intertek
Total Quality. Assured.

CIWEM - UDG CONFERENCE 2023

Improving Efficiency From SOAF to AMP8 Assessments - Flexible Modelling Approaches for River Quality Assessment

1 December 2023

Intertek Energy & Water Consultancy Services
Exchange House, Station Road, Liphook, Hampshire GU30 7DW, United Kingdom

Abstract

River water quality assessments in the UK are undertaken across a wide range of catchments with various and potentially complex factors contributing to performance. Four levels of water quality modelling have been defined; from simple stochastic model to complex calibrated and validated fully dynamic models with bespoke survey data. Requirements to apply the highest modelling level in AMP8 is a significant issue due to tight delivery deadlines and the extended programme this would require.

An AMP8 modelling approach based on the SOAF methodology applies available data and defined assumptions to quickly assess the impact of individual assets. The vast quantity of data collected on watercourses allows for the construction of models capable of assessing impacts from known assets, such as WwTW, CSOs, and diffuse sources, to determine their contribution to water quality performance. These simplified models have been successfully applied to demonstrate the impacts of flow transfer schemes and can identify where further data is required.

Simplified approaches cannot be applied universally as the complexity of select catchments will necessitate Level 4 modelling. However, with flexibility of approach, effective communication of modelling limitations, and coordinated planning it will be possible to successfully achieve the AMP8 water quality modelling programme.

This paper presents my thoughts on how this type of approach can be used, and how a simplified approach should be the basis of development, recognising that there will still be requirement for more detailed approaches where complexity demands it.

Introduction

River water quality modelling in the UK requires assessments to be undertaken across a wide range of environments, from natural upland catchments with limited human influence on rivers which originate in the middle of major urban areas with heavily modified watercourses, to everything in-between. Modelling guidance for river water quality has a wider set of guidance and assessment standards than coastal waters to cover this range of variability and complexity, with Water Framework Directive (WFD) and Urban Pollution Management (UPM) forming the standard performance criteria applied when assessing water quality performance in a catchment.

The WFD and UPM investigations require assessment of the catchment as a whole, covering inputs from diffuse sources, sewer networks, industrial discharges, and road runoff. These form complex studies due to the requirement to consider and quantify the wide range of sources which may contribute to water quality. Recently the Storm Overflow Assessment Framework (SOAF) investigations have introduced a simplified methodology to assess impact from individual assets, allowing for quicker, but less detailed, assessments to be undertaken. There is also growing interest around inland Bathing Waters (BW) with the view to designating sections of rivers.

Modelling approaches applied in the investigations need to be flexible to effectively assess water quality issues across all environments to effectively identify sources of pollution, from both point and diffuse sources, while not becoming overly complex that the model cannot be efficiently constructed or applied. Current modelling requirements need to be viewed in context of the Environment Agency's (EA) guidelines for the Asset Management Plan 8 (AMP8) period, with all water quality modelling initially potentially required to be undertaken at Level 4 (this has been, and is currently, under review), and the Environment Act targeting a 10-spill solution at all CSOs. Water quality modelling is required to determine if the 10-spill solution resolves water issues, does this target result in an over-performing solution, or are other discharges driving poor performance in the catchment.

Modelling Approaches

There are four modelling levels which have been defined by the EA. The level applied in the water quality assessment is determined by the assessment requirements and the catchment. These levels are detailed below from the simplest to the most complex.

- Level 1 – Stochastic Model. This level of assessment mixed randomly picked river flow and quality from statistical distributions with asset discharges produced from a verified sewer network model and applying default discharge concentrations. A simplified trapezoidal channel is utilised with hydraulic equations to simulate the depth and velocity of the mixed flow and sewer discharge. Simplified water quality modelling is applied to simulate the key oxygen demand processes (BOD decay and nitrification). Reaeration is simulated to assess Dissolved Oxygen (DO) and un-ionised ammonia. This level of modelling is capable of undertaking WFD and UPM percentile investigations. The stochastic approach is not capable of modelling the UPM Fundamental Intermittent Standards (FIS), which are duration exceedance standards requiring the model to include the time component.
- Level 2 – This level is similar to Level 1 but utilises a timeseries approach to enable better representation of the dilution of discharges and the calculation of FIS standards. The same simplified river hydraulics and water quality process applied at Level 1 can be applied at this level.
- Level 3 – This level utilises calibrated flow routing models to ensure an accurate representation of travel time and the modelling of more complex catchments. More complex water quality processes are simulated with calibration of key parameters, including BOD, ammonia, and DO. Event sampling data is required for model calibration, this data can be collected by sondes or autosamplers.
- Level 4 – The most complex modelling level uses calibrated hydrodynamic river models which simulate varying depth and velocity. The hydrodynamic simulation includes advection and dispersion along with complex water quality processes. Survey data is applied in model calibration for hydrodynamics and water quality parameters.

All modelling levels require outputs from a verified sewer network model, this is key to ensure that asset spill volumes and frequencies are accurately represented in the water quality model. A 10-year timeseries is typically applied, this is a minimum and a longer period can be utilised. Rainfall should be representative of the catchment can obtained from a variety of sources including, measured (tipping bucket) rain gauges, radar, or synthetic. The same rainfall applied in the sewer network model is applied in the hydraulic modelling to link the two and ensure the correct timing, and therefore dilution, of spill events.

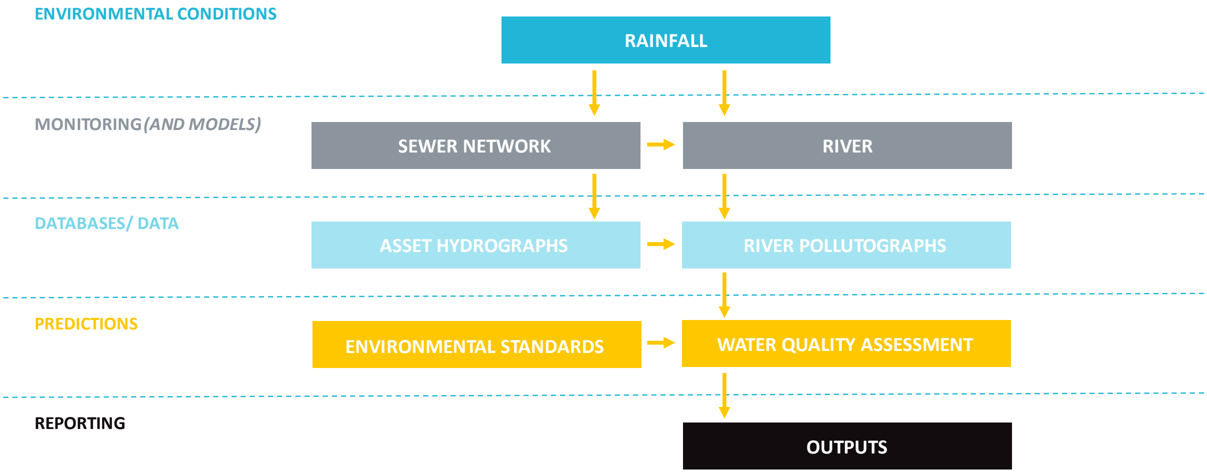
Level 1 and 2 models can be constructed using available data, such as EA monitoring data and regulatory sampling. There is no requirement to undertake bespoke water quality surveys. These levels are typically applied in SOAF assessments as they enable the impact from individual assets to be quickly determined using the simplified approach. At Intertek, we typically undertake Level 2 modelling as this enables the FIS component of the UPM standards to be assessed correctly (with a time series and impacts occurring in the calendar year), which Level 1 models cannot, as they handle the process stochastically.

Level 3 and Level 4 models both require survey data to calibrate and validate the flow and water quality components. Survey data is collected using level monitors for flow, converted using a rating curve to flow volume, and sondes and autosamplers for water quality. Field surveys typically last 12-months with level monitors and sondes installed for the full period to sample during the full range of flow conditions and seasons. Autosamplers typically collect data from three dry weather events and three wet weather events, though this can vary depending on project needs, and can removed upon completion of these events.

There are no restrictions on the software that can be applied at each level so long as the complexity requirements are achieved. Software capable of undertaking a Level 4 assessment can be applied at Level 1, however considerations of the ease of application and efficiency of utilising a more complex software should be considered.

Regardless of the selected level, the model build approach is consistent across all four levels. Figure 1 shows the schematic of inputs, models, and model outputs which form the process of undertaking WFD, UPM, SOAF, or BW assessments. As previously mentioned, rainfall forms the direct link between the sewer network and the river hydrographs. The detail and resolution of the model is determined by the selected level, but in all cases the most accurate assessment should be undertaken in all situations using the best available data. Calibration and validation of the model should be undertaken to the required level to confirm the reliability of model outputs and provide an understanding of key inputs and the application of default parameters.

Figure 1: Modelling Approach Schematic



Model Selection

Modelling level is determined by a combination of assessment type or through an initial scoping phase. Specific assessments, such as SOAF investigations, state that a simple modelling approach (Level 1 or Level 2) is sufficient. Existing models may be used enabling higher level models to be applied in simpler assessments. In all cases the selected level should be agreed with both client and regulator prior to undertaking the water quality assessment to ensure agreement of the approach and an understanding of the applications and limitations. In practice the level will be determined by the available flow and quality data, catchment complexity (channel structures and bifurcations), project needs, or client requirements.

Water quality modelling software is flexible and capable of undertaking a range of modelling levels, enabling the setup to be adapted to suit project requirements. There are no restrictions preventing models with more complex water quality processes or flow routing from being applied at lower levels. However, consideration is needed to determine if the additional complexity improves understanding of catchment pressures and if there is sufficient data to suitability calibrate the model. Application of more complex models risk adding detail without clarity. A balance is required to develop effective models suitable for the assessment needs.

AMP8

There are significant water quality modelling needs in AMP8 which have several competing factors influencing modelling requirements. Initially the EA requested that all water quality in AMP8 to be undertaken at Level 4, necessitating 12-month surveys to be undertaken for each water quality model. A deadline for delivering model results by the end of 2024 would result in extremely tight programmes which are likely to be undeliverable for several reasons. Subsequently a reduction on modelling level to Level 3 was introduced. This does not resolve the issues with programme timescales as the 12-month survey period remains. Factors impacting programme are:

- Field survey length – Field surveys typically last for 12-months to collect water quality and flow data across the full range of conditions. Currently surveys would be completed with insufficient time to build water quality models.
- Site access permissions – previous experience has shown that obtaining site permission can take a significant period of time, with landowners being unresponsive or unclear of who has responsibility. Acquiring permission has taken more than 12-momths to secure in extreme circumstances.
- Laboratory capacity and capability – analysis of water quality samples must be undertaken to a sufficient level of detection (LOD) to enable assessment of High WFD status. Laboratory capacity also needs to be sufficient to take samples from multiple autosamplers, which will collect 24 samples per site during sampling events. Currently there are few laboratories available that can analyse samples to the required LOD, with orthophosphate being a notable limitation, with the required capacity.
- Field equipment and technicians – water quality surveys will be required across the UK simultaneously to meet the current timeline. Environment Act monitoring requirements also adds pressures for equipment and maintenance technicians due to the requirement to install sondes upstream and downstream of CSOs. There are probably insufficient monitors and trained personnel to meet the significant demand AMP8 and the Environment Act require – although the response can be scaled up in the end.
- Water quality modellers – trained water quality modellers are required to interpret data and construct water quality models. There are insufficient modellers across the industry to build the large number of models to the required standards.

In combination with the AMP8 assessments, the Environment Act requires that all CSOs achieve a minimum standard of 10-spills per year. This requirement does not consider if achieving this standard is sufficient to achieve compliance with environmental standards. Meeting this standard could be accomplished with sewer network modelling alone.

Consideration is also needed of the growing interest in designating inland BWs. Needs of these sites will be more acute with fewer spills required to archive standards at amenity sites. It is assumed assets impacting inland BWs will need to meet a two-spills per year limit. There are also expectations that BW standards will be achieved all year round. Contrasting with the costal bathing seasons which covers 15 May to 30 September.

While it would be simpler to forego water quality modelling exercise and focus on achieving the 10-spill target this approach would not consider the water quality impacts. Therefore, despite the challenges, there will be a significant need for modelling in AMP8.

Catchment-Impact; SOAF to UPM and WFD

A flexible approach is needed in AMP8 to sourcing the survey data required for Level 3 and Level 4 assessments. Bespoke surveys are not possible within the AMP8 timescales; however the UK is fortunate to have large repositories of data which can be used for model construction. River flow and level data, EA monitoring data, water company monitoring data, cross sections, and LiDAR data can all be utilised in model construction. In lieu of data there are default values which can be applied, either for literature or previous experience within the local area.

Sufficient data exists in most major catchments to define boundary conditions and to validate models in dry weather conditions. Ungauged or un-monitored catchments can utilise data from a donor catchment with similar characteristics or utilise data from modelled sources, such as LowFlows2. The lack of wet weather event data means that the assessment results will, in most cases, be conservative due to the use of default values for intermittent discharges. These limitations need to be understood and considered as part of the modelling exercise.

All this data means that models can be constructed using the selected software to the equivalent of a Level 3 or 4 model but cannot be considered level 3 or 4 due to the lack of calibration data. While this is a limitation these, models developed using this methodology can demonstrate the impacts of assets on water course and the effects of proposed solutions and have been used for several investigations.

At Intertek we have developed a flexible tool, CATCHMENT-IMPACT (C-I), to undertake Level 1 to Level 3 assessments. C-I utilises a simplified hydrodynamic model but simulates complex water quality process. C-I has been developed and updated over a long period of time and is our preferred option for modelling assessments, but the same process could be followed using other software in more hydraulically complex catchments.

The simplified hydrodynamic component of C-I reduces the requirement for detailed cross-section surveys, reducing model run times compared to more complex software, enabling a large number of assessments to be undertaken quickly. Following this method we have undertaken over 200 SOAF investigations. The SOAF methodology uses available data and applies defined assumptions to infill gaps, mainly a lack of BOD data. While C-I has its benefits, the limitations are that it cannot be used where complex features are key for understanding flow and quality. Bifurcations, weirs, long culverts which surcharge, and in-river structures cannot be represented in the model. Where these are key to understanding flow and quality a more hydraulically complex software would be required.

While the lower level modelling, levels 1 and 2, do not require complex WQ process (BOD decay, ammonification, nitrification, reaeration, respiration, SOD), they can still be included. Software, such as C-I, that include these processes can be used to undertake Level 1 to Level 3 assessments. The key difference between the levels being the availability of survey and calibration data for the model, which as mentioned is likely to be a limiting factor in AMP8.

This approach has been undertaken by Intertek for Severn Trent Water using our in-house catchment tool, C-I to develop models demonstrating the effect of flow transfer schemes. Model results have been reviewed and accepted by the EA as being demonstrative of the impacts of these schemes, if there is an impact on water quality standards, and solutions which could be implemented to achieve compliance.

Example Level 2Assessment Results

Example results from a Level 2 SOAF assessment produced using C-I are provided in Figure 2 and Figure 3. SOAF assessments determine the impact of an individual asset on the watercourse, therefore only the asset of interest is included in the model. The model domain covers the river reach immediately upstream of the asset and downstream to the next major confluence. Freshwater inputs are defined using available EA monitoring and default concentrations values are applied to the CSO with along with default water quality calibration parameters. This is a simple model to developed quickly assess the impact from the CSO following the SOAF guidance and is suitable for this level of assessment.

Under the SOAF methodology the UPM standards are processed to determine the level of impact – clearly the impact of this asset is significant, with changes in classification and a high number of FIS exceedances. Results from this assessment show that a SOAF classification of Severe is achieved and further solution testing would be undertaken to reduce the impact from the asset.

Figure 2: SOAF Assessment - UPM BOD Results

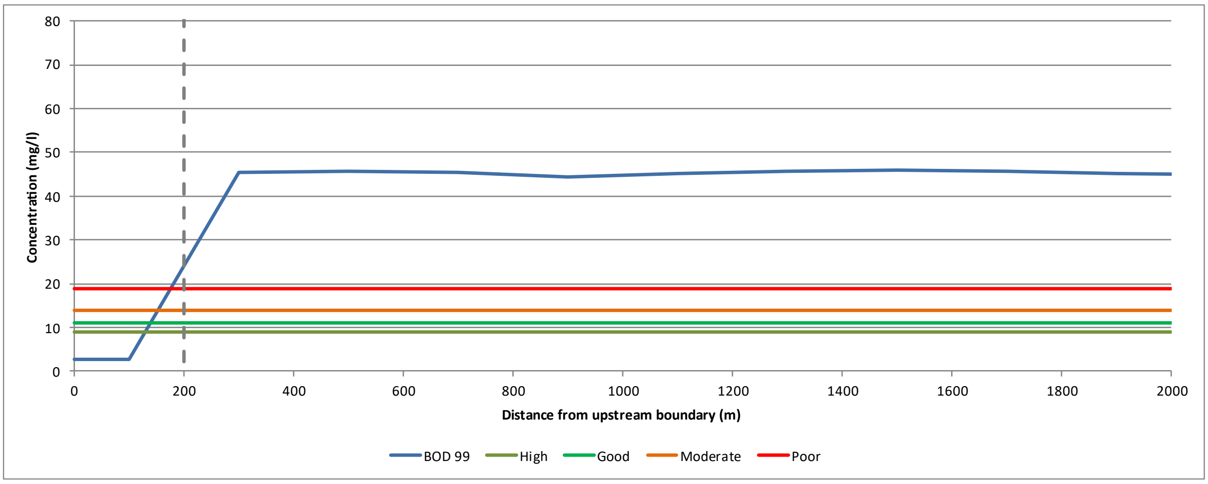
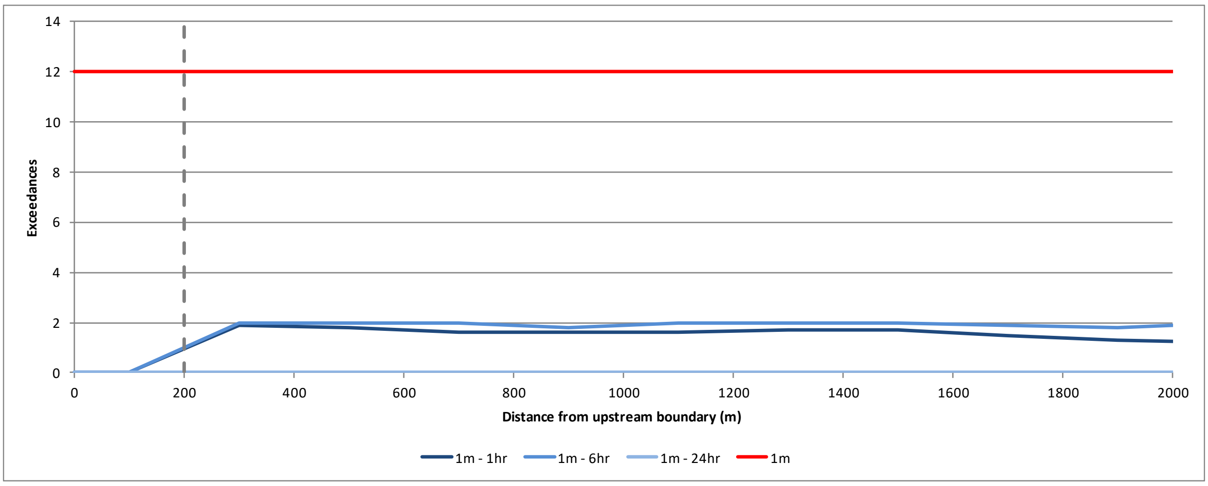


Figure 3: SOAF Assessment – UPM Un-ionised Ammonia FIS Results



A similar process can be applied to a Level 2 model in more complex systems. Example results in Figure 4 and Figure 5 show outputs from a larger catchment model which includes all discharges from the sewer network model, along with a tributary which impacts the catchment being assessed. Key Wastewater Treatment Work (WwTW) Final Effluent (FE) and CSO discharges as highlighted as they are the focus of the proposed flow transfer scheme. All other CSOs, Surface Waters (SW), and any other discharge included in the sewer network model is in the water quality model. Two scenarios are shown in the plots. The Pre-Transfer scenario includes the WwTW FE discharging at the current location, while the Post-Transfer scenario has removed the WwTW FE discharge from the models. No other changes have been applied to the two scenarios.

Setup of this model is the same as the Level 2 SOAF model. Available flow and freshwater data are analysed to develop boundary conditions and define the impact from the tributary. Regulatory sampling data collected at the WwTW FE discharge is analysed to determine the load from this source. Intermittent discharges are defined using default values, with default water quality parameters applied.

Model results show that the WwTW FE discharge has a noticeable impact on the SRP concentration, with the FE being a major source of phosphorus. The transfer scheme, moving the WwTW FE out of the catchment, achieves a significant reduction in concentration, improving the classification and achieving High throughout the watercourse.

UPM results similarly show that the WwTW FE transfer has reduced the FIS exceedances to zero at all return periods and durations. This CSO does not discharge frequently enough, or at large enough volumes to cause exceedances of the UPM standards, with the WwTW FE discharge driving exceedances in the Pre-Transfer scenario.

This methodology is conservative, applying default values to the assets which are known to vary and may be lower in reality. This process is useful in assessing the expected outcome of a proposed scheme, or identifying what is driving water quality issues in the catchment, without undertaking a full 12-month survey required for a Level 3 or 4 assessment.

The tool allows for the development of solutions which can be tested quickly, typically reduction in spills. A range of different volumes can be tested to develop a solution which achieves compliance with WQ targets without the need to run the sewer network model, which can be time consuming for the large models. Once a solution is developed, this would of course be run though the network model to verify the results.

It should be noted that all WFD and UPM standards are covered by the water quality assessment. Examples are selected to demonstrate the impact of the proposed scheme.

Figure 4: Flow Transfer Assessment – SRP Results

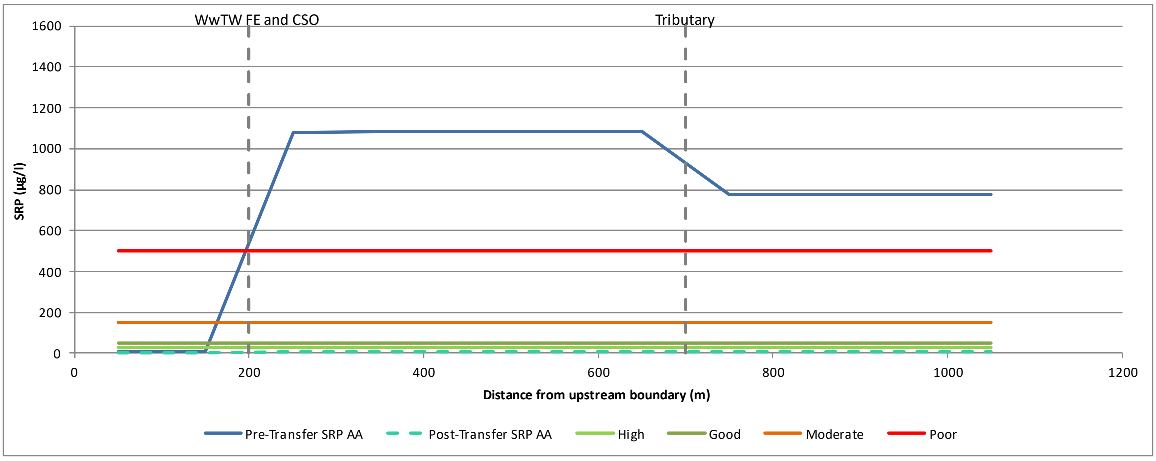
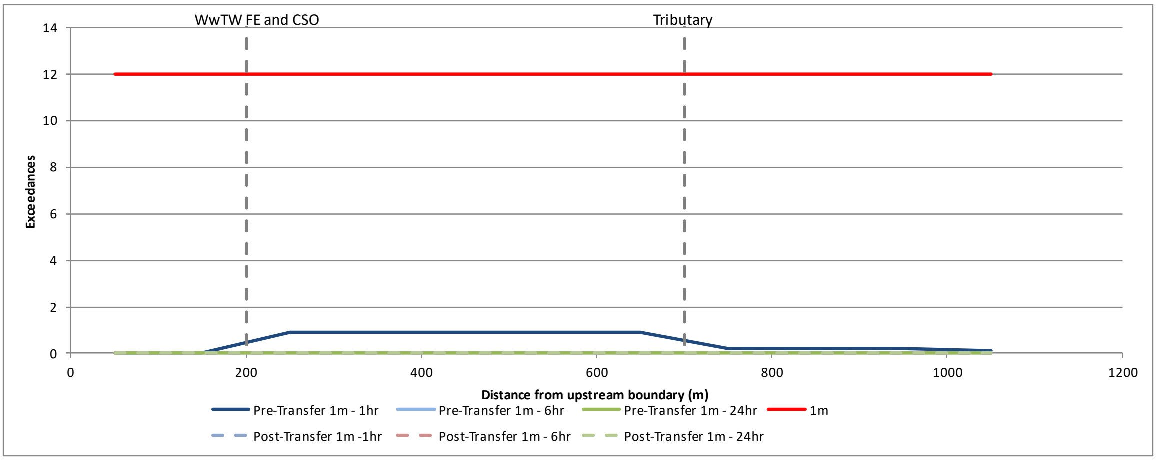


Figure 5: Flow Transfer Assessment – Un-ionised Ammonia FIS Results



Summary and Conclusions

In an ideal world, with no consideration of timescales and budgets, all water quality modelling would be undertaken at Level 4. However, given the AMP8 programme which we are working towards, and the practical limitations, this is not possible.

The modelling approach which has been outlined uses the wealth of data available in the UK and the readily available tools to construct water quality models capable of meeting the Level 2 requirement. While these models will have implied limitations, and will by necessity be conservative, they are capable of demonstrating the impacts from known discharges and identifying drivers of poor water quality performance. Solutions can be developed to resolve identified issues and additional surveys targeted at key locations where there is uncertainty.

Some catchments will be so complex that a simpler modelling level is wholly unsuitable and Level 4 model must be applied. In these situations a flexible and realistic programme needs to be agreed, to allow models to be developed and water quality issues to be fully understood.

With agreement and understanding of the modelling limitations, and remaining flexible, it is possible to undertake the large number of assessments which are required in AMP8.