range from 2.0 – 4.5 mg/L at 85% of sites, but with concentrations as low as 1.1 mg/L and as high as 5.7 mg/L. As with P, upstream sites on monitored tributaries tended to have lower annual mean nitrate-N concentrations than downstream sites but not always. Dilution of N concentrations under very high river flows was noted at a number of sites and seasonal increases in nitrate-N during spring and decreases in summer were observed but a longer time series of data is required to assess the consistency of this

seasonality. There was no clear correlation between orthophosphate-P and nitrate-N concentrations across sites.

Ammonia-N concentrations were not always measured, not detectable (i.e. zero values) on many of the sampling dates and highly variable. Annual mean concentrations (including zero values) never exceeded 0.3 mg/L, although peak concentrations of up to 4 mg/L occurred on individual sampling days. There was no overall correlation between orthophosphate-P concentrations and ammonia-N values. Turbidity measurements were too insensitive to detect differences in suspended sediment concentrations, although clear increases in turbidity up to 240 BTU were observed during high flow storm events.

Temperature and pH measurements typically averaged between 10.0 and 13.5 °C and between 7.0 and 8.5, respectively and showed wide seasonal variability with lowest values in winter and highest values in summer, as expected. Limited comparison between site recorded river flow and daily mean river flows at the two current gauging stations showed generally good agreement providing some confidence in C-CAP measurements, but further calibration of site measured flows is needed once more gauged flow data becomes available.

A comparison between C-CAP measured N and P concentration data and NRW measured N and P data for sites common to both monitoring programmes over broadly the same 2024/2025 monitoring period showed good agreement for nitrate-N at all sites but there was much less agreement for orthophosphate-P. Mean C-CAP P concentrations were higher than mean NRW concentrations at a number of tributary sites and especially in the Eastern Cleddau catchment and estuary sites. These differences reflect not only the higher frequency of concentration spikes in the C-CAP time series but also the very poor frequency of measurements undertaken by NRW.

Preliminary data provided by CEH suggested orthophosphate-P represented from 0- 65% of total P in the water column across five sites in the catchment over two sampling dates. This large variability in the proportional contribution highlights the significant contribution of forms of P other than orthophosphate. C-CAP measurements on paired samples on the same date showed good agreement with CEH measurements for nitrate-N, but as with NRW data, there was less agreement for orthophosphate-P. Ammonia-N concentrations were lower than CEH measured at some sites. These NRW and CEH comparisons suggest the accuracy of C-CAP orthophosphate and ammonia measurements may need to be improved.

4.2 Recommendations

The value of the C-CAP monitoring programme lies in providing a frequent, consistent and accurate time series of nutrient concentrations alongside simultaneous measurements of water flow for as long a time period of monitoring as resources allow and across a representative number of monitoring sites. To enhance the value of the C-CAP project, it is therefore recommended to both continue the monitoring programme and improve the accuracy of sampling and measurements:

- (a) complete calibration of C-CAP river flow measurements once the National Flow Archive has been updated with daily flow rates for the two gauging stations in the catchment.
- (b) increase the scope of future sampling to include measurement of dissolved oxygen and to investigate the apparent discrepancies between C-CAP measurements and NRW monitoring data for common monitoring sites using paired sampling and especially for the Eastern Cleddau catchment sites.
- (c) expand comparisons of C-CAP monitoring results with more detailed assessment of the dissolved and particulate P forms in the water column as recently carried out by CEH
- (d) enhance water quality control of P measurements by repeating very high and very low measurements and routinely calibrating the Hanna instruments against standard water samples of known orthophosphate-P content
- (e) cross check C-CAP monitoring protocols and results with those of other Citizen Science groups on other rivers using the same apparatus
- (f) continue the C-CAP monitoring programme beyond Phase 3 to extend the time series of measurements to allow enhanced evaluation of sources of nutrient pollution and their seasonal variation across the catchment.

5. Acknowledgements

Funding for the C-CAP Phase 2 analysis was provided by Welsh Government through the MPA Management Grant Scheme. The data for this analysis were generated by the considerable efforts of the volunteers involved in the organisation of the C-CAP project and regular site sampling. The assistance of Ric Cooper and James Perrins from the C-CAP project, and Arwen Skinner at Southampton University in providing background information and previous data analysis and reports is also gratefully acknowledged. Dr Kirsty Ross at Lancaster University helped assess site catchment areas and prepare catchment maps.

6. References

Arcadis, (2025). Afonydd Cleddau Nutrient Management Board: Afonydd Cleddau Nutrient Management Plan. Arcadis Consulting (UK) Ltd, London.

Bowes M. J., Smith J. T., Jarvie H. P. and Neal C. (2008). Modelling of phosphorus inputs to rivers from diffuse and point sources. *Science of the Total Environment* 395, 125–138.

Brownlie, W. J., Sutton, M. A., Heal, K. V., Reay, D. S., and Spears, B. M., eds. (2022b). *Our Phosphorus Future*. Edinburgh: UK Centre for Ecology and Hydrology. Available at: <https://nora.nerc.ac.uk/id/eprint/533099/1/N533099CR.pdf>

Cameron, K.C., Di, H.J. and Moir, J.L. (2013). Nitrogen losses from the soil/plant system: a review. *Annals of Applied Biology* 162, 145-173.

Centre for Ecology and Hydrology (2026). National River Flow Archive. Available at: <https://nrfa.ceh.ac.uk>

Edwards A. C. and Withers P. J. A. (2008). Transport and delivery of suspended solids, nitrogen and phosphorus from various sources to freshwaters in the UK. *Journal of Hydrology* 350, 144–153.

Environment Agency (2024). River Wye Management Catchment Integrated Data Analysis Report 2023. Available at: <https://engageenvironmentagency.uk.engagementhq.com/river-wye-water-quality>

European Inland Fisheries Advisory Commission (1969). Water quality criteria for European freshwater fish—extreme pH values and inland fisheries. *Water Research* 3, 593-611.

Hatton-Ellis, T.W. and Jones, T.G. (2021). Compliance Assessment of Welsh River SACs against Phosphorus Targets. NRW Evidence Report No: 489, 96pp, Natural Resources Wales, Bangor. Available at: <https://cdn.cyfoethnaturiol.cymru/693025/compliance-assessment-of-welsh-sacs-against-phosphorus-targets-final-v10.pdf?mode=pad&rnd=132557227300000000>

Heathwaite, A.L. and Johnes, P.J. (1996), Contribution of nitrogen species and phosphorus fractions to stream water quality in agricultural catchments. *Hydrological Processes* 10, 971-983.

Jackson-Bué, M., Wynter, E., Cuthbertson, S. and Hatton-Ellis, M. (2025). Condition Assessments for Estuaries in Welsh Special Areas of Conservation. NRW Evidence Report No. 895, 115pp, Natural Resources Wales, Cardiff.

Jarvie H. P., Withers P. J. A. and Neal C. (2002). Review of robust measurement of phosphorus in river water: sampling, storage, fractionation and sensitivity. *Hydrology and Earth System Sciences* 6(1), 113–132.

Jarvie H. P., Neal A. and Withers P. J. A. (2006). Sewage-effluent phosphorus a greater risk to river eutrophication than agricultural phosphorus. *Science of the Total Environment* 360, 246–253.

Jarvie H. P., Withers P. J. A., Bowes M. J., Palmer-Felgate E. J., Harper D., Wasiak K., Wasiak P., Hodgkinson R. A., Bates A., Stoate C., Neal M., Wickham H. D., Harman S. A. and Armstrong L. K. (2010). Streamwater phosphorus and nitrogen across a gradient in rural-agricultural land use intensity. *Agriculture, Ecosystems and Environment* 135, 238–252.

Jarvie, H.P., Sharpley, A.N., Scott, J.T., Haggard, B.E., Bowes, M.J. and Massey, L.B. (2012). Within-river phosphorus retention: Accounting for a missing piece in the watershed phosphorus puzzle. *Environmental Science and Technology* 46(24), 13284-13292.

Marsh, T. J. and Hannaford, J. (Eds). (2008). UK Hydrometric Register. Hydrological data UK series. Centre for Ecology & Hydrology. 210 pp.

Moatar, F., Abbott, B., Minaudo, C., Curie, F., and Pinay, G. (2017). Elemental properties, hydrology, and biology interact to shape concentration- discharge curves for carbon, nutrients, sediment, and major ions. *Water Resources Research*, 53, 1270–1287.

Naden, P., Bell, V., Carnell, E., Tomlinson, S., Dragosits, U., Chaplow, J., May, L., and Tipping, E. (2016). Nutrient fluxes from domestic wastewater: A national-scale historical perspective for the UK 1800–2010. *Science of The Total Environment*, 572, 1471–1484.

Nikolaidis, N.P., Phillips, G., Poikane, S., Várbbíró, G., Bouraoui, F., Malagó, A. and Lilli, M.A. (2022). River and lake nutrient targets that support ecological status: European scale gap analysis and strategies for the implementation of the Water Framework Directive. *Science of The Total Environment* 813, 151898,

NRW (2016). Cleddau and Pembrokeshire Coastal Rivers Management Catchment Summary. Available at: https://cdn.cyfoethnaturiol.cymru/679390/2016-updated-pembrokeshire_catchment_summary_nrw.pdf

NRW (2022). Core Management Plan including Conservation Objectives for Afonydd Cleddau /Cleddau rivers SAC. Available at: <https://naturalresources.wales/media/682866/afonydd-cleddau-plan-english.pdf>

NRW (2024). Update to phosphorus targets for water bodies in Special Area of Conservation (SAC) rivers in Wales. Available at: <https://naturalresourceswales.gov.uk/evidence-and-data/research-and-reports/water-reports/water-quality/update-to-phosphorus-targets-for-water-bodies-in-special-area-of-conservation-sac-rivers-in-wales/?lang=en>

NRW (2026a). Principles of nutrient neutrality in relation to development or water discharge permit proposals. Available at: <https://naturalresources.wales/guidance-and-advice/business-sectors/planning-and-development/advice-for-planning-authorities/principles-of-nutrient-neutrality-in-relation-to-development-or-water-discharge-permit-proposals/?lang=en#:~:text=Nutrient%20neutrality%20is%20an%20approach,discharges%20into%20affected%20designated%20sites.>

NRW (2026b). NRW Water Quality Archive. Available at: https://datamap.gov.wales/layers/geonode:nrw_water_quality_archive_stations

Pearce, N.J.T., Parsons, C.T., Pomfret, S.M. and Yates, A.G. (2023). Periphyton phosphorus uptake in response to dynamic concentrations in streams: Assimilation and changes to intracellular speciation. *Environmental Science and Technology* 57(11), 4643-4655.

Reynolds C. S. and Davies P. S. (2001). Sources and bioavailability of phosphorus fractions in freshwaters: a British perspective. *Biological Reviews of the Cambridge Philosophical Society*, 76, 26–64.

Ricardo (2025). Phosphorus in the River Wye: Evidence Base for Wales. Evidence base and options appraisal. Report ED21132 Issue: 4 to Herefordshire Council. Available at: <https://councillors.herefordshire.gov.uk/documents/s50131135/Phosphorus%20in%20the%20River%20Wye%20Evidence%20Base%20for%20Wales%20Evidence%20base%20and%20options%20appraisal%20Issue%204%20.pdf>

Smith, K.A., Jackson, D.R. and Withers, P.J.A. (2001). Nutrient losses by surface run-off following the application of organic manures to arable land. 1. Nitrogen. *Environmental Pollution* 112, 41-51.

Sutton, M.A., Howard, C.M., Erismann, J.W., Billen, G., Bleeker, A., Grennfelt, P., van Grinsven, H. and Grizzetti, B. (Eds.), (2011). *The European Nitrogen Assessment: Sources, Effects and Policy Perspectives*. Cambridge University Press, Cambridge, UK, 612pp. Available at: <http://www.nine-esf.org/node/360/ENA-Book.html>

Syers, J.K., Johnston, A.E. and Curtin, D. (2008). Efficiency of soil and fertilizer phosphorus use: reconciling changing concepts of soil phosphorus behaviour with agronomic information. *FAO Fertilizer and Plant Nutrition Bulletin* No. 18. Rome, FAO.

von Benzon, E., Bagshaw, E.A., Perkins, R., Browning, S. and Tibbits, T.N.D. (2025) Reliability of low-cost colorimetric phosphate and nitrate tests used by citizen scientists to assess river water quality. *Frontiers in Environmental Science* 13, 1667241.

Wang, S., Roy, J.W., Yates, A.G., Parsons, C.T. and Robinson, C.E. (2025). Examining the impact of stream pH changes on transient P storage in streambed sediments across multiple temporal scales. *Journal of Hydrology: Regional Studies* 62, 102788.

Welsh Government (2025). *Annual Survey of Agriculture and Horticulture (June Survey)*. Available at: <https://www.gov.wales/survey-agriculture-and-horticulture>

WFD-UKTAG (2013). *Updated Recommendations on Environmental Standards. River Basin Management (2015-21) .Water Framework Directive – United Kingdom Technical Advisory Group*. Available at: <https://www.wfduk.org/sites/default/files/Media/Environmental%20standards/River%20Phosphorus%20UKTAG%20Method%20Statement.pdf>

Withers, P.J.A. and Lord, E.I. (2002). Agricultural nutrient inputs to rivers and groundwaters in the UK: policy, environmental management and research needs. *The Science of the Total Environment* 282-283, 9-24.

Withers, P.J.A. and Jarvie, H.P. (2008). Delivery and cycling of phosphorus in UK rivers: implications for catchment management. *Science of the Total Environment* 400, 379-395.

Withers, P.J.A., Rothwell, S.A., and Ross, K.J. (2026). Phosphorus legacies and water quality in the Somerset Levels and Moors. *Regional Environmental Change* (In review).

Withers, P.J.A., Rothwell, S.A., and Ross, K.J. (2026). Phosphorus and Water Quality in the Cleddau catchment. A Report to the West Wales Management Board, May 2026.

Withers, P.J.A., Edwards, A.C. and Foy, R.H. (2001). Phosphorus cycling in UK agriculture and implications for phosphorus loss from soil. *Soil Use and Management* 17, 139-149.

Appendix 1. Numerical list of Phase 2 Monitoring Sites.

Station ID	Name
1	Trecwn / Nant Y Bugail
2	Schleddau / N Cleddau
3	Mathry/Cleddau Wen
4	Llangloffan / NW Cleddau
5	A40 / N. Cleddau
6	Lower Anghof Cemy
7	Upper Anghof/ Puncheston
8	Lower Nant Y Coy
9	Upper Nant Y Coy
10	Lower Spittal
11	Upper Spittal / Wallis
12	Lower Camrose
14	Upper Camrose/ Cafferne
15	Lower Rudbaxton/Kilbarth
16	Upper Rudbaxton
17	Lower Cartlett/ Dingle lane
18	Upper Cartlett/ Newbridge
19	Lower Pelcomb
20	Upper Pelcomb
21	Central HaverfordWest
23	Lower Cartlett/Shoals Hook
24	Crowhill
25	Wern
26	Mynaclog-ddu
28	Deepford

Station ID	Name
29	Syfywny at Gelli
30	Eastern Cleddau at Gelli
32	Lower Narbeth Brook
40	Lower Merlins Brook
41	Upper Merlins Denant Mill
42	Lower Millin Brook
43	Upper Millin Brook
44	Hanton Brook
47	Westfield Pill / Rosemarket
48	Hubberston Pill / Milford
49	Lower Sandy Haven
50	Upper Sandy Haven 1
51	Upper Sandy Haven 2
52	Bentlass East
53	Bentlass West
54	Quoits Mill/ Pembroke River
55	Lambeeth
56	Goldborough Pill
57	Pembroke River Ty Castell
58	Lanphrey / Upper Pembroke
59	Pembroke Commons Footbridge
60	Carew/ Sageston
61	Lower Cresswell/ Castle
62	Upper Cresswell/Loveston

Appendix 2. Details of single outliers not included in the statistical analysis of N and P measurements.

Site ID	Site name	Sampling date	Orthophosphate-P (mg/L)	Nitrate-N (mg/L)
5	N. Cleddau at A40	25/05/2025		0.05
8	Lower Nant y Coy	13/10/2024	1.21	
10	Lower Spittal	18/08/2024	0.75	0.8
18	Upper Cartlett	10/11/2024		12.1
		08/06/2025		0.7
23	Lower Cartlett	19/01/2025		0.6
19	Lower Pelcombe	13/10/2024	0.815	
		07/07/2024		0.3
24	Crowhill	29/09/2024		30
44	Hanton Brook	24/11/2024		30
47	Westfield Pill	05/01/2025		0.3
60	Carew river	16/02/2025	0.815	
62	Upper Cresswell	24/11/2024	0.003	

Appendix 3. Mean, median and range values for measured parameters in the C-CAP Phase 2 monitoring of the Cleddau catchment.

Site	Site name	Orthophosphate-P (mg/L)			Nitrate-N (mg/L)			Ammonia-N (mg/L)		
		Mean (s.e.)	Median	Range	Mean (s.e.)	Median	Range	Mean (s.e.)	Median	Range
1	Nant y Bugail				3.5 (0.22)	3.5	1.7 - 5.9	0.13 (0.030)	0.08	0 – 0.69
3	Mathry	0.020 (0.004)	0.016	0.003 - 0.075	4.8 (0.29)	4.7	1.7 - 7.2	0.02 (0.008)	0	0 – 0.20
4	Llangloffan	0.044 (0.006)	0.033	0.003 - 0.124	5.7 (0.31)	5.7	1.7 – 7.8	0.03 (0.016)	0	0 – 0.34
5	N. Cleddau A40	0.131 (0.026)	0.080	0.007 - 0.489	3.4 (0.19)	3.5	1.3 - 4.9	0.19 (0.14)	0.02	0 – 3.5
6	Wolfscastle	0.038 (0.006)	0.024	0.003 - 0.104	3.1 (0.23)	3.2	0.2 - 6.2			
7	Puncheston	0.011 (0.002)	0.010	0.003 - 0.026	2.1 (0.14)	2.0	0.7 - 3.4			
8	Nant y Coy	0.051 (0.018)	0.023	0.003 - 0.349	4.2 (0.45)	3.9	0.8 - 10.6	0.04 (0.015)	0.02	0 – 0.27
9	Upper Nant y Coy	0.052 (0.021)	0.003	0.003 - 0.362	3.4 (0.27)	3.4	1.4 – 6.2	0.12 (0.026)	0.09	0 – 0.45
10	Lower Spittal	0.040 (0.007)	0.029	0.003 - 0.160	4.3 (0.28)	4.2	1.5 - 9.3			
11	Upper Spittal				3.4 (0.24)	3.2	1.5 – 5.9	0.21 (0.04)	0.14	0 – 0.91
12	Lower Camrose	0.139 (0.031)	0.075	0.022 - 0.577	3.5 (0.17)	3.4	2.1 – 5.2	0.27 (0.106)	0.09	0 – 2.24
14	Upper Camrose	0.050 (0.014)	0.033	0.003 - 0.261	2.5 (0.24)	2.7	0.4 – 3.9	0.06 (0.027)	0.01	0 – 0.42
15	Lower Rudbaxton	0.300 (0.052)	0.238	0.033 - 0.815	3.2 (0.22)	3.2	0.9 – 5.3	0.13 (0.027)	0.07	0 – 0.43
16	Upper Rudbaxton	0.135 (0.047)	0.044	0.003 - 0.815	1.5 (0.22)	1.5	0.2 – 4.1	0.08 (0.015)	0.06	0 – 0.23
17	Lower Cartlett	0.075 (0.013)	0.062	0.003 - 0.349	4.1 (0.16)	4.1	2.2 – 5.5			
18	Upper Cartlett	0.946 (0.139)	0.815	0.022 – 1.63	4.0 (0.16)	4.1	2.5 – 5.2	0.05 (0.018)	0.01	0 – 0.15*
19	Lower Pelcombe	0.030 (0.005)	0.029	0.003 - 0.068	3.2 (0.25)	2.5	1.9 – 5.9	0.03 (0.016)	0	0 – 0.31
20	Upper Pelcombe	0.066 (0.011)	0.049	0.003 - 0.230	3.3 (0.24)	3.6	1.0 – 6.0	0.10 (0.057)	0.01	0 – 1.29
21	HaverfordWestern	0.027 (0.004)	0.026	0.003 - 0.055	3.8 (0.21)	3.6	2.8 - 5.3	0.07 (0.01)	0.04	0 – 0.23
23	Shoals Hook	0.118 (0.026)	0.080	0.016 - 0.584	4.3 (0.26)	4.3	1.7 – 6.6			
24	Crowhill	0.089 (0.034)	0.036	0.007 - 0.685	3.7 (0.34)	3.7	0.3 - 6.4			
40	Lower Merlins	0.044 (0.008)	0.039	0.003 - 0.153	2.5 (0.21)	2.2	0.8 – 5.5			
41	Upper Merlins	0.023 (0.006)	0.011	0.003 - 0.082	2.3 (0.23)	2.5	0.5 – 3.8	0.07 (0.02)	0.05	0 – 0.28

Appendix 3 continued

Site	Site name	Orthophosphate-P (mg/L)			Nitrate-N (mg/L)			Ammonia-N (mg/L)		
		Mean (s.e.)	Median	Range	Mean (s.e.)	Median	Range	Mean (s.e.)	Median	Range
42	Lower Millins	0.102 (0.015)	0.082	0.015 - 0.293	2.8 (0.20)	3.0	0.7 - 4.8			
43	Upper Millins	0.174 (0.032)	0.147	0.023 - 0.815	2.8 (0.20)	2.7	0.9 - 4.5	0.07 (0.02)	0.09	0 – 1.26
44	Hanton Brook	0.027 (0.007)	0.016	0.003 - 0.140	1.2 (0.08)	1.2	0.5 - 2.0			
25	Wern	0.134 (0.033)	0.103	0.003 - 0.815	1.4 (0.15)	1.2	0.5 - 2.9	0.08 (0.02)	0.06	0 – 0.35
26	Mynaclog Ddu	0.115 (0.032)	0.108	0.003 - 0.815	1.1 (0.14)	0.9	0.1 - 1.1	0.16 (0.09)	0.10	0 – 1.11
28	Deepford	0.189 (0.066)	0.033	0.003 - 0.815	4.0 (0.26)	4.1	0.6 - 5.6	0.05 (0.02)	0	0 – 0.5
29	Syfywny at Gelli	0.145 (0.032)	0.085	0.003 - 0.717	3.0 (0.13)	3.0	1.7 - 4.6	0.06 (0.02)	0.04	0 – 0.24
30	E.C. at Gelli	0.087 (0.021)	0.046	0.003 - 0.541	2.1 (0.15)	2.0	0.8 - 3.9			
32	Narberth	0.165 (0.036)	0.124	0.020 - 0.782	2.9 (0.18)	3.0	1.1 - 4.4	0.02 (0.01)	0	0 – 0.14
47	Westfield Pill	0.131 (0.034)	0.071	0.003-0.815	4.1 (0.24)	3.7	2.6-6.6	0.10 (0.02)	0.08	0 – 0.35
48	Hubbertson Pill	0.061 (0.006)	0.059	0.003-0.121	3.6 (0.24)	3.5	1.6-7.3	0.13 (0.06)	0	0 – 1.31
49	Sandy Haven	0.172 (0.043)	0.091	0.010-0.815	3.7 (0.22)	3.7	1.9-6.3	0.13 (0.09)	0.02	0 – 2.3
50	Upper S. Haven	0.090 (0.017)	0.055	0.01-0.339	3.3 (0.30)	3.6	0.5-6.1	0.02 (0.01)	0	0 – 0.17
53	Bentlass West	0.083 (0.024)	0.036	0.003-0.551	2.7 (0.21)	3.1	0.5-4.1			
54	Quoits Mill	0.373 (0.091)	0.078	0.003-1.63	5.3 (0.27)	5.6	2.2-7.8	0.03 (0.02)	0	0 – 0.37
55	Lambeeth	0.312 (0.058)	0.205	0.003-0.815	4.2 (0.25)	4.2	1.6-6.6	0.23 (0.08)	0.05	0 – 1.59
56	Goldborough Pill	0.158 (0.034)	0.085	0.026-0.786	3.3 (0.18)	3.3	1.1-5.0			
57	Ty Castell	0.393 (0.094)	0.130	0.007-1.63	2.8 (0.16)	2.8	0.8-4.5	0.01 (<0.01)	0	0 – 0.12
58	Upper Pembroke	0.176 (0.056)	0.071	0.01-1.22	2.1 (0.17)	2.4	0.2-3.3	0.05 (0.02)	0	0 – 0.38
59	C. Footbridge	0.166 (0.027)	0.143	0.086-0.584	4.6 (0.18)	4.6	2.2-5.8			
60	Carew river	0.045 (0.010)	0.024	0.003-0.173	2.2 (0.21)	2.1	0.5-4.6	0.15 (0.02)	0.14	0.01 – 0.37
61	Lower Cresswell	0.141 (0.023)	0.127	0.013-0.554	2.4 (0.15)	2.5	0.9-4.0	0.04 (0.02)	0	0 – 0.60
62	Upper Cresswell	0.504 (0.060)	0.571	0.082-0.815	4.1 (0.41)	3.8	0.5-8.0	0.30 (0.17)	0.10	0 – 4.29

Appendix 4. Mean, median and range values for measured parameters in the Phase 2 monitoring survey of the Cleddau catchment.

Site	Site name	River flow (m ³ /s)			pH (units)			Temp (°C)		
		Mean (s.e.)	Median	Range	Mean (s.e.)	Median	Range	Mean (s.e.)	Median	Range
1	Nant y Bugail	1.13 (0.12)	1.10	0.12-2.50	7.0 (0.20)	7.0	4.7-8.5	11.6 (0.45)	12.2	7.4-16.1
3	Mathry	0.22 (0.07)	0.13	0.02-1.71	7.8 (0.22)	8.0	5.2-9.0	10.8 (0.52)	10.9	6.7-14.7
4	Llangloffan	0.34 (0.06)	0.24	0.07-1.15	7.6 (0.17)	7.9	6.1-9.0	11.1 (0.46)	11.3	7.3-14.5
5	N. Cleddau A40	1.52 (0.15)	1.56	0.41-3.56	8.0 (0.26)	8.1	6.7-9.2	11.3 (0.52)	11.3	7.3-15.6
6	Wolfscastle	1.75 (0.44)	1.15	0.48-11.2	6.3 (0.13)	6.1	4.3-7.8	11.2 (0.57)	11.3	6.8-16.1
7	Puncheston				6.2 (0.14)	6.3	3.9-7.2	11.2 (0.56)	11.5	6.9-15.7
8	Nant y Coy	0.29 (0.04)	0.25	0.09-0.83	7.4 (0.13)	7.2	6.1-9.3	10.3 (0.44)	10.8	7.4-13.8
9	Upper Nant y Coy	0.14 (0.06)	0.08	0.05-0.56	7.0 (0.08)	6.9	6.1-7.7	10.4 (0.54)	11.0	6.7-14.5
10	Lower Spittal	0.62 (0.10)	0.46	0.24-2.71	7.2 (0.22)	7.2	4.2-9.0	10.4 (0.53)	11.0	5.3-15.3
11	Upper Spittal	0.46 (0.10)	0.26	0.01-1.8	6.7 (0.27)	6.8	2.9-8.5	11.2 (0.52)	11.6	6.9-15.2
12	Lower Camrose	0.56 (0.16)	0.30	0.05-4.1	8.0 (0.16)	8.0	6.7-9.8	12.0 (0.60)	11.7	6.8-17.9
14	Upper Camrose	0.50 (0.21)	0.15	0.01-2.7	8.1 (0.08)	8.2	7.3-8.5	12.0 (0.64)	12.2	7.6-17.1
15	Lower Rudbaxton	0.34 (0.16)	0.16	0.03-3.85	7.3 (0.10)	7.4	6.4-8.3	11.2 (0.73)	11.6	4.9-19.3
16	Upper Rudbaxton				7.0 (0.12)	7.0	6.0-8.3	12.0 (0.75)	11.9	5.9-18.9
17	Lower Cartlett	0.86 (0.22)	0.46	0.10-5.73	7.7 (0.13)	8.0	6.7-8.9	11.5 (0.61)	12.1	6.5-16.6
18	Upper Cartlett				7.4 (0.05)	7.3	7.1-8.0	10.8 (0.57)	11.0	6.0-15.3
19	Lower Pelcombe	0.72 (0.16)	0.30	0.05-2.68	7.2 (0.10)	7.1	6.5-8.6	11.9 (0.59)	11.7	7.0-16.7
20	Upper Pelcombe				7.7 (0.13)	7.7	6.4-8.9	11.8 (0.56)	11.5	6.6-15.9
21	HaverfordWest	10.2 (3.06)	5.33	0.46-47.0	7.2 (0.08)	7.2	6.7-7.8	12.2 (0.71)	12.3	8.2-16.2
23	Shoals Hook				8.0 (0.07)	8.0	7.1-8.4	11.3 (0.67)	11.2	6.7-16.5
24	Crowhill				6.6 (0.15)	6.5	4.1-7.4			
40	Lower Merlins	1.43 (0.35)	0.79	0.41-7.5	8.6 (0.05)	8.6	8.2-9.0	11.0 (0.74)	10.4	5.0-18.2
41	Upper Merlins				7.5 (0.28)	7.7	4.1-9.2	10.9 (0.77)	10.4	6.1-17.2

Appendix 4 continued

Site	Site name	River flow (m ³ /s)			pH (units)			Temp (°C)		
		Mean (s.e.)	Median	Range	Mean (s.e.)	Median	Range	Mean (s.e.)	Median	Range
42	Lower Millins	0.43 (0.22)	0.12	0.01-3.70	8.1 (0.11)	8.2	6.6-8.8	11.5 (0.57)	12.0	5.0-16.6
43	Upper Millins				8.1 (0.08)	8.2	6.7-8.7	11.3 (0.66)	11.4	5.9-16.4
44	Hanton Brook	0.51 (0.17)	0.33	0.12-4.35	8.4 (0.07)	8.5	7.8-8.9	10.9 (0.60)	10.7	5.0-16.0
25	Wern				7.6 (0.07)	7.6	6.1-8.2	10.2 (0.55)	10.7	6.3-14.9
26	Mynaclog Ddu				7.4 (0.13)	7.5	4.4-8.1	9.8 (0.58)	10.6	5.7-15.0
28	Deepford	0.77 (0.27)	0.43	0.02-5.50	7.3 (0.09)	7.4	6.4-8.1	10.3 (0.70)	10.0	5.1-16.0
29	Syfywny at Gelli	4.02 (0.39)	3.86	1.44-8.98	7.1 (0.15)	7.4	5.4-7.9	10.9 (0.65)	11.6	5.5-16.5
30	E.C. at Gelli	3.38 (0.62)	2.61	0.59-14.2	7.1 (0.16)	7.5	5.5-8.0	11.0 (0.67)	11.1	6.4-17.9
32	Narberth	1.18 (0.27)	0.70	0.35-4.2	7.7 (0.06)	7.7	7.1-8.2	10.8 (0.64)	10.6	6.3-16.8
47	Westfield Pill	0.66 (0.13)	0.58	0.06-3.45	8.0 (0.14)	8.1	6.8-9.0	10.9 (0.57)	10.5	7.5-15.2
48	Hubbertson Pill	0.37 (0.07)	0.25	0.05-1.16	8.1 (0.15)	8.0	7.0-10.4	11.3 (0.61)	11.3	6.9-16.7
49	Sandy Haven	0.43 (0.11)	0.23	0.07-2.26	7.5 (0.09)	7.5	6.8-8.2	11.1 (0.68)	11.6	5.8-16.2
50	Upper S. Haven				7.5 (0.10)	7.5	6.8-8.3	11.7 (0.73)	12.2	5.8-16.5
53	Bentlass West	0.05 (0.04)	<0.01	<0.01-1.04	8.0 (0.14)	8.3	6.2-8.8	12.5 (0.48)	12.7	8.7-17.3
54	Quoits Mill	0.09 (0.02)	0.05	0.01-0.45	7.7 (0.11)	7.8	6.7-8.8	12.4 (0.63)	12.2	7.7-17.8
55	Lambeeth	0.21 (0.10)	0.02	<0.01-2.21	8.2 (0.15)	8.1	6.2-9.6	11.4 (0.64)	11.7	5.2-16.7
56	Goldborough Pill	0.19 (0.12)	0.03	<0.01-3.03	8.0 (0.13)	8.2	5.9-8.8	11.7 (0.61)	12.5	5.9-17.1
57	Ty Castell	3.89 (0.85)	2.00	0.08-11.28	8.2 (0.06)	8.1	7.8-8.7	12.3 (0.45)	12.9	8.7-15.7
58	Upper Pembroke				8.1 (0.07)	8.2	7.1-8.6	12.5 (0.54)	12.8	8.6-17.8
59	C. Footbridge	0.21 (0.09)	0.10	0.02-2.36	7.9 (0.13)	7.8	7.2-9.4	12.0 (0.55)	12.3	7.6-17.0
60	Carew river	0.39 (0.07)	0.26	0.05-1.79	8.0 (0.05)	8.1	7.2-8.4	11.0 (0.64)	11.3	6.0-16.2
61	Lower Cresswell	1.08 (0.26)	0.65	0.14-6.70	7.9 (0.08)	8.0	7.1-8.8	11.3 (0.66)	11.4	5.9-17.5
62	Upper Cresswell	0.47 (0.13)	0.24	0.07-2.34	7.8 (0.09)	7.8	7.2-8.7	13.3 (0.63)	13.5	8.7-17.6

Appendix 5. Location of C-CAP sampling sites in relation to points of wastewater discharge from Wastewater Treatment Works (WwTW, Combined Sewer Overflows (CSO), Pumping Stations, and other Domestic, Commercial and Institutional sources.

