UPDATING THE SAGIS AFON GWYRFAI MODEL

SAGIS Non-Technical Calibration Report for the River Afon Gwyrfai

30 MAY 2023

Dŵr Cymru Welsh Water

Cyfoeth Naturiol Cymru Natural Resources Wales

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MODEL AUDIT

AUDITOR	ORGANISATION	DATE
CP/ES/LK/NH	Binnies on behalf of Natural Resources Wales	31 March 2023

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FIGURES

1. MODELLING THE AFON GWYRFAI SAC

The purpose of this note is to provide an overview of the computer modelling approach being used to develop plans for wastewater investment to help ensure waterbodies in the Afon Gwyrfai Special Area of Conservation (SAC) achieve its water quality objectives for phosphorus. The modelling work has now completed and has been subject to NRW's quality assurance process, which was undertaken by Binnies.

The Afon Gwyrfai is designated as a SAC under the Conservation of Habitats and Species Regulations 2017, as amended (referred to as the 'Habitats Regulations'). In January 2021, Natural Resources Wales (NRW) published a report on the compliance assessment for tightened phosphorus targets showing that the Afon Gwyrfai SAC waterbodies achieve their targets.

Recently, NRW and Dŵr Cymru Welsh Water (DCWW) have implemented a programme of water quality modelling to develop an improved understanding of the sources of phosphorus for the catchment, and to explore possible approaches for further improving water quality within the SAC. Figure 1 shows the SAC waterbodies. Note that whereas the term 'phosphorus' is used in this document, the form of phosphorus that has been modelled is known as 'orthophosphate', the form measured and compared with environmental targets. This may be understood to represent the most bioavailable form of phosphorus.

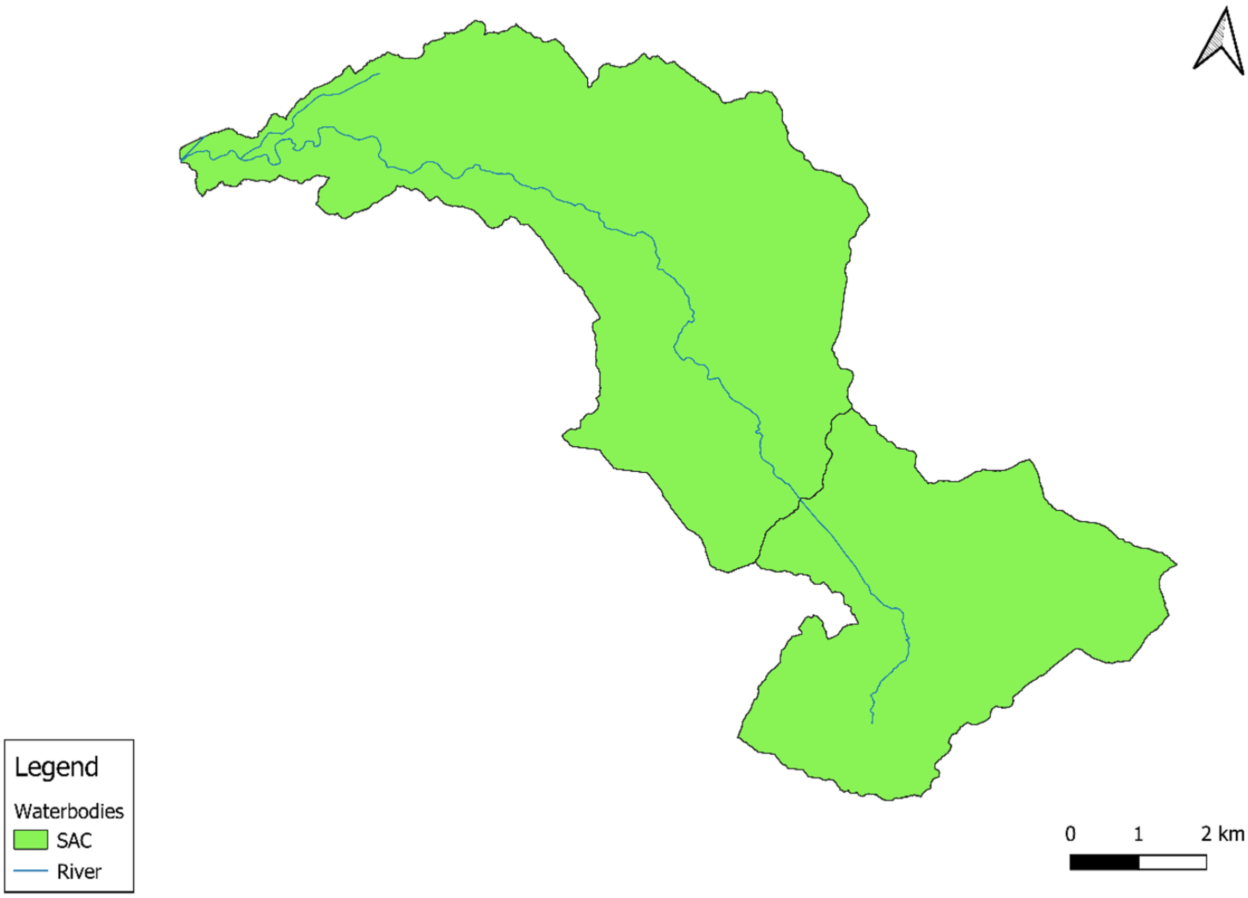

Figure 1 – Map showing the Afon Gwyrfai catchment waterbodies.

2. WATER QUALITY MODELLING

Water quality modelling enables the effectiveness of controls on sources of pollution and interventions to be tested in a virtual environment to help identify those that are likely to be most effective in reality. Modelling helps to provide confidence that measures will deliver the envisaged environmental outcomes.

Computer models, however, provide only a simplified representation of complex natural systems and consequently, their limitations must be considered as part of the process of developing plans of action. Indeed, modelling is most useful when deployed as part of a 'weight of evidence' approach where it is used in combination with information from other sources, including local knowledge and input from other subject matter experts. Key stages in the modelling process include:

- Models are updated and calibrated so that they provide a reasonable representation of recent catchment conditions.
- Important limitations and uncertainties are identified and characterised.
- Water quality improvement scenarios are simulated following regulatory guidance to identify the most effective combinations of measures.

NRW uses water quality models to define new discharge quality permits for DCWW's wastewater assets and where necessary to target further monitoring and investigations. Permit conditions for water company assets are subsequently formalised and implemented through normal investment planning and delivery processes.

3. SOURCE APPORTIONMENT GEOGRAPHICAL INFORMATION SYSTEM (SAGIS MODELLING)

The Source Apportionment Geographical Information System (SAGIS) has been used to create a virtual representation of the Afon Gwyrfai.

SAGIS is derived from earlier modelling approaches (SIMCAT and RQP) that have been in use in the UK for several decades which have underpinned the investment made by the UK Water Industry in measures to improve water quality. Together with SIMCAT, SAGIS (also known as SAGIS-SIMCAT) is the standard tool used by regulators and the water industry to identify assets where controls on effluent quality are required. The SAGIS build version used in this study was 1.0.8112.21765. The version of SIMCAT was 15.7.

MODEL DATA

There are two main types of data contained within SAGIS model databases, namely, measurement data and sector data (further information is provided in Appendix A):

- **Measurement data** – river flow (for the period 2015 to 2019) and quality (phosphorus) measurements, as well as wastewater treatment works (WwTWs) discharge flow and quality (for the data period 2016 to 2019). A four -year period for river flow was used because period statistics are less likely to be impacted by unusual conditions within a single year. A four-year period for river quality was used due to concerns over anomalous measurements in 2014 and 2015. Where measured effluent quality data was not available a default value of 5mg/L is applied. For treatment works with descriptive permits, discharge flow was estimated as the population served multiplied by 165 litres per person per day. For other sites discharge flow was based on either measured data or the permitted discharge flow.

• **Sector data** – Inputs from sources other than wastewater.

• Estimates of diffuse inputs are included in the model by sector as an annual load input by waterbody. Within the modelling process, waterbody loads are distributed across the river reaches in the originating waterbody[1].

• Storm Overflows (CSOs) – SAGIS includes representation of inputs from intermittent discharges such as CSOs and storm tanks. A method development study was undertaken to develop an approach to use sewer model data to improve the representation of storm overflows within SAGIS for the Gwyrfai. This was not intended as a substitute for or alternative to sewer modelling, but rather was a means of maximising the value and benefit from the investment made in creating EDM and sewer model data. The SAGIS model was updated to reflect inputs from two intermittent discharges for which sewer model data were available.

MODEL CALIBRATION

SAGIS calibration is a process through which the level of agreement between observed and simulated values is optimised. Within the calibration process, the parameters controlling the sector input loads (the total input load) and variability (the variability associated with the total input load) are adjusted along with the determinand decay rate (a parameter representing a combination of effects, including in-river losses arising from uptake into the environment, deposition to sediment, and chemical transformation).

MODEL CONFIDENCE

Following the calibration process, the level of agreement between measured and simulated values is assessed. The level of agreement helps to identify locations or regions where modelled values diverge from measured values, and therefore where the model may be inappropriate to support decision making (or at least to identify where there may be uncertainty associated with the outcomes of actions that are supported by model outputs)[2].

For the Afon Gwyrfai SAC model, the level of agreement between observed and simulated concentrations was evaluated at four locations, with a Good level of agreement at two out of four locations.

MODEL AUDIT

To provide assurance that the model is robust and can be used as the basis for wastewater planning, NRW commissioned a quality assurance of the SAGIS-SIMCAT modelling of phosphorus in the river. The aims of the QA were to: ensure the models have been built and calibrated in line with agreed guidance; check that the correct water quality targets have been applied at the correct locations, and that the spatial location of model features is correct; identify any discrepancies between the models and guidance and help prioritise any required changes; ensure the outputs from the models have been correctly represented tools to be used for wastewater planning purposes.

In summary, the QA has concluded that the model is in line with agreed guidance and fit for the purpose of informing wastewater planning decisions. A number of lower priority recommendations for model development will be taken forward for review later in the year.

[1] An occasional consequence is that, within the modelling process, inputs from certain sectors may be distributed to river reaches in which they are not expected to occur. This arises as a consequence of constraints on the resolution of the sector data and the simplified representation of how diffuse inputs are distributed within a waterbody.

[2] The following criteria have been used to characterise model certainty/confidence:
• Good. Where there is a difference of <0.005mg/L between observed and simulated values.
• Moderate. Where there is a difference of >0.005mg/L between observed and simulated values but the difference is not statistically significant (or the number of samples is <12).
• Poor. Where there is a difference of >0.005mg/L between observed and simulated values.

4. MODEL RESULTS

At the furthest downstream point in the (modelled) river, the results show that, under current conditions, approximately 4 kg of phosphorus is discharged from the catchment on a daily basis.

The SAGIS model results show that a large proportion of phosphorus[3] originates from WwTWs. The model shows that WwTWs, rural land use, intermittents and other sources[4] account for 87.8%, 10.6%, 0.5% and 1.1%, respectively, of the phosphorus concentration (results extracted from the downstream boundary of the Afon Gwyrfai SAC). The results also show that WwTWs, rural land use, intermittents and other sources account for 79.9%, 15.6%, 3.6% and 0.9%, respectively, of the phosphorus load. As per recently agreed NRW modelling guidance, decision making should be based on the concentrations[5].

Note that the concentration and load apportionment are different because inputs from different sources tend to occur under differing river flow conditions. For example, inputs from treatment works occur continuously (i.e. under high and low flow conditions) whereas inputs from diffuse sources tend to occur under higher river flow conditions where there is a higher level of dilution available in the receiving water. This means that, on balance, a kilogram of phosphorus discharged from a treatment works will have a relatively greater impact on the in-river concentration than the equivalent input from diffuse sources. Concentration apportionment information is important because this underpins the basis for measures undertaken by different sectors to reduce inputs. Note that apportionment will differ at different locations within the catchment.

The modelling also takes account of decay effects which, in this context, represents a combination of influences, including in-river losses due to uptake into the environment, deposition to sediment, and chemical transformation. The loads at the furthest downstream point are therefore not necessarily equivalent to the total input loads.

SAGIS also provides an estimate of the phosphorus contribution from CSOs in the catchment. These were estimated at c0.5% of the phosphorus concentration and c3.6% of the phosphorus load entering the catchment. Storm overflows were found to have a limited impact on annual average concentrations (the form in which standards for phosphorus are expressed). This information is visualised in Figure 2. The availability of water quality monitoring data and sewage treatment works performance data, means that SAGIS modelling provides a robust framework for use in decision-making for wastewater investment planning. In general, estimates of loadings from diffuse sources from other sectors, within SAGIS, have a greater degree of uncertainty.

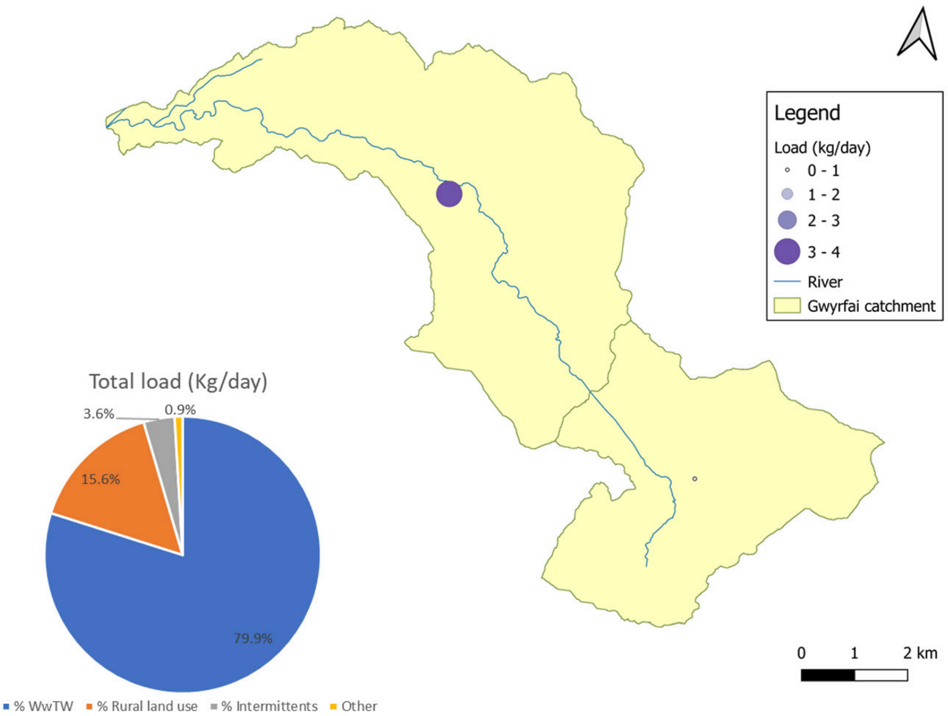

Figure 2 – Phosphorus apportionment by source at the furthest downstream point on the Afon Gwyrfai. Note that the 'Other'category is comprised of the estimated contribution from diffuse sources of urban, industry and septic tanks.

[3] Orthophosphate and phosphorus used interchangeably.
[4] Includes septic tanks, industry, highways and urban runoff.
[5] Since this is the form in which standards are expressed.

5. SCENARIO MODELLING

The SAGIS model has been calibrated and will be used shortly to test the theoretical impact of changes in effluent quality at a range of WwTWs in the catchment (i.e. 'what if' scenarios). Scenarios are not necessarily meant to represent practical options, but rather, help inform on the scale of management challenges within the catchment.

APPENDIX

MODEL DATA

There are two main types of data contained within SAGIS model databases, namely, measurement data and sector data. Measurement data are derived from routine monitoring activities, and include river quality information obtained by NRW, and river flow information reported at national river flow gauges. Models are calibrated to the measurement data so that models are expected to recreate (virtually) conditions that span the period of time over which the measurement data was obtained. The model for the Afon Gwyrfai SAC has been developed using data covering the period 2016 to 2019[6].

It was found that results from two different analytical methods were reported for many individual samples (NRW data); a 'low' (method 21) and a 'very low' (method 24) result. Where both method 21 and 24 result were reported, the method 24 result was used to derive summary statistics as agreed with NRW. Extraneous values well above expected concentrations were additionally removed. For the Afon Gwyrfai, two samples with very high values were removed, both of these from different sites.

The sector data contained within the model databases represent estimates of inputs from sources other than wastewater treatment works, primarily diffuse sources. Estimates of diffuse inputs are included in the model by sector as an annual load input, by waterbody[7]. Within the modelling process these waterbody loads are distributed across the river reaches within the originating waterbody. An occasional consequence is that within the modelling process inputs from certain sectors may be distributed to river reaches in which they are not expected to occur although this tends to primarily affect river reaches situated in headwater locations.

Rural land use input estimates are based on data from the Phosphorus and Sediment Yield CHaracterisation In Catchment model (PSYCHIC; Davison et al., 2008; Stromqvist et al., 2008) model, which provides an estimate of phosphorus 'losses' to waterbodies at a 1km2 grid scale, but which have been aggregated to a waterbody scale for use within SAGIS[8]. Modelled transfer pathways include release of soil phosphorus, detachment of sediment and associated particulate phosphorus, incidental losses from manure and fertiliser applications, losses from hard standings and the transport of all the above to watercourses in underdrainage (where present) and via surface pathways. The model is sensitive to a number of crop and animal husbandry decisions, as well as to environmental factors such as soil type and field slope angle. The PSYCHIC model utilises the mean climate drainage model (MCDM, Anthony, 2003) to calculate the evapotranspiration, soil moisture deficit and soil drainage. The presence of artificial drainage systems the relative importance of different sub-surface drainage pathways are based on the Hydrology of Soil Types (HOST; Boorman et al., 1993) classification. PSYCHIC has been applied across the UK in support of government policy (e.g. Anthony et al., 2005; Gooday et al., 2015) and has also been applied to a number of European catchments (Silgram et al., 2008). The current phosphorus data within SAGIS for England and Wales is from the PSYCHIC model (Davison et al., 2008) based agricultural census data for 2010.

[6] Implies that future conditions will be representative of conditions within the snapshot period. Models are updated and recalibrated on a periodic basis.
[7] This is the scale at which diffuse sector inputs can be quantified with reasonable confidence.
[8] The substantial uncertainty associated with estimates for individual 1 km2 grids is well accepted.

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