Environment Agency

Phosphorus Source Apportionment data for the Windermere Catchment

Date: November 2023

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Introduction

This short report describes the phosphorus[1] source apportionment data for the Windermere catchment that has been produced by the Environment Agency (EA).

The Windermere Catchment

Windermere, England's largest freshwater lake, is located in the Lake District National Park in Cumbria, UK. It is formed of two connected but distinct basins, the North Basin and the South Basin.

Windermere North Basin is fed by The River Rothay Catchment (that includes Grasmere), the River Brathay catchment (that includes Elterwater and Langdale), the Trout Beck catchment, the Blelham Beck catchment (including Blelham Tarn) and Mill Beck. Windermere South basin is additionally fed by the Cunsey Beck catchment (that includes Hawkshead and Esthwaite Water).

The lake suffers from nutrient enrichment and these nutrients cause algal blooms.

Models used to produce the source apportionment data

The phosphorus source apportionment data has been produced using SAGIS-SIMCAT modelling tools[2].

SAGIS (Source Apportionment Geographical Information System) and SIMCAT (Simulation of water quality in Catchments) are the main water quality catchment modelling tools that are used by all the environmental regulators in the UK including the EA. SIMCAT is a well-established model and has been used for over 40 years. SAGIS has been jointly developed with UKWIR (the UK Water Industry Research group) since 2010. Their primary use has been to drive water company investment, but the models are increasingly being used to help understand the significance of other sources of pollution.

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[1] The form of Phosphorus modelled is Total Phosphorus. We have focused on Phosphorus rather than nitrogen because Phosphorus is understood to be the limiting nutrient and the one that needs controlling.

[2] To use the models themselves users require licenses from UKWIR and Wallingford Hydro Solutions. The models also contain other 3rd party datasets that may need to be restricted.

The models can model both river water quality (in SIMCAT) and lake water quality (using an intermediate lake model using the equations derived by Professor Steven Chapra[3]).

Outputs have been produced using SIMCAT version 15.7 and SAGIS v3 (Add-In Release versions up to 1.0.8.1112.21765).

Model Confidence

The models have been calibrated following nationally agreed model build and model calibration standards. The calibration process optimises the level of agreement between measured and simulated values through reasonable and systematic adjustments to model parameters and data. To assess confidence in the models, the level of agreement between measured and simulated values was assessed. The integrated river and lake model has been validated against observed water quality data. The river and lake models are therefore considered to be fit for purpose for catchment planning.

The post-2020 scenario results show good agreement with the improvements predicted in 2014 when the 2020 UU improvements were being developed. They also show close agreement with post 2020 observed water quality data in the North and South Basins.

Data used in the model

The data used in the model are summarised in the table below.

Data Set	Data used	Comments
River Flows	EA Flow Gauging Station data for period 2014-2018	Used to calibrate the flows in the models
River and Lake Quality (England)	2014-2021 EA monitoring data	Used to calibrate water quality in the rivers and lakes
Large UU Sewage Treatment Works (STW) Flows	Certified measured flows 2014-2018 & 2020 -2023	Used to characterise the inputs

[3] Steven Chapra | Department of Civil and Environmental Engineering (tufts.edu)

Small / Private STWs (package treatment plants) Flows	Permitted flow or estimated flow from population	Used to characterise the inputs
STW Quality	2014-2020 & 2020-2023 monitoring data. Default mean 6 mg/l used where no data available	Used to characterise the inputs
Industrial discharges	None in the catchment	
Storm Overflows	Annual loadings and spill duration provided by United Utilities. This was average modelled spill data from a 10-year period. The spill duration was checked against monitored Event Duration Monitoring (EDM) Data. At one site, Near Sawrey, the modelled data was lower but in this case a conservative approach was taken to derive the load. The load entering Lake Windermere from Near Sawrey is less than 5 % of the load discharged from the other overflows.	Used to characterise the inputs
Rural Land Run-off (e.g. from farmland, forestry, grassland, moorland)	Annual 1 km loadings from the ADAS psychic[4] model. 2010 data adjusted to reflect a better understanding of present land use	Diffuse inputs are included in the model at a waterbody scale with loadings spread evenly along each modelled reach
Septic Tanks	Estimated annual loadings from unsewered properties	
Urban Run-off (e.g. contaminated surface water from towns and villages)	Estimated annual loadings from urban areas	

Table 1 – Data used in SAGIS

4 Davison, P.S., Withers, P.J.A., Lord, E.I., Betson, M.J. and Stromqvist, J., (2008) PSYCHIC – a process-based model of phosphorus and sediment transfers within agricultural catchments. Part 1. Model description and parameterisation. Journal of Hydrology, 350(3-4), 290-302

Model Results (Figures 1 and 2)

The models have been used to produce results for 3 scenarios:

- Pre-2020: the calibrated baseline period using 2014-2018 flow data and water and discharge quality data up to 2020.
- Post-2020: this scenario examines the reductions in load and resulting water quality improvements arising from improvements the Environment Agency required United Utilities to make to the Glebe Road storm overflow in Windermere and at Grasmere STW, Ambleside STW, Outgate STW, Windemere STW.
- Post-2030: this scenario examines the further load reductions and resulting water quality improvements that will be delivered through additional improvements to United Utilities storm overflows at Langdale (Elterwater), Ambleside WwTW, Hawkshead and Near Sawrey WwTW.

At this stage we are only able to model and quantify the changes arising from the UU improvements. The UU sources are currently the only ones that are monitored regularly for phosphorus and the only sources where predicted changes as a result of future improvements can be accurately quantified. Other sources are not assessed or monitored as frequently but action is being planned to address this, for example through additional monitoring and soil testing for Phosphorus. **We would like in future to run further scenarios to quantify the additional improvements that are being made to other sources and will do this when data is available.**

The models predict that the UU improvements delivered in 2020 have led to a **31% reduction** in phosphorus inputs into the **Windermere North Basin** which has led to just over a 26 % decrease in Total Phosphorus concentration. The average Total Phosphorus concentration in the North Basin is currently at good status. The models predict that the additional planned UU improvements will deliver a **further 8 % reduction** in phosphorus inputs to the North Basin.

The models predict that the UU improvements delivered in 2020 have led to a **30% reduction** in phosphorus inputs into the **Windermere South Basin** which has led to just over a 33 % decrease in Total Phosphorus concentration. The average Total Phosphorus concentration in the South Basin is also currently at good status. The models predict that the additional planned UU improvements will deliver a **further 4 % reduction** in phosphorus inputs to the South Basin.

The UU 2020 improvements we believe have reduced the amount of Total Phosphorus entering Windermere by around **3,000 kg/year**.

Although Total Phosphorus is currently modelled and observed to be at good status in both basins, the lake ecology is not at good status. More research needs to be done to understand the future risks to the lake from climate change and increased tourism.

To mitigate against these risks and obtain a resilient healthy lake it is recognised that nutrient loads to Windermere need to be further reduced.

Sensitivity analysis has been done on the sector inputs where the confidence in the input data is lower.

Current Phosphorus Source apportionment (Figures 3 and 4)

Our models show that currently:

- 52 % of the phosphorus in Windemere North Basin comes from Point Sources (sewage) and 48 % from diffuse sources.

- 59 % of the phosphorus in Windemere South Basin comes from Point Sources (sewage) and 41 % from diffuse sources.

The current Total Phosphorus Source apportionment is summarised below and shown in Figures 3 and 4.

Sector	Contribution to current (post-2020) Total Phosphorus lake concentration
Rural Land Use	33-41 %
Storm Overflows	18-25 %
UU STWs	12-16 %
Private STWs	10-13 %
Urban	6-12 %
Septic Tanks	5-9 %

Table 2 – Windermere North Basin Phosphorus Source apportionment

Sector	Contribution to current (post-2020) Total Phosphorus lake concentration
Rural Land Use	28-36 %
Storm Overflows	17-24 %
UU STWs	18-22 %
Private STWs	10-14 %
Septic Tanks	6-10 %
Urban	4-10 %

Table3 – Windermere South Basin Phosphorus Source apportionment

How will the Model Outputs be used?

These outputs have two primary uses:

- To inform the Action Plan and help to prioritise where additional work is needed to take place.
- To help identify the areas requiring more investigation due to the largest uncertainties.

Future Improvements to the model

More research or data collection in the following areas would support the development of proposals to further improve water quality in Windermere:

- nutrients locked away in the sediments and their potential to be released. The parameters used in the model have been obtained from literature and adjusted through model calibration to match the current lake conditions.
- rural land use data. The data used to derive phosphorus loadings from rural land originates from the 2010 agricultural census survey. Local knowledge has been used to improve this. The use of the 2021 survey data would reduce the uncertainty in these loadings even further.
- the concentrations of nutrients in storm overflow discharges. There is limited data available and sampling data would reduce the uncertainty in these loadings.
- impact of climate change. More research is needed to understand how the cumulative effects of changing rainfall, river flows, temperature, land use will affect the lake.

- changes resulting from improvements to other sectors. The post 2020 and post 2030 scenarios so far only consider the changes arising from improvements to UU discharges.

Charts

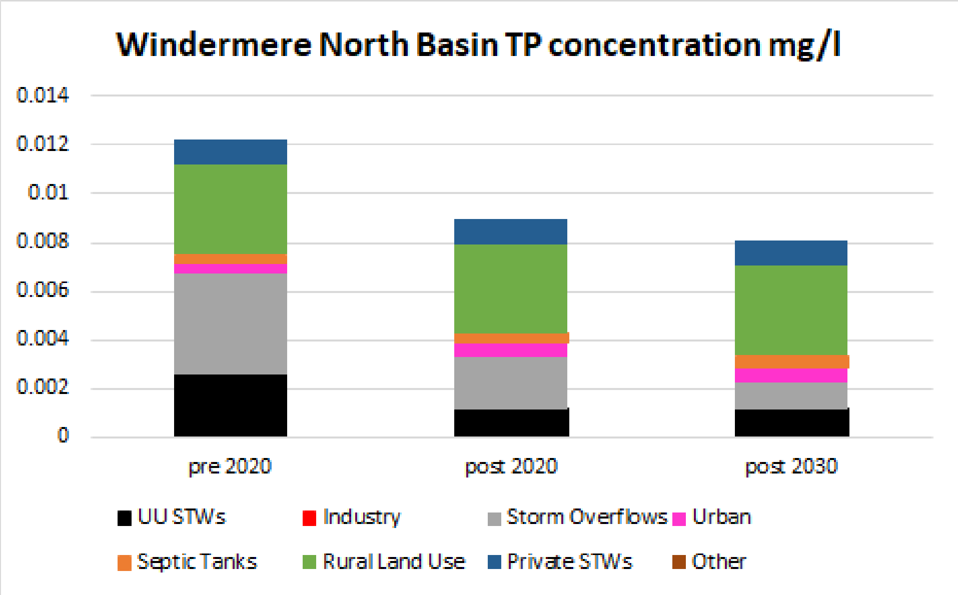

Figure 1 – Source apportionment data (total phosphorus concentration) for each of the scenarios – Windermere North Basin

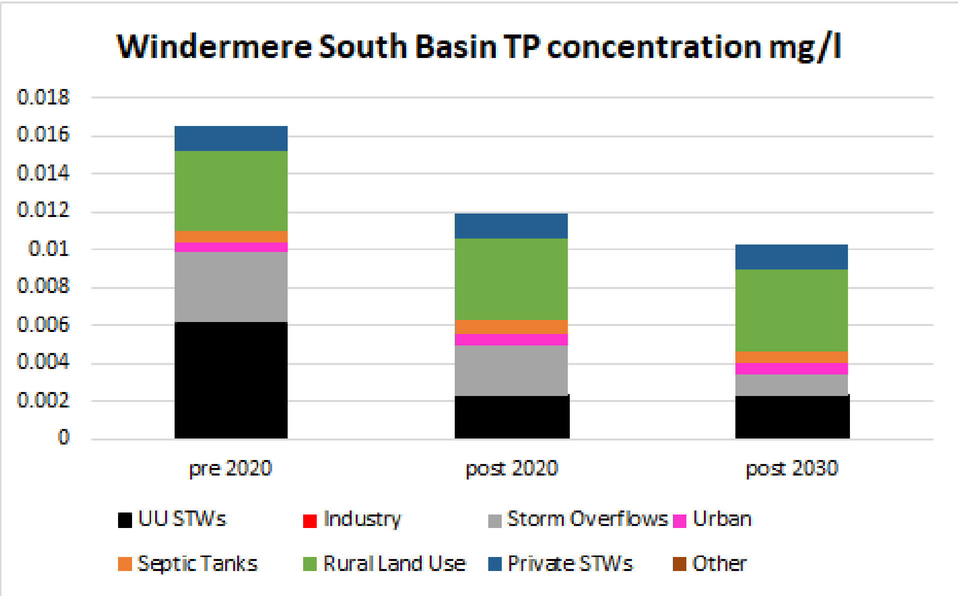

Figure 2 – Source apportionment data (total phosphorus concentration) for each of the scenarios – Windermere South Basin

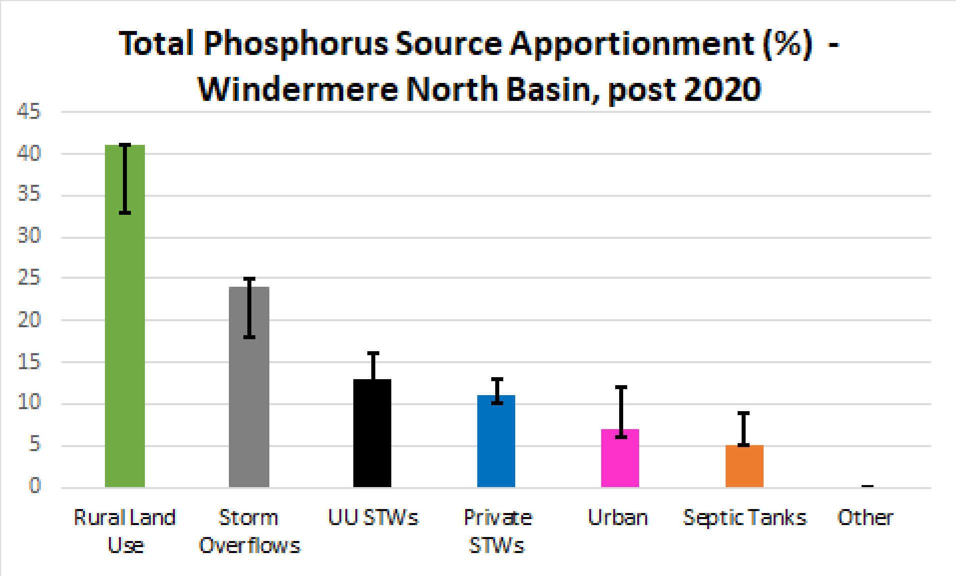

Figure 3 – Source apportionment data (total phosphorus concentration) for the post 2020 scenario – Windermere North Basin including the upper and lower confidence limits for each source.

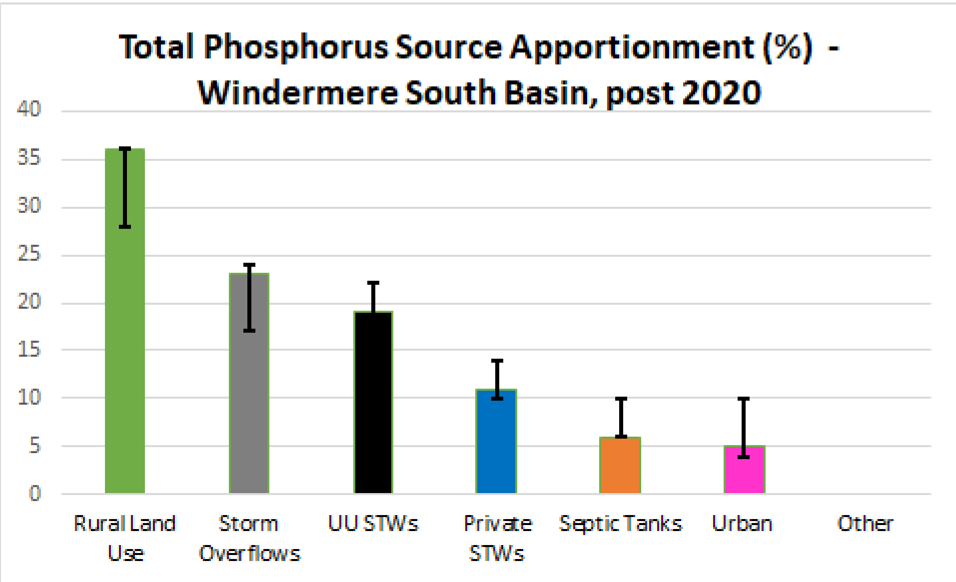

Figure 4 – Source apportionment data (total phosphorus concentration) for the post 2020 scenario – Windermere South Basin including the upper and lower confidence limits for each source.

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