Strategic Regional Water Resource Solutions: Annex B3.2: Water Quality Assessment Report

Standard Gate Two Submission for River Severn to River Thames Transfer (STT)

Date: November 2022

Severn to Thames Transfer

Water quality assessment

STT-G2-S3-113

November 2022

Disclaimer

This document has been written in line with the requirements of the RAPID Gate 2 Guidance and to comply with the regulatory process pursuant to Thames Water's, Severn Trent Water's and United Utilities' statutory duties. The information presented relates to material or data which is still in the course of completion. Should the solution presented in this document be taken forward, Thames Water, Severn Trent Water and United Utilities will be subject to the statutory duties pursuant to the necessary consenting processes, including environmental assessment and consultation as required. This document should be read with those duties in mind.

SEVERN THAMES TRANSFER (STT) SOLUTION

Environmental Water Quality Assessment Report

Ricardo ref. ED15323 Issue: 005 11/10/2022

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1. INTRODUCTION

1.1 BACKGROUND AND DESCRIPTION OF THE STT SCHEME

1.1.1 The River Severn to River Thames Transfer Description

The aim of the Severn Thames Transfer is to provide additional raw water resources of 300 to 500Ml/d to the South East of England during drought, with 500Ml/d preferred by the Water Resources in the South East (WRSE) group's emerging regional plan. The water would be provided from flows in the River Severn and transferred via an interconnector to the River Thames. For the completion of the Gate 2 assessment, a pipeline "Interconnector" has been selected as the preferred option to transfer water from the River Severn to the River Thames.

Due to the risk of concurrent low flow periods in both river catchments, additional sources of water, apart from those naturally occurring in the River Severn, have been identified to augment the baseline flows. These multiple diverse sources of additional water provide resilience in the provision of raw water transfer to the River Thames. A 'put and take' arrangement has been agreed in principle with the Environment Agency (EA) and Natural Resources Wales (NRW) which means that if additional source water is 'put' into the river, then the Interconnector can 'take' that volume, less catchment losses, regardless of the baseline flows in the River Severn itself.

The regional planning process will determine the volume, timing, and utilisation of water to be transferred. The diversity of sources means they can be developed in a phased manner to meet the ultimate demand profile as determined by the regional planning. These additional sources of water are being provided by United Utilities (UU) and Severn Trent Water (STW) who are working in collaboration with Thames Water (TW) to develop this solution. The additional sources are:

- **Vyrnwy Reservoir**: Release of 25Ml/d water licensed to UU from Lake Vyrnwy directly into the River Vyrnwy;
- **Vyrnwy Reservoir**: Utilisation of 155Ml/d water licensed to UU from Lake Vyrnwy and transferred via a bypass pipeline ("Vyrnwy Bypass") to the River Severn;
- **Shrewsbury**: Diversion of 25Ml/d treated water from UU's Oswestry Water Treatment Works (WTW) via an existing emergency transfer (the Llanforda connection), thus enabling a reduction in abstraction from the River Severn at Shelton WTW to remain in the River Severn for abstraction at Deerhurst;
- **Mythe**: 15Ml/d of the Severn Trent Water licensed abstraction at Mythe remaining in the River Severn for abstraction at Deerhurst;
- **Minworth**: The transfer of 115Ml/d of treated wastewater discharge from Severn Trent Water's Minworth Wastewater Treatment Works (WwTW) via a pipeline, to the River Severn via the River Avon at Stoneleigh; and
- **Netheridge**: The transfer of 35Ml/d of treated wastewater discharge at Severn Trent Water's Netheridge WwTW to the River Severn at Haw Bridge, via a pipeline, upstream of the current discharge to the River Severn.

The STT Gate 1 submission was assessed by the Regulators' Alliance for Progressing Infrastructure Development (RAPID) who concluded that it should progress to standard Gate 2. The recommendations and actions received from RAPID and feedback from stakeholders from the Gate 1 process have been reflected in the scheme development and environmental assessments.

1.1.2 Gate 2

RAPID issued a guidance document[1] in April 2022 to describe the Gate 2 process and set out the expectations for solutions at standard Gate 2.

[1] RAPID (2022) Strategic regional water resource solutions guidance for Gate 2

The guidance stated the environmental assessment methodologies should be consistent with any relevant legislation and guidance, and follow best practice. This includes, where relevant, WRMP24, All Company Working Group (ACWG) guidance[2], and the Environment Agency Invasive Non-native Species risk assessment tool.

Figure 1.1 shows the investigations being undertaken for STT Gate 2 and their interactions, in order to show the full scope of work across both environmental and engineering disciplines. Reporting for the environmental investigations has been undertaken in a phased way to account for, and incorporate all previous assessments, data collection and feedback (i) the evidence reports were produced first, and set out the data and evidence to be used in the assessment; (ii) assessment reports were then produced using the evidence to determine the potential effect of the STT solution on the physical environment, water quality and ecological receptors (dark blue box in Figure 1.1); (iii) based on the evidence and assessments, the statutory reports and assessments required to meet the RAPID and regulatory expectations for solutions at Gate 2 were produced.

This report presents an assessment of the effect of the solution on water quality. It informs other assessments, including the statutory assessments.

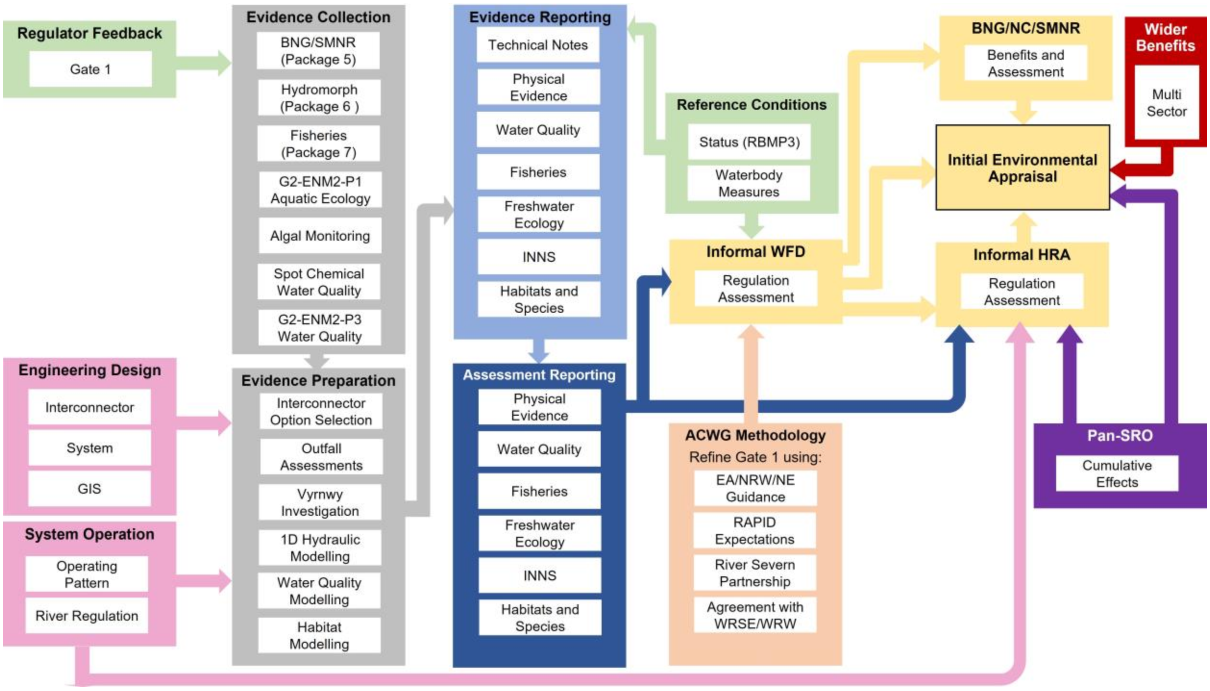

Figure 1.1 Flow chart showing the scope of investigations for STT Gate 2 and their interactions

1.2 STUDY AREA

The study area for the STT solution for Gate 2 assessment is limited to specific reaches, as shown in **Figure 1.2**:

1. The River Vyrnwy catchment (River Vyrnwy from Vyrnwy Reservoir to the confluence with the River Severn);
2. The River Severn catchment (River Severn from the confluence with the River Vyrnwy to the Severn Estuary), as well as those tributaries of the River Severn which could indirectly be affected by the operation of the STT solution;
3. The Warwickshire River Avon upstream of Warwick to the River Severn confluence; and

[2] All Companies Working Group (2020) WRMP environmental assessment guidance and applicability with SROs

4. The River Thames catchment (River Thames from Culham to Teddington Weir)

It should be noted that the consideration of impacts in the River Tame and Trent, from the transfer of treated discharge from Minworth Wastewater Treatment Works (WwTW) to the River Avon, is included in Severn Trent Water's Minworth Strategic Resource Option (SRO) and therefore excluded from the STT solution assessment.

Similarly, the STT solution assessment accounts for the effects from the relevant SROs related to the supply of water into the STT system (United Utilities and Severn Trent Water Sources). It therefore includes an assessment of the potential effects of the water arising from the outfalls from the transfers (Minworth and Netheridge). It does not cover the impact of infrastructure construction, as this is included in Severn Trent Water's Minworth and Sources SRO assessments.

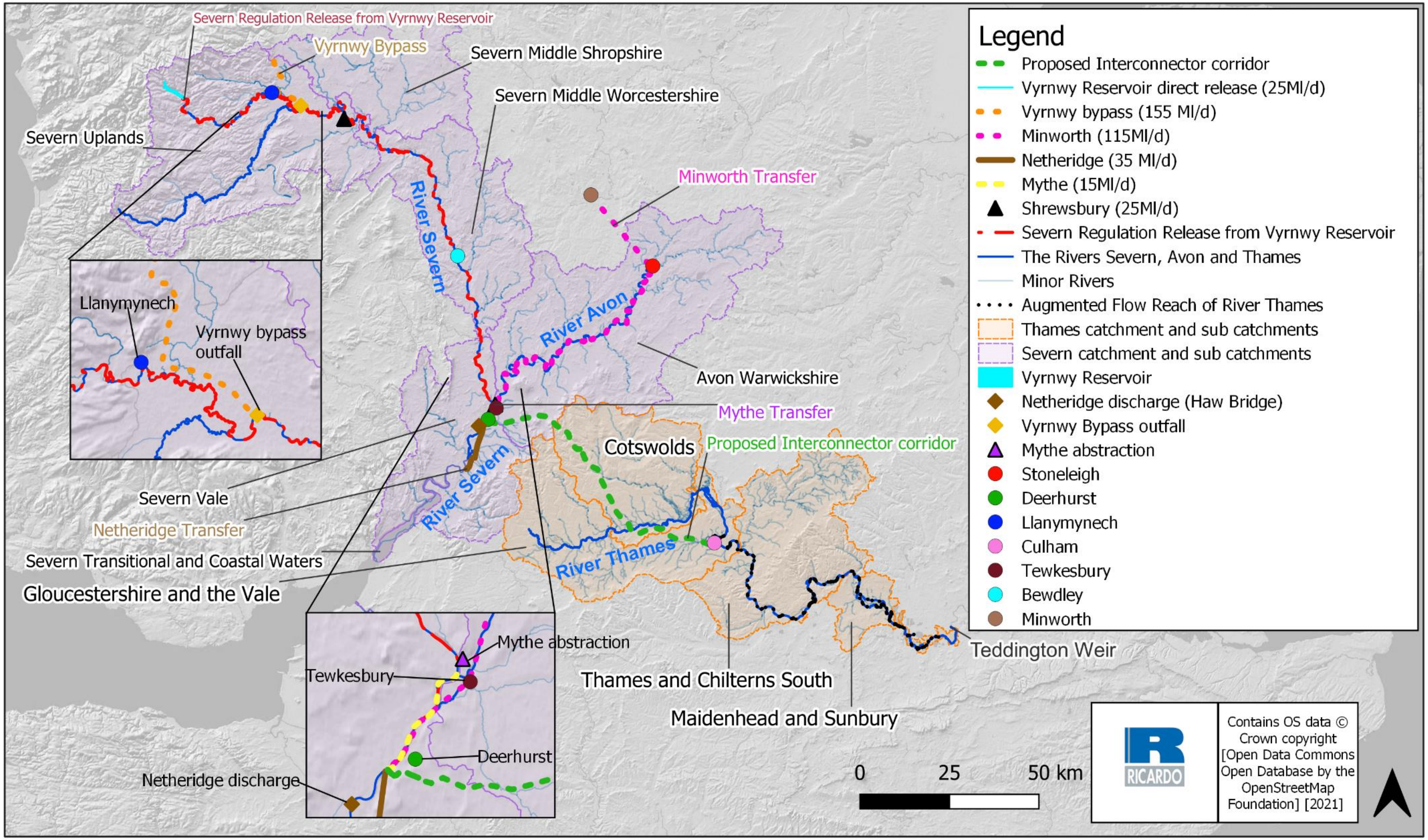

Figure 1.2 Map showing the proposed interconnector corridor

Similarly, the STT solution assessment accounts for the effects from the relevant SROs related to the supply of water into the STT system (United Utilities and Severn Trent Water Sources) and therefore includes an assessment of the potential effects of the outfalls from the transfers (Minworth and Netheridge) not the impact of infrastructure construction as included in Severn Trent Water's Minworth and Sources SROs.

1.3 SUMMARY OF THE SOLUTION COMPONENTS AND OPERATION

The STT solution developed for Gate 2 is described through its engineering components in the Conceptual Design Report. For environmental assessment purposes, as these relate to in-river physical environment effects, the solution has been split into two phases, with and without support, described as (i) an *early phase* of the STT solution, which is without the inclusion of most of the support options that augment flow in the River Severn (see Section 1.1.1), and (ii) a *full STT* solution, which includes all the support options. The river flow changes that comprise these two phases are set out in Table 1-1.

Supporting options would be operational at those times when the STT is transferring water from the River Severn to the River Thames, and when flows in the River Severn are lower than hands-off flow (HoF) thresholds in the River Severn. The EA has advised that a STT abstraction licence would be imposed so flows at Deerhurst flow gauging station do not drop below 2,568 Ml/d. Above this HoF, there is a maximum abstraction limit of 172 Ml/d, up to the next HoF condition of 3,333 Ml/d, where 355 Ml/d can be abstracted, in addition to the available 172 Ml/d unsupported[3]. This is summarised in Table 1-2.

The EA has advised the STT Group of appropriate values of "in-river losses" to include in the hydraulic modelling[4] and subsequent environmental assessments. The advised values include a 20% loss in the River Vyrnwy and the consequent 13km of the River Severn to the Montford gauging station, with the loss occurring evenly over the distance. Separately a 10% loss for water transferred into the River Avon, in the augmented flow reach between Stoneleigh and the River Severn confluence at Tewkesbury, with the loss occurring evenly over the distance. As such, of the total 370Ml/d supporting flows augmenting flows into the River Severn catchment for full STT, the equivalent re-abstraction value at Deerhurst used for the environmental assessment is 353Ml/d as represented in Figure 1.3.

Table 1-1 Components of Early Phase and Full STT Operation

Early Phase STT	Full STT
500Ml/d interconnector pipeline.	500Ml/d interconnector pipeline
Part-time, *unsupported* abstraction up to 500Ml/d from the River Severn at Deerhurst and transferred to the River Thames at Culham, subject to hands-off flow conditions identified by the EA.	Part-time, *unsupported* abstraction up to 500Ml/d from the River Severn at Deerhurst and transferred to the River Thames at Culham, subject to hands-off flow conditions identified by EA
Part-time, *supported* abstraction up to 35Ml/d from the River Severn at Deerhurst and transferred to the River Thames at Culham, at flows constrained by hands-off flow conditions, provided by 35Ml/d flow volume from the Netheridge Transfer. The early phase STT solution does not include the full range of support options and as such supported abstraction is limited to the value of the Netheridge Transfer, 35 Ml/d.	Part-time, supported abstraction up to 353Ml/d from the River Severn at Deerhurst and transferred to the River Thames at Culham, at flows constrained by hands-off flow conditions, and accounting for assumed river transfer losses. Flow provided by UU and STW sources. The order in which these sources are utilised has been determined by optimising the engineering solution and through the regional water resilience modelling by Water Resource South East (WRSE): 1. **Vyrnwy Reservoir:** Release of 25Ml/d water licensed to UU from Lake Vyrnwy directly into the River Vyrnwy; 2. **Vyrnwy Reservoir**: Utilisation of 155Ml/d water licensed to UU from Lake Vyrnwy and transferred via a bypass pipeline ("Vyrnwy Bypass") to the River Severn; 3. **Shrewsbury**: Diversion of 25Ml/d treated water from UU's Oswestry Water Treatment Works (WTW) via an existing emergency transfer (the Llanforda connection), thus enabling

[3] Email from Caroline Howells (Environment Agency Environment Planning Officer) to Peter Blair (Thames Water, Water Resources Modelling Specialist) 27 February 2020.

[4] Email from Alison Williams (Environment Agency Senior Water Resources Officer) to Helen Gavin (Ricardo) and Valerie Howden (HRW) on 10 February 2022.

Early Phase STT	Full STT
	a reduction in abstraction from the River Severn at Shelton WTW to remain in the River Severn for abstraction at Deerhurst; 4. **Mythe**: 15Ml/d of the Severn Trent Water licensed abstraction at Mythe remaining in the River Severn for abstraction at Deerhurst; 5. **Minworth**: The transfer of 115Ml/d of treated wastewater discharge from Severn Trent Water's Minworth Wastewater Treatment Works (WwTW) via a pipeline, to the River Severn via the River Avon at Stoneleigh; and 6. **Netheridge**: 35Ml/d of the Severn Trent Water licensed abstraction piped to the River Severn for abstraction at Deerhurst.
Continuous abstraction from River Severn at Deerhurst of 20Ml/d to provide a pipeline maintenance flow, with continuous transfer to River Thames at Culham: • Either unsupported abstraction when not limited by hands-off flow conditions; or • Supported abstraction by flow volume matching from Netheridge Transfer	Continuous abstraction from River Severn at Deerhurst of 20Ml/d to provide a pipeline maintenance flow, with continuous transfer to River Thames at Culham: • Either unsupported abstraction when not limited by hands-off flow conditions; or • Supported abstraction by flow volume matching from Netheridge Transfer

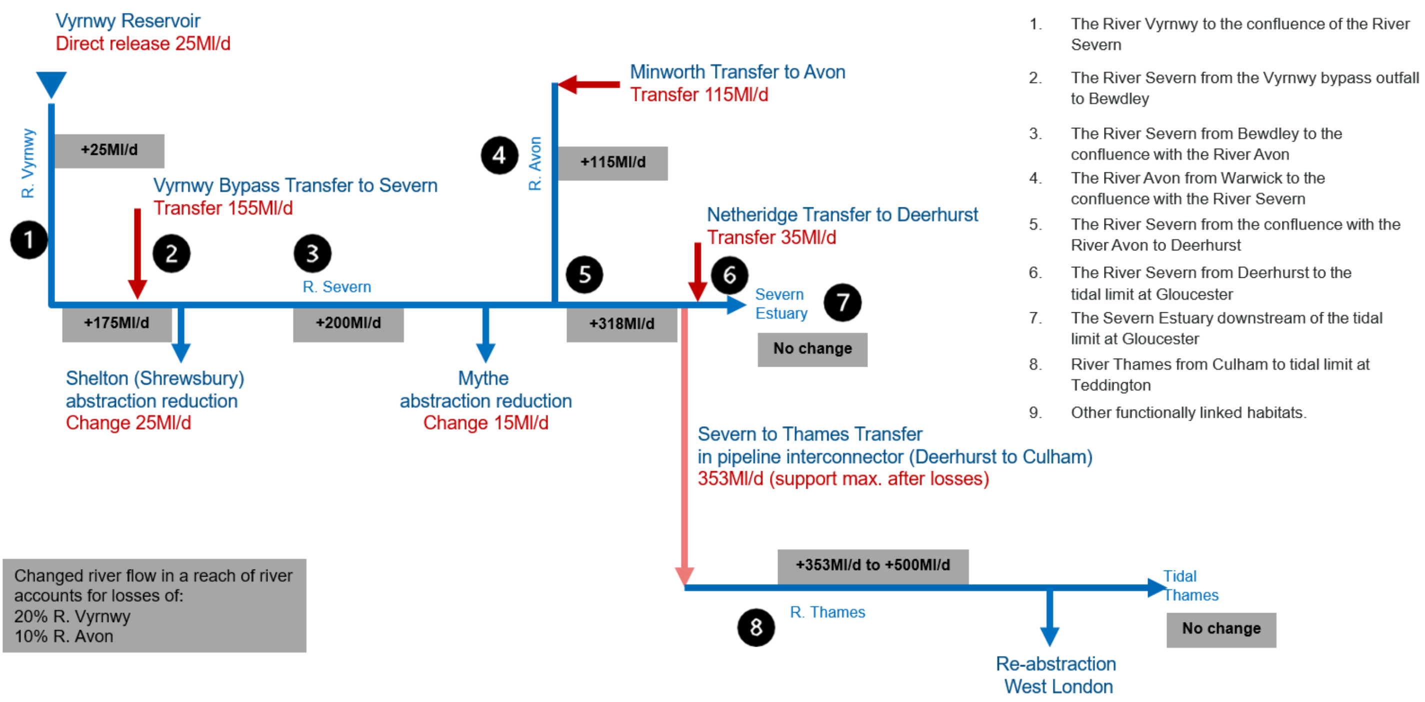

Figure 1.3 Schematic representing flow changes (accounting for losses) of STT Solution

Table 1-2 River Severn at Deerhurst: HoF conditions provided by EA

HoF	Flow threshold (Ml/d)	Maximum abstraction value at flows greater than the threshold (Ml/d)
1	2,568	172
2	3,333	527

To support the environmental assessments at Gate 2, an indicative operating pattern has been developed. The approach uses the 19,200 year stochastic flow series developed separately for the River Severn catchment for the Water Resources West (WRW) group and for the River Thames catchment for the WRSE group. The stochastic flow series represents contemporary climate conditions and provides information on the return frequency, or regularity, of both the likely river flow conditions and STT operation. The stochastic years have been made available as 48-year continuous periods, and one of those has been selected as having representative flow characteristics to inform the environmental assessments. The selected 48-year series[5] includes a suitable range of regular low and moderate low flow periods. It does not include extreme low flows that are considered to be less regular than once every fifty years. This is described further in Section 2.2.3 of the Physical Environment Assessment Report, with the derived representation of dates with the full STT in operation (for water resources purposes) as used in environmental assessment shown in **Figure 1.4.** It should be noted that this operating pattern is for the STT solution used on its own for Thames Water, without conjunctive use with other Thames Water SROs (such as the South East Strategic Resource Option (SESRO). It also uses the controlling triggers developed by Thames Water for SESRO based on lower River Thames flows and Thames Water's total London reservoir storage.

Figure 1.4 Representation of dates full STT solution would be on (for water resources purposes) as used in the environmental assessment

Where: purple indicate periods when the early phase STT would be in operation (unsupported abstraction); and the combined purple and blue periods (supported abstraction) indicate the full STT

The general description in **Figure 1.4** identifies periods in purple when the early phase STT pattern would be in operation: the combined purple and blue periods shows the periods when the full STT operation pattern is being deployed. The review of river flows and operating patterns for the environmental assessment has

[5] Note these are 48 calendar years. The environmental assessment period has been selected as a water resources year (1 April to 31 March) and as such the selected period includes 47 water resources years from the 48 calendar years,

identified that all support options would be on at the same time, rather than any selective or preferential use of support sources. These patterns of river flow and operational need inform the range of likely environmental effects of the scheme. Having identified these patterns, selected return frequencies have been selected for the detailed assessment for Gate 2, which has included hydraulic modelling of different scenarios. The scenarios modelled are:

- a 1:5 return frequency year with moderate-low flows in the River Severn at Deerhurst with a 1:5 return frequency operating pattern in terms of duration and season (model reference A82); and
- a 1:20 return frequency year with very low flow years in the River Severn at Deerhurst with a 1:20 return frequency operating pattern in terms of duration and season (model reference M96).

Noting the scheme would only be used on a 1:2 return frequency, these scenarios capture a suitable range of circumstances and have been discussed and reviewed with the regulators during Gate 2.

It should be noted that, in addition to the above, a 1:50 return frequency year of extremely low flows in the River Severn at Deerhurst and with a 1:20 return frequency operating pattern in terms of duration and season (model reference N17), has been prepared and reviewed for the consideration of scheme resilience. Such a low return frequency is outside the regularity of occurrence included in WFD assessments and is thus not described further in this report.

The Gate 2 assessment also incorporates climate change scenarios into 1D hydraulic models for the assessment for the rivers and Severn Estuary pass-forward flows. The A82 Future and M96 Future years are illustrative of the potential types of changes to river flows and operating patterns in the future. This is described further in Section 2.2.3. At this stage, as the full 19,200 stochastic years have not been reworked as 2070s RCM8.5 futures, it is not possible to derive a suitable 48 year period that is representative of the return frequencies for the environmental assessments.

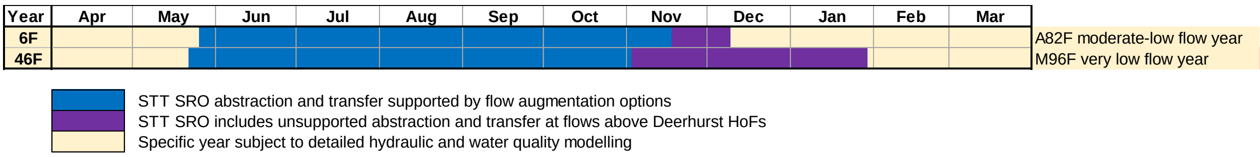

Figure 1.5 Representation of dates full STT solution would be on (for water resources purposes) for selected future scenarios as used in the environmental assessment

Where: purple indicates periods of unsupported abstraction and blue indicates periods of supported abstraction

1.4 SCOPE OF THIS REPORT

This report presents an assessment of the effect of the STT solution on water quality. It informs other assessments, including the statutory assessments. It presents analysis and findings from the examination of the information and data set out in the Evidence Report. The findings of the analysis are presented on a reach by reach basis, addressing each metric of change. The information is presented in this way so there is clarity over where effects from the scheme are observed.

This report also identifies where greater confidence could be placed in the findings, through further evidence collection and analysis. NB the Evidence Report also identifies remaining data/evidence gaps, provides a summary of the proposed programme of works and approach to address any data/evidence gaps as part of RAPID's gated assessment for the SRO.

1.4.1 Link with other Reports

The Environmental Water Quality Evidence Report sets out a data catalogue of the information sources that have been used to perform the assessment.

The results and findings presented in this report shows the effect of the STT scheme on environmental water quality changes – general physico-chemical water quality, chemical quality, and the quality of substances associated with inhibition of fish olfaction. These findings are used by many of the STT Gate 2 Environmental Assessment and Statutory reports which interpret the significance of the changes for their specific feature(s) or topic of interest.

2. ASSESSMENT

2.1 SUMMARY OF THE APPROACH

The scope of the assessment of environmental water quality effects arising from the STT solution required for Gate 2 and the approach to undertaking this assessment is described in **Table 2.1**. This is replicated from the Gate 2 Environmental Water Quality Evidence Report.

Table 2-1 Approach to the Gate 2 environmental water quality assessment

Task item	Scope of assessment	Approach to assessment
a. General physico-chemical change	• Assessment of modelled Water Framework Directive (WFD) water quality parameters throughout the study area for the range of reference conditions and scenarios with STT operation	• Interrogate 1D river modelling outputs for freshwater River Avon, River Severn from River Avon to estuarine interface, River Thames study reaches • Empirical modelling of water temperature and potential associated effects on dissolved oxygen (DO) saturation variation in River Vyrnwy
b. WFD chemicals	• Assessment of WFD and Environmental Quality Standards Directive (EQSD) chemical quality for the range of reference conditions and scenarios with STT operation for study areas: • From Minworth transfer outfall along flow pathway of the River Avon and River Severn to the estuarine interface; • From Netheridge transfer outfall along flow pathway of the River Severn to the estuarine interface; • From pipeline interconnector outfall along flow pathway of the freshwater River Thames	• Interrogate conservative tracer results from 1D river modelling fluvial models to inform dilution and zone of influence of discharged water
c. Olfactory water quality assessment[6]	• Assessment of specific olfactory cues and inhibitors for the range of reference conditions and scenarios with reuse option for study areas: • From Minworth transfer outfall along flow pathway of the River Avon and River Severn to the estuarine interface	• Interrogate conservative tracer results from 1D river modelling fluvial model for River Avon and downstream River Severn freshwater study reaches to inform concentrations of olfactory cues and inhibitors in freshwater reaches and concentration and load change at Severn Estuary interface

2.2 MODELLING STEPS UNDERTAKEN

2.2.1 Overview

Specialist consultancies have provided support to STT Group to provide modelling to support decision making and reporting for the Gate 2 submission. The modelling contractors have worked collaboratively with the STT solution environmental assessment consultant, other contractors supporting the STT solution development to Gate 2, and key environmental regulators and stakeholders to produce the required modelling for the STT solution submission. It is noted that at Gate 2 the linked hydraulic and water quality modelling of the River Severn catchment has been undertaken by a different consultant to the linked hydraulic and water quality modelling of the River Thames catchment. The complexity of the collaborative approach is represented in **Figure 2.1**.

2.2.2 Engagement with Stakeholders

In order to engage with regulators over the approach, evidence collection, monitoring programmes, and data analysis for Gate 2, the environmental assessment team have held monthly meetings with the Environment Agency (EA), Natural Resources Water (NRW) and Natural England (NE), in addition to topic-specific sessions and workshops with technical specialists. The regulators are asked to provide insights and inputs on specific

[6] Olfaction, the sense of smell, is of great importance for species survival in terms of both reproduction and food selection, especially when taken together with the sense of taste. The detection of volatile chemical compounds is an important attribute for any animal to survive and reproduce in the natural environment.

aspects where needed in order to ensure the work undertaken is as robust as possible. They will review the Gate 2 assessment reports and findings.

In the monthly meetings, the programme, progress and deliverables are reviewed; issues are raised for clarification and resolution, and the regulators are asked for their views and advice on different topics or issues.

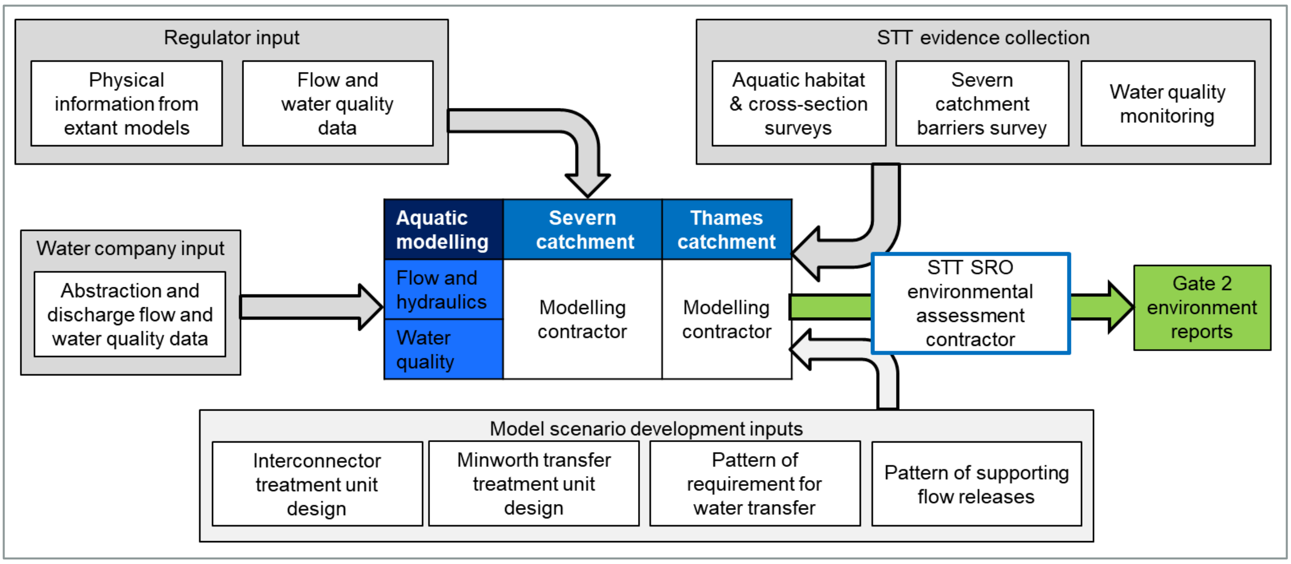

Figure 2.1 Representation of the collaborative approach to STT Solution Gate 2 environmental modelling

2.2.2.1 SRO Engineering teams

The hydraulic/water quality models scenarios have been parameterised using representations of the discharge quality as provided by the SRO project engineers. For the Minworth transfer, the post-SRO treatment discharge water quality into the River Avon near Warwick has been provided by the Minworth SRO project engineers, Jacobs. For the Netheridge transfer, the post-SRO treatment discharge water quality into the River Severn near Deerhurst has been provided by the Severn Trent Sources SRO project engineers, WSP. For the pipeline interconnector transfer, the post-SRO treatment discharge water quality into the River Thames at Culham has been provided by the STT solution interconnector engineers, Mott MacDonald.

2.2.2.2 Modelling Working Group

In order to gain direct and technical inputs along the modelling journey, the modelling and environmental assessment team invited specialists within the regulatory agencies to join a Working Group.

Five meetings with the Working Group were held, in which progress and findings were shared, and feedback solicited. The slides presented and a recording of the session were circulated after every meeting.

Drafts of reports have been issued to the Working Group for review and have been revised according to the comments reviewed. The points raised in discussion and on the drafts have been used to finalise the approach, and outputs, and inform the wider environmental assessment for Gate 2.

2.2.2.3 The River Thames Modellers

A key member of the modelling and environmental assessment team liaised with the River Thames Modellers (the modelling work was split with Ricardo and HRW covering the modelling of the Rivers Avon and Severn; Atkins covered the modelling of the River Thames). This liaison was important to ensure consistency between the modelling approaches, particularly over the choice of scenarios which were to be simulated.

Data has been provided by the River Thames Modellers and presented in this report for the relevant reaches in Section 3.

Environmental modelling of the River Thames has been undertaken for Gate 2 as joint working between all SROs that Thames Water is a partner in. The modelling was contracted through the SESRO programme of works with other SROs providing details of their requirements for modelling, scenario parameterisation and model output formats. The 1D hydrodynamic and water quality model build, calibration and validation was overseen for RAPID by the Thames Area National Advisory Unit (NAU). Model build, calibration and validation reports are part of the SESRO Gate 2 submission.

The STT solution environmental assessment contractor worked closely with the Thames modelling contractor to develop an agreed model extent and to agree the hydraulic parameters to be modelled and output. Central to the collaborative working was the development of consistent scenarios, described in Section 2.2.3.

2.2.3 Development of consistent scenarios

A common set of scenarios across the STT solution was applied to both the River Severn and River Thames catchments for consistency. The selected scenarios enable a comparison of the effects of the operation of the STT solution against the reference condition of no STT solution.

Following the incorporation of feedback from the environmental regulators in Gate 1, scenarios were selected to address water quality effects from STT solution operation in the following way[7]:

- In a range of increasing severity of low flow years
- Under a range of future climate conditions
- For a pattern of STT solution operation, as identified by WRSE.

For water quality modelling, each model scenario covers 365 days from 1 April to 31 March (a water year). The in-river environmental modelling assessments have been undertaken through a range of different scenarios representing (a) appropriate reference conditions without STT, and (b) with the inclusion of the Gate 2 STT scheme components based on the understanding of the likely operational pattern presented in **Section 1.3**. The scenarios, reference conditions and purpose of the modelling work is summarised in **Table 2-2**. The specific model runs associated with this assessment are described in **Table 2-3**.

Table 2-2 Scenarios performed across different return periods for current and future scenarios

Scenario		Flow (baseline without STT solution)	Water quality (baseline without STT solution)	Purpose	Stochastic year code
1	Moderate-low flow (1:5-1:10 return period)	Represents current meteorological patterns, current demands and abstractions, current sewage returns and representative Severn Regulation pattern	Based on the last 5 years measured data and also AMP7 sewage improvements	Central to Gate 2 environmental assessments, WFD etc	A82
2	Very low flow (1:20 return period)			Central to Gate 2 environmental assessments, WFD etc	M96
3	Extremely low flow (1:50-1:100 return period)			Assists resilience understanding Not used in Gate 2 environmental assessments.	N17
4	**Future** (2070s) version of “moderate low flow” or ‘very low flow’	Represents a selected version of 2070s meteorological patterns using RCP8.5. Demands and abstractions set at RCM08 scenario 1 in 500 deployable output level. Representative Severn Regulation pattern set by water resource model.	As Scenario 1	Central to Gate 2 environmental futures assessments, IEA etc	A82F (Severn) M96F (Thames)

The water quality model output, available throughout the modelled reaches, includes location-specific daily values for water temperature, dissolved oxygen concentration, biochemical oxygen demand, total ammonia, nitrite, nitrate (addable as dissolved available inorganic nitrogen), soluble reactive phosphate, and suspended solids. The River Avon / Severn water quality model also includes a conservative tracer for the Minworth discharge transfer, to represent the likely dilution of discharge and which can be attributed to any of the chemicals not directly modelled. The River Thames water quality model also includes a conservative tracer for the pipeline interconnector transfer, to represent the likely dilution of discharge which can be attributed to any of the chemicals not directly modelled. Model output locations are throughout the modelled study area of

[7] It is noted the hydraulic modelling included in the Gate 2 Physical Environment Assessment Report also includes a representation of naturalised flow. There is no representation of water quality in the naturalised flow scenarios, these are for hydraulics only.

the River Avon, River Severn, River Thames and River Severn pass-forward water quality to the Severn Estuary.

Table 2-3 Specific model runs and catchments modelled for the scenarios used in the assessment

Reference conditions		Early Phase STT		Full STT	
A82 - ref	Moderate low flow conditions in River Severn - in **Severn model**	A82- unsupported	Purple pattern of unsupported abstraction (see **Figure 1.4**) showing 1:5 return frequency of abstraction, at Deerhurst in **Severn Model**	A82- full STT	Blue pattern of support and supported abstraction; and purple pattern of unsupported abstraction (see **Figure 1.4**) showing 1:5 return frequency of abstraction, at Deerhurst **in Severn Model**
	Moderate low flow conditions in River Thames **- in Thames model**		Discharge of same abstracted water at Culham in **Thames model**		Discharge of same abstracted water at Culham in **Thames model**
M96 - ref	Very low flow conditions in River Severn - in **Severn model**	M96- unsupported	Purple pattern of unsupported abstraction (see **Figure 1.4**) showing 1:20 return frequency of abstraction, at Deerhurst in **Severn Model**	M96- full STT	Blue pattern of support and supported abstraction; and purple pattern of unsupported abstraction (see **Figure 1.4** showing 1:20 return frequency of abstraction, at Deerhurst in **Severn Model**
	Very low flow conditions in River Thames in **- Thames model**		Discharge of same abstracted water at Culham in **Thames model**		Discharge of same abstracted water at Culham in **Thames model**
A82F - ref	Moderate low flow conditions in River Severn, with climate change factors applied - in **Severn model**	Scenario not considered; noting early phase is not applicable to the future		A82F- full STT	Future blue pattern of support and supported abstraction; and purple pattern of unsupported abstraction (see **Figure 1.5**) showing 1:5 future return frequency of abstraction, at Deerhurst in **Severn Model**
M96F-ref	Very low flow conditions in River Thames, with climate change factors applied - in **Thames model**			M96F-full STT	Discharge of future blue pattern of supported and purple pattern of unsupported abstraction (see **Figure 1.5**) showing 1:20 future return frequency discharge at Culham in **Thames model**

2.2.4 River Severn catchment water quality modelling

Water quality model outputs including water temperature, oxygen cycle (dissolved oxygen concentration and dissolved oxygen saturation), nitrogen cycle (ammoniacal nitrogen, nitrite, nitrate), soluble reactive phosphate as used in this assessment are catalogued in the Gate 2 Environmental Water Quality Evidence Report. Output for a conservative tracer representing dilution of the Minworth Transfer discharge to the River Avon near Stoneleigh is also catalogued in the Gate 2 Environmental Water Quality Evidence Report.

2.2.5 River Thames catchment water quality modelling

Water quality model outputs including water temperature, oxygen cycle (dissolved oxygen saturation), nitrogen cycle (ammonia, nitrite, nitrate), and total phosphorus as used in this assessment are catalogued in the Gate 2 Environmental Water Quality Evidence Report. Output for a conservative tracer representing dilution of the STT discharge to the River Thames at Culham is also catalogued in the Gate 2 Environmental Water Quality Evidence Report.

2.3 ASSESSMENT OF STT OUTFALLS

2.3.1 Overview

Collaborative working with the STT solution engineering consultants has identified the planned discharge qualities from each of the four STT solution outfall locations, with the objective of aiming for no water quality impacts and no WFD deterioration risk. The solution engineering consultants have reviewed and refined the planned and costed treatment units in support of this environmental objective. These are described further below. It is noted that the water quality values listed pertain to those included directly in 1D river water quality scenario modelling parameterisation. Section 2.3.6 consequently describes the approach used at Gate 2 to identify discharge quality target setting and screening of WFD chemicals for Minworth Transfer and Netheridge Transfer and to determine chemicals at risk of not complying with in-river EQS following discharge.

2.3.2 Vyrnwy Bypass outfall

STT solution engineering consultants have confirmed that the infrastructure used to make STT solution flow augmentation releases from Vyrnwy Reservoir into the middle River Severn near Ponthen would be sourced from the same part of the water column as the compensation water. It is important to note that the reservoir scour valves sourcing water from the bottom of the reservoir would not be used to support the STT solution. Continuous water temperature monitoring at a range of depths in Vyrnwy Reservoir during Gate 1 identified that the lower water column is cooler and the reservoir does not stratify. It is also noted that there would be no change in the volume of water in Vyrnwy Reservoir as consequence of STT Solution - the STT Solution would be a same-rate replacement for abstraction from the reservoir by UU at present. The transferred water would be conveyed in an open aqueduct and pipeline along the transfer route and would likely adjust, either warming or cooling in response to ambient conditions, during the transfer process.

2.3.3 Netheridge Transfer outfall

Severn Trent Sources SRO has advised the planned, costed advanced water quality treatment units that would be used to additionally treat the source water - Netheridge WwTW secondary treated final effluent – prior to discharge to the River Severn for the STT solution. The treatment units have been selected by Severn Trent Sources SRO with the objective of aiming for no water quality impacts and no WFD deterioration risk in the River Severn. Design has utilised the extensive pan-SRO water quality monitoring dataset (see Gate 2 Environmental Water Quality Evidence Report) of both Netheridge WwTW final effluent and the River Severn at Deerhurst monitoring site.

The Gate 2 engineering conceptual design of the Severn Trent Sources SRO states the inclusion of ferric dosing, CoMAG cloth filter filtration, and granular activated carbon (GAC) prior to discharge, as presented in the Conceptual Design Report. The planned discharge quality, in terms of physico-chemical water quality, is set out in Table 2-4 below. The likely efficacy of the planned treatment on removal or reduction of chemicals is discussed in Section 3 below. It is noted that the quality of discharge would be far superior to standard treated wastewater.

Table 2-4 Planned discharge quality of Netheridge Transfer as included in Gate 2 conceptual design

Water quality parameter	Mean target value	Standard deviation
BOD (5 day ATU) (mg/l)	5.6	4.1
Dissolved oxygen (mg/l)	4.1	0.3
Suspended solids (mg/l)	6.2	4.5
Ammoniacal nitrogen mgN/l)	1.0	0.8
Total oxidised nitrogen (mgN/l)	14.8	5.7
Reactive phosphate (µg/l)	150	5.0
Water temperature (°C) (NB this is not a target value but an anticipated discharge value)	11.2	4.2

Environmental Permit consented discharge conditions for named chemicals and the statistical compliance rate of the Netheridge Transfer discharge would need to be agreed between the EA and Severn Trent Water. This may also include for chemicals, such as iron, added as part of treatment processes. Environmental permitting is not a requirement of Gate 2 SRO assessments.

2.3.4 Minworth Transfer outfall

Minworth SRO has advised the planned, costed advanced water quality treatment units that would be used to additionally treat the source water - Minworth WwTW tertiary treated final effluent – prior to discharge to the River Avon for the STT solution. The treatment units have been selected by Minworth SRO with the objective of aiming for no water quality impacts and no WFD deterioration risk in the River Avon. Design has utilised the extensive pan-SRO water quality monitoring dataset (see Gate 2 Environmental Water Quality Evidence Report) of both Minworth WwTW final effluent and the River Avon at sites both upstream and downstream of Warwick.

The Gate 2 engineering conceptual design of the Minworth SRO states the inclusion of ferric dosing, CoMAG cloth filter filtration, and granular activated carbon (GAC) prior to discharge, as presented in the Conceptual Design Report. The planned discharge quality, in terms of physico-chemical water quality, is set out in Table 2-5 below. The likely efficacy of the planned treatment on removal or reduction of chemicals is discussed in Section 3 below. It is noted that the quality of discharge would be far superior to standard treated wastewater.

Table 2-5 Planned discharge quality of Minworth Transfer as included in Gate 2 conceptual design

Water quality parameter	Mean target value	Standard deviation
BOD (5 day ATU) (mg/l)	1.9	2.0
Dissolved oxygen (mg/l)	5.3	0.4
Suspended solids (mg/l)	6.9	5.8
Ammoniacal nitrogen mgN/l)	0.5	0.8
Total oxidised nitrogen (mgN/l)	16.4	6.0
Reactive phosphate (µg/l)	150	5.0
Water temperature (°C) (n.b. not a target value but an anticipated discharge value)	11.3	4.7

Environmental Permit consented discharge conditions for named chemicals and the statistical compliance rate of the Minworth Transfer discharge would need to be agreed between the EA and Severn Trent Water. This may also include for chemicals, such as iron, added as part of treatment processes. Environmental permitting is not a requirement of Gate 2 SRO assessments.

2.3.5 STT Interconnector pipeline outfall

The STT solution interconnector engineers have advised the planned, costed water quality treatment units that would be used to treat the source water – River Severn river water – prior to discharge to the River Thames for the STT solution. The treatment units have been selected by the STT solution interconnector engineers with the objective of reducing pollutants in the River Severn source water. Design has utilised the extensive pan-SRO water quality monitoring dataset (see Gate 2 Environmental Water Quality Evidence Report) of both the River Severn at Deerhurst monitoring site and the River Thames at Culham monitoring site.

The STT solution Gate 2 engineering conceptual design of the interconnector treatment unit states the inclusion of clarifiers and rapid gravity filters (RGF) prior to piping and aeration prior to discharge, as presented in the Conceptual Design Report. The planned discharge quality, in terms of physico-chemical water quality, is set out in **Table 2-6** below. The likely efficacy of the planned treatment on removal or reduction of chemicals is discussed in Section 3 below. It is noted that both the source and receiving waters are river waters.

Table 2-6 Planned discharge quality of STT interconnector as included in Gate 2 conceptual design

Water quality parameter	Mean target value
BOD (5 day ATU) (mg/l)	2.9
Dissolved oxygen (mg/l)	11.0
Suspended solids (mg/l)	2.0
Ammoniacal nitrogen mgN/l)	0.1
Total oxidised nitrogen (mgN/l)	5.1
Reactive phosphate (µg/l)	430
Water temperature (°C) (n.b. not a target value but an anticipated discharge value)	11.9 (3.2 standard deviation)

The Gate 2 treatment train for the interconnector treatment unit does not include ferric dosing or other treatments specifically targeting soluble phosphorus reduction. The clarification and filtration units would reduce solids and therefore total phosphorus, but further treatment stages, such as ferric dosing, may be required to reduce reactive phosphate prior to discharge to the River Thames. The need for water quality conditions on a water transfer licence has not been confirmed between STT Group and EA. Such permitting considerations are not a requirement of Gate 2 SRO assessments.

2.3.6 STT solution Gate 2 discharge quality target setting and screening of WFD chemicals

Noting that environmental permitting for discharges is not a RAPID requirement for Gate 2 SRO assessments, the emphasis of water quality assessment at Gate 2 is on WFD Regulations compliance and supporting ecological assessments. It is noted that discharge permitting requirements through Environment Agency LIT 13134 *Permitting of Hazardous Chemicals and Elements in Discharges to Surface Waters* and Environment Agency Guidance H1 Annex D2 for the *Assessment of Sanitary and Other Pollutants within Surface Waters* are different to the tests for WFD Regulations compliance set out in the accompanying STT Solution Gate 2 WFD Assessment Report.

This section describes the approach used at Gate 2 to identify discharge quality target setting and screening of WFD chemicals for Minworth Transfer and Netheridge Transfer and to determine chemicals at risk of not complying with in-river EQS following discharge. It is noted that for several WFD specific pollutants that EQS[8] in *salt waters* (which includes the Severn Estuary) are of lower value than in freshwaters and where there are risks of change in these chemicals from STT Solution discharges, then the pass-forward concentration and load from river to estuary has been included in the review. These specific pollutants with more stringent EQS for estuaries are: arsenic; benzyl butyl phthalate; chromium (VI); 2, 4 dichlorophenol; permethrin; toluene, and zinc. Similarly there are several priority substances and other pollutants used to clarify chemical status that EQS in *other surface waters* (which includes the Severn Estuary) is of lower value than in inland surface waters and where there are risks of change in these chemicals from STT Solution discharges, then the pass-forward concentration and load from river to estuary has been included in the review. These chemical status pollutants with more stringent EQS for estuaries are: benzene; cadmium and its compounds; cyclodiene persticides (aldrin, dieldrin, endrin); endosulfan; hexachloro-cyclohexane; octylphenols; pentachloro-benzene; benzo(a)pyrene; benzo(g,h,i)-perylene; dicofol; PFOS; quinoxyfen; aclonifen; bifenox; cypermethrin; dichlorvos; HBCDD; heptachlor and heptachlor epoxide; and terbutryn. The assessment also considered that unionised ammonia is a specific pollutant only in *salt waters* and there are several specific pollutants for which there are no EQS for *salt waters*.

An approach has been developed during Gate 2 with SRO Engineering Consultants and reviewed with the EA[9] to identify discharge quality target setting and screening of WFD chemicals for Minworth Transfer and Netheridge Transfer. That approach is applicable to the use of the bespoke, targeted pan-SRO water quality monitoring programme data described in the Environmental Water Quality Evidence Report. The approach is set out as a flow diagram at **Figure 2-2**.

[8] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

[9] Netheridge and Minworth discharge targets meeting between Severn Trent Water and Environment Agency 22 November 2022

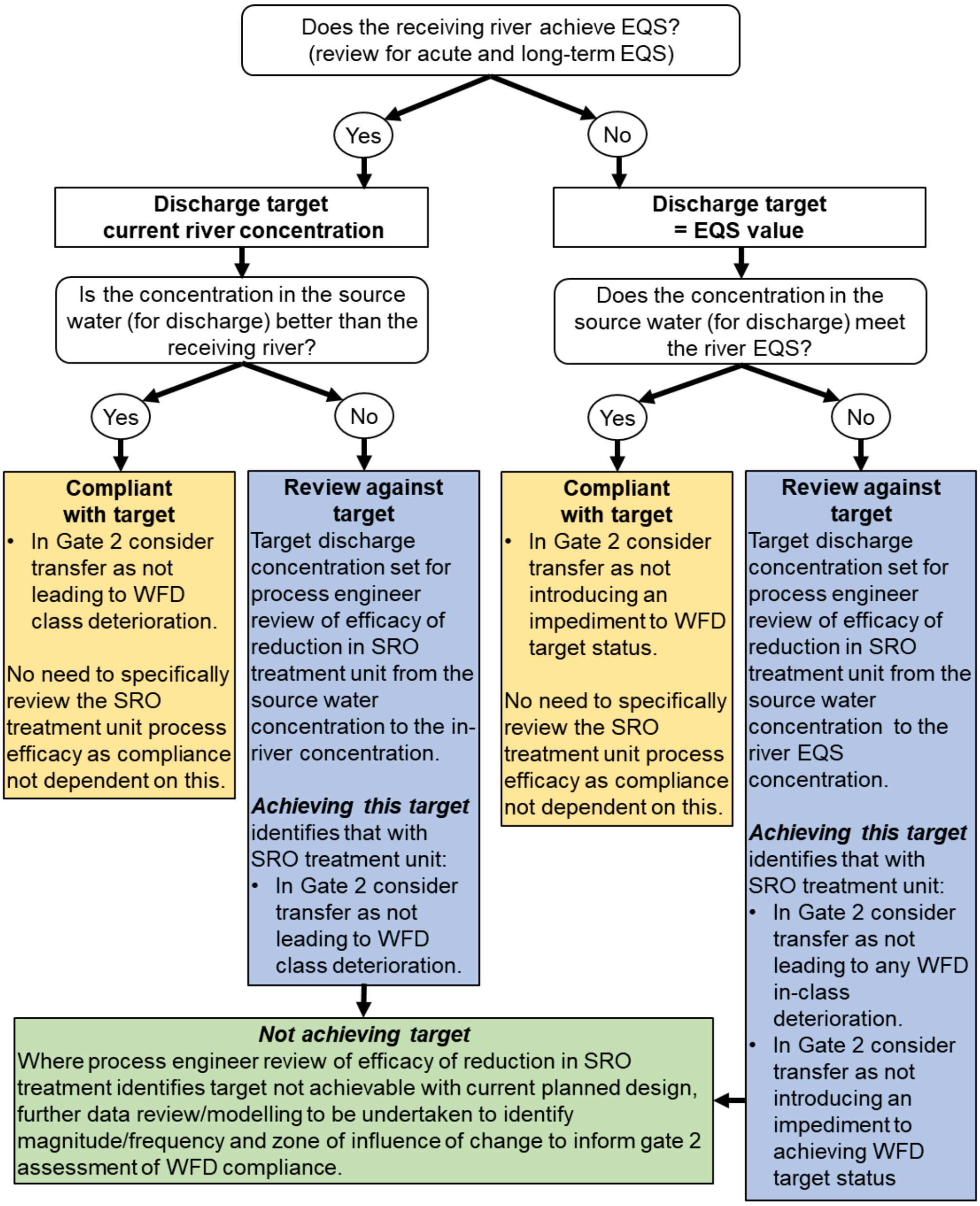

Figure 2-2 Flow chart showing STT solution Gate 2 discharge quality target setting and screening of WFD chemicals (an individual chemical assessment)

Following categorisation of the risk of chemicals in discharge not complying with in-river EQS following discharge, discussions with SRO Engineering Consultants for Minworth SRO and Severn Trent Sources SRO have established whether the target discharge concentration is likely to be achieved by the planned advanced treatment units. Where the review with process engineers of the efficacy of reduction in SRO treatment units from the source water concentration to the in-river concentration has established a remaining risk, the magnitude and frequency of that risk has been modelled using the Severn catchment 1D water quality model.

3. REACH BY REACH ASSESSMENT

3.1 INTRODUCTION

This section addresses the effects of the STT Scheme on a reach by reach basis, addressing each metric of change in turn. The reaches, as shown in **Figure 1.3** and with reference to **Figure 1.2** are as follows:

- The River Vyrnwy from Vyrnwy Reservoir to the confluence with the River Severn
- The River Severn from the confluence with the River Vyrnwy to Bewdley
- The River Severn from Bewdley to the confluence with the River Avon
- The River Avon from Warwick to the confluence with the River Severn
- The River Severn from the confluence with the River Avon to Deerhurst
- The River Severn from Deerhurst to the tidal limit at Gloucester
- The Severn Estuary downstream of the tidal limit at Gloucester
- River Thames from Culham to tidal limit at Teddington.

3.2 THE RIVER VYRNWY FROM THE VYRNWY RESERVOIR TO THE CONFLUENCE WITH THE RIVER SEVERN

In this reach of the study area, the pathways of environmental water quality change from STT solution operation are limited. STT solution engineering consultants have confirmed that the infrastructure used to make STT solution flow augmentation releases from Vyrnwy Reservoir into the River Vyrnwy directly below the reservoir would be sourced from the same part of the water column as the compensation water. It is important to note that the reservoir scour valves would not be used to support the STT solution. As such flow released from Vyrnwy Reservoir into the River Vyrnwy would remain at exactly the same quality with or without the STT solution, with only the flow rate changed. The water is also native upper River Vyrnwy water and as such the chemical composition is considered appropriate for the River Vyrnwy.

The Gate 2 approach (see Section 2.1) identifies that in this reach assessment is required of the potential for changes in water temperature in the River Vyrnwy and any potential associated effects on dissolved oxygen saturation variation in River Vyrnwy.

3.2.1 Baseline

Consistent with the Gate 2 environmental water quality assessment approach for this reach, the baseline information and assessment of STT operation are specific to the general water quality parameters water temperature and dissolved oxygen saturation. There are additional consistent water quality monitoring data collected in the reach since December 2020 through the SRO water quality monitoring programme, as documented in the Gate 2 Environmental Water Quality Evidence Report. These are signposted below for information only. In addition, dRBMP3 baseline WFD water quality status, as assessed by NRW from NRW monitoring data in the reach, is catalogued in the Gate 2 WFD Regulations Compliance Assessment Report.

3.2.1.1 General water quality

Baseline temperature measurements over a 1.5 year period over 2021 and 2022 between Vyrnwy Reservoir and the confluence with the River Severn are shown in **Figure 3.1**. A strong seasonal pattern is observed. For a period generally between April and October the outflow from Vyrnwy Reservoir is colder than the downstream River Vyrnwy. The reservoir outflow temperature data represent all managed releases from the reservoir – compensation flow, Severn Regulation releases, flood drawdown releases - and for short periods during the period shown, reservoir overtopping. During this period there is a general inter-site pattern of river temperature warming with distance from the reservoir. The inter-site variability shows that the Meifod Valley site (25km downstream of the Reservoir and downstream of the Afon Banwy confluence) can be 1-3°C cooler than the lower River Vyrnwy sites. It is also noted that there is a strong diurnal variability in water temperature shown from the 30-minute data of a similar order of magnitude.

For a period generally between November and March the outflow from Vyrnwy Reservoir is neither distinct nor substantially different to the sites in the downstream River Vyrnwy. During the period of water temperature data, the November to Mach period associates with higher water level in the Afon Banwy as a general guide to catchment flow contributions.

Temperature changes show some response to changes in reservoir outflow volume. This is highlighted for the September 2021 period which is shown on **Figure 3.2** to include 100Ml/d Severn Regulation releases (in addition to 45Ml/d compensation flow) for the periods 8-13 September and 17-24 September and 300Ml/d Severn Regulation releases (in addition to 45Ml/d compensation flow) for the period 25-26 September. For the period until 27th September, water levels in the Avon Banwy are constant and low. Although this is part of a wider seasonal pattern of temperature change in the River Vyrnwy there is a distinct and substantial difference in water temperature between the Meifod Valley site and the further downstream sites that associates with the periods of release from Vyrnwy Reservoir. The pattern is observed to become less distinct and less substantially different shortly after the releases cease. At the times of release, the additional 100-300Ml/d of cooler water from Vyrnwy Reservoir is observed to influence the Meifod Valley site, cooling it by the 1-3°C as reported in the general pattern analysis.

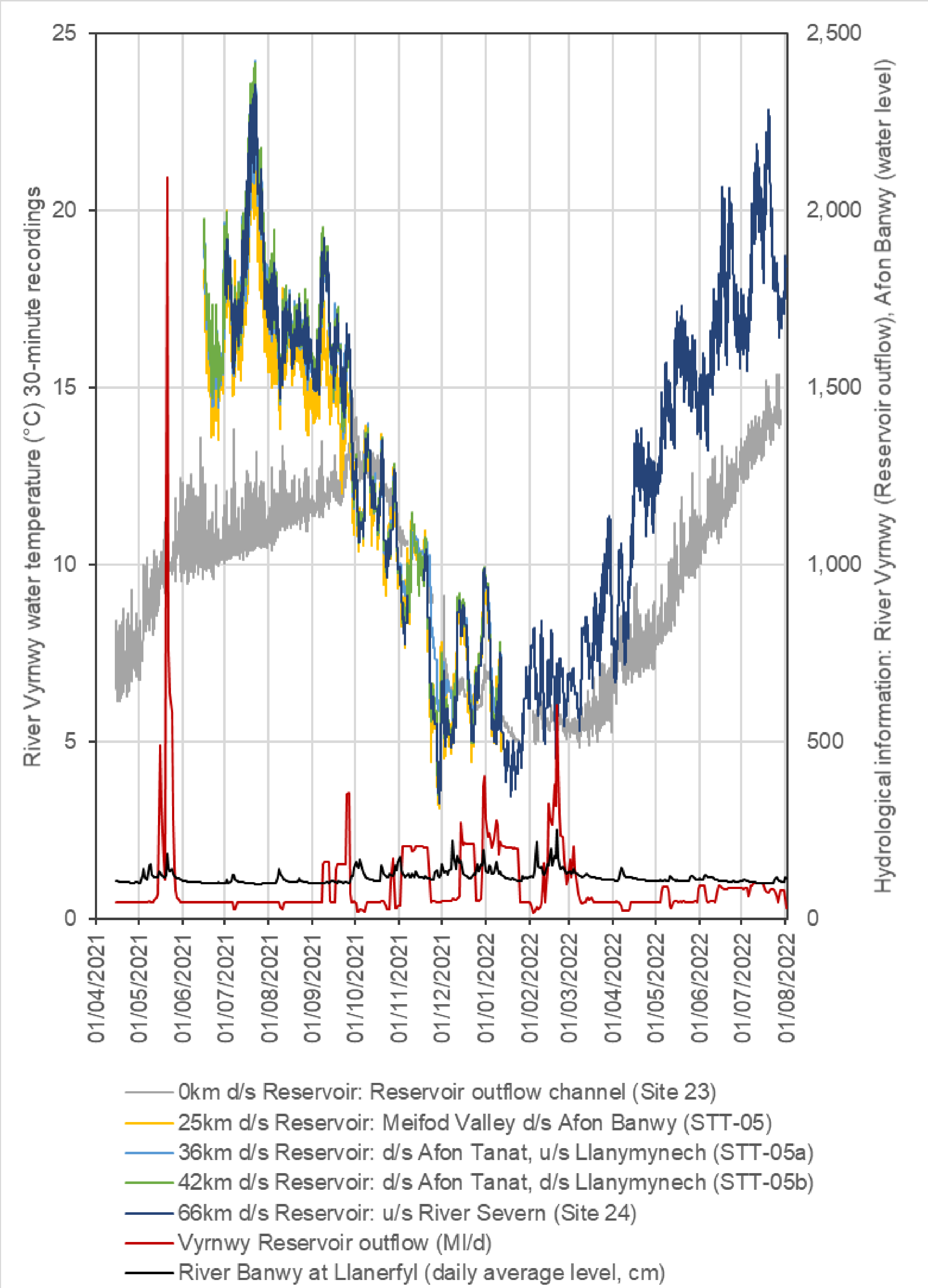

Figure 3.1 Water temperature data in the River Vyrnwy collected for Gate 2

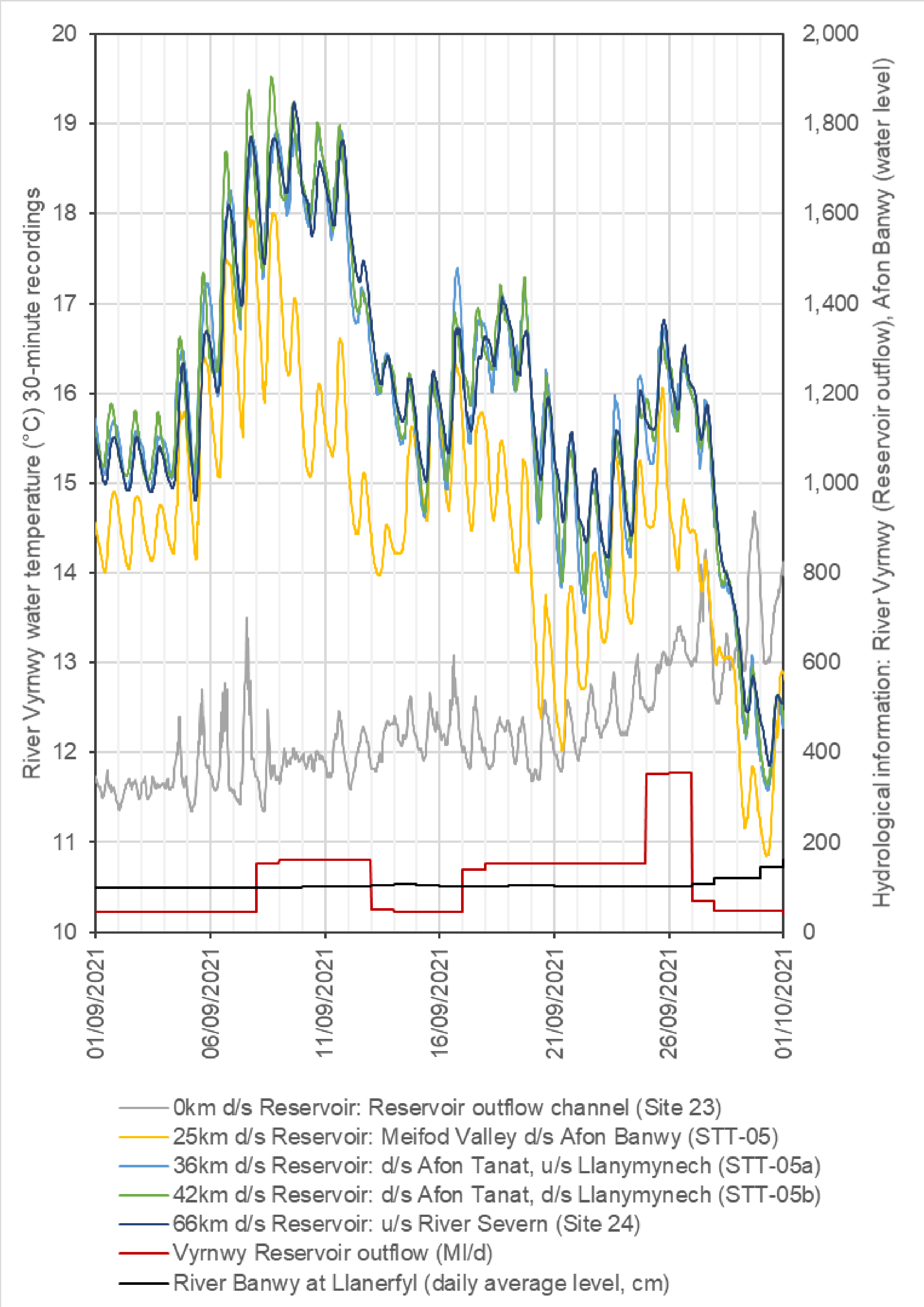

Figure 3.2 Selected water temperature data in the River Vyrnwy at Gate 2

Data review for the Site 23 River Vyrnwy downstream of Vyrnwy dam water quality monitoring sonde for the period of record April 2021 to July 2022 (20,000 half hourly readings) identify a 10 percentile of 75% saturation, consistent with Good WFD status. Additional information on other general water quality parameters: pH, acid neutralising capacity, biochemical oxygen demand, ammoniacal nitrogen, nutrients (reactive phosphate) is available to be reviewed in the Gate 2 Environmental Water Quality Evidence Report. This bespoke evidence for the STT SRO is available for five sites in the reach: Site 22 UU intake at Vyrnwy dam; Site 23 River Vyrnwy downstream of Vyrnwy dam; Site 39 River Vyrnwy Meifod Valley; 40 River Vyrnwy downstream Llanymynech; and 24 River Vyrnwy.

3.2.1.2 Chemicals

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#WFD_chem'

Data for five sites is available from the pan-SRO chemical monitoring programme, with up to 16 datapoints per determinand per site collected in 2020/2021. The sites, available to be selected using the pick-from-list menus on cells C4 or C5 are: Site 22 UU intake at Vyrnwy dam; Site 23 River Vyrnwy downstream of Vyrnwy dam; Site 39 River Vyrnwy Meifod Valley; 40 River Vyrnwy downstream Llanymynech; and 24 River Vyrnwy. By choosing an upstream site as the X-dataset in cell C4 and a downstream site as the Y-dataset in cell C5 any pattern in changes in quality along the river can be reviewed.

Monitoring data have been reviewed against EQS set out in the WFD Regulations[10]. This is summarised in Table 3-1 for the site representing the receiving water quality for a Vyrnwy Direct Release for both short term (either maximum values or 95 percentiles) and long term (mean) EQS, where these are applicable. It is noted that this is not a WFD status statement as that is undertaken by the NRW using NRW sampling and analysis at specified WFD monitoring locations within WFD water bodies.

The STT solution monitoring data indicate that the River Severn below the River Vyrnwy confluence location does not achieve EQS for one WFD chemical, with one chemical without suitable data for analysis. For 10 chemicals the assessment is incomplete as the laboratory limit of detection is higher than the EQS; however, for all 10 chemicals all reported values were less than the limit of detection used.

Table 3-1 Review of measured baseline for WFD chemicals against EQS at the Site 23 River Vyrnwy downstream of Vyrnwy dam SRO monitoring site (2020/2021, typically 16 samples)

Substance	Substance	Substance
1,2-dichloroethane	cyanide total	mecoprop
2,4-dichlorophenol	cybutryne (Irgarol)	mercury dissolved
2,4-dichlorophenoxyacetic acid (2,4-D)	cypermethrin	methiocarb
3,4-dichloroaniline	DDT total	naphthalene
aclonifen	di(2-ethylhexyl)phthalate (DEHP)	nickel dissolved
alachor	diazinon	nonylphenols
aldrin	dichloromethane	octylphenols
anthracene	dichlorvos	PBDEs
arsenic total	dicofol	pendimethalin
atrazine	dieldrin	pentachlorobenzene
benzene	dimethoate	pentachlorophenol
benzo(a)pyrene	diuron	perfluorooctane sulfonic acid and its derivatives
benzo(b)fluoranthene	endosulfan	permethrin
benzo(g,h,i)perylene	endrin	phenol
benzo(k)fluoranthene	fluoranthene	polycyclic aromatic hydrocarbons (PAH) sum
benzyl butyl phthalate	glyphosate	quinoxyfen
bifenox	heptachlor and heptachlor epoxide	simazine
C10-13 chloroalkanes (total)	hexabromocyclododecane (HBCDD)	terbutryn
cadmium total	hexachlorobenzene	tetrachloroethane
carbendazim	hexachlorobutadiene	tetrachloroethylene
carbon tetrachloride	hexachlorocyclohexane	toluene
chlorfenvinphos	indeno(1,2,3-cd)pyrene	tributyltin compounds (as tributyltin cation)

[10] Schedule 3 of The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015;

Substance	Substance	Substance
chlorine total	iron dissolved	trichlorobenzenes
chlorothalonil	isoproturon	trichloroethylene
chlorpyrifos (chlorpyrifos-ethyl)	lead dissolved	trichloromethane (chloroform)
chromium (III) dissolved	lead dissolved	triclosan
chromium (VI) dissolved	linuron	trifluralin
copper dissolved	manganese dissolved	zinc dissolved

Legend:

All reported values achieve applicable EQS
Reported values identify short-term EQS not achieved
Reported values identify long-term EQS not achieved
Reported values identify neither short-term or long-term EQS achieved
Limit of detection used does not enable full comparison of reported data with EQS
No data for analysis at Gate 2

3.2.1.3 Olfaction

There is no pathway of chemical change in this reach from STT SRO operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here. The bespoke olfactory inhibitor monitoring suite has not been included in the analysis for this reach. However, where there is overlap with the suite of WFD chemicals, this information is available to be reviewed in the Gate 2 Environmental Water Quality Evidence Report. This bespoke evidence for the STT SRO is available for five sites in the reach: Site 22 UU intake at Vyrnwy dam; Site 23 River Vyrnwy downstream of Vyrnwy dam; Site 39 River Vyrnwy Meifod Valley; 40 River Vyrnwy downstream Llanymynech; and 24 River Vyrnwy.

3.2.2 STT operation – current climate

This section sets out the findings of the effect of the STT scheme operation during current or contemporary (‘now’) climate conditions for water quality parameters and pathways scoped into the Gate 2 assessment.

3.2.2.1 Change to general water quality

The effect of high rate releases on water temperature during low flow river flow periods are reviewed in Section 3.2.1.1. The 100-300Ml/d Severn Regulation releases (in addition to the 45Ml/d compensation flow) reviewed in the reference conditions are at times of year consistent with STT Solution flow augmentation of 25Ml/d direct from Vyrnwy Reservoir. Where a 1-3°C cooling of the River Vyrnwy in the Meifod Valley and likely to the Afon Cain and Afon Tanat confluences associates with a 100Ml/d Severn Regulation release, a 25Ml/d STT Solution release can be considered to associate with a 0.25-0.75°C cooling. As seen in the reference conditions there are strong diurnal and daily changes in water temperature and an over-riding seasonal pattern. As such given the scale of background variability already present, the water temperature changes predicted for STT Solution at the Meifod Valley site are largely indistinct and not substantial. Between Vyrnwy Reservoir and the Meifod Valley site, the River Vyrnwy temperature reflects moving from the cold reservoir water towards ambient aerial conditions.

As there is no distinct substantial water temperature change associated with the STT Solution, there is no pathway to change in the oxygen carrying capacity, the dissolved oxygen saturation, of the River Vyrnwy. It is also noted that colder water has higher oxygen carrying capacity and as such any effects of STT Solution that there may be, are considered as positive for dissolved oxygen, not negative.

Other than the assessed general water quality parameters above, there is no pathway of general water quality change in this reach from STT SRO operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here. The potential for water quality benefits in this reach associated with the enhanced dilution, of polluting pressures, from the flow augmentation are not included in this assessment.

3.2.2.2 Chemicals

Section 3.2.1.2 identifies potential EQS failure in the managed release water from Vyrnwy Reservoir for chlorine (total). Comparison with water in Vyrnwy Reservoir (Site 22 UU intake at Vyrnwy dam) chlorine (total) is lower in the manged release. Chlorine (total) monitored at all other sites in the River Vyrnwy also all identify potential EQS failure. It is not considered that a 25Ml/d direct release from Vyrnwy Reservoir would increase the concentration of chlorine (total) in the River Vyrnwy.

3.2.2.3 Olfaction

There is no pathway of chemical change in this reach from STT SRO operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here.

3.2.3 STT operation - future climate

A future flow assessment of environmental water quality effects from STT SRO operation in this reach has not been scoped in for the Gate 2 assessment due to the absence of pathways.

3.3 THE RIVER SEVERN FROM THE CONFLUENCE WITH THE RIVER VYRNWY TO BEWDLEY

In this reach of the study area, the pathways of environmental water quality change from STT solution operation are limited. The STT solution engineering consultants have confirmed that the infrastructure used to make the STT solution flow augmentation releases from Vyrnwy Reservoir into the middle River Severn would be sourced from the same part of the water column as the compensation water. It is important to note that the reservoir scour valves would not be used to support the STT solution. As such, flow released from the Vyrnwy bypass pipeline near Ponthen would be native upper River Vyrnwy water and as such, the chemical composition is considered appropriate for the outfall location in the River Severn, which is 3.5km downstream of the confluence with the River Vyrnwy.

The Gate 2 approach (see Section 2.1) identifies that, in this reach of the study area, there are no pathways of environmental water quality change from the STT solution. The information presented in this section is therefore proportionate to that scope.

3.3.1 Baseline

Consistent with the Gate 2 environmental water quality assessment approach for this reach, there is no pathway of environmental water quality change in this reach from STT operation. There are consistent water quality monitoring data collected in the reach since December 2020 through the solution water quality monitoring programme, as documented in the Gate 2 Environmental Water Quality Evidence Report. These are signposted below for information only. In addition, dRBMP3 baseline WFD water quality status, as assessed by EA from EA monitoring data in the reach, is catalogued in the Gate 2 WFD Regulations Compliance Assessment Report.

3.3.1.1 General water quality

Baseline temperature measurements over a 1.0 year period over 2021 and 2022 at the potential site of a Vyrnwy Bypass outfall to the River Severn are shown in **Figure 3.3**. A strong seasonal pattern is observed albeit with considerable diurnal and day-to-day variability. Some of the variability associates with flow peaks, typically resulting in water temperature reductions, such as on 1st October 2021 and 1st November 2021.

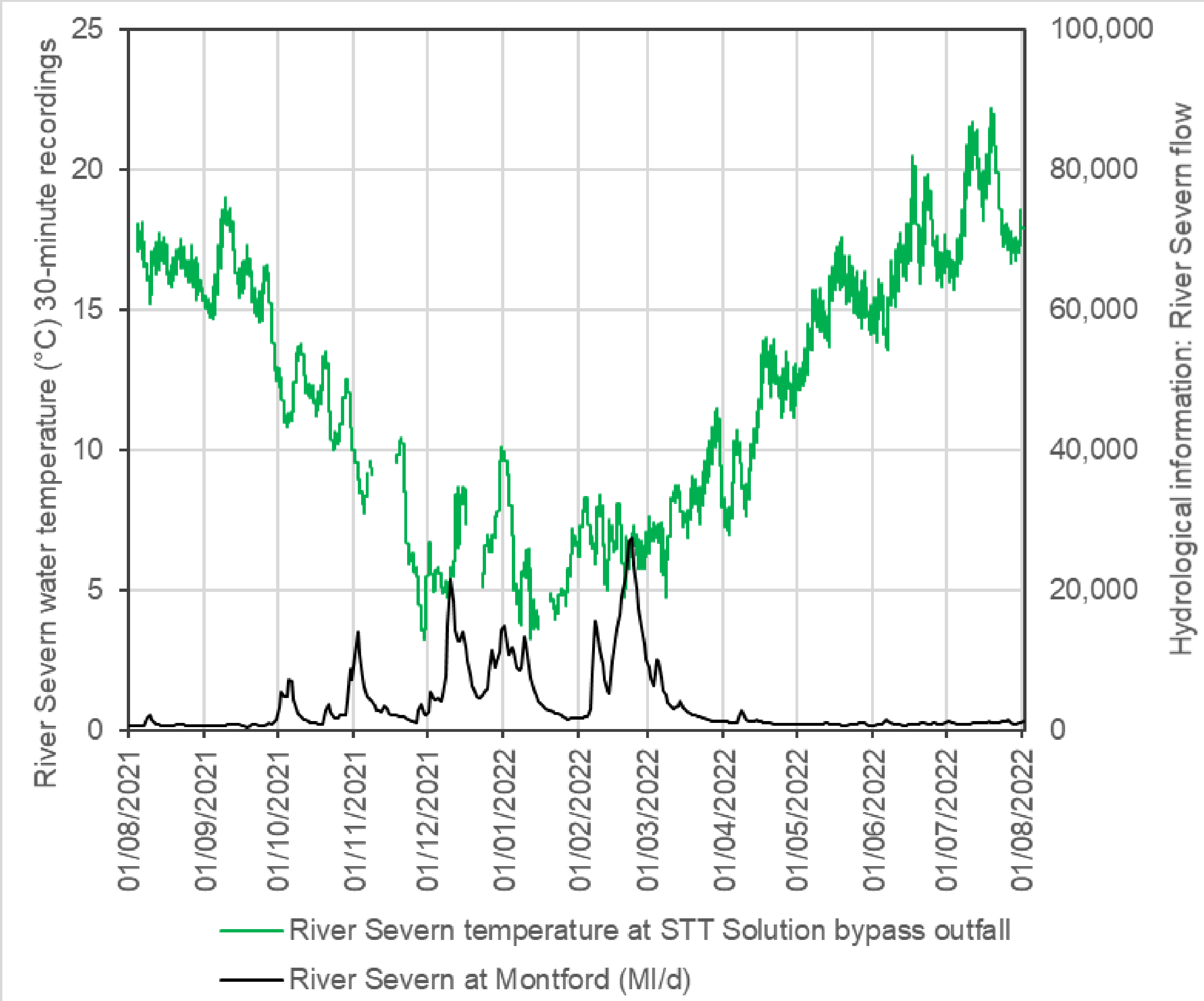

Figure 3.3 Water temperature data in the River Severn collected for Gate 2

Data review for the Site 25 River Severn (upper) downstream Option 4 water quality monitoring sonde for the period of record August 2021 to July 2022 (10,000 half hourly readings) identify a 10 percentile of 85% saturation, consistent with High WFD status. Additional information on other general water quality parameters: pH, acid neutralising capacity, biochemical oxygen demand, ammoniacal nitrogen, nutrients (reactive phosphate) is available to be reviewed in the Gate 2 Environmental Water Quality Evidence Report. This bespoke evidence for the STT SRO is available for one site in the reach: 25 River Severn (upper) downstream Option 4.

3.3.1.2 Chemicals

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#WFD_chem'

Data for one site is available from the pan-SRO chemical monitoring programme, with up to 16 datapoints per determinand per site collected in 2020/2021. The site, available to be selected using the pick-from-list menus on cells C4 or C5 is: Severn_below_Vyrnwy.

Monitoring data have been reviewed against EQS set out in the WFD Regulations[11]. This is summarised in Table 3-2 for the site representing the receiving water quality for a Vyrnwy Bypass for both short term (either maximum values or 95 percentiles) and long term (mean) EQS, where these are applicable. It is noted that this is not a WFD status statement as that is undertaken by the EA using EA sampling and analysis at specified WFD monitoring locations within WFD water bodies.

[11] Schedule 3 of The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015;

The STT solution monitoring data indicate that the River Severn below the River Vyrnwy confluence location does not achieve EQS for one WFD chemical, with one chemical without suitable data for analysis. For 10 chemicals the assessment is incomplete as the laboratory limit of detection is higher than the EQS; however, for all 10 chemicals all reported values were less than the limit of detection used.

It is noted that for chlorine (total) that there are four recorded values, greater than the limit of detection used, of the 16 values for the Severn below Vyrnwy monitoring site. The limit of detection used is itself greater than the WFD EQS. At the Vyrnwy before Severn monitoring site (Site 24), sampled on the same date, there are three recorded values greater than the limit of detection used, of which two are on the same dates as samples recorded as greater than limit of detection at the Severn below Vyrnwy monitoring site. As such there are some monitored occurrences when water chlorine (total) quality in the River Severn downstream of the River Vyrnwy confluence is influenced by the River Vyrnwy and some when this is not the case.

Table 3-2 Review of measured baseline for WFD chemicals against EQS at the Severn_below_Vyrnwy SRO monitoring site (2020/2021, typically 16 samples)

Substance	Substance	Substance
1,2-dichloroethane	cyanide total	mecoprop
2,4-dichlorophenol	cybutryne (Irgarol)	mercury dissolved
2,4-dichlorophenoxyacetic acid (2,4-D)	cypermethrin	methiocarb
3,4-dichloroaniline	DDT total	naphthalene
aclonifen	di(2-ethylhexyl)phthalate (DEHP)	nickel dissolved
alachor	diazinon	nonylphenols
aldrin	dichloromethane	octylphenols
anthracene	dichlorvos	PBDEs
arsenic total	dicofol	pendimethalin
atrazine	dieldrin	pentachlorobenzene
benzene	dimethoate	pentachlorophenol
benzo(a)pyrene	diuron	perfluorooctane sulfonic acid and its derivatives
benzo(b)fluoranthene	endosulfan	permethrin
benzo(g,h,i)perylene	endrin	phenol
benzo(k)fluoranthene	fluoranthene	polycyclic aromatic hydrocarbons (PAH) sum
benzyl butyl phthalate	glyphosate	quinoxyfen
bifenox	heptachlor and heptachlor epoxide	simazine
C10-13 chloroalkanes (total)	hexabromocyclododecane (HBCDD)	terbutryn
cadmium total	hexachlorobenzene	tetrachloroethane
carbendazim	hexachlorobutadiene	tetrachloroethylene
carbon tetrachloride	hexachlorocyclohexane	toluene
chlorfenvinphos	indeno(1,2,3-cd)pyrene	tributyltin compounds (as tributyltin cation)
chlorine total	iron dissolved	trichlorobenzenes
chlorothalonil	isoproturon	trichloroethylene
chlorpyrifos (chlorpyrifos-ethyl)	lead dissolved	trichloromethane (chloroform)
chromium (III) dissolved	lead dissolved	triclosan
chromium (VI) dissolved	linuron	trifluralin
copper dissolved	manganese dissolved	zinc dissolved

Legend:

All reported values achieve applicable EQS
Reported values identify short-term EQS not achieved
Reported values identify long-term EQS not achieved
Reported values identify neither short-term or long-term EQS achieved
Limit of detection used does not enable full comparison of reported data with EQS
No data for analysis at Gate 2

3.3.1.3 Olfaction

There is no pathway of chemical change in this reach from the STT solution operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here. The bespoke olfactory inhibitor monitoring suite has not been included in the analysis for this reach. However, where there is overlap with the suite of WFD chemicals, this information is available to be reviewed in the Gate 2 Environmental Water Quality Evidence Report. This bespoke evidence for the STT solution is available for one site in the reach: 25 River Severn (upper) downstream Option 4.

3.3.2 STT operation – current climate

3.3.2.1 General water quality

At Gate 2 there is no bespoke information on the water temperature of a Vyrnwy Bypass release to the River Severn. Although continuous water temperature data could be collected for the end of the current Vyrnwy Aqueduct, that itself would not provide a reliable guide to the temperature discharged as it does not take into account the higher rate of transfer of water along the Aqueduct for a STT Solution, nor the effect of pipeline transmission. Surrogate data used in the Gate 2 assessment are from Vyrnwy Reservoir – the Site 22 UU intake at Vyrnwy dam (a measure of near surface water temperature in Vyrnwy Reservoir) and Site 23 River Vyrnwy downstream of Vyrnwy dam (a measure of water temperature lower in the water column which corresponds with managed releases from the reservoir). Each of these datasets have been reviewed with the Site 25 data shown in **Figure 3.3**, for a continuous discharge rate of 155Ml/d. This is a precautionary approach to assessing the scope of water temperature effects from a Vyrnwy Bypass. **Figure 3.4** identifies no distinct change in water temperature pattern and substantial changes only when the River Severn temperatures are warm (greater than 15°C) and river flows low (c.700Ml/d in late July 2022). Mixing water of the temperature of Vyrnwy Reservoir near-surface would have a full range of change in the measured data of 3.2°C cooling to 0.5°C warming, with a median of no change and inter-quartile range of 0.3°C change. Mixing water of the temperature of Vyrnwy Reservoir managed outfalls would have a full range of change in the measured data of 5.7°C cooling to 0.7°C warming, with a median of 0.4°C cooling and inter-quartile range of 0.9°C change.

If the precautionary assessment is valid, then the Vyrnwy Bypass could assist water temperatures becoming consistent with WFD High status for salmonid waters of 20°C (98-percentile).

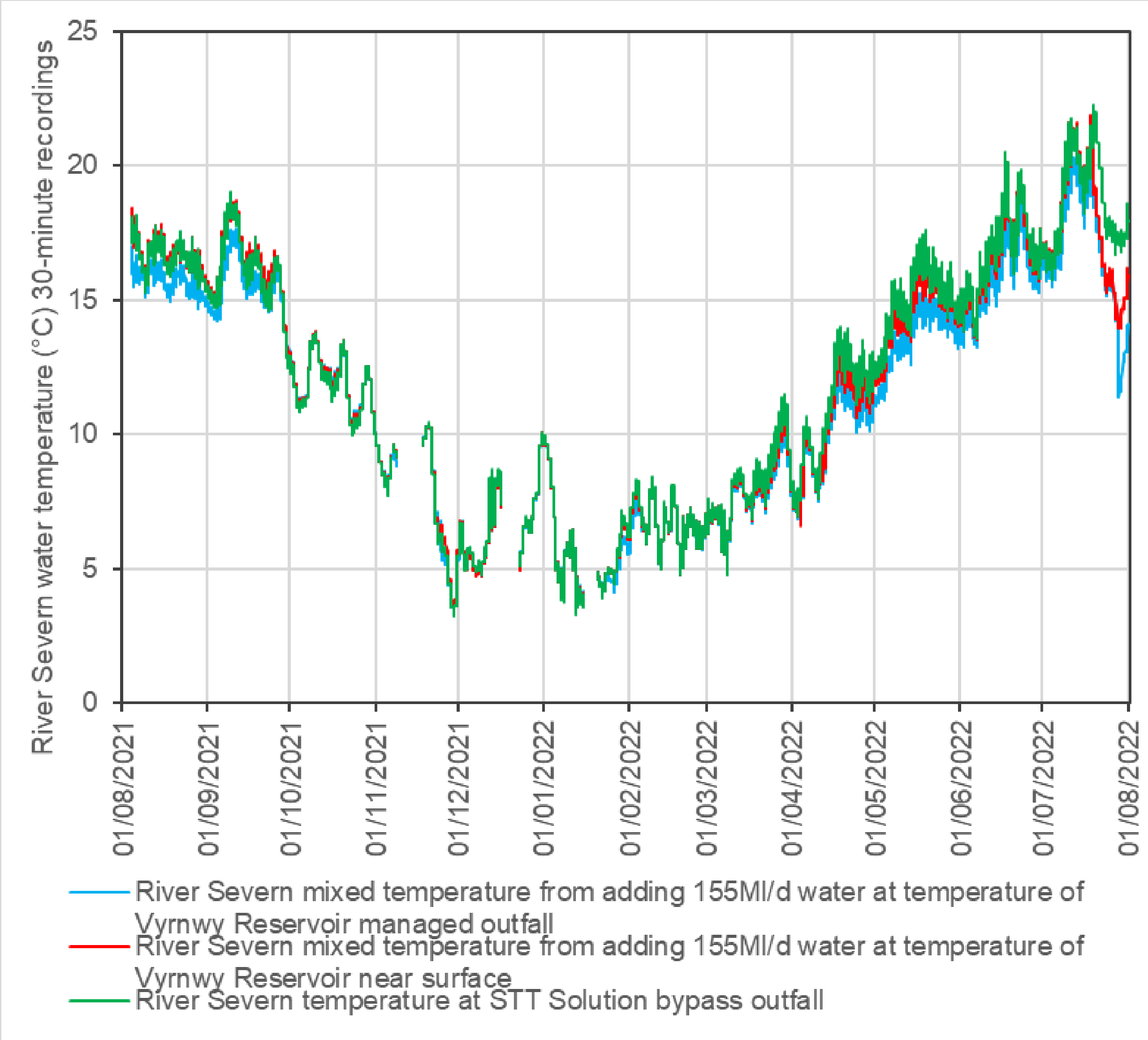

Figure 3.4 Precautionary assessment of Vyrnwy Bypass effect on water temperature in the River Severn

As there is no distinct substantial water temperature change associated with the Vyrnwy Bypass, there is no pathway to change in the oxygen carrying capacity, the dissolved oxygen saturation, of the River Vyrnwy. It is also noted that colder water has higher oxygen carrying capacity and as such any effects created by the STT Solution are considered as positive for dissolved oxygen, not negative.

Other than the assessed general water quality parameters above, there is no pathway of general water quality change in this reach from STT SRO operation. The potential for water quality benefits in this reach associated with the enhanced dilution of wastewater discharges (e.g. Shrewsbury (Monkmoor) WwTW), and other pollution pressures, from the flow augmentation are not included in this assessment.

3.3.2.2 Chemicals

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#WFD_chem'

At Gate 2 there is no bespoke information on the water quality for a Vyrnwy Bypass release to the River Severn, noting that this water would originate from Vyrnwy Reservoir. Surrogate data used in the Gate 2 assessment are from Vyrnwy Reservoir – the Site 22 UU intake at Vyrnwy dam (a measure of near surface water temperature in Vyrnwy Reservoir) and Site 23 River Vyrnwy downstream of Vyrnwy dam (a measure of water temperature lower in the water column which corresponds with managed releases from the reservoir). Each of these datasets have been reviewed with the Site 25 data. The chemical quality of water at Site 23 is summarised in Table 3-1 and for Site 25 in Table 3-2. Review of data for Site 22 identifies EQS risks for chlorine (total) as per Site 23, with fewer values greater than the limit of detection at each of these sites that at Site 25. As such Vyrnwy Bypass would not lead to deterioration in quality of the River Severn at the outfall point.

In addition the Site 22 data records one value of C10-13 chloroalkanes (total) of 2.7µg/l, which is greater than the maximum allowable concentration for this Priority Hazardous Substance of 1.4µg/l. These short chain chlorinated paraffins are prohibited from sale and use. All other recorded values for at this site, River Vyrnwy sites and Site 25 are below the limit of detection used of 0.4µg/l. This is considered a one-off value and not indicative of the quality of Vyrnwy Bypass discharge to the River Severn.

3.3.2.3 Olfaction

There is no pathway of chemical change in this reach from the STT solution operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here. The bespoke olfactory inhibitor monitoring suite is included in the analysis for this reach. This information is available to be reviewed in the Gate 2 Environmental Water Quality Evidence Report. This bespoke evidence for the STT solution is available for one site in the reach: Severn_below_Vyrnwy.

3.3.3 STT operation - future climate

A future flow assessment of environmental water quality effects from STT solution operation in this reach has not been scoped in for the Gate 2 assessment due to the absence of pathways.

3.4 THE RIVER SEVERN FROM BEWDLEY TO THE CONFLUENCE WITH THE RIVER AVON

The Gate 2 approach (see Section 2.1) identifies that, in this reach of the study area, there are no pathways of environmental water quality change from STT solution operation. The information presented in this section is therefore proportionate to that scope.

3.4.1 Baseline

Consistent with the Gate 2 environmental water quality assessment approach for this reach, there is no pathway of environmental water quality change in this reach from STT operation. There are consistent water quality monitoring data collected in the reach since 2022 through the solution water quality monitoring programme, as documented in the Gate 2 Environmental Water Quality Evidence Report. These are signposted below for information only. In addition, dRBMP3 baseline WFD water quality status, as assessed by EA from EA monitoring data in the reach, is catalogued in the Gate 2 WFD Regulations Compliance Assessment Report.

3.4.1.1 General water quality

There is no pathway of general water quality change in this reach from STT solution operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here. At the one STT solution monitoring site in the reach, physico-chemical water quality data are not part of the analysis suite.

3.4.1.2 Chemicals

There is no pathway of chemical change in this reach from STT solution operation. As such, no assessment is included at Gate 2 in this reach and no baseline information is described here. At the one STT solution monitoring site in the reach, chemical water quality data are not part of the analysis suite.

3.4.1.3 Olfaction

There is no pathway of chemical change in this reach from the STT solution operation. As such no assessment is included at Gate 2 in this reach and no baseline information is described here. The bespoke olfactory inhibitor monitoring suite is included in the analysis for this reach. This information is available to be reviewed in the Gate 2 Environmental Water Quality Evidence Report. This bespoke evidence for the STT solution is available for one site in the reach: STT-Mythe River Severn at Mythe U/S confluence with River Avon.

3.4.2 STT operation – current climate

A current flow conditions assessment of environmental water quality effects from the STT solution operation in this reach has not been scoped in for the Gate 2 assessment due to the absence of pathways. The potential for water quality benefits in this reach associated with the enhanced dilution, of wastewater discharges (e.g. Worcester WwTW) and other pollution pressures, from the flow augmentation are not included in this assessment.

3.4.3 STT operation - future climate

A future flow assessment of environmental water quality effects from the STT solution operation in this reach has not been scoped in for the Gate 2 assessment due to the absence of pathways.

3.5 THE RIVER AVON FROM STONELEIGH TO THE CONFLUENCE WITH THE RIVER SEVERN

The area of interest extends about 108 km from Stoneleigh to the confluence with the River Severn at Tewkesbury. Shortly downstream of Stoneleigh, the Avon merges with River Sowe. The flow from the River Sowe includes the effluent from the Coventry Finham STW. This assessment has been informed using the STT solution River Severn catchment linked hydraulic-water quality model.

Flows from the following tributaries were included in the modelling used for the assessment:

- River Avon at Stoneleigh
- River Sowe at Stareton
- River Leam at Leamington
- River Dene at Wellesbourne
- River Stour at Alscot Park
- River Arrow at Broom
- Badsey Brook at Offenham
- River Isbourne at Hinton
- Piddle Brook at Wyre Piddle
- Bow Brook at Besford Bridge.

The following Severn Trent Water wastewater treatment works which discharge directly to the River Avon were also included in water quality modelling:

- Warwick (Longbridge) WwTW
- Wellesbourne WwTW
- Stratford (Milcote) WwTW
- Bidford on Avon WwTW
- Evesham WwTW
- Tewkesbury WwTW.

The loads from wastewater treatment works that discharge into the tributaries listed above, are captured in the loads assigned to the tributary. This is because there is a routine water quality sampling site located between the works and the confluence with the Avon.

3.5.1 Baseline

This section describes baseline conditions using measured and modelled evidence presented in the Environmental Water Quality Evidence Report.

3.5.1.1 General water quality

This section is supported by charts and data in the following excel workbooks. In the text, reference to the workbook is given as "Workbook [number] - tab 'name'".
[1] AvonDsMinworthOutfall.xlsm
[2] AvonDsWarwickSTW.xlsm
[3] AvonAtEvesham.xlsm
[4] AvonPriorToConfluenceSevern.xlsm

In the upper Avon, water temperature is predicted to vary seasonally between 7 and 17°C [Workbooks [1] and [2] – tab 'Temp']. There is a wider range in temperature at the confluence with the Severn (6 to 20°C) [Workbooks [3] and [4] – tab 'Temp'].

Dissolved oxygen concentrations vary seasonally between 9 and 11.5 mg/l at all sites along the River Avon, with the higher values occurring in the winter. During the period when the scheme would be operating the dissolved oxygen is at 90%sat upstream of Warwick [Workbook [1] – tab 'DO'] and 94%sat downstream of Warwick [Workbook [2] – tab 'DO'] and at Evesham [Workbook [3] – tab 'DO']. There are occasional values in the observation data set where minimum dissolved oxygen is outside the range quoted here. During model calibration, it was noted that the model did not reproduce these low events, however there was no clear cause based on the available input and in river data to indicate what caused such low values.

Ammoniacal nitrogen concentrations are in the range of 0.05 – 0.25 mg/l along the River Avon, with no obvious seasonal variation [Workbooks [1], [2],[3] and [4]– tab 'NH4'].

Soluble reactive phosphate concentrations are in the range of 0.1 – 0.8 mg/l upstream of Warwick [Workbook [1] – tab 'P'], gradually changing to 0.1 – 0.5 mg/l (A82), 0.15 – 0.6 mg/l (M92) by the confluence with the River Severn [Workbook [4] – tab 'P'].

3.5.1.2 Chemicals

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#WFD_chem'

Data for four sites in the River Avon are available from the pan-SRO chemical monitoring programme, with up to 16 datapoints per determinand per site collected in 2020/2021. The four sites, available to be selected using the pick-from-list menus on cells C4 or C5 are: Avon_above_Warwick; Avon_below_Warwick; Avon_Evesham; and Avon_Twyning. By choosing an upstream site as the X-dataset in cell C4 and a downstream site as the Y-dataset in cell C5 any pattern in changes in quality along the river can be reviewed.

Monitoring data have been reviewed against EQS set out in the WFD Regulations[12]. This is summarised in **Table 3-3** for the site representing the receiving water quality for a Minworth Transfer for both short term (either maximum values or 95 percentiles) and long term (mean) EQS, where these are applicable. It is noted that this is not a WFD status statement as that is undertaken by the EA using EA sampling and analysis at specified WFD monitoring locations within WFD water bodies.

The STT solution monitoring data indicate that the River Avon upstream of Warwick does not achieve EQS for 6 WFD chemicals, with one chemical without suitable data for analysis. For ten chemicals the assessment is incomplete as the laboratory limit of detection is higher than the EQS; however, for all 10 chemicals all reported values were less than the limit of detection used.

Table 3-3 Review of measured baseline for WFD chemicals against EQS at the Avon above Warwick SRO monitoring site (2020/2021, typically 16 samples)

Substance	Substance	Substance
1,2-dichloroethane	cyanide total	mecoprop
2,4-dichlorophenol	cybutryne (Irgarol)	mercury dissolved
2,4-dichlorophenoxyacetic acid (2,4-D)	Cypermethrin	methiocarb
3,4-dichloroaniline	DDT total	naphthalene
aclonifen	di(2-ethylhexyl)phthalate (DEHP)	nickel dissolved
alachor	Diazinon	nonylphenols
aldrin	Dichloromethane	octylphenols
anthracene	Dichlorvos	PBDEs
arsenic total	Dicofol	pendimethalin
atrazine	Dieldrin	pentachlorobenzene
benzene	Dimethoate	pentachlorophenol
benzo(a)pyrene	Diuron	perfluorooctane sulfonic acid and its derivatives
benzo(b)fluoranthene	Endosulfan	permethrin
benzo(g,h,i)perylene	Endrin	phenol
benzo(k)fluoranthene	Fluoranthene	polycyclic aromatic hydrocarbons (PAH) sum
benzyl butyl phthalate	Glyphosate	quinoxyfen
bifenox	heptachlor and heptachlor epoxide	simazine
C10-13 chloroalkanes (total)	hexabromocyclododecane (HBCDD)	terbutryn
cadmium total	Hexachlorobenzene	tetrachloroethane
carbendazim	Hexachlorobutadiene	tetrachloroethylene
carbon tetrachloride	Hexachlorocyclohexane	toluene
chlorfenvinphos	indeno(1,2,3-cd)pyrene	tributyltin compounds (as tributyltin cation)
chlorine total	iron dissolved	trichlorobenzenes

12 Schedule 3 of The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015;

Substance	Substance	Substance
chlorothalonil	Isoproturon	trichloroethylene
chlorpyrifos (chlorpyrifos-ethyl)	lead dissolved	trichloromethane (chloroform)
chromium (III) dissolved	lead dissolved	triclosan
chromium (VI) dissolved	Linuron	trifluralin
copper dissolved	manganese dissolved	zinc dissolved

Legend:

All reported values achieve applicable EQS
Reported values identify short-term EQS not achieved
Reported values identify long-term EQS not achieved
Reported values identify neither short-term or long-term EQS achieved
Limit of detection used does not enable full comparison of reported data with EQS
No data for analysis at Gate 2

3.5.1.3 Olfaction

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#olfaction'

Olfactory inhibitors have been included in the analysis of the STT solution monitoring site on the Avon at Twyford as an indicator of the current influence of the River Avon on migratory routes in the River Severn. The detected presence or absence of the selected list of chemicals is summarised in Table 3-4. It is noted that the concentration at which individual or groups of chemicals may be disruptive to individual relevant migratory fish species are poorly understood, as is the potential role of bioaccumulation, laboratory limits of detection are not a guide to absence of influence of a chemical, and nor is detected presence of chemical a reliable guide to presence of influence.

Table 3-4 Review of measured baseline chemicals of interest as olfactory inhibitors at the Avon at Twyning SRO monitoring site (2021, typically 6 samples)

Group	Specific substance	
Metals	Aluminium (dissolved and total)	Iron (dissolved and total)
	Cadmium (dissolved and total)	Mercury (dissolved and total)
	Chromium(III) (dissolved)	Nickel (dissolved and total)
	Chromium(VI) (dissolved)	Selenium (dissolved and total)
	Chromium (total)	Silver (dissolved and total)
	Cobalt (dissolved and total)	Zinc (dissolved and total)
	Copper (dissolved and total)	
Carbamate pesticides	Methiocarb	Pirimicarb
	Oxamyl	
Organophosphate pesticides	Carbophenothion	Fenitrothion
	Chlorpyrifos	Malathion
	Diazinon	Parathion
	Dichlorvos	
Phenylurea pesticides	Chlorotoluron	Linuron
	Diuron	Monuron
	Flucofuron	Sulcofuron
	Isoproturon	
Pyrethroid pesticides	Cyfluthrin	Permethrin
	Cypermethrin	
Alkylbenzene-sulfonates	C10-C14 alkyl benzene sulphonic acids	Linear sodium Dodecylbenzene sulfonate
	Branched sodium Dodecylbenzene sulfonate	Sodium tridecylbenzene sulfonate
	Calcium Dodecylbenzene sulfonate	Triethanolammonium dodecylbenzene sulfonate
Diamines	1,6-hexanediamine	
Quaternary Ammonium Salts	Benzalkonium chlorides	Lauryldimethylbenzyl ammonium chloride
	Di(hydrogenated tallow)dimethylammonium chloride	Stearyldimethylbenzyl ammonium chloride
	Dodecylammonium chloride	
Endocrine disrupting chemicals, including pharmaceuticals	Triclosan	19-norethindrone
	17α – ethinylestradiol (EE2)	Norgestrel
	17 ß-estradiol (E2)	Bisphenol A, S and F
	4-nonylphenol	Ibuprofen
	Trenbolone (TB)	Ethinylestradiol
	Chlorophene	Raloxifene
	Hydroxymetabolites of vinclozolin (VZ)	Bifenthrin
	Dibutylbenzyle phthalate (DBP)	Levonorgestrel
	Flutamide	

Legend:

All reported values less than limit of detection used
Substance detected in analysis
No data for analysis at Gate 2

3.5.2 STT operation – current climate

In this reach, the STT solution would augment flows through a 115 Ml/d advanced treated effluent transfer from Minworth WwTW at selected times. The indicative system operation pattern was identified from stochastic data, as described in **Section** 1.3**,** and shown as blue periods on **Figure 1.4**. It describes a typical pattern of the STT operation for river flow augmentation, on the River Avon, from a transfer from Minworth, during current climate conditions. The planned discharge quality of the Minworth Transfer, in terms of physico-chemical water quality, is set out in Table 2-5.

3.5.2.1 Change to general water quality

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report. The reader is advised to look at the stated workbook tab when reading the text in order to see the accompanying chart(s):
[1] AvonDsMinworthOutfall.xlsm
[2] AvonDsWarwickSTW.xlsm
[3] AvonAtEvesham.xlsm
[4] AvonPriorToConfluenceSevern.xlsm
AvonSevern_LongSection_DO.xlsm
AvonSevern_LongSection_NH4.xslm
AvonSevern_LongSection_SRP.xslm

Similar changes in water quality are generally predicted for both the A82 and M96 scenarios under the fully supported STT scheme.

During the scheme operation, the river water temperature would be higher than the baseline in early stages before the river temperature has reached its summer peak (mid-July). This increase is similar for both scenarios: up to 0.8°C upstream of Warwick [Workbook [1] – tab 'Temp'], and up to 0.5°C at Evesham and at the confluence with River Severn [Workbooks [3] and [4]– tab 'Temp']. In late summer and autumn, the scheme is predicted to decrease river water temperature. The increase in river water temperature compared to the baseline increases with time. As the M96 scenario operates for a longer period and later into the autumn period, the maximum increase in temperature is around 1.5°C upstream of Warwick (downstream of the Minworth discharge) [Workbook [1] – tab 'Temp'], while for A82 the increase is about 1.0°C. This increase in temperature due to the scheme decreases along the River Avon, such that the maximum reduction at the confluence with the River Severn is 1.1°C (M96) and 0.8°C (A82) [Workbook [4] – tab 'Temp']. Note that the model does not allow for any heat exchange with the atmosphere, so that the predicted increase in the lower Avon may be over-represented. Snapshot longitudinal plots of temperature along the River Avon for 18th July are shown in Figure 3-5 and Figure 3-6. Note that the unsupported STT predictions are identical to the baseline conditions, so the lines in the plots lie on top of each other. It is noted that the modelling of water temperature is a conservative estimate as the 1D model does not include any atmospheric influence on water temperature.

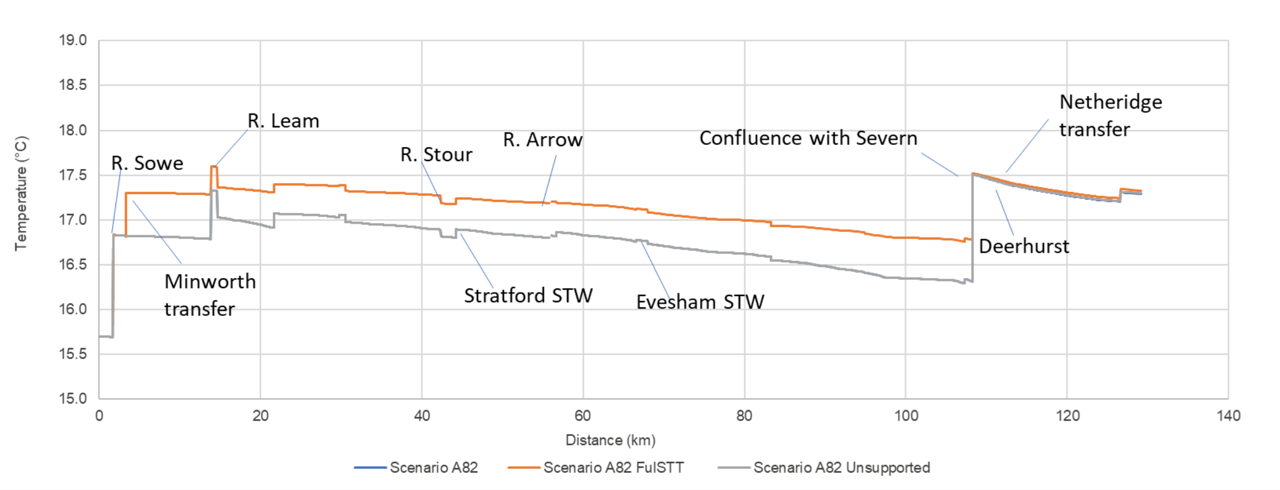

Figure 3-5 Longitudinal profile of temperature along Avon and lower Severn, scenario A82, 18th July

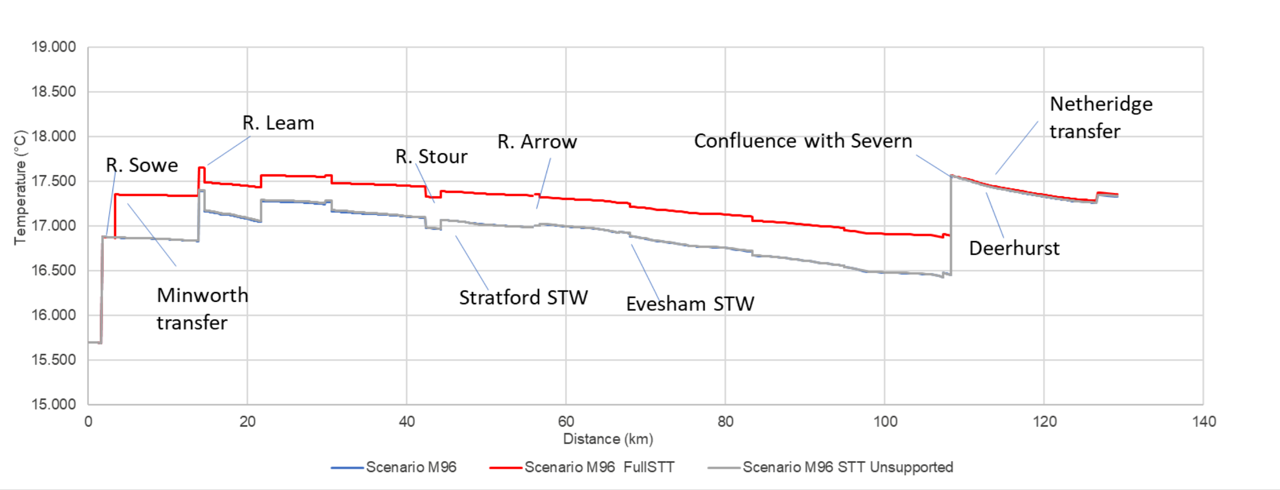

Figure 3-6 Longitudinal profile of temperature along Avon and lower Severn, scenario M96, 18th July

Dissolved oxygen concentrations in both scenarios is reduced by up to 1.5 mg/l during the operation downstream of the Minworth discharge. This means that the saturated concentrations during the operation of the scheme become 75-80%sat for A82, and 72-78%sat for M96 [Workbook [1] – tab 'DO']. Downstream of Warwick STW, the reduction in DO is 0.2 mg/l (2%sat reduction) [Workbook [2] – tab 'DO'], <0.1 mg/l (<1%sat reduction) at Evesham [Workbook [3] – tab 'DO'], with no change due to the scheme predicted at the confluence [Workbook [4] – tab 'DO']. Snapshot longitudinal plots of dissolved oxygen concentration (as %sat) along the Avon for 18 July are shown in **Figure 3-7** (A82) and **Figure 3-8** (M96).

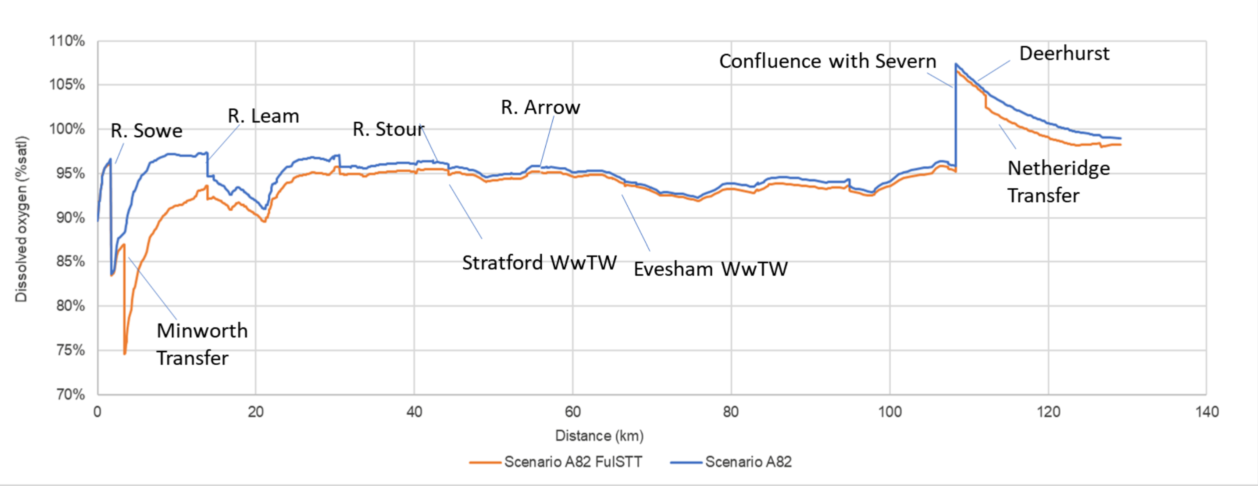

Figure 3-7 Longitudinal profile of dissolved oxygen (%sat) along Avon and lower Severn, scenario A82, 18th

July

Ammoniacal nitrogen is predicted to increase during the scheme operation by around 0.2 mg/l (from a baseline of 0.05 mg/l) upstream of Warwick [Workbook [1] – tab 'NH4'], by 0.1 to 0.15 mg/l downstream of Warwick [Workbook [2] – tab 'NH4'], by 0.05 mg/l at Evesham [Workbook [3] – tab 'NH4'], and by 0.02 mg/l at the confluence [Workbook [4] – tab 'NH4']. Snapshot longitudinal plots of ammoniacal nitrogen concentrations along the Avon for 18th July are shown in **Figure 3-9** (A82) and **Figure 3-10** (M96). Note the step-change due to the Stratford (Milcote) WwTW effluent.

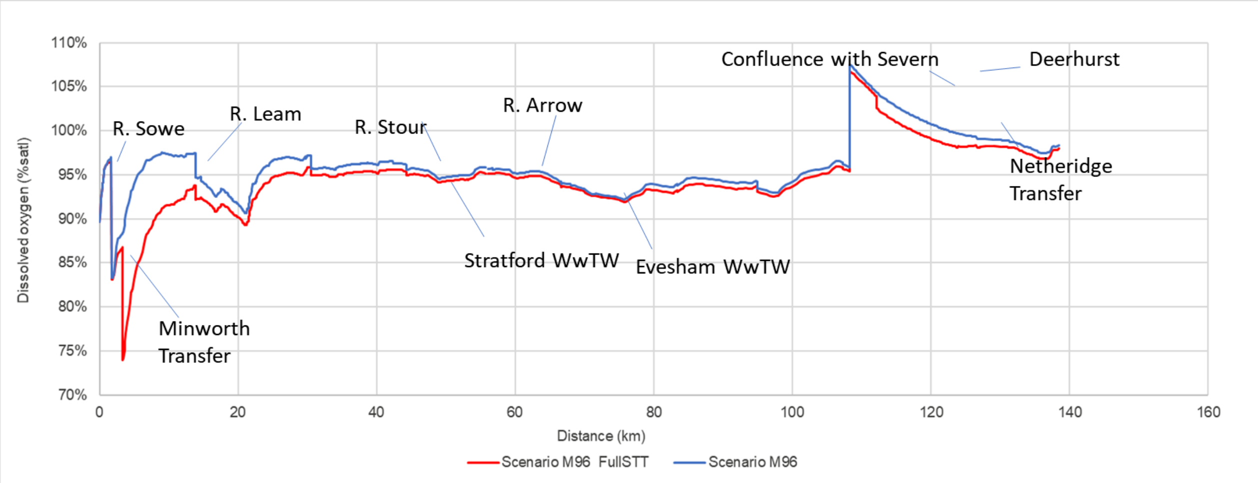

Figure 3-8 Longitudinal profile of dissolved oxygen (%sat) along Avon and lower Severn, scenario M96, 18th July

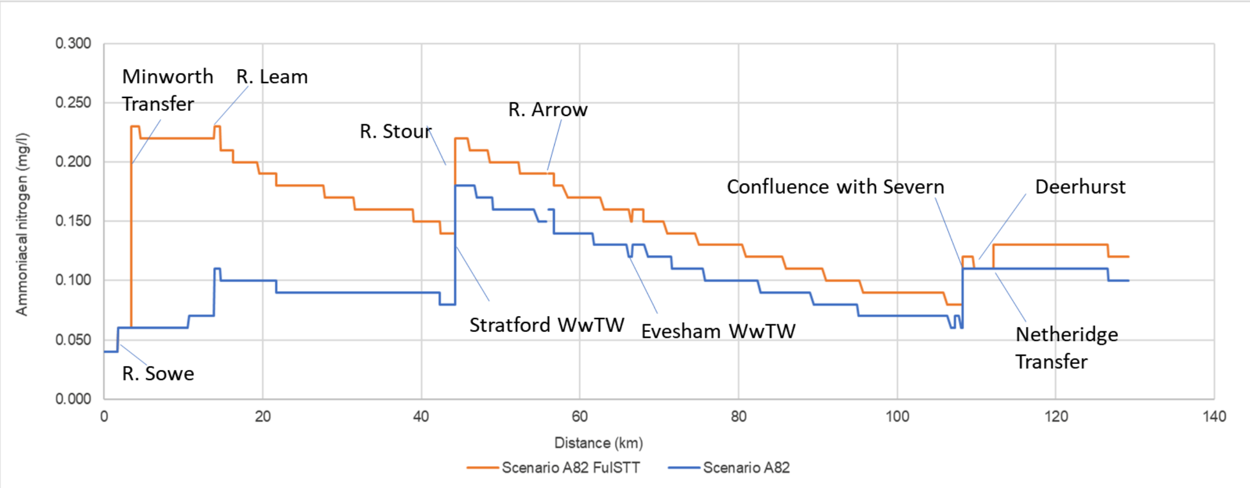

Figure 3-9 Longitudinal profile of ammoniacal nitrogen along Avon and lower Severn, scenario A82, 18th July

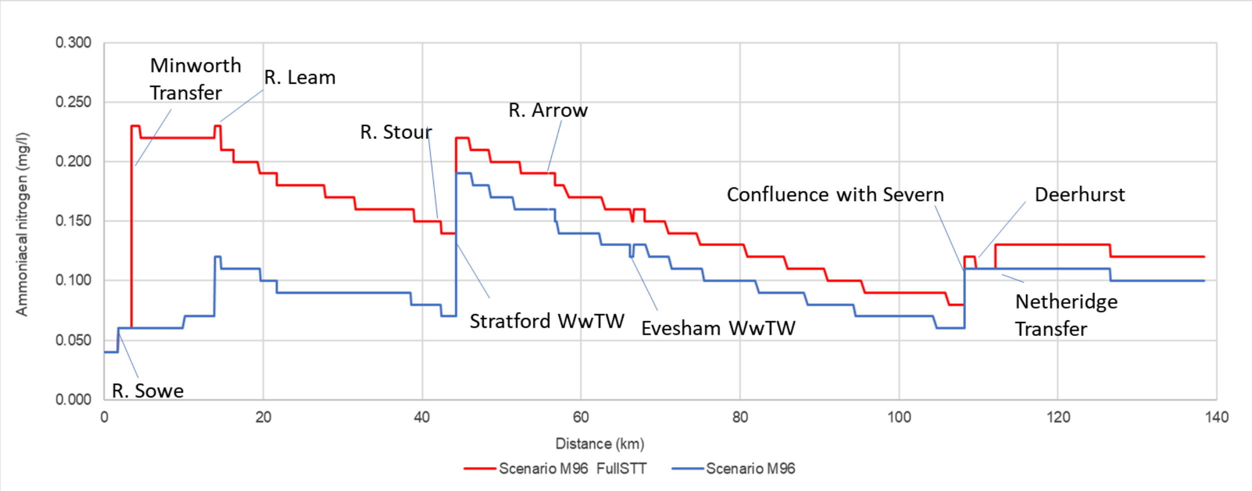

Figure 3-10 Longitudinal profile of ammoniacal nitrogen along Avon and lower Severn, scenario M96, 18th July

Soluble reactive phosphate concentrations are reduced by the scheme throughout the River Avon. Upstream of Warwick, the concentrations are reduced by 0.05 to 0.1 mg/l [Workbook [1] – tab 'P'], by 0.05 mg/l downstream of Warwick [Workbook [2] – tab 'P'], by less than 0.1 mg/l at Evesham [Workbook [3] – tab 'P'] and at the confluence [Workbook [4] – tab 'P']. Snapshot longitudinal plots of soluble reactive phosphate concentrations along the River Avon for 18th July are shown in **Figure 3-11** (A82) and **Figure 3-12** (M96).

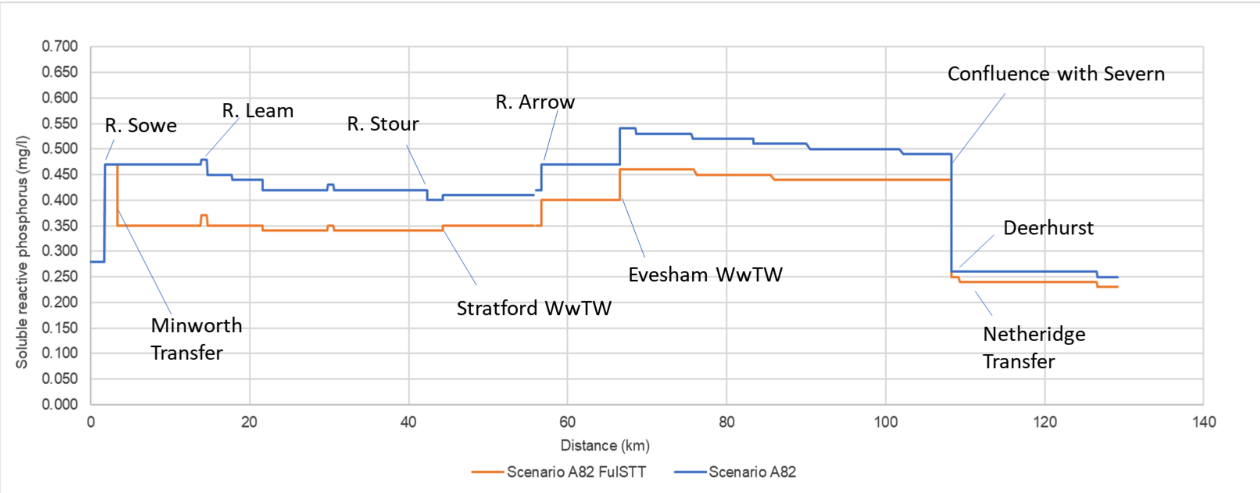

Figure 3-11 Longitudinal profile of SRP along Avon and lower Severn, scenario A82, 18th July

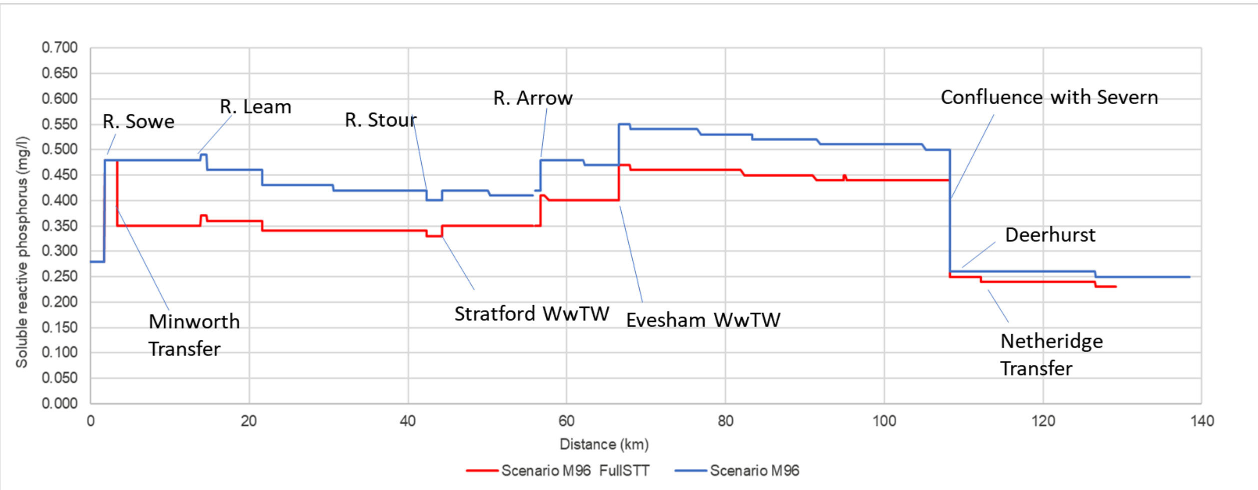

Figure 3-12 Longitudinal profile of SRP along Avon and lower Severn, scenario M96, 18th July

3.5.2.2 Change to chemicals

This section uses:
This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#WFD_chem'

A categorisation of the pre-treatment risk of chemicals associated with the Minworth Transfer has been undertaken using the approach set out in Section 2.3.6. It is important to note that the Minworth SRO at Gate 2 is proposed to include the advanced treatment processes set out in Section 2.3.4. The initial risk categorisation in Table 3-5 is of those chemicals that would need additional treatment prior to discharge based on measured concentrations from the pan SRO monitoring dataset in the current final effluent at Minworth WwTW which is in effect the source water for advanced treatment, and the in-river concentration in the River Avon upstream of Warwick.

Data for this assessment can be reviewed in the excel workbook STT_Chemical_Data_Viewer.xlsm on the tab name '#WFD_chem' by choosing *Avon_above_Warwick* as the X-dataset in cell C4 and *Final_Effluent_Minworth_STW* as the Y-dataset in cell C5.

Table 3-5 Review of pre-treatment risk of WFD chemicals associated with the Minworth Transfer

From comparison of Minworth WwTW final effluent SRO monitoring site concentration with River Avon above Warwick SRO monitoring site (both 2020/2021, typically 16 samples) using the methodology in Figure 2 1

1,2-dichloroethane	cyanide total	mecoprop
2,4-dichlorophenol	cybutryne (Irgarol)	mercury dissolved
2,4-dichlorophenoxyacetic acid (2,4-D)	Cypermethrin	methiocarb
3,4-dichloroaniline	DDT total	naphthalene
aclonifen	di(2-ethylhexyl)phthalate (DEHP)	nickel dissolved
alachor	Diazinon	nonylphenols
aldrin	Dichloromethane	octylphenols
anthracene	Dichlorvos	PBDEs
arsenic total	Dicofol	pendimethalin
atrazine	Dieldrin	pentachlorobenzene
benzene	Dimethoate	pentachlorophenol
benzo(a)pyrene	Diuron	perfluorooctane sulfonic acid and its derivatives
benzo(b)fluoranthene	Endosulfan	permethrin
benzo(g,h,i)perylene	Endrin	phenol
benzo(k)fluoranthene	Fluoranthene	polycyclic aromatic hydrocarbons (PAH) sum
benzyl butyl phthalate	Glyphosate	quinoxyfen
bifenox	heptachlor and heptachlor epoxide	simazine
C10-13 chloroalkanes (total)	hexabromocyclododecane (HBCDD)	terbutryn
cadmium total	hexachlorobenzene	tetrachloroethane
carbendazim	hexachlorobutadiene	tetrachloroethylene
carbon tetrachloride	hexachlorocyclohexane	toluene
chlorfenvinphos	indeno(1,2,3-cd)pyrene	tributyltin compounds (as tributyltin cation)
chlorine total	iron dissolved	trichlorobenzenes
chlorothalonil	Isoproturon	trichloroethylene
chlorpyrifos (chlorpyrifos-ethyl)	lead dissolved	trichloromethane (chloroform)
chromium (III) dissolved	lead dissolved	triclosan
chromium (VI) dissolved	Linuron	trifluralin

copper dissolved	manganese dissolved	zinc dissolved

Legend:

Discharge of Minworth WwTW final effluent achieves river targets in the River Avon without requirement for additional treatment
Requires review, River Avon upstream Warwick achieves EQS
Requires review, River Avon upstream Warwick does not achieve EQS
Limit of detection used does not enable full comparison of reported data with EQS
No data for analysis at Gate 2

The pan-SRO monitoring data reviewed in Table 3-5 identified 17 WFD chemicals as requiring review, with 14 of these already achieving EQS in the River Avon upstream Warwick. Of the nine chemicals for which the assessment is incomplete as the laboratory limit of detection is higher than the EQS, all reported values in the Minworth WwTW final effluent are also less than the limit of detection used.

In addition to WFD chemicals, all chemicals with EQS that are included in permitting guidance from the EA[13] have been included in the pan-SRO monitoring programme for these two sites. The same review process has identified further review is needed for 11 chemicals: boron (total), chloride, cobalt (dissolved), EDTA, fluoride, mancozeb, maneb, MCPA, omethoate, propyzamide, tin (total).

Process engineers from the Minworth SRO engineering consultant team reviewed the list of chemicals identified above. The review established where the advanced treatment processes set out in Section 2.3.4 for Minworth SRO may not effectively reduce the source water (Minworth WwTW final effluent) sufficiently to achieve target values proposed by the STT solution environmental consultants as either existing in-river concentration (no WFD deterioration risk) or EQS (no impediment to WFD target status).

That review identified that there are post advanced treatment risks to proposed targets associated with eight WFD chemicals. These WFD chemicals are reviewed further in **Table 3-6** through use of the STT_Chemical_Data_Viewer.xlsm.

Table 3-6 Review of post-treatment risk of WFD chemicals associated with the Minworth Transfer

WFD chemical	Summary	Notes
Chromium (III) dissolved	No change	Apart from one high river value, all other reported values achieve long term ES.
Hexabromocyclododecane (HBCDD)	No change	~6% increase in mean value of river, remains achieving EQS
Nonylphenols	Risk to long term EQS	~56% increase in mean value of river, potential change from achieving long term EQS to not
Terbutryn	No change	~1% increase in mean value of river, remains achieving EQS
Trichloromethane (chloroform)	No change	~4% increase in mean value of river, remains achieving EQS
Cypermethrin	Risk of worsening non-achievement of long term EQS	~34% increase in mean value of river, remains not achieving EQS
Perfluorooctane sulfonic acid and its derivatives	Risk of worsening non-achievement of long term EQS	~34% increase in mean value of river, remains not achieving EQS
Permethrin	Risk of worsening non-achievement of long term EQS	~32% increase in mean value of river, remains not achieving EQS

In accordance with the approach set out in Section Table 2-1, for the four WFD chemicals with remaining risk, the magnitude and frequency of that risk has been modelled using the conservative tracer dilution rates in the Severn catchment 1D water quality model. This has been illustrated for 25th August in the A82 modelling – a date selected in the Gate 2 Physical Environment Assessment Report for the reference condition where the low summer flow increases from 60 Ml/d to 205 Ml/d after the confluence with the River Sowe, then to 273 Ml/d at Warwick after the confluence with the River Leam. At Evesham the flow in the river has almost doubled, increasing by 200 Ml/d.

Nonylphenols are a priority hazardous substance under the WFD Regulations and have been prohibited from production and use in UK since 2005[14] and in the EU; and has consequently in 2021 been banned in imported

[13] https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit
[14] Controls on Nonylphenol and Nonylphenol Ethoxylate Regulations 2004 SI (2004) No. 1816

clothing and textiles[15]. They were a component of household detergents and are environmentally persistent and considered as endocrine disruptors. Nonylphenols concentration change from point of discharge at a Minworth Transfer outfall along the River Avon and lower River Severn is shown on **Figure 3-13**. This includes the mean concentration from the STT solution monitoring at Minworth WwTW final effluent (0.33 µg/l), diluted by 36% at point of discharge and showing a profile of further dilution of influence along the downstream flow pathway. Note that there is a step change down at the River Severn confluence as the River Severn adds significant additional flow that is not influenced by the Minworth Transfer. The mean concentrations (pertinent to the long term EQS of 0.3µg/l) from the STT solution monitoring of reference conditions at *Avon_above_Warwick*, *Avon_below_Warwick*, *Avon_Evesham*, *Avon_Twyning* and *Severn_Deerhurst* is shown, together with the concentration from addition of the Minworth Transfer under low river flow conditions at those sites. The outputs illustrate the Minworth Transfer would increase the concentration of Nonylphenols in the River Avon particularly in the 11km reach between the transfer outfall and the confluence with the River Leam. This would not lead to an increase in concentration of Nonylphenols in the River Avon sufficient to exceed the long-term EQS value. It is noted that the Minworth Transfer would operate for around 15% of days overall and that is considered insufficient regularity to influence long term average concentrations in the river.

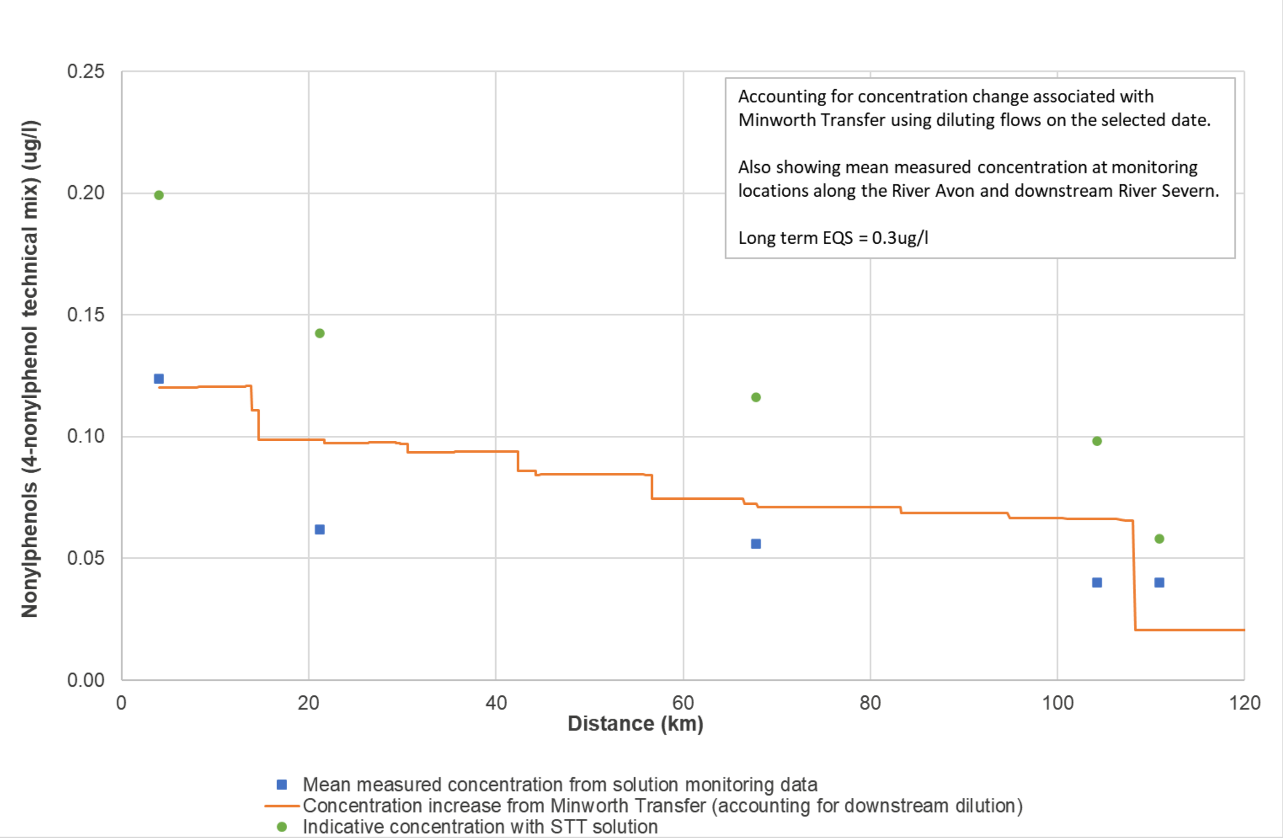

Figure 3-13 Longitudinal profile of Nonylphenols along Avon and lower Severn, scenario A82, 25th August

Cypermethrin is a priority substance under the WFD Regulations. It is a synthetic pyrethroid insecticide, used in the UK to control a range of pests in both arable and livestock farming, in homes and gardens, and in public and commercial buildings[16]. Cypermethrin concentration changes from point of discharge at a Minworth Transfer outfall along the River Avon and lower River Severn is shown on **Figure 3-14**. This includes the mean concentration from the STT solution monitoring at Minworth WwTW final effluent (0.00021 µg/l), diluted by 36% at point of discharge and showing a profile of further dilution of influence along the downstream flow pathway. The mean concentrations (pertinent to the long term EQS of 0.00008 µg/l) from the STT solution monitoring of reference conditions at *Avon_above_Warwick*, *Avon_below_Warwick*, *Avon_Evesham*,

[15] Environment Agency: REACH update, February 2021. REACH Annex 17, entry 46a: Nonylphenol Ethoxylates within the textile sector. https://brc.org.uk/media/677248/21_03_15_pdf-reach-anx-17-46a-textile-update-uk-ea.pdf

[16] Environment Agency (2019) Cypermethrin: Sources, pathways and environmental data. October 2019 https://consult.environment-agency.gov.uk/++preview++/environment-and-business/challenges-and-choices/user_uploads/cypermethrin-pressure-rbmp-2021.pdf

Avon_Twyning and *Severn_Deerhurst* is shown, together with the concentration from addition of the Minworth Transfer under low river flow conditions at those sites. The outputs illustrate the Minworth Transfer would increase the concentration of cypermethrin in the River Avon, a deterioration of the current quality. Mean values calculated from the reported concentrations of cypermethrin indicate EQS failure in much of the River Avon and that the Minworth Transfer could impede the reduction in concentration to EQS pass. It is noted that the Minworth Transfer would operate for around 15% of days overall and that for cypermethrin that could be sufficient regularity to influence long term average concentrations in the river.

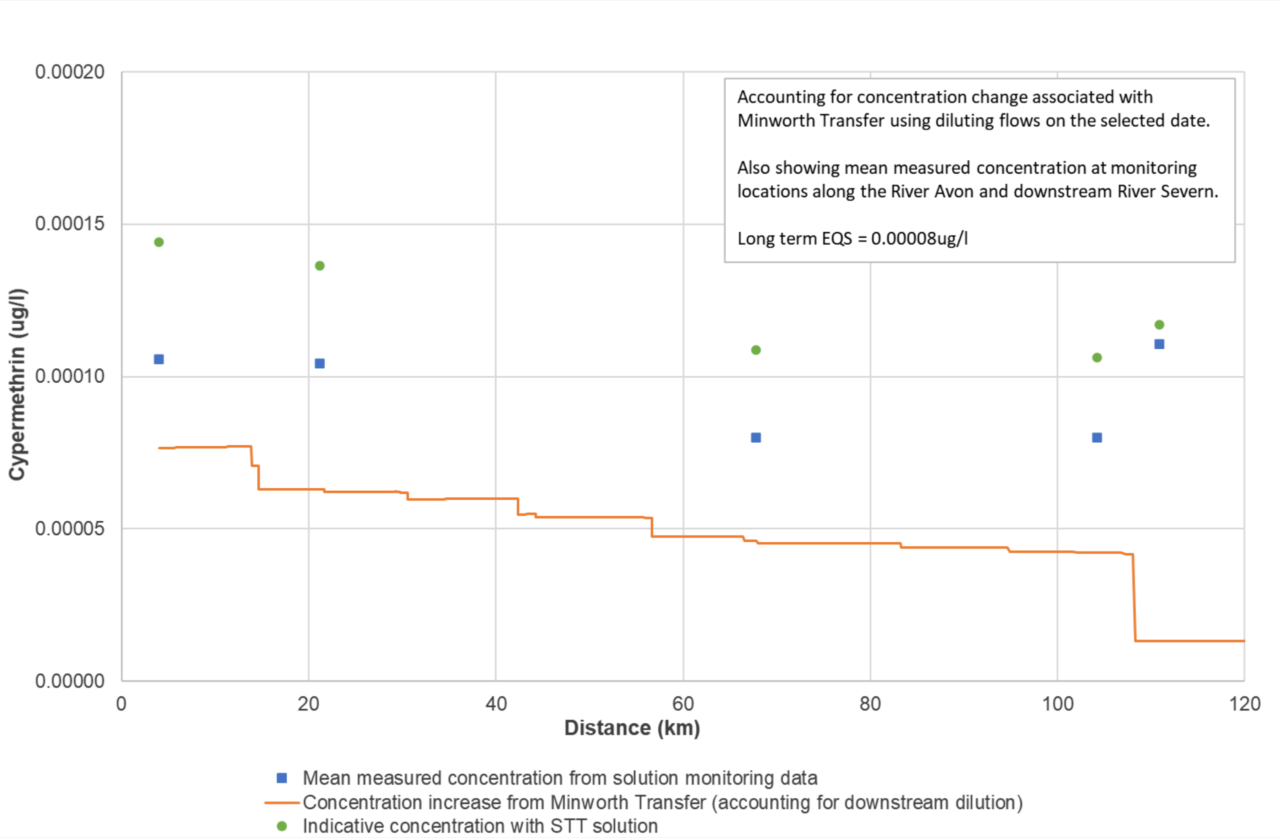

Figure 3-14 Longitudinal profile of Cypermethrin along Avon and lower Severn, scenario A82, 25th August

Perfluorooctane sulfonate (PFOS) and related substances are a priority hazardous substance under the Priority Substances Directive (2013/39/EU) and most uses are phased out, banned or restricted in the UK[17]. They are extremely persistent, toxic and bioaccumulating chemicals that belong to a large, diverse group of man-made substances known for their water, grease and stain repellent properties[18]. PFOS concentration change from point of discharge at a Minworth Transfer outfall along the River Avon and lower River Severn is shown on **Figure 3-15**. This includes the mean concentration from the STT solution monitoring at Minworth WwTW final effluent (0.0194 µg/l), diluted by 36% at point of discharge and showing a profile of further dilution of influence along the downstream flow pathway. The mean concentrations (pertinent to the long term EQS of 0.00065µg/l) from the STT solution monitoring of reference conditions at *Avon_above_Warwick*, *Avon_below_Warwick*, *Avon_Evesham*, *Avon_Twyning* and *Severn_Deerhurst* is shown, together with the concentration from addition of the Minworth Transfer under low river flow conditions at those sites. Mean values calculated from the reported concentrations of PFOS indicate EQS failure by an order of magnitude throughout the River Avon study reach. The model outputs illustrate the Minworth Transfer would increase the concentration of PFOS in the River Avon, a deterioration of the current quality. Throughout the River Avon in the study reach, the Minworth Transfer could impede the reduction in concentration to EQS pass. It is noted

[17] Environment Agency (2021) Perfluorooctane sulfonate (PFOS) and related substances: challenges for the environment https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1027501/PFOS-challenges-for-the-water-environment.odt

[18] Environment Agency (2019) Perfluorooctane sulfonate (PFOS) and related substances: sources, pathways and environmental data https://consult.environment-agency.gov.uk/environment-and-business/challenges-and-choices/user_uploads/perfluorooctane-sulfonate-and-related-substances-pressure-rbmp-2021.pdf

that the Minworth Transfer would operate for around 15% of days overall and that for PFOS that could be sufficient regularity to influence long term average concentrations in the river.

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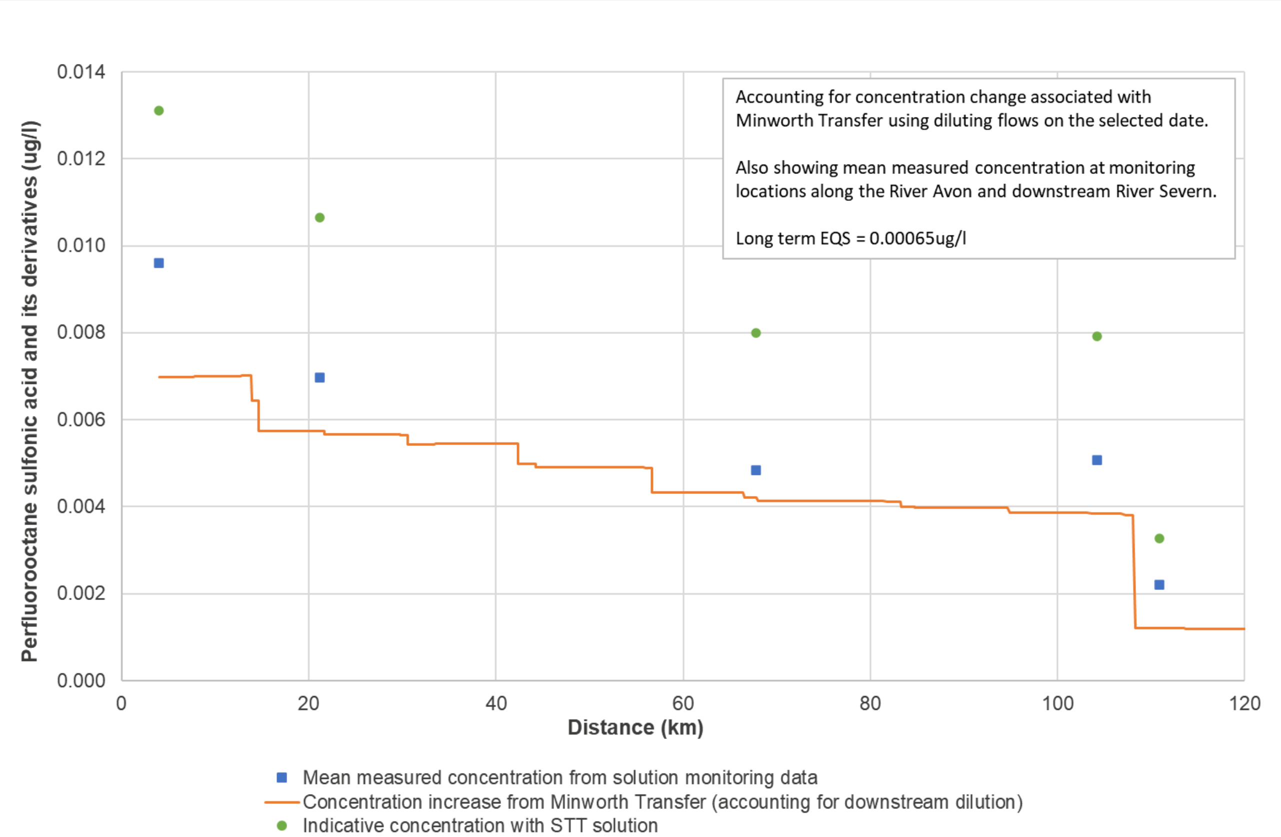

Figure 3-15 Longitudinal profile of Perfluorooctane sulfonic acid and its derivatives along Avon and lower Severn, scenario A82, 25th August

Permethrin is a specific pollutant under the WFD Regulations. It is a synthetic pyrethroid insecticide with a wide range of uses[19] including agriculture and medicine. Permethrin concentration changes from point of discharge at a Minworth Transfer outfall along the River Avon and lower River Severn is shown on **Figure 3-16**. This includes the mean concentration from the STT solution monitoring at Minworth WwTW final effluent (0.003 µg/l), diluted by 36% at point of discharge and showing a profile of further dilution of influence along the downstream flow pathway. The mean concentrations (pertinent to the long term EQS of 0.001 µg/l) from the STT solution monitoring of reference conditions at *Avon_above_Warwick*, *Avon_below_Warwick*, *Avon_Evesham*, *Avon_Twyning* and *Severn_Deerhurst* is shown, together with the concentration from addition of the Minworth Transfer under low river flow conditions at those sites. Mean values calculated from the reported concentrations of permethrin indicate EQS failure in the initial 25km of the modelled study area downstream of the River Sowe confluence – with four of 16 reported values at *Avon_above_Warwick* and two of 16 reported values at *Avon_below_Warwick* greater than the limit of detection which mirrors the EQS. The model outputs illustrate the Minworth Transfer would increase the concentration of permethrin in the River Avon, a deterioration of the current quality. For the assessment points *Avon_above_Warwick*, and *Avon_below_Warwick*, the Minworth Transfer could impede the reduction in concentration to EQS pass. It is noted that the Minworth Transfer would operate for around 15% of days overall and that for permethrin that could be sufficient regularity to influence long term average concentrations in the river. At downstream assessment points in the River Avon, the reported data indicate EQS pass (with no reported detection of permethrin) and maintenance of EQS pass with Minworth Transfer, albeit with medium confidence.

[19] Environment Agency / SNIFFER (2007) Proposed EQS for Water Framework Directive Annex VIII substances: permethrin. Science Report: SC040038/SR11. SNIFFER Report: WFD52(xi) https://www.wfduk.org/sites/default/files/Media/permethrin.pdf

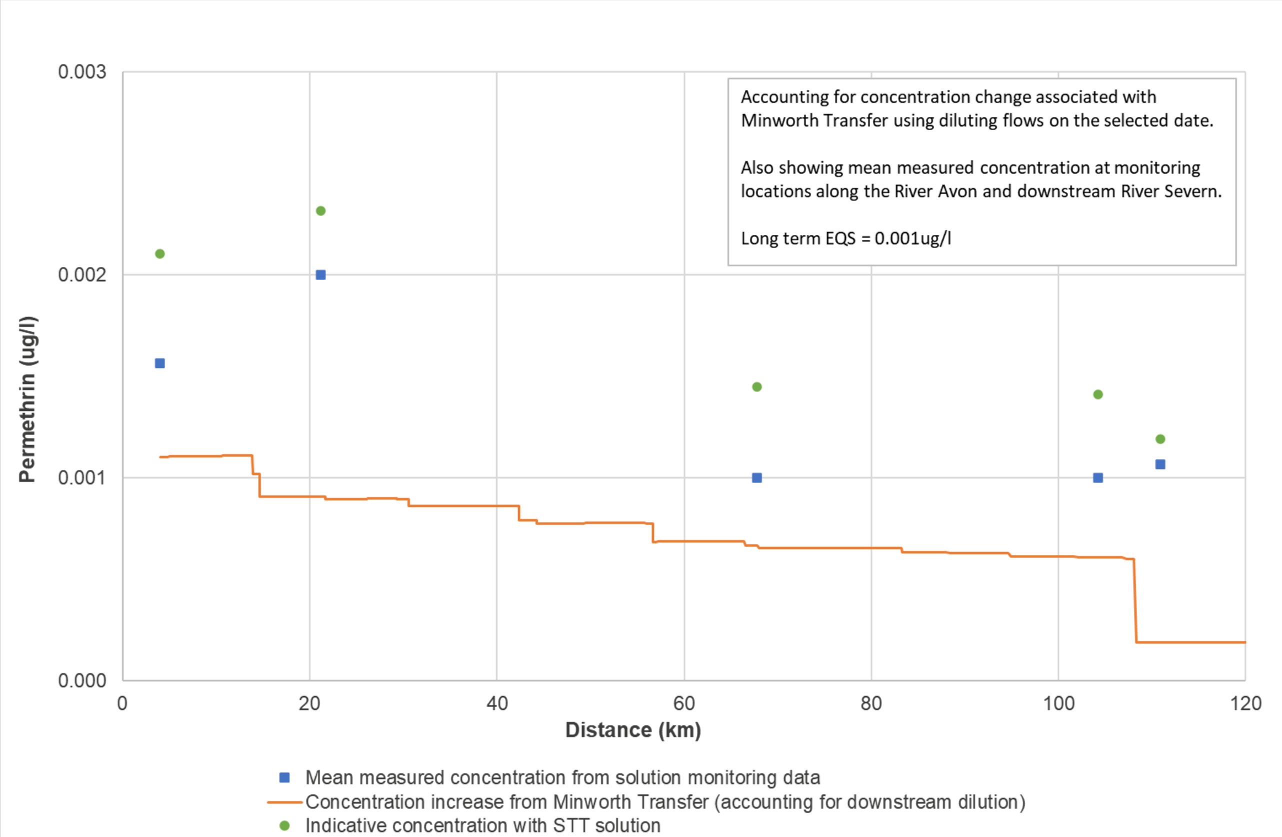

Figure 3-16 Longitudinal profile of Permethrin along Avon and lower Severn, scenario A82, 25th August

The review also identified that there are post advanced treatment risks to proposed targets associated with four of the other permitting chemicals: Cobalt (dissolved), EDTA, Mancozeb, Omethoate. Permitting considerations are not a requirement of Gate 2 SRO assessments and this is noted here for information only.

3.5.2.3 Change to Olfaction

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#olfaction'

An initial categorisation of the pre-treatment risk of potential olfactory inhibitors associated with the Minworth Transfer has been undertaken. It is important to note that the Minworth SRO at Gate 2 is proposed to include the advanced treatment processes set out in Section 2.3.4. The initial risk categorisation in Table 3-7 is without consideration of that treatment. It is noted, as above, that of the risk chemicals, the Gate 2 proposed treatment units would have good removal efficiency for mercury, nickel, isoproturon and triclosan; and limited efficacy for chromium (III), cobalt, cypermethrin and permethrin

Data for this assessment can be reviewed in the excel workbook STT_Chemical_Data_Viewer.xlsm on the tab name '#olfaction' by choosing *Avon_Twyning* as the X-dataset in cell C4 and *Final_Effluent_Minworth_STW* as the Y-dataset in cell C5.

Table 3-7 Review of pre-treatment risk of chemicals of interest as olfactory inhibitors associated with the Minworth Transfer

From comparison of Minworth WwTW final effluent SRO monitoring site (2020/2021, typically 16 samples) concentration with River Avon at Twyning monitoring site (2021, typically 6 samples)

Substance potentially impacting olfaction	Reported in River Avon at Twyning	Reported in Minworth WwTW final effluent (prior to advanced treatment)	Notes
Aluminium (dissolved and total)	Detected	Detected	River concentrations higher than Minworth WwTW final effluent
Cadmium (dissolved and total)	Detected	Detected	River concentrations higher than Minworth WwTW final effluent
Chromium(III) (dissolved)	Not detected	Detected	Increased risk to River Avon effect on River Severn with Minworth Transfer
Chromium(VI) (dissolved)	Not detected	Detected	Increased risk to River Avon effect on River Severn with Minworth Transfer
Chromium (total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Cobalt (dissolved and total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Copper (dissolved and total)	Detected	Detected	River concentrations higher than Minworth WwTW final effluent
Iron (dissolved and total)	Detected	Detected	River concentrations higher than Minworth WwTW final effluent
Mercury (dissolved and total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Nickel (dissolved and total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Selenium (dissolved and total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Silver (dissolved and total)	Not detected	Not detected	
Zinc (dissolved and total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Pirimicarb	Not detected	Not detected	
Carbophenothion	Not detected	Not detected	
Chlorpyrifos	Not detected	Not detected	
Diazinon	Not detected	Not detected	Reduced risk to River Avon effect on River Severn with Minworth Transfer
Dichlorvos	Not detected	Not detected	
Fenitrothion	Not detected	Not detected	
Malathion	Not detected	Not detected	
Parathion	Not detected	Not detected	
Chlorotoluron	Not detected	Not detected	
Diuron	Not detected	Not detected	
Flucofuron	Not detected	Not detected	
Isoproturon	Not detected	Detected	Increased risk to River Avon effect on River Severn with Minworth Transfer
Linuron	Not detected	Not detected	
Monuron	Not detected	Not detected	
Sulcofuron	Not detected	Not detected	
Cyfluthrin	Not detected	Not detected	
Cypermethrin	Not detected	Detected	Increased risk to River Avon effect on River Severn with Minworth Transfer
Permethrin	Not detected	Detected	Increased risk to River Avon effect on River Severn with Minworth Transfer
Triclosan	Not detected	Detected	Increased risk to River Avon effect on River Severn with Minworth Transfer

3.5.3 STT operation - future climate

In comparison with the A82 scenario, the A82 Future scenario would include a 40% longer period of flow augmentation releases - with extensions 35 days earlier, to include late May and all of June; and also 36 days later, to include all of October and the first half of November. The increase in regularity of the need for STT support options in late spring, early summer and later into autumn is a significant change.

This section sets out the findings of the effect of the STT solution operation during future climate conditions.

3.5.3.1 Change to general water quality

The futures assessment of general water quality is an assessment of the change in dilution only. It does not account for future climate temperature changes nor changes to pollutant load in the future.

Under Scenario A82F, the predicted water quality in the River Avon is very similar to that predicted under A82 and M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for A82/M96 in the upper part of the River Avon occurs over a longer period, the peak changes in concentrations are very similar to A82/M96 for all parameters. [Workbooks [1] [2] [3] and [4] – tabs 'Temp', 'DO,'NH4 and 'P']. Note that the simulations only changed the Avon, Severn and tributary flows; the water quality data for all inputs and sewage works flows remained the same in all simulations.

3.5.3.2 Change to chemicals

The futures assessment of chemicals is an assessment of the change in dilution of the currently legislated chemicals (WFD and other permitted chemicals with operational EQS) at their current concentrations. As such, the assessment is not of emerging chemicals (which may be added for Gate 3 assessment) or of the change in contamination level of the currently legislated chemicals due to future patterns of use.

The change in dilution rates in the River Avon has been modelled. This shows around a 10% reduction in dilution capacity along the River Avon. With review of concentrations of the three key chemicals identified in the current climate assessment (cypermethrin, PFOS and permethrin) this leads to around a 2-3% increase in concentration downstream of the Minworth Transfer discharge. It is considered that the increased duration of operation of a Minworth Transfer is more significant in terms of effects on long-term water quality than the magnitude of the concentration increase.

3.5.3.3 Change to Olfaction

As the assessment of olfaction risk for the current climate conditions in Section 3.5.2.3 is based on discharge rather than dilution, there is no change in the olfaction risk based on future river flows.

3.6 THE RIVER SEVERN FROM THE CONFLUENCE WITH THE RIVER AVON TO DEERHURST

This reach is 2.6km long and with no significant inputs other than the River Severn and the River Avon. This assessment has been informed using the STT solution River Severn catchment linked hydraulic-water quality model.

3.6.1 Baseline

This section describes baseline conditions using measured and modelled evidence presented in the Environmental Water Quality Evidence Report.

3.6.1.1 General water quality

This section is supported by charts and data in the following excel workbooks. , part of the Evidence Report. The reader is advised to look at the stated workbook tab when reading the text in order to see the accompanying chart(s):
[5] SevernAtDeerhurstUsOfftake.xlsm

In the River Severn upstream of Deerhurst, water temperature is predicted to vary seasonally between 6 and 20°C [Workbook [5] – tab 'Temp'].

Dissolved oxygen concentrations vary seasonally between 8.5 and 14 mg/l, with the higher values occurring in the winter. During the period of scheme operation, this is 85–100%sat [Workbook [5] – tab 'DO'].

Ammoniacal nitrogen concentrations are in the range of 0.04 – 0.18 mg/l, with no obvious seasonal variation [Workbook [5] – tab 'NH4'].

Soluble reactive phosphate concentrations are in the range of 0.1 – 0.4 mg/l, with the lowest values in the winter [Workbook [5] – tab 'P'].

3.6.1.2 Chemicals

Baseline chemical quality in this reach is described using the pan-SRO chemical monitoring point *Severn_Deerhurst*, described in Section 3.7.1.2.

3.6.1.3 Olfaction

Baseline quality of chemicals linked to olfaction inhibition in this reach is described using the pan-SRO chemical monitoring point *Severn_Deerhurst*, described in Section 3.7.1.3.

3.6.2 STT operation – current climate

In this reach, the STT solution would augment flows through a 25 Ml/d direct release from Vyrnwy Reservoir; an additional 155 Ml/d Vyrnwy bypass release at the confluence of the Weir Brook with the River Severn (upstream of Montford); an abstraction reduction at the Shelton intake at Shrewsbury; and a 115 Ml/d advanced treated effluent transfer from Minworth WwTW at selected times. Accounting for flow losses in the river systems, the STT solution flow augmentation in this reach would be up to 287 Ml/d. The indicative system operation pattern was identified from stochastic data, as described in **Section 1.3,** and shown as blue periods on **Figure 1.4**. It describes a typical pattern of the STT operation for river flow augmentation. Of these flow augmentation releases, only the Minworth Transfer, indirectly, has the potential for amending water quality in this reach.

3.6.2.1 Change to general water quality

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report. The reader is advised to look at the stated workbook tab when reading the text in order to see the accompanying chart(s):
[5] SevernAtDeerhurstUsOfftake.xlsm

In the River Severn upstream of Deerhurst, water temperature is not predicted to change due to the scheme [Workbook [5] – tab 'Temp'].

Dissolved oxygen concentrations are predicted to change by around 0.1 mg/l (~1% saturation) due to the scheme [Workbook [5] – tab 'DO'].

Ammoniacal nitrogen concentrations are predicted to change by a maximum of 0.006 mg/l due to the scheme, compared to a baseline range of 0.04-0.18 mg/l. [Workbook [5] – tab 'NH4'].

Soluble reactive phosphate concentrations are predicted to be reduced by up to 0.05 mg/l during the operation of the scheme [Workbook [5] – tab P'].

3.6.2.2 Change to chemicals

With regards the Minworth Transfer, Section 3.5.2.2 reviewed four WFD chemicals at risk of quality deterioration at point of discharge and downstream in the River Avon. Data for this assessment can be reviewed in the excel workbook STT_Chemical_Data_Viewer.xlsm on the tab name '#WFD_chem' by choosing *Severn_Deerhurst* as the X-dataset in cell C4 and *Avon_Twyning* as the Y-dataset in cell C5. The carry-forward of that risk from the River Avon into the River Severn is assessed utilising the modelled conservative tracer analysis presented for each of these chemicals in Section 3.5.2.2 for the Severn at Deerhurst monitoring point:

- Nonylphenols: Mean values calculated from the reported concentrations indicate EQS pass at Deerhurst, with nonylphenols not detected at the *Severn_Deerhurst* monitoring site. A concentration increase could be associated with the Minworth Transfer during the 15% of time that transfer would be in operation, but that would not lead to EQS failure.

- Cypermethrin: Mean values calculated from the reported concentrations indicate EQS fail at the *Severn_Deerhurst* monitoring site, with four of the 15 reported values greater than the limit of detection which mirrors the EQS. A concentration increase could be associated with the Minworth Transfer but during the 15% of time that transfer would be in operation, this is considered with medium confidence to not lead to long-term deterioration in quality or impeding achievement of targets as the main pressures to the reach lie with the upstream River Severn, not the River Avon.

- Perfluorooctane sulfonic acid and its derivatives: Mean values calculated from the reported concentrations indicate routine EQS fail at the *Severn_Deerhurst* monitoring site. A concentration increase could be associated with the Minworth Transfer and it is considered with medium confidence to potentially impede achievement of targets in the lower River Severn where the River Avon is a significant pressure to PFOS concentration in the downstream River Severn.

- Permethrin: Mean values calculated from the reported concentrations indicate EQS fail at the *Severn_Deerhurst* monitoring site, with one of the 15 reported values greater than the limit of detection which mirrors the EQS. A concentration increase could be associated with the Minworth Transfer but during the 15% of time that transfer would be in operation, this is considered with medium confidence to not lead to long-term deterioration in quality or impeding achievement of targets, noting the very low detection rate at the assessment point.

3.6.2.3 Change to Olfaction

An initial categorisation of the pre-treatment risk of potential olfactory inhibitors associated with the Minworth Transfer relevant to this short reach has been undertaken in Section 3.5.2.3.

3.6.3 STT operation - future climate

This section sets out the findings of the effect of the STT solution operation during future climate conditions.

3.6.3.1 Change to general water quality

The futures assessment of general water quality is an assessment of the change in dilution only. It does not account for future climate temperature changes nor changes to pollutant load in the future.

Under Scenario A82F, the predicted water quality in the River Severn between the River Avon confluence and Deerhurst is very similar to that predicted under A82 and M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for A82F in this sub-reach occurs over a longer period, the peak changes in concentrations are very similar to A82/M96 for all parameters. [Workbook [5]– tabs 'Temp', 'DO,'NH4' and 'P'].

It is noted that for the Severn Estuary, sea level rise 2100 RCP8.5 UKCIP[20] is between 0.51m (5th percentile) and 1.13m (5th percentile). At Deerhurst River Severn water level varies in a normal range between 6.5m and 10.5m AoD[21]. Projected 2100 sea level rise will not be enough to induce brackish conditions at Deerhurst. However, Severn Bore events may be greater intensity, and high suspended sediment concentrations associated with the bore could influence operational controls at the Deerhurst intake for the STT solution.

3.6.3.2 Change to chemicals

The futures assessment of chemicals is an assessment of the change in dilution of the currently legislated chemicals (WFD and other permitted chemicals with operational EQS) at their current concentrations. As such the assessment is not of emerging chemicals (which may be added for Gate 3 assessment) or of the change in contamination level of the currently legislated chemicals due to future patterns of use.

The change in dilution rates in the River Severn has been modelled. This shows limited change in dilution capacity along the River Severn compared with current climate conditions. It is considered that the increased duration of operation of a Minworth Transfer is more significant in terms of effects on long-term water quality than the magnitude of the concentration increase.

3.6.3.3 Change to Olfaction

As the assessment of olfaction risk for the current climate conditions in Section 3.5.2.3 is based on discharge rather than dilution, there is no change in the olfaction risk based on future river flows.

3.7 THE RIVER SEVERN FROM DEERHURST TO THE TIDAL LIMIT AT GLOUCESTER

The area of interest extends about 12.5 km from Deerhurst to the normal tidal limit of the main channel of the River Severn at Maisemore Weir. There are no major inputs included in the assessment for this reach. Under the STT solution, an outfall transferring effluent from Netheridge WwTW would be located near Haw Bridge, 3.9 km downstream of the location of the proposed abstraction point for the STT interconnector pipeline

[20] https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/summaries/headline-findings
[21] https://check-for-flooding.service.gov.uk/station/2078

transfer. This assessment has been informed using the STT solution River Severn catchment linked hydraulic-water quality model.

3.7.1 Baseline

This section describes baseline conditions using measured and modelled evidence presented in the Environmental Water Quality Evidence Report.

3.7.1.1 General water quality

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report. The reader is advised to look at the stated workbook tab when reading the text in order to see the accompanying chart(s): [6] SevernAtDeerhurstDsOfftake.xlsm [7] SevernAtModelEnd.xlsm

In the River Severn downstream of Deerhurst and at the tidal limit, water temperature is predicted to vary seasonally between 6 and 20°C [Workbooks [6] and [7] – tab 'Temp'].

Dissolved oxygen concentrations vary seasonally between 8.5 and 14 mg/l, with the higher values occurring in the winter, at both locations. During the period when the scheme would be operating, the concentration is between 85%sat and 100%sat. [Workbooks [6] and [7] – tab 'DO']

Ammoniacal nitrogen concentrations are in the range of 0.04 – 0.18 mg/l, with no obvious seasonal variation [Workbooks [6] and [7] – tab 'NH4'].

Soluble reactive phosphate concentrations are in the range of 0.1 – 0.4 mg/l, with the lowest values in the winter [Workbooks [6] and [7]] – tab 'P']'.

3.7.1.2 Chemicals

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#WFD_chem'

Data for one site in the River Severn are available from the pan-SRO chemical monitoring programme, with up to 16 datapoints per determinand per site collected in 2020/2021. The site, available to be selected using the pick-from-list menus on cells C4 or C5 is: Severn_Deerhurst.

Monitoring data have been reviewed against environmental quality standards (EQS) set out in the WFD Regulations[22]. This is summarised in **Table 3-8** for the site representing the receiving water quality for a Netheridge Transfer for both short term (either maximum values or 95 percentiles) and long term (mean) EQS, where these are applicable. It is noted that this is not a WFD status statement as that is undertaken by the EA using EA sampling and analysis at specified WFD monitoring locations within WFD water bodies.

The STT solution monitoring data indicate that the River Avon upstream of Warwick does not achieve EQS for 6 WFD chemicals, with one chemical without suitable data for analysis. For nine chemicals the assessment is incomplete as the laboratory limit of detection is higher than the EQS; however, for nine of these chemicals all reported values were less than the limit of detection used. The exception is Chromium (VI) dissolved for which there was one detected result greater than limit of detection, noting there is only a long term EQS for that chemical.

[22] Schedule 3 of The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015;

Table 3-8 Review of measure baseline for WFD chemicals against EQS at the Severn at Deerhurst SRO monitoring site (2020/2021, typically 15 samples)

1,2-dichloroethane	cyanide total	mecoprop
2,4-dichlorophenol	cybutryne (Irgarol)	mercury dissolved
2,4-dichlorophenoxyacetic acid (2,4-D)	cypermethrin	methiocarb
3,4-dichloroaniline	DDT total	naphthalene
Aclonifen	di(2-ethylhexyl)phthalate (DEHP)	nickel dissolved
Alachor	diazinon	nonylphenols
Aldrin	dichloromethane	octylphenols
Anthracene	dichlorvos	PBDEs
arsenic total	dicofol	pendimethalin
Atrazine	dieldrin	pentachlorobenzene
Benzene	dimethoate	pentachlorophenol
benzo(a)pyrene	diuron	perfluorooctane sulfonic acid and its derivatives
benzo(b)fluoranthene	endosulfan	permethrin
benzo(g,h,i)perylene	endrin	phenol
benzo(k)fluoranthene	fluoranthene	polycyclic aromatic hydrocarbons (PAH) sum
benzyl butyl phthalate	glyphosate	quinoxyfen
Bifenox	heptachlor and heptachlor epoxide	simazine
C10-13 chloroalkanes (total)	hexabromocyclododecane (HBCDD)	terbutryn
cadmium total	hexachlorobenzene	tetrachloroethane
carbendazim	hexachlorobutadiene	tetrachloroethylene
carbon tetrachloride	hexachlorocyclohexane	toluene
chlorfenvinphos	indeno(1,2,3-cd)pyrene	tributyltin compounds (as tributyltin cation)
chlorine total	iron dissolved	trichlorobenzenes
chlorothalonil	isoproturon	trichloroethylene
chlorpyrifos (chlorpyrifos-ethyl)	lead dissolved	trichloromethane (chloroform)
chromium (III) dissolved	lead dissolved	triclosan
chromium (VI) dissolved	linuron	trifluralin
copper dissolved	manganese dissolved	zinc dissolved

Legend:

All reported values achieve applicable EQS
Reported values identify short-term EQS not achieved
Reported values identify long-term EQS not achieved
Reported values identify neither short-term or long-term EQS achieved
Limit of detection used does not enable full comparison of reported data with EQS
No data for analysis

3.7.1.3 Olfaction

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#olfaction'

The scope of works identifies the potential effect of the STT solution on inhibiting olfaction of migratory fish as applicable only to functionally linked habitat associated with the Severn Estuary Special Area of Conservation. This reach of the River Severn is directly relevant to the assessment. Olfactory inhibitors have been included in the analysis of the STT solution monitoring site on the Severn at Deerhurst as an indicator of the current influence on migratory routes through the lower River Severn. The detected presence or absence of the selected list of chemicals is summarised in **Table 3-9**. It is noted that the concentration at which individual or groups of chemicals may be disruptive to individual relevant migratory fish species are poorly understood, as is the potential role of bioaccumulation, laboratory limits of detection are not a guide to absence of influence of a chemical, and nor is detected presence of chemical a reliable guide to presence of influence.

Table 3-9 Review of measured baseline chemicals of interest as olfactory inhibitors at the Severn at Deerhurst monitoring site (2020/2021, typically 15 samples)

Group	Specific substance	
Metals	Aluminium (dissolved and total)	Iron (dissolved and total)
	Cadmium (dissolved and total)	Mercury (dissolved and total)
	Chromium(III) (dissolved)	Nickel (dissolved and total)
	Chromium(VI) (dissolved)	Selenium (dissolved and total)
	Chromium (total)	Silver (dissolved and total)
	Cobalt (dissolved and total)	Zinc (dissolved and total)
	Copper (dissolved and total)	
Carbamate pesticides	Methiocarb	Pirimicarb
	Oxamyl	
Organophosphate pesticides	Carbophenothion	Fenitrothion
	Chlorpyrifos	Malathion
	Diazinon	Parathion
	Dichlorvos	
Phenylurea pesticides	Chlorotoluron	Linuron
	Diuron	Monuron
	Flucofuron	Sulcofuron
	Isoproturon	
Pyrethroid pesticides	Cyfluthrin	Permethrin
	Cypermethrin	
Alkylbenzene-sulfonates	C10-C14 alkyl benzene sulphonic acids	Linear sodium Dodecylbenzene sulfonate
	Branched sodium Dodecylbenzene sulfonate	Sodium tridecylbenzene sulfonate
	Calcium Dodecylbenzene sulfonate	Triethanolammonium dodecylbenzene sulfonate
Diamines	1,6-hexanediamine	
Quaternary Ammonium Salts	Benzalkonium chlorides	Lauryldimethylbenzyl ammonium chloride
	Di(hydrogenated tallow)dimethylammonium chloride	Stearyldimethylbenzyl ammonium chloride
	Dodecylammonium chloride	
Endocrine disrupting chemicals, including pharmaceuticals	Triclosan	19-norethindrone
	17α – ethinylestradiol (EE2)	Norgestrel
	17 ß-estradiol (E2)	Bisphenol A, S and F
	4-nonylphenol	Ibuprofen
	Trenbolone (TB)	Ethinylestradiol
	Chlorophene	Raloxifene
	Hydroxymetabolites of vinclozolin (VZ)	Bifenthrin
	Dibutylbenzyle phthalate (DBP)	Levonorgestrel
	Flutamide	

Legend:

All reported values less than limit of detection used
Substance detected in analysis
No data for analysis at Gate 2

3.7.2 STT operation – current climate

In this reach, the STT solution would abstract flow for transfer in the STT interconnector. As well as the patterns of abstraction described in **Section 1.3** and illustrated as the blue and purple periods of the 47 water resources years in **Figure 1.4**, there would be flow augmentation releases from advanced treated wastewater transfer from Netheridge WwTW to the River Severn upstream Haw Bridge. Of the flow augmentation releases, only the Minworth Transfer (indirectly) and the Netheridge Transfer (directly) have the potential for amending water quality in this reach.

3.7.2.1 Change to general water quality

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report. The reader is advised to look at the stated workbook tab when reading the text in order to see the accompanying chart(s):
[6] SevernAtDeerhurstDsOfftake.xlsm
[7] SevernAtModelEnd.xlsm

In the River Severn downstream of Deerhurst (upstream of the Netheridge discharge) and at the tidal limit, the scheme is predicted to reduce water temperature by 0.2°C (A82) and 0.3°C (M96) [Workbooks [6] and [7] – tab 'Temp'].

Dissolved oxygen concentrations are predicted to be reduced by about 0.1 mg/l at both sites (a reduction of less than 1%sat) [Workbooks [6] and [7] – tab 'DO'].

Ammoniacal nitrogen concentrations are predicted to be increased by about 0.02 mg/l at both sites [Workbooks [6] and [7] – tab 'NH4'].

Soluble reactive phosphate concentrations are predicted to be reduced by up to 0.02 mg/l during the operation of the scheme at both sites [Workbooks [6] and [7] – tab 'P'].

3.7.2.2 Change to chemicals

With regards to the Minworth Transfer, Section 3.6.2.2 reviews four WFD chemicals which are at risk of causing water quality deterioration in the River Severn downstream of the River Avon. The carry-forward of that risk downstream of the STT solution intake at Deerhurst remains as described in Section 3.6.2.2 as abstraction itself does not change in-river concentrations.

With regards the Netheridge Transfer and the planned advanced treatment processes included in the Severn Trent Sources SRO Gate 2 scheme. Following review by Severn Trent Sources SRO, for those chemicals with an EQS, there would be no change in concentration from EQS pass to EQS fail; no reduction in quality where there is EQS pass; no further reduction in quality where there is currently EQS fail; and for chemicals with current EQS fail, no impediments to achieving EQS pass. The review has been undertaken using River Severn at Deerhurst chemical concentrations and post-removal treatment efficacy from Severn Trent Sources SRO engineers, and is without recourse to the minimum 1:37 dilution rate of the River Severn at the Netheridge Transfer outfall. Treatment efficacy relates to the treatment train set out in Section 2.3.3 and is the efficacy set out in the Severn Trent Sources SRO Conceptual Design Report.

3.7.2.3 Change to Olfaction

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#olfaction'

An initial categorisation of the pre-treatment risk of potential olfactory inhibitors associated with the Minworth Transfer has been undertaken against the local risk of presence of chemicals of interest as olfactory inhibitors in the lowest freshwater reaches of the River Severn. It is important to note that the Minworth SRO at Gate 2 is proposed to include the advanced treatment processes set out in Section 2.3.4. The initial risk categorisation in **Table 3-10** is without consideration of that treatment. It is noted, as above, that of the risk chemicals, the Gate 2 proposed treatment units would have good removal efficiency for mercury, nickel, isoproturon and triclosan; and limited efficacy for chromium (III), cobalt, cypermethrin and permethrin.

Data for this assessment can be reviewed in the excel workbook STT_Chemical_Data_Viewer.xlsm on the tab name '#olfaction' by choosing *Severn_Deerhurst* as the X-dataset in cell C4 and *Final_Effluent_Minworth_STW* as the Y-dataset in cell C5.

Table 3-10 Review of pre-treatment risk of chemicals of interest as olfactory inhibitors associated with the Minworth Transfer

From comparison of Minworth WwTW final effluent SRO monitoring site concentration with River Severn at Deerhurst monitoring site (both 2020/2021, typically 16 samples)

Substance potentially impacting olfaction	Reported in River Severn at Deerhurst	Reported in Minworth WwTW final effluent (prior to advanced treatment)	Notes
Aluminium (dissolved and total)	Detected	Detected	River concentrations higher than Minworth WwTW final effluent
Cadmium (dissolved and total)	Detected	Detected	River concentrations higher than Minworth WwTW final effluent
Chromium(III) (dissolved)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Chromium(VI) (dissolved)	Detected	Detected	River concentrations higher than Minworth WwTW final effluent
Chromium (total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Cobalt (dissolved and total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Copper (dissolved and total)	Detected	Detected	River concentrations higher than Minworth WwTW final effluent
Iron (dissolved and total)	Detected	Detected	River concentrations higher than Minworth WwTW final effluent
Mercury (dissolved and total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration

Nickel (dissolved and total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Selenium (dissolved and total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Silver (dissolved and total)	Not detected	Not detected	
Zinc (dissolved and total)	Detected	Detected	Minworth WwTW final effluent concentration higher than river concentration
Pirimicarb	Not detected	Not detected	
Carbophenothion	Not detected	Not detected	
Chlorpyrifos	Not detected	Not detected	
Diazinon	Detected	Not detected	Reduced risk to River Severn with Minworth Transfer
Dichlorvos	Not detected	Not detected	
Fenitrothion	Not detected	Not detected	
Malathion	Not detected	Not detected	
Parathion	Not detected	Not detected	
Chlorotoluron	Not detected	Not detected	
Diuron	Not detected	Not detected	
Flucofuron	Not detected	Not detected	
Isoproturon	Not detected	Detected	Increased risk to River Severn with Minworth Transfer
Linuron	Not detected	Not detected	
Monuron	Not detected	Not detected	
Sulcofuron	Not detected	Not detected	
Cyfluthrin	Not detected	Not detected	
Cypermethrin	Detected	Detected	Increased risk to River Severn with Minworth Transfer
Permethrin	Detected	Detected	Increased risk to River Severn with Minworth Transfer
Triclosan	Not detected	Detected	Increased risk to River Severn with Minworth Transfer

3.7.3 STT operation - future climate

This section sets out the findings of the effect of the STT solution operation during future climate conditions.

3.7.3.1 Change to general water quality

The futures assessment of general water quality is an assessment of the change in dilution only. It does not account for future climate temperature changes nor changes to pollutant load in the future.

Under Scenario A82F, the predicted water quality in the River Severn downstream of Deerhurst is very similar to that predicted under A82 and M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for A82F in this sub-reach occurs over a longer period, the peak changes in concentrations are very similar to A82/M96 for all parameters. [Workbooks [6] and [7]– tabs 'Temp', ‘DO,’NH4’ and ‘P’].

3.7.3.2 Change to chemicals

The futures assessment of chemicals is an assessment of the change in dilution of the currently legislated chemicals (WFD and other permitted chemicals with operational EQS) at their current concentrations. As such, the assessment is not of emerging chemicals (which may be added for Gate 3 assessment) or of the change in contamination level of the currently legislated chemicals due to future patterns of use.

The change in dilution rates in the River Severn has been modelled. This shows limited change in dilution capacity along the River Severn compared with current climate conditions. It is considered that the increased duration of operation of a Minworth Transfer is more significant in terms of effects on long-term water quality than the magnitude of the concentration increase.

3.7.3.3 Change to Olfaction

As the assessment of olfaction risk for the current climate conditions in Section 3.7.2.3 is based on discharge rather than dilution, there is no change in the olfaction risk based on future river flows.

3.8 THE SEVERN ESTUARY DOWNSTREAM OF THE TIDAL LIMIT AT GLOUCESTER

The Severn Estuary is one of Britain's largest estuaries. It covers 55,700 hectares, including 20,000 hectares of inter-tidal habitat and a 14.5 metre tidal range (one of the largest in the world). Its combination of immense tidal range and classic funnel shape make it unique in the UK and rare worldwide. The Severn and its ten sub-estuaries represent about seven percent of the UK's total estuary resource.

The tidal volume of the Severn Estuary on a spring tide at high water (14.5m) is circa 5.4 x 109 m^3. Tidal volume of the Severn estuary on a neap tide at high water (6.5m) drops to about 2.8 x 109 m^3.

The Severn is a fully mixed estuary and, given the tidal range, the estuary is 'tide dominated'. The outer estuary is polyhaline and when freshwater flows start to influence the salinity regime the estuary becomes mesohaline until freshwater inputs become dominant i.e. oligohaline.

3.8.1 Baseline

This section describes baseline conditions using measured and modelled evidence presented in the Environmental Water Quality Evidence Report.

3.8.1.1 General water quality

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report. The reader is advised to look at the stated workbook tab when reading the text in order to see the accompanying chart(s):. [7] SevernAtModelEnd.xlsm

In the River Severn at the tidal limit, river water temperature is predicted to vary seasonally between 6 and 20°C [Workbook [7] – tab 'Temp'].

Dissolved oxygen concentrations vary seasonally between 8.5 and 14 mg/l, with the higher values occurring in the winter, at both locations [Workbook [7] – tab 'DO'].

Ammoniacal nitrogen concentrations are in the range of 0.04 – 0.18 mg/l, with no obvious seasonal variation [Workbook [7] – tab 'NH4'].

Oxidised nitrogen (mostly comprising NO_3-N) is in the range of 3.0 – 6.8 mg/l with highest values during the summer. Dissolved inorganic nitrogen (DIN) is therefore in the range 3.1 – 8.0 mg/l [Workbook [7] – tabs 'NO3','NH4', 'NO2'].

3.8.1.2 Chemicals

Baseline chemical quality in this reach is described using the pan-SRO chemical monitoring point *Severn_Deerhurst*, described in Section 3.7.1.2.

3.8.1.3 Olfaction

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#olfaction'

The scope of works identifies the potential effect of the STT solution on inhibiting olfaction of migratory fish as applicable only to functionally linked habitat associated with the Severn Estuary Special Area of Conservation. The quality of the pass-forward flow from the freshwater River Severn to the Severn Estuary is directly relevant to the assessment. Olfactory inhibitors have been included in the analysis of the STT solution monitoring site on the Severn at Deerhurst as an indicator of the current quality passed forward from the lower River Severn to the Estuary. The detected presence or absence of the selected list of chemicals is summarised in Table 3-9. It is noted that the concentration at which individual or groups of chemicals may be disruptive to individual relevant migratory fish species are poorly understood, as is the potential role of bioaccumulation, laboratory limits of detection are not a guide to absence of influence of a chemical, and nor is detected presence of chemical a reliable guide to presence of influence.

3.8.2 STT operation – current climate

At the tidal limit, the residual effects on flow and water quality of the River Severn from flow augmentation and abstraction from the STT solution would be passed forward to the Severn Estuary. As well as the patterns of abstraction described in **Section 1.3** and illustrated as the blue and purple periods of the 47 water resources years in **Figure 1.4**, there would be flow augmentation releases from advanced treated wastewater transfer from Netheridge WwTW to the River Severn upstream Haw Bridge. Of the flow augmentation releases, only the Minworth Transfer (indirectly) and the Netheridge Transfer (directly) have the potential for amending water quality in the pass forward flow. Changes to the quantity of pass forward flow have the potential for interacting with tidal processes which drive salinity patterns within the Severn Estuary.

3.8.2.1 Change to general water quality

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report. The reader is advised to look at the stated workbook tab when reading the text in order to see the accompanying chart(s):
[7] SevernAtModelEnd.xlsm

In the River Severn at the tidal limit, the scheme is predicted to reduce water temperature by 0.2°C (A82) and 0.3°C (M96) [Workbook [7] – tab 'Temp'].

Dissolved oxygen concentrations are predicted to be reduced by about 0.1 mg/l for both scenarios [Workbook [7] – tab 'DO'].

Ammoniacal nitrogen concentrations are predicted to be increased by about 0.02 mg/l for both scenarios [Workbook [7] – tab 'NH4'].

Oxidised nitrogen is increased by about 0.8 mg/l during the scheme (~10% increase on baseline). DIN concentrations are increased by a similar amount [Workbook [7] – tabs 'NO3','NH4', 'NO2'].

Specific additional analysis has been undertaken in relation to DIN using the EA long term water quality monitoring point at Haw Bridge[23] for the 10 year period 2013-2022. The 117 data points identify DIN concentration as 5.65 mg-N/l with a standard deviation of 1.14 mg-N/l. Allowing for the expected removal rates of the Minworth SRO's advanced treatment processes for the Minworth Transfer, discharged concentration to the Avon could be 16.9mg-N/l. Allowing for the expected removal rates of the Severn Trent Sources SRO's advanced treatment processes for the Netheridge Transfer, discharged concentration to the Severn at Haw Bridge could be 15.8 mg-N/l. Modelled assessment identifies:

- For the full year of the A82 moderate-low flow year scenario, and including abstraction rates for full STT, this could lead to a decrease in annual DIN contribution from the freshwater River Severn to the Severn Estuary of 96 tonnes from a baseline of 15,369 tonnes – a reduction of 0.63%. This includes 192 tonnes/year load addition from Minworth Transfer and 67 tonnes/year addition from Netheridge Transfer; together with a 356 tonnes/year load reduction from STT abstraction. It is noted that under these circumstances at least a further 67 tonnes/year less DIN would be input into the Severn Estuary from Netheridge WwTW at the current outfall.
- For the full year of the M96 very low flow year scenario, and including abstraction rates for full STT, this could lead to a decrease in annual DIN contribution from the freshwater River Severn to the Severn Estuary of 112 tonnes from a baseline of 14,804 tonnes – a reduction of 0.76%. This includes 268 tonnes/year load addition from Minworth Transfer and 90 tonnes/year addition from Netheridge Transfer; together with a 470 tonnes/year load reduction from STT abstraction. It is noted that under these circumstances at least a further 90 tonnes/year less DIN would be input into the Severn Estuary from Netheridge WwTW at the current outfall.

As such there would be an overall reduction in DIN input from the freshwater River Severn and Netheridge WwTW combined into the Severn Estuary as result of STT solution.

3.8.2.2 Change to chemicals

With regards the Minworth Transfer, Section 3.6.2.2 reviews four WFD chemicals which are at risk of causing water quality deterioration in the River Severn downstream of the River Avon. The carry-forward of that risk into the tidal reach is assessed utilising the modelled conservative tracer analysis presented for each of these chemicals in Section 3.5.2.2 for the Severn at Deerhurst monitoring point:

- Nonylphenols: EQS for transitional waters match those for freshwaters[24]. Mean values calculated from the reported concentrations indicate EQS pass at Deerhurst, with nonylphenols not detected at

[23] https://environment.data.gov.uk/water-quality/view/sampling-point/MD-00025085

[24] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

the *Severn_Deerhurst* monitoring site. A concentration increase could be associated with the Minworth Transfer during the 15% of time that transfer would be in operation, but that would not lead to EQS failure at Deerhurst or in the pass-forward flow to the estuary. An initial review of load change passed forward to the Severn Estuary, based on the mean reported concentrations for *Final_Effluent_Minworth_STW* and accounting for partial re-abstraction at Deerhurst for STT solution, indicates an additional 3.6 - 5.0 kg/y for the moderate low flow and very low flow years respectively. As nonylphenols were not detected at the *Severn_Deerhurst* monitoring site this cannot be expressed as a proportion change.

- Cypermethrin: At 0.000008 µg/l, long term average, EQS for transitional waters are 1/10th that for freshwaters[25]. Mean values calculated from the reported concentrations indicate EQS fail at the *Severn_Deerhurst* monitoring site, with four of the 15 reported values greater than the limit of detection which mirrors the freshwater long term average EQS. A concentration increase could be associated with the Minworth Transfer but during the 15% of time that transfer would be in operation, this is considered with medium confidence to not lead to long-term deterioration in quality or impeding achievement of targets as the main pressures to the reach lie with the upstream River Severn, not the River Avon. An initial review of load change passed forward to the Severn Estuary, based on the mean reported concentrations for *Final_Effluent_Minworth_STW* and accounting for partial re-abstraction at Deerhurst for the STT solution, indicates an additional 2.2 – 3.1 g/y for the moderate low flow and very low flow years respectively. As cypermethrin was not regularly detected at the *Severn_Deerhurst* monitoring site this cannot be expressed as a proportion change.

- Perfluorooctane sulfonic acid and its derivatives: EQS for transitional waters are, at 0.00014 µg/l (long term average), tighter than for freshwaters. A mean value of 0.00221 µg/l s calculated from the reported concentrations indicate routine EQS fail at the *Severn_Deerhurst* monitoring site. A concentration increase could be associated with the Minworth Transfer and it is considered with medium confidence to potentially impede achievement of targets in the lower River Severn where the River Avon is a significant pressures to PFOS concentration in the downstream River Severn. An initial review of load change passed forward to the Severn Estuary, based on the mean reported concentrations for *Final_Effluent_Minworth_STW* and accounting for partial re-abstraction at Deerhurst for the STT solution, indicates an additional 0.21 – 0.29 kg/y for the moderate low flow and very low flow years respectively. Based on the mean reported concentrations for the *Severn_Deerhurst* monitoring site this represents a 3-5% increase during years when the STT solution would be in operation.

- Permethrin: At 0.0002µg/l, long term average, EQS for transitional waters are 1/5th that for freshwaters[26]. Mean values calculated from the reported concentrations indicate EQS fail at the *Severn_Deerhurst* monitoring site, with one of the 15 reported values greater than the limit of detection which mirrors the freshwater long term average EQS. A concentration increase could be associated with the Minworth Transfer but during the 15% of time that transfer would be in operation, this is considered with medium confidence to not lead to long-term deterioration in quality or impeding achievement of targets, noting the very low detection rate at the assessment point. An initial review of load change passed forward to the Severn Estuary, based on the mean reported concentrations for *Final_Effluent_Minworth_STW* and accounting for partial re-abstraction at Deerhurst for the STT solution, indicates an additional 33 - 46 g/y for the moderate low flow and very low flow years respectively. As permethrin was not regularly detected at the *Severn_Deerhurst* monitoring site this cannot be expressed as a proportion change.

A further four chemicals were listed in **Table 3-6** as potentially increasing form a Minworth Transfer into the River Avon, prior to additional consideration of permitting needs and additional treatment processes in Gate 3. Of these, HBCDD and terbutryn have more stringent EQS in the Severn Estuary than in the River Severn.

- HBCDD: EQS for transitional waters are, at 0.0008 µg/l (long term average), ½ that for freshwaters. The limit of detection used is lower than the transitional water EQS. A mean value of 0.00027 µg/l calculated from the reported concentrations indicate routine EQS pass at the *Severn_Deerhurst* monitoring site. Mean concentration at the *Final_Effluent_Minworth_STW*, prior to any reduction from Minworth SRO advanced treatment processes, is 0.0009 µg/l. A concentration increase could be

[25] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015
[26] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

associated with the Minworth Transfer in the River Avon but with the increased dilution downstream and lower concentration in the River Severn it is considered with medium confidence to not lead to EQS failure in the Severn Estuary. HBCDD is a flame retardant and its use, production, import and export are prohibited.

- Terbutryn: EQS for transitional waters are, at 0.0065 µg/l (long term average), 1/10th that for freshwaters. At 0.02 µg/l the limit of detection used is higher than the transitional water EQS. All reported concentrations at the *Severn_Deerhurst* monitoring site are less than the limit of detection. Fifteen of the 16 reported concentrations at the *Final_Effluent_Minworth_STW monitoring site are less than limit of detection*, prior to any reduction from Minworth SRO advanced treatment processes. Full analysis is impeded by the limit of detection. Terbutryn is a herbicide and its use is prohibited.

With regards the Netheridge Transfer and the planned advanced treatment processes included in the Severn Trent Sources SRO Gate 2 scheme. For those chemicals with an EQS, there would be no change in concentration that changes from EQS pass to EQS fail; no reduction in quality where there is EQS pass; no further reduction in quality where there is currently EQS fail; and for chemicals with current EQS fail, no impediments to achieving EQS pass. The review has been undertaken using River Severn at Deerhurst chemical concentrations and post-removal treatment efficacy from Severn Trent Sources SRO engineers, and is without recourse to the minimum 1:37 dilution rate of the River Severn at the Netheridge Transfer outfall.

3.8.2.3 Change to Olfaction

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#olfaction'

An initial categorisation of the pre-treatment risk of potential olfactory inhibitors associated with the Minworth Transfer has been undertaken against the local risk of presence of chemicals of interest as olfactory inhibitors in the lowest freshwater reaches of the River Severn in Table 3-10. It is important to note that the Minworth SRO at Gate 2 is proposed to include the advanced treatment processes set out in Section 2.3.4. The initial risk categorisation is without consideration of that treatment. It is noted, as above, that of the risk chemicals, the Gate 2 proposed treatment units would have good removal efficiency for mercury, nickel, isoproturon and triclosan; and limited efficacy for chromium (III), cobalt, cypermethrin and permethrin. Therefore, for those chemicals of interest as olfactory inhibitors which are included in the monitoring programme reported at Gate 2, water passed forward to the Severn Estuary is considered likely to be higher in concentration for:

- Chromium (III) and total
- Selenium
- Zinc
- Cypermethrin
- Permethrin.

It is also noted that for any of the chemicals of interest listed as detected in Table 3-10, principally metals, diazinon, isoproturon, cypermethrin, permethrin, triclosan, there would likely be a load increase in the pass forward flow to the Severn Estuary at times the STT solution operation includes the Minworth Transfer.

3.8.3 STT operation - future climate

This section sets out the findings of the effect of the STT solution operation during future climate conditions.

3.8.3.1 Change to general water quality

The futures assessment of general water quality is an assessment of the change in dilution only. It does not account for future climate temperature changes nor changes to pollutant load in the future, nor future changes to sea level.

Under Scenario A82F, the predicted water quality in the River Severn at the tidal limit is very similar to that predicted under A82 and M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for A82F in this sub-reach occurs over a longer period, the peak changes in concentrations are very similar to A82/M96 for all parameters. [Workbook [7]– tabs 'Temp', 'DO,'NH4', 'NO3' and 'NO2'].

3.8.3.2 Change to chemicals

The futures assessment of chemicals is an assessment of the change in dilution of the currently legislated chemicals (WFD and other permitted chemicals with operational EQS) at their current concentrations. As such, the assessment is not of emerging chemicals (which may be added for Gate 3 assessment) or of the change in contamination level of the currently legislated chemicals due to future patterns of use.

The change in dilution rates in the River Severn has been modelled. This shows limited change in dilution capacity along the River Severn compared with current climate conditions. It is considered that the increased duration of operation of a Minworth Transfer is more significant in terms of effects on long-term pass-forward water quality – including load - than the magnitude of the concentration increase.

3.8.3.3 Change to Olfaction

As the assessment of olfaction risk for the current climate conditions in Section 3.8.2.3 is based on discharge rather than dilution, there is no change in the olfaction risk based on future river flows.

3.9 RIVER THAMES DOWNSTREAM OF CULHAM TO TIDAL LIMIT AT TEDDINGTON

This assessment has been informed using the pan-SRO River Thames linked hydraulic-water quality model. The model extent is about 200 km from Cricklade to the tidal limit at Teddington. The area of interest for the STT solution extends from the STT solution flow augmentation point at Culham to the tidal limit at Teddington.

Flows from the following tributaries were included in the modelling used for the assessment:

- Ampney Brook
- River Churn
- River Cole
- River Coln
- River Ray
- River Leach
- River Windrush
- River Loddon
- River Evenlode
- River Cherwell
- River Ock
- Ginge Brook
- River Thame
- River Pang
- River Kennet
- River Wye
- The Cut
- Colne Brook
- River Colne
- River Wey
- River Mole/River Ember.

The model also includes Didcot Power station abstraction and discharge.

Wastewater treatment works which discharge directly to the River Thames were also included in water quality modelling. The following Thames Water wastewater treatment works which discharge directly or indirectly to the River Thames downstream of Culham are of particular importance for considering the effects of the STT Solution:

- Didcot STW
- Culham STW
- Benson STW
- Cholsey STW
- Goring STW
- Pangbourne STW
- Henley STW
- Hurley STW
- Marlow STW
- Slough STW
- Windsor STW.

Public water supply abstractions are also included in hydraulic modelling. In addition to the Thames Water abstraction in the middle River Thames at Farmoor (upstream of Culham), Thames Water, Affinity Water and South East Water abstractions in the lower River Thames which are of particular importance for considering the effects of the STT Solution are:

- Bray
- Datchet
- Sunnymeads
- Staines
- Egham
- Laleham/Littleton
- Chertsey
- Walton (Affinity Water)
- Walton (Thames Water)
- Hampton
- Surbiton.

3.9.1 Baseline

This section describes baseline conditions using measured and modelled evidence presented in the Environmental Water Quality Evidence Report.

3.9.1.1 General water quality

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report. The reader is advised to look at the stated workbook tab when reading the text in order to see the accompanying chart(s):
[8] ThamesAtCulhamDsOutfall.xlsm
[9] ThamesUsPang.xlsm
[10] ThamesUsDatchetIntake.xlsm

In the middle Thames at Culham and at downstream sites to Windsor, water temperature is predicted to vary seasonally between 7 and 17°C [Workbooks [8], [9] and [10] – tab 'Temp'].

Daily average dissolved oxygen saturation is modelled as always greater than 95% [Workbooks [8], [9] and [10] – tab 'DO'] with super-saturation a common feature.

Ammoniacal nitrogen concentrations are modelled in the range of 0.02 – 0.06 mg/l in the middle Thames at Culham [Workbook [8]– tab 'NH4']. This range increases downstream - 0.03 - 0.15 mg/l upstream of the River Pang [Workbook [9]– tab 'NH4'] and reduces again by Windsor [Workbook [10]– tab 'NH4'], where the range is similar to at Culham.

Phosphorus concentrations are in the range of 0.12 – 0.35 mg/l in the middle Thames at Culham [Workbook [8]– tab 'P'] increasing in range downstream to 0.15 – 0.57 mg/l at the middle Thames sites and at Windsor [Workbooks [9] and [10] – tab 'P'].

Spot monitoring data from the pan-SRO monitoring programme 2020-2021 identify a pH range in the middle Thames at Culham of 7.9 - 8.4 (mean 8.1). The hardness of the middle Thames at Culham is categorised as very hard with mean 289 mg/l $CaCO_3$ (range 223-317 mg/l $CaCO_3$). Acid neutralising capacity is very low at 24mg/l.

3.9.1.2 Chemicals

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#WFD_chem'

Data for one site in the River Thames are available from the pan-SRO chemical monitoring programme, with up to 16 datapoints per determinand per site collected in 2020/2021. The site, available to be selected using the pick-from-list menus on cells C4 or C5 is: Thames_Culham.

Monitoring data have been reviewed against environmental quality standards (EQS) set out in the WFD Regulations[27]. This is summarised in **Table 3-11** for the site representing the receiving water quality for a STT solution Transfer for both short term (either maximum values or 95 percentiles) and long term (mean) EQS, where these are applicable. It is noted that this is not a WFD status statement as that is undertaken by the EA using EA sampling and analysis at specified WFD monitoring locations within WFD water bodies.

Table 3-11 Review of measured baseline for WFD chemicals against EQS at the Thames at Culham SRO monitoring site (2020/2021, typically 15 samples)

1,2-dichloroethane	cyanide total	mecoprop
2,4-dichlorophenol	cybutryne (Irgarol)	mercury dissolved
2,4-dichlorophenoxyacetic acid (2,4-D)	cypermethrin	methiocarb
3,4-dichloroaniline	DDT total	naphthalene
Aclonifen	di(2-ethylhexyl)phthalate (DEHP)	nickel dissolved
Alachlor	diazinon	nonylphenols
Aldrin	dichloromethane	octylphenols
Anthracene	dichlorvos	PBDEs
arsenic total	dicofol	pendimethalin

[27] Schedule 3 of The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015;

Atrazine	dieldrin	pentachlorobenzene
Benzene	dimethoate	pentachlorophenol
benzo(a)pyrene	diuron	perfluorooctane sulfonic acid and its derivatives
benzo(b)fluoranthene	endosulfan	permethrin
benzo(g,h,i)perylene	endrin	phenol
benzo(k)fluoranthene	fluoranthene	polycyclic aromatic hydrocarbons (PAH) sum
benzyl butyl phthalate	glyphosate	quinoxyfen
Bifenox	heptachlor and heptachlor epoxide	simazine
C10-13 chloroalkanes (total)	hexabromocyclododecane (HBCDD)	terbutryn
cadmium total	hexachlorobenzene	tetrachloroethane
carbendazim	hexachlorobutadiene	tetrachloroethylene
carbon tetrachloride	hexachlorocyclohexane	toluene
chlorfenvinphos	indeno(1,2,3-cd)pyrene	tributyltin compounds (as tributyltin cation)
chlorine total	iron dissolved	trichlorobenzenes
chlorothalonil	isoproturon	trichloroethylene
chlorpyrifos (chlorpyrifos-ethyl)	lead dissolved	trichloromethane (chloroform)
chromium (III) dissolved	lead dissolved	triclosan
chromium (VI) dissolved	linuron	trifluralin
copper dissolved	manganese dissolved	zinc dissolved

Legend:

All reported values achieve applicable EQS
Reported values identify short-term EQS not achieved
Reported values identify long-term EQS not achieved
Reported values identify neither short-term or long-term EQS achieved
Limit of detection used does not enable full comparison of reported data with EQS
No data for analysis

The STT solution monitoring data indicate that the River Thames at Culham does not achieve EQS for 6 WFD chemicals, with one chemical without suitable data for analysis. For both cypermethrin and permethrin, which do not achieve the long-term EQS, only one of the 16 reported values is greater than the EQS, with all others at the limit of detection – which in both cases is the same value as the EQS. If a lower limit of detection was available, it is likely that both permethrin and cypermethrin meet the long term EQS. For nine chemicals, the assessment is incomplete as the laboratory limit of detection is higher than the EQS; however, for all nine of these chemicals all reported values were less than the limit of detection used.

3.9.1.3 Olfaction

As set out in Gate 2 environmental water quality study scope in **Table 2.1**, the review of olfaction has been undertaken to assess risks from the Minworth Transfer only on the River Severn and Severn Estuary as these relate to requirements for Habitats Regulations Assessment (HRA) of the Severn Estuary Special Area of Conservation (SAC), Special Area of Protection (SPA) and Ramsar site. An assessment of olfactory inhibitors has not been scoped into the Gate 2 assessment of the STT solution in the River Thames catchment.

3.9.2 STT operation – current climate

In this reach, the STT solution would augment flow via the STT interconnector. The flow augmentation regime is dependent on the maturity of the STT solution.

For the early phase STT, flow augmentation would be unsupported up to 500Ml/d at selected times, subject to hands-off flow conditions in the River Severn at Deerhurst identified by the EA. The indicative system operation pattern was identified from stochastic data, as described in Section 1.3 and shown as purple periods in **Figure 1.4**. It describes a typical pattern of early phase STT operation for river flow augmentation, on the River Thames, from a STT solution transfer. The planned discharge quality of the STT interconnector pipeline, in terms of physico-chemical water quality, is set out in Table 2-6.

For the full STT, flow augmentation would be unsupported up to 500 Ml/d at selected times, subject to hands-off flow conditions in the River Severn at Deerhurst identified by the EA, and supplemented by flow augmentation of the River Severn at additional times. The indicative system operation pattern was identified from stochastic data, as described in Section 1.3 and shown as purple and blue periods in **Figure 1.4**. It describes a typical pattern of full STT operation for river flow augmentation, on the River Thames, from a STT solution transfer. The planned discharge quality of the STT interconnector pipeline, in terms of physico-chemical water quality, is set out in Table 2-6.

3.9.2.1 Change to general water quality

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report. The reader is advised to look at the stated workbook tab when reading the text in order to see the accompanying chart(s):
[8] ThamesAtCulhamDsOutfall.xlsm
[9] ThamesUsPang.xlsm
[10] ThamesUsDatchetIntake.xlsm
Thames_LongSection_DO.xlsm
Thames_LongSection_NH4.xslm
Thames_LongSection_P.xslm

Similar changes in water quality are generally predicted for both the A82 and M96 scenarios under the fully supported STT scheme.

During periods of scheme operation in early summer (June and July) when River Thames water temperatures are at their highest (17°C), flow augmentation from the STT solution could cool river temperatures by up to 1°C. As river temperatures fall in late summer and early autumn (September and October) there is a slight pattern that the STT solution could shift water temperature decline by 1-4 days [Workbook [8] – tab 'Temp']. As the model does not allow for any heat exchange with the atmosphere, a temperature change pattern is retained for the remainder of the model extent although this is considered to be an over-representation [Workbooks [9] and [10] – tab 'Temp'].

Dissolved oxygen saturation in both scenarios is increased by 4%sat at times of STT solution augmenting low flows in the River Thames at Culham. However, as this is at times of super-saturation, this may be an over-representation [Workbook [8] – tab 'DO']. At higher river flows, the effect of flow augmentation is less. The modelling identifies a potential zone of influence of the increase in saturation as far as the River Thame confluence, 12km downstream of the STT interconnector outfall.

Ammoniacal nitrogen is predicted to increase during the scheme operation by around 0.03 mg/l (from a baseline of 0.02 – 0.06 mg/l) at Culham downstream of the STT interconnector outfall [Workbook [8] – tab 'NH4'].

Phosphorus is predicted to increase during the scheme operation by around 0.05 mg/l (from a baseline of 0.12 – 0.35 mg/l) at Culham downstream of the STT interconnector outfall [Workbook [8] – tab 'P'] with a lower rate of increase downstream. Downstream of Culham, the River Thame is modelled to increase pressure on phosphorus concentrations and the Rivers Pang and Kennet to reduce pressure. Increases are greatest at times of low flow in the River Thames, which, in the modelled scenarios, coincide with 353 Ml/d supported transfer from the River Severn (Full STT solution). At times of up to 500Ml/d unsupported transfer (both early phase and full STT solution), baseline river flows in the River Thames are modelled as higher, and as such phosphorus concentrations are modelled to increase by around 0.03 mg/l. Snapshot longitudinal plot of phosphorus concentrations along the River Thames for 18th July are shown in **Figure 3-17** (A82).

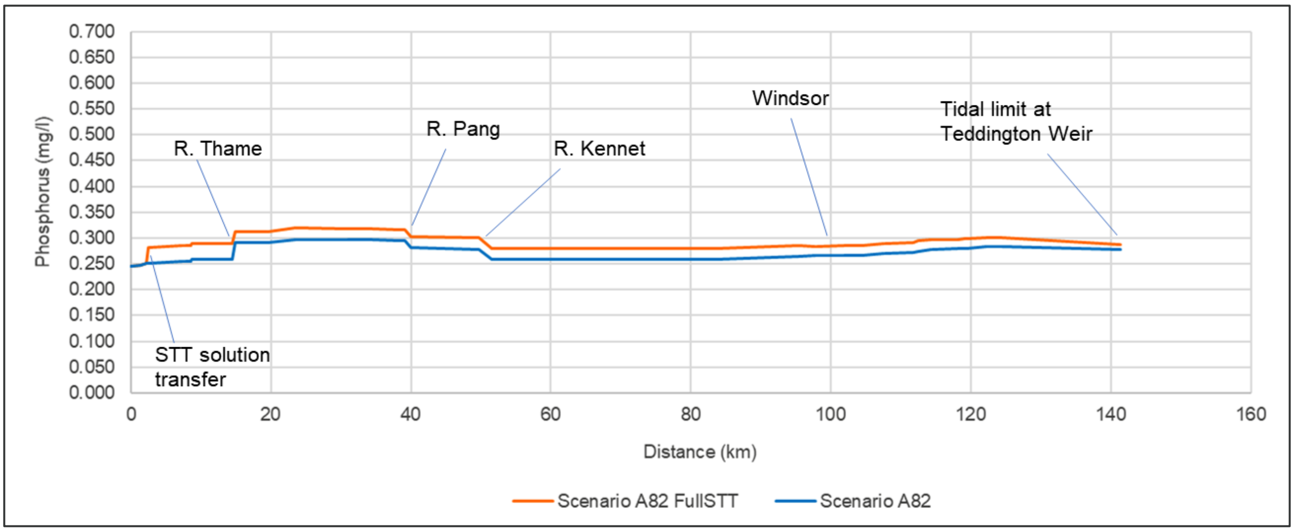

Figure 3-17 Longitudinal profile of Phosphorus along Thames, scenario A82, 18th July

The pH change was calculated from pan-SRO monitoring data. Those spot monitoring data identify a pH range in the lower Severn at Deerhurst of 7.5 – 8.7 (mean 8.1). Although there is greater variability in the range of pH In the lower Severn than the middle Thames, the difference in mean value is not substantial.

The hardness of the lower Severn at Deerhurst is also categorised as very hard, with mean 211mg/l $CaCO_3$ (range 108 – 318 mg/l $CaCO_3$). Although the calcium ion content of the lower Severn is only 60% that of the middle Thames, the magnesium ion content of the lower Severn is three times as high as the middle Thames. This could result in a reduction in hardness of the middle Thames at Culham under low flow conditions in the River Thames at times of supported STT solution transfer from the River Severn. Supported STT solution transfer is for 12% of time. Despite the reduction, hardness would remain as very hard at around 250 mg/l $CaCO_3$. The zone of influence of the STT solution on the River Thames requires further assessment through consideration of tributary input hardness.

Acid neutralising capacity in the middle Thames is very low. In the lower Severn, acid neutralising capacity is better, and at times of STT solution flow augmentation, there would be a marked improvement in acid neutralising capacity of the middle Thames, as shown on **Figure 3-18** for the A82 scenario using mean values for indicative purposes.

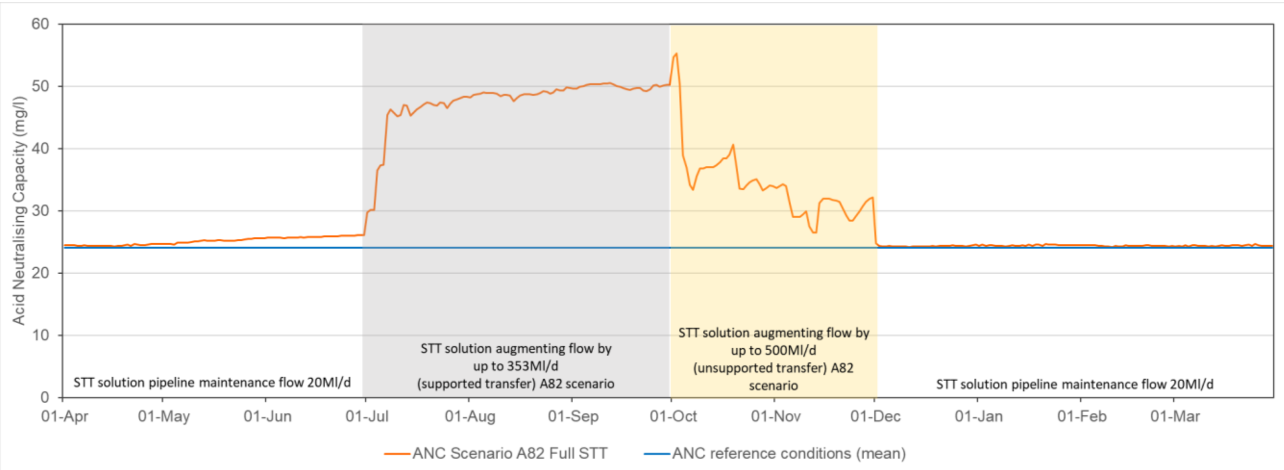

Figure 3-18 Longitudinal profile of acid neutralising capacity along Thames, scenario A82, 18th July

3.9.2.2 Change to chemicals

This section is supported by charts and data in the excel workbook STT_Chemical_Data_Viewer.xlsm for the tab name '#WFD_chem'

A categorisation of the risk to EQS associated with the STT solution transfer has been undertaken. It is important to note that the STT solution at Gate 2 is proposed to include the treatment processes set out in Section 2.3.5.

The pan-SRO monitoring data for the Severn at Deerhurst SRO monitoring site reviewed in **Table 3-8** identified four WFD chemicals as not achieving EQS in the source water for the interconnector treatment unit: the polyaromatic hydrocarbon benzo(g,h,i)perylene; two synthetic pyrethroid insecticide (permethrin and cypermethrin); and PFOS. Furthermore, the assessment presented in Section 3.6.2.2 identified that, with a Minworth Transfer supporting abstraction to the STT solution interconnector at Deerhurst, the concentration of permethrin, cypermethrin and PFOS may increase in the River Severn water abstracted to the interconnector pipeline at Deerhurst.

Using the concentrations in the measured dataset (see **Table 3-12**), monte-carlo combined distribution modelling has been undertaken, specific to the flow conditions in the River Thames at Culham at times of STT solution transfer (**Table 3-13**). It is noted that the STT solution would discharge continuously to the River Thames and should not be considered as a part-time discharge. Flows are as used in the A82 and M96 scenarios.

Table 3-12 Selected chemical quality used in assessment of change in chemical concentrations from flow augmentation of the River Thames at Culham by a STT solution

Chemical	Relevant EQS for testing	Indicative transferred quality	Receiving quality (Thames at Culham)
Benzo(g,h,i)perylene	0.0082 µg/l maximum	Mean 0.0056 µg/l Max 0.0186 µg/l	Mean 0.0047 µg/l Max 0.0279 µg/l
Cypermethrin	0.00008 µg/l mean	Mean 0.00011 µg/l St.dev 0.00006 µg/l	Mean 0.00009 µg/l St.dev 0.00004 µg/l
Permethrin	0.001 µg/l mean	Mean 0.0011 µg/l St.dev 0.0003 µg/l	Mean 0.0011 µg/l St.dev 0.0003 µg/l
PFOS	0.00065 µg/l mean	Mean 0.0022 µg/l St.dev 0.0011 µg/l	Mean 0.0067 µg/l St.dev 0.0020 µg/l

Table 3-13 Flow conditions used in assessment of change in chemical concentrations from flow augmentation of the River Thames at Culham by a STT solution

Scenario	Part of dataset	Transferred flow	River flow (Thames at Culham)
1:5 year return frequency (A82)	Supported transfer period	Mean 322 Ml/d St.dev 58 Ml/d	Mean 484 Ml/d Q95 427 Ml/d
	Full water resources transfer period	Mean 381 Ml/d St.dev 103 Ml/d	Mean 1,780 Ml/d Q95 727 Ml/d
	Full period	Mean 173 Ml/d St.dev 191 Ml/d	Mean 2,416 Ml/d Q95 405 Ml/d
1:20 year return frequency (M96)	Supported transfer period	Mean 327 Ml/d St.dev 47 Ml/d	Mean 775 Ml/d Q95 371 Ml/d
	Full water resources transfer period	Mean 383 Ml/d St.dev 92 Ml/d	Mean 1,501 Ml/d Q95 672 Ml/d
	Full period	Mean 229 Ml/d St.dev 193 Ml/d	Mean 1,890 Ml/d Q95 342Ml/d

The assessment summarised in **Table 3-14** identifies a potential improvement in the maximum concentration of the polyaromatic hydrocarbon benzo(g,h,i)perylene in the River Thames from operation of a STT solution. The assessment applies at all times of STT solution transfer – both supported and unsupported, which is presented as 23% of the time. Both rivers are currently measured as failing benzo(g,h,i)perylene short term EQS. Although this betterment of the River Thames is realistic it would not improve the River Thames to achieving EQS. There is also the retained risk that highest concentrations in the River Thames occur at times when the STT solution is providing pipeline maintenance flow only, with little influence on the concentration in the River Thames. The assessment is based on 16 datapoints for each chemical for each location. Further data will provide further confidence in this assessment.

The assessment summarised in **Table 3-14** identifies no substantial change in the concentrations of the synthetic pyrethroid insecticides permethrin or cypermethrin in the River Thames from operation of a STT solution. Any change in the concentration of permethrin or cypermethrin in the abstracted water at Deerhurst from Minworth Transfer, at times of supported transfer only, would be low. It is noted that as supported transfer would be in use 12% of time overall, these changes are not considered significant from the perspective of long-term change. As such, for these chemicals measured as failing EQS in the River Thames at Culham, the STT solution is considered to neither cause (further) deterioration or impede betterment to achieving EQS. The assessment is based on 16 datapoints for each chemical for each location. Further data will provide further confidence in this assessment.

The assessment summarised in **Table 3-14** identifies an improvement in the concentration of PFOS in the River Thames from operation of a STT solution. The assessment applies at all times of STT solution transfer – both supported and unsupported, which is presented as 23% of the time. Both rivers are currently measured as failing PFOS long term EQS. Although this betterment of the River Thames is realistic it would not improve the River Thames to achieving EQS.

Table 3-14 Assessment of change in chemical concentrations for selected risk chemicals from flow augmentation of the River Thames at Culham by a STT solution

Scenario	Part of dataset	Benzo(g,h,i) perylene maximum	Cypermethrin mean	Permethrin mean	PFOS mean
1:5 year return frequency (A82)	Supported transfer period	0.0239 µg/l	0.00010 µg/l	0.00106 µg/l	0.00493 µg/l
	Full water resources transfer period	0.0247 µg/l	0.00009 µg/l	0.00106 µg/l	0.00594 µg/l
	Full period	NA	0.00009 µg/l	0.00106 µg/l	0.00644 µg/l
1:20 year return frequency (M96)	Supported transfer period	0.0235 µg/l	0.00010 µg/l	0.00106 µg/l	0.00540 µg/l
	Full water resources transfer period	0.0245 µg/l	0.00009 µg/l	0.00106 µg/l	0.00582 µg/l
	Full period	NA	0.00009 µg/l	0.00106 µg/l	0.00625 µg/l

3.9.2.3 Change to Olfaction

As set out in Gate 2 environmental water quality study scope in **Table 2.1**, the review of olfaction has been undertaken to assess risks from the Minworth Transfer only on the River Severn and Severn Estuary as these relate to requirements for HRA of the Severn Estuary SAC, SPA and Ramsar site.

3.9.3 STT operation - future climate

In comparison with the M96 scenario, the M96 Future scenario (M96F) would include a 22% longer period of flow augmentation releases - with extension both 24 days earlier, to include late May and all of June; and 21 days later, to include most of January. The M96 Future scenario would include a period of flow augmentation for 253 days from mid-June to early January, including flow augmentation at a peak rate of 500Ml/d for 88 continuous days from early November. Between mid -June and early November, flow augmentation would be at the supported rate of 353 Ml/d. The increase in regularity of the need for STT support options in late spring, early summer and later into winter is a significant change.

This section sets out the findings of the effect of the STT scheme operation during future climate conditions.

3.9.3.1 Change to general water quality

The futures assessment of general water quality is an assessment of the change in dilution only. It does not account for future climate temperature changes nor changes to pollutant load in the future. Note that the simulations only changed the River Thames and tributary flows; the water quality data for all inputs, including the STT interconnector discharge and sewage works flows remained the same in all simulations.

Under Scenario M96F, the predicted water quality in the River Thames is only a minor change from predicted under M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for M96F in the middle Thames at Culham occurs over a longer period, the peak changes in concentrations are very similar to M96 for all parameters. [Workbooks [8] [9] and [10] – tabs 'Temp', ‘DO,’NH4 and ‘P’].

3.9.3.2 Change to chemicals

The futures assessment of chemicals is an assessment of the change in dilution of the currently legislated chemicals (WFD and other permitted chemicals with operational EQS) at their current concentrations. As such, the assessment is not of emerging chemicals (which may be added for Gate 3 assessment) or of the change in contamination level of the currently legislated chemicals due to future patterns of use.

The change in dilution rates in the River Thames has been modelled. This shows around a 20% reduction in dilution capacity along the River Thames. The monte-carlo combined distribution modelling has been repeated for River Thames at Culham flows during the extended period of 165 consecutive days of supported transfer in the M96F scenario (mean modelled flow in River Thames at Culham 548 Ml/d, Q_{95} modelled flow 261 Ml/d; mean transferred flow 319 Ml/d, standard deviation 50 Ml/d)). For the synthetic pyrethroid insecticides permethrin and cypermethrin, there remains no substantial modelled change in concentration in the River Thames. For polyaromatic hydrocarbon benzo(g,h,i)perylene (currently measured as not achieving short term EQS) and PFOS (currently measured as not achieving long term EQS), the extent of potential betterment of the River Thames is greater in terms of both concentration reduction and duration of benefit – however it is restated that this is not an improvement to achieving EQS.

3.9.3.3 Change to Olfaction

As set out in Gate 2 environmental water quality study scope in **Table 2.1**, the review of olfaction has been undertaken to assess risks from the Minworth Transfer only on the River Severn and Severn Estuary as these relate to requirements for HRA of the Severn Estuary SAC, SPA and Ramsar site.

4. CONCLUSIONS

The potential impacts of the STT solution have been considered in the context of the current and potential future environmental water quality. The outputs from the 1D linked hydraulic-water quality models developed for use in Gate 2, throughout key parts of the fluvial study area, provide a robust evidence base for the Gate 2 assessment. The evidence used in this assessment is documented in the accompanying STT solution Gate 2 Environmental Water Quality Evidence Report. That includes the environmental water quality survey work undertaken bespoke to the STT solution; and a catalogue of water quality model output.

4.1 SUMMARY OF THE EFFECTS UNDER CURRENT CLIMATE

4.1.1 Early phase STT solution

For the early phase of the STT solution, there are no effects on water quality predicted by the scenarios in the River Severn catchment. Of the scenarios tested to date, unsupported transfers to the River Thames catchment in the early phase of the STT solution are at times when flows have begun to increase in the River Thames and flow augmentation to the rate of 500 Ml/d does not coincide with periods of lowest river flow in the River Thames. As such, the modelled increases to phosphorus concentrations with unsupported STT solution are lower than with supported STT solution in the summer period, with an increase predicted to be of around 0.03 mg/l. It is noted that the early phase solution would only be in use for around 11% of time and predominantly in the months October to December which are outside of algal and plant growth seasons. Although this is arithmetically-speaking assessed as introducing an impediment to target quality for reactive phosphate in the middle River Thames, it is recognised that reactive phosphate is a WFD supporting element to plant growth.

4.1.2 Full STT solution

The assessment of the potential effects of the full STT solution on environmental water quality has included those parts of the full study area associated with pathways of water quality change from the scheme. This includes the River Avon and the downstream River Seven; and the River Thames catchment, from the point of flow addition effects on environmental water quality to the tidal limits and pass-forward water quality to estuaries.

To assist the environmental assessment, a representative pattern of operation has been developed for Gate 2 from water resources modelling. This includes a representative 47 year period and selected environmental conditional and operating patterns for detailed assessment. The 365 day detailed assessment periods were used to assess the effects of the STT solution during a moderate low flow period in the River Severn/ River Thames, at a 1:5 return frequency, noting the scheme would only be in operation on a 1:2 return frequency. The detailed period used in the assessment also included a rarer 1:20 return frequency. Detailed scenario development has included extensive collaborative working across the STT Group, other SROs in the Thames catchment and the Environment Agency. A modelling working group was set up with regulators to develop scenarios and the use of modelling, and to receive feedback.

The assessment of environmental water quality is made in support of other assessments. The scope of the Gate 2 environmental water quality assessment has been informed by the Gate 1 assessment and feedback. It is noted that the Gate 2 environmental water quality assessment is not final and represents only a position of knowledge at Gate 2. Also, the assessment of effects on the environmental water quality is not definitive – it is used to support aquatic ecology assessments; and used to assist the assessments made for Gate 2 in the WFD Regulations compliance assessment, Habitats Regulations Assessment and Integrated Environmental Assessment.

In the **74 km of the River Vyrnwy from Vyrnwy Reservoir to the confluence with the River Severn**, the pathways of environmental water quality change from the STT solution operation are limited to water temperature change and any associated changes to dissolved oxygen saturation. Review of measured water temperature data identifies no distinct substantial water temperature change compared with reference conditions as result of a 25Ml/d additional release from Vyrnwy Reservoir. As there is no distinct substantial water temperature change associated with the STT Solution, there is no pathway to change in the oxygen carrying capacity, the dissolved oxygen saturation, of the River Vyrnwy. Review of chemicals in the managed outflow from Vyrnwy Reservoir identified no increase in risk from a 25Ml/d additional release.

In the **112 km of the River Severn from the confluence of the River Vyrnwy to Bewdley**, the pathways of environmental water quality change from the STT solution operation are limited. A precautionary water temperature assessment using measured data identified no distinct substantial water temperature change associated with the Vyrnwy Bypass. Review of chemicals in each of the Vyrnwy Reservoir itself and the managed outflow from Vyrnwy Reservoir identified no increase in risk from a 155Ml/d Vyrnwy Bypass release into the River Severn. The potential for water quality benefits in this reach associated with the enhanced dilution of wastewater discharges (e.g. Shrewsbury (Monkmoor) WwTW) and other pollution pressures from the flow augmentation, are not included in this assessment.

In the **56 km of the River Severn from Bewdley to the confluence with the River Avon**, the pathways of environmental water quality change from the STT solution operation are limited and not scoped into the Gate 2 assessment. The potential for water quality benefits in this reach associated with the enhanced dilution of wastewater discharges (e.g. Worcester WwTW) and other pollution pressures from the flow augmentation, are not included in this assessment.

In the **108 km of the River Avon from Warwick to the confluence with the River Severn**, the STT solution would episodically augment flow via a 115 Ml/d treated effluent transfer from Minworth SRO to an outfall on the River Avon at Stoneleigh, near Kenilworth. During typical operation, river flows at point of discharge would be such that the Transfer would be in the order of 36% of the combined river flow. The Minworth Transfer has the potential to influence water quality for the full 108km of the River Avon downstream of the point of discharge and the river quality with the STT solution is highly dependent on the planned treatment process of Minworth SRO. For the predicted effects of the advanced treatment unit provided at Gate 2, there is potential for ammoniacal nitrogen increase and dissolved oxygen saturation decrease, with water qualities remaining consistent with high WFD status. Soluble reactive phosphate concentrations are reduced by the scheme throughout the River Avon. Water temperature variation is seasonal and dependent on the timing of scheme operation – water temperature could vary by between -1.1°C (cooling in late summer and autumn) and +1.5°C (warming in late autumn) for the 1:20 return period operating pattern in a very low flow year. The review of all WFD chemicals screened those which would require effective reduction by the planned treatment process of Minworth SRO to avoid deterioration on the River Avon or where Transfer could contribute to WFD targets not being met in future. The assessment uses the STT solution water quality monitoring dataset. Taking into account the treatment efficacy provided by Minworth SRO process engineers, three chemicals: cypermethrin, perfluorooctane sulfonic acid and its derivatives, and permethrin are considered a risk. All three would associate with further deterioration in current EQS failures in the River Avon and impede the River Avon reaching targets. It is noted that of these, cypermethrin is banned and perfluorooctane sulfonic acid and its derivatives is heavily restricted. As such, the future concentrations of these chemicals at Minworth WwTW should reduce such that the risk from Transfer recedes. Permethrin is in widespread use as an insecticide and there is risk of deterioration in the River Avon from transfer. An initial review of potential olfactory inhibitors associated with the Minworth Transfer has been undertaken to provide evidence for the fisheries assessment in the Gate 2 Fisheries Assessment Report.

In the **2.6 km of the River Severn from the confluence with the River Avon to Deerhurst**, the water quality change pathway from Minworth Transfer is weaker, due to the large flow increase from the River Severn, including additionally augmented flows from the STT solution at times coincident with the Minworth Transfer. As such, the effects on ammoniacal nitrogen, dissolved oxygen saturation and water temperature identified in the River Avon are not passed forward into the River Severn. The potential for improvement in soluble reactive phosphate in the River Avon from Minworth Transfer is, however, sufficiently great to also lead to improvements in the River Severn. The pass-forward risk for WFD chemicals is chemical specific. Pan-SRO monitoring data indicate the lower River Severn fails EQS for cypermethrin and that is the dominant pressure on water quality in the River Severn, not the contribution of the River Avon or Minworth Transfer. Perfluorooctane sulfonic acid and its derivatives has such a large EQS failure in both rivers that increases from the Minworth Transfer could impede targets being reached, noting that PFOS use is heavily restricted, and this should see concentrations reduce in the future. Permethrin is rarely detected in the lower Avon or lower Severn at present and risks to long-term EQS from Minworth Transfer are considered low. An initial review of potential olfactory inhibitors associated with the Minworth Transfer has been undertaken to provide evidence for the fisheries assessment in the Gate 2 Fisheries Assessment Report.

In the **12.5 km of the River Severn from Deerhurst to the normal tidal limit at Gloucester**, there remains the water quality change pathway from Minworth Transfer and additional a change pathway from the Netheridge Transfer discharge. Modelled ammoniacal nitrogen, dissolved oxygen saturation, water temperature and soluble reactive phosphate changes are very low. The pass-forward risk to WFD chemicals concentration from the Minworth Transfer remains as upstream of Deerhurst. The planned advanced treatment processes included in the Severn Trent Sources SRO Gate 2 scheme for Netheridge Transfer would not lead to changes in WFD chemicals in the River Severn.

The effect of the STT solution on pass-forward water quality into the Severn Estuary downstream of the tidal limit at Gloucester has also been assessed. Modelled ammoniacal nitrogen, dissolved oxygen concentration and water temperature changes are very low. With regards to DIN, the regulated nutrient for transitional waters, there would be an overall reduction in DIN input from the freshwater River Severn and Netheridge WwTW combined into the Severn Estuary as result of the STT solution – this accounts for small additional annual loads from Minworth Transfer and Netheridge Transfer and a larger reduction in load associated with the Deerhurst abstraction, as well as less load remaining at the Netheridge WwTW outfall. The four WFD chemicals associated with low removal efficacy at the planned advanced treatment unit at Minworth SRO for Minworth Transfer were reviewed. There is potential for load increase into the Severn Estuary for each of the banned chemicals nonylphenols and cypermethrin, and the heavily restricted perfluorooctane sulfonic acid and its derivatives, as well as the widely used permethrin. None of nonylphenols, cypermethrin or permethrin have been regularly detected in the SRO chemical monitoring in the lower Severn, as concentration changes are difficult to reliably predict. For perfluorooctane sulfonic acid and its derivatives a 3-5% increase in concentration is calculated from reported data during years when the STT solution would be in operation. An initial review of potential olfactory inhibitors associated with the Minworth Transfer has been undertaken to provide evidence for the fisheries assessment in the Gate 2 Fisheries Assessment Report.

In the **c.140 km of the River Thames from Culham to the tidal limit at Teddington**, the STT solution would episodically augment flow via a 353 Ml/d supported transfer (12% of the time) or up to 500Ml/d unsupported transfer (an additional 11% of time). During times of supported transfer, water quality at the abstraction point for transfer, the lower River Severn at Deerhurst, would be influenced by the Minworth transfer. At all other times, water quality at the abstraction point for transfer would be as represented by measured data in the lower River Severn. An interconnector treatment unit, including coagulation and filtration would treat water prior to transfer and an aeration step would be included prior to discharge to the River Thames. At Gate 2, no specific treatment train for soluble phosphorus reduction has been included at the interconnector treatment unit.

During typical operation, river flows at point of discharge would be such that the Transfer would be in the order of 50% of the combined river flow. The STT solution has the potential to influence water quality for the full 140km of the River Thames downstream of the point of discharge. However, the River Thame, which confluences some 12km downstream of the STT interconnector outfall at Culham, is modelled to exert a significant pressure on general water quality downstream in the River Thames and the majority of the zone of influence of STT solution is within the Culham to River Thame reach. With the interconnector treatment unit in place, the modelled water quality predicts a small benefit to dissolved oxygen saturation and a small increase in ammoniacal nitrogen and phosphorus concentrations. Further scenarios are recommended to add confidence to this assessment. Water temperature and pH is predicted to not significantly change. Hardness may reduce, but still remains categorised as very hard, and acid neutralising capacity would be benefitted.

The review of all WFD chemicals identified six as measured to not comply with EQS in the River Thames at Culham. Two of these are measured to achieve EQS in the lower Severn and the STT solution transfer may support achievement of the EQS in the River Thames. These are the PAHs benzo(b)fluoranthene and benzo(k)fluoranthene. Of the remaining four, a STT solution was modelled to not substantially change the concentration of the synthetic pyrethroid insecticides permethrin and cypermethrin in the River Thames. For PFOS and the polyaromatic hydrocarbon benzo(g,h,i)perylene, the lower River Severn is measured as closer to EQS compliance than the middle River Thames, so the STT solution may result in some betterment, although not sufficient to lead to the EQS being achieved in the River Thames. The Gate 2 agreed scope of works does not include consideration of potential inhibitors of fish olfaction in the River Thames from STT solution.

4.2 SUMMARY OF THE EFFECTS UNDER FUTURE CONDITIONS

The futures assessment of general water quality is an assessment of the change in dilution only. It does not account for future climate temperature changes nor changes to pollutant load in the future.

The predicted water quality for the A82F scenario in the River Avon and River Severn and M96F scenario in the River Thames is very similar to that predicted under current climate conditions. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. This means that the modelled changes in water quality described for the current climate are observed over that longer period of time.

4.3 UNCERTAINTY AND CONFIDENCE DATA GAPS

Sufficient environmental water quality evidence is available for the Gate 2 assessment. However, there likely remain gaps in water quality data and in the understanding of the possible scheme operation. Further scenario modelling using the 1D hydraulic and water quality models can be assessed as the Gated process progresses. For example, further model scenarios can be developed to assess alternative STT operating regimes, and cumulative assessments with other water resources options selected by both WRW and WRSE in their respective Regional Plans.

All models rely on the quality of the data available to specify inputs, and the representation of incoming water quality is based on approximate monthly spot observations. This means that some relatively short-term events may not be represented. Equally, the effect of some short-term events may be exaggerated in duration.

For the River Severn and Avon environmental water quality model, there are significant missing data, which means that for some sources (rivers and WwTWs), there are no data for certain parameters at all or there are periods of missing data. However, as these have the same impact on both the reference conditions and the STT solution scenario simulations, the model outputs can be considered as reliably indicating where and when marked changes are likely to occur as a result of the operation of the STT scheme.

The pan-SRO water quality monitoring programme, which commenced in 2020, has provided substantial evidence for the Gate 2 environmental water quality assessment. For most monitoring sites and most chemicals, there are 16 reported values per site and the programme continues at key sites, building towards a catalogue of 36 data points as recommended by the EA at time of environmental permit application. For some chemicals, there are difficulties with commercially available limits of detection not being sufficiently low compared to EQS values and for potential olfactory inhibitors, it is recognised that the commercially available limit of detection may be altogether too high to draw conclusions. The main limitation with the chemical data in the Gate 2 assessment, however, lies with the STT solution process engineers designing treatment plant for Minworth Transfer and Netheridge Transfer as there are no cases to date in UK of reduction performance efficacy and operational reliability for the planned treatment processes.

4.4 RECOMMENDATIONS FOR GATE 3

4.4.1 Refining Water Quality Evidence to Support Ecological Assessments

As listed above, the pan-SRO water quality monitoring programme, which commenced in 2020 is recommended to continue during Gate 3. This is recommended to continue to collect continuous monitoring data for water temperature and dissolved oxygen at strategic locations of importance to the STT Solution. It is also recommended to continue spot water quality monitoring at key locations associated with source waters and outfall locations. This will enhance treatment design and the understanding of the effect of discharges on receiving watercourses during Gate 3.

It is recommended that potential inhibitors of fish olfaction in the River Thames from the STT solution is undertaken for Gate 3. Monitoring for these chemicals commenced during Gate 2. This is in addition to further refinement of the fish olfaction assessment in the River Severn catchment that commenced in Gate 2.

The 1D hydraulic models of the River Severn catchment and River Thames catchment built during Gate 2 are recommended for continued development and use in Gate 3. This includes improvements to the models themselves and to the range of scenarios tested, as set out in the Physical Environment Assessment Report recommendations for Gate 3.

4.4.2 Refining Chemical Water Quality Evidence and Supporting Environmental Permitting

At the spot water quality monitoring locations, the core chemical analysis suite is recommended to continue into Gate 3. This should include the full WFD suite of specific pollutants, priority substances and priority hazardous substances. At STT Solution locations requiring environmental permits to discharge, this should include the full EQSD suite of chemicals. At the Gate 2-identified key locations to characterise the pressure of potential inhibitors of fish olfaction, the programme should continue.

The pan SRO monitoring team continue to review the limits of detection that can be analysed for those chemicals where the EQS is lower. There are also other chemicals where the limit of detection used is equivalent to the EQS, where there are some recorded values at Gate 2 greater than the limit of detection which then limits confidence in mean values for permit modelling. Cypermethrin is an example and a lower limit of detection would enhance understanding of reference conditions and treatment needs of the STT Solution.

The pan SRO monitoring team continue to review chemicals of emerging concern. It is noted that the recent Environment Agency document[28] at point 22 identifies that the Agency has *a program of investigations and studies underway to monitor and assess emerging substances. Where substances have an impact on the environment and/or human health there is a process to bring them into regulation. Once regulated, they will be considered in any new permit conditions where appropriate.*

RAPID[29] list *progress on applications for relevant permits and licences with regulators* as a key deliverable for Gate 3. At Gate 3 the STT Solution will move emphasis on chemical quality assessments from WFD Regulations compliance to environmental permitting. This will include following the data control and modelling requirements of Environment Agency LIT 13134 Permitting of Hazardous Chemicals and Elements in Discharges to Surface Waters and Environment Agency Guidance H1 Annex D2 for the Assessment of Sanitary and Other Pollutants within Surface Waters. RAPID Gate 3 guidance also states that the *Environment Agency and Natural Resources Wales will provide bespoke advice on Environmental Permitting requirements in accordance with their pre-application services* and closer co-working on treatment needs linked to permitting of discharges will be undertaken. Demonstrating WFD Regulations compliance at Gate 3 remains, but in the context of development planning[30], rather than strategic assessments for water resources management planning (as was the focus in Gate 2). It is recognised by STT Group that a WFD Regulation 19 exemption cannot be made for chemical status deterioration or jeopardising target chemical status. As such a promotable STT Solution has to be WFD Regulations compliant for chemical quality.

Recommendations for monitoring for drinking water safety planning requirements are set out elsewhere in the STT Solution documentation.

REFERENCES

This report is supported by charts and data in the following excel workbooks, which form part of the body of evidence. Below is the list of files referenced in this report:

[1] AvonDsMinworthOutfall.xlsm

[2] AvonDsWarwickSTW.xlsm

[3] AvonAtEvesham.xlsm

[4] AvonPriorToConfluenceSevern.xlsm

[5] SevernAtDeerhurstUsOfftake.xlsm

[6] SevernAtDeerhurstDsOfftake.xlsm

[7] SevernAtModelEnd.xlsm

[8] ThamesAtCulhamDsOutfall.xlsm

[9] ThamesUsPang.xlsm

[10] ThamesUsDatchetIntake.xlsm

Thames_LongSection_DO.xlsm

Thames_LongSection_NH4.xslm

Thames_LongSection_P.xslm

AvonSevern_LongSection_DO.xlsm

AvonSevern_LongSection_NH4.xslm

AvonSevern_LongSection_SRP.xslm

[28] Environment Agency. National Appraisal Unit Water Quality Permitting for Strategic Resource Options: Transferring Recycled Effluent via Water Bodies for Water Supply. July 2022

[29] Regulators' Alliance for Progressing Infrastructure Development. Strategic regional water resource solutions guidance for gate three. August 2022

[30] Planning Inspectorate Advice Note 18. https://infrastructure.planninginspectorate.gov.uk/legislation-and-advice/advice-notes/advice-note-18/