Strategic Regional Water Resource Solutions: Annex B3.1: Physical Environmental Assessment Report

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

Date: November 2022

Severn to Thames Transfer

Physical environment assessment

STT-G2-S3-112

November 2022

SEVERN THAMES TRANSFER (STT) SOLUTION

Physical Environment Assessment Report

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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, Water Resource Management Plan (WRMP) guidance for 2024, 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 assessments; (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 in Figure 1-1); (iii) based on the evidence and assessments, the informal 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 the physical environment. It informs other assessments, including the statutory assessments.

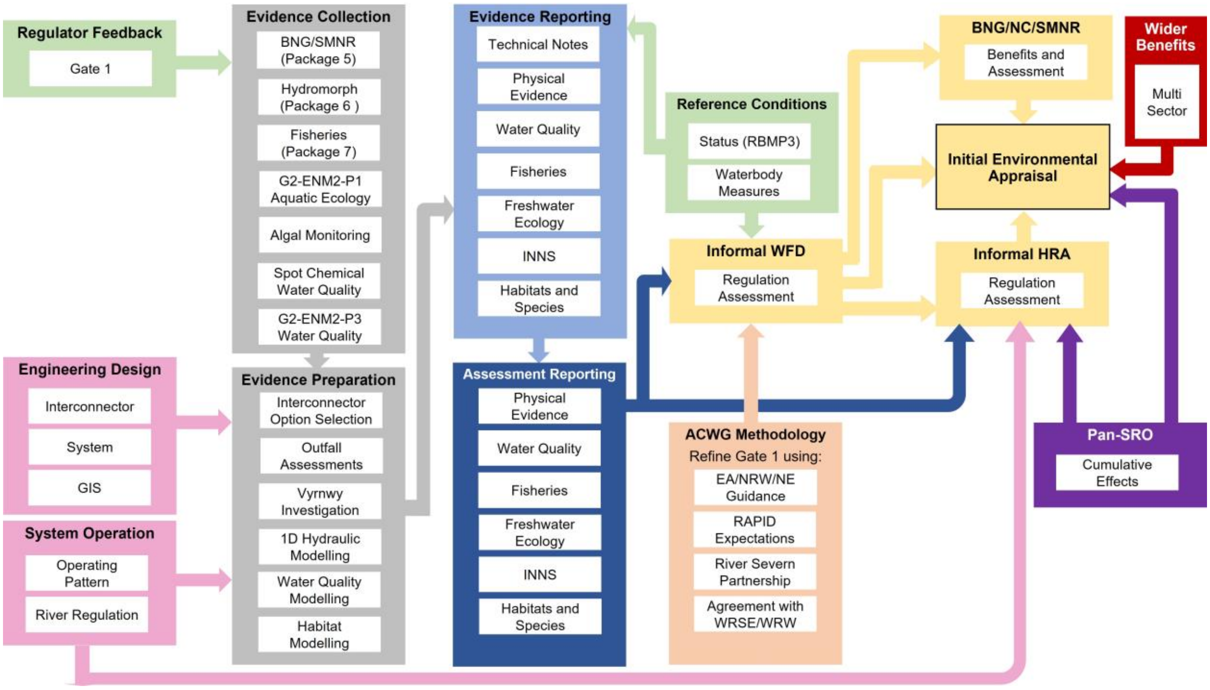

Figure 1-1 Flow chart showing the scope of investigations for STT Gate 2 and their interactions

1.2 STUDY AREA

The study area for the STT solution for Gate 2 assessment covers 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
4. The River Thames catchment (River Thames from Culham to Teddington Weir).

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

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 Solution and therefore excluded from the STT solution assessment.

Similarly, the STT solution assessment accounts for the effects from the relevant solutions 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 Solution assessments.

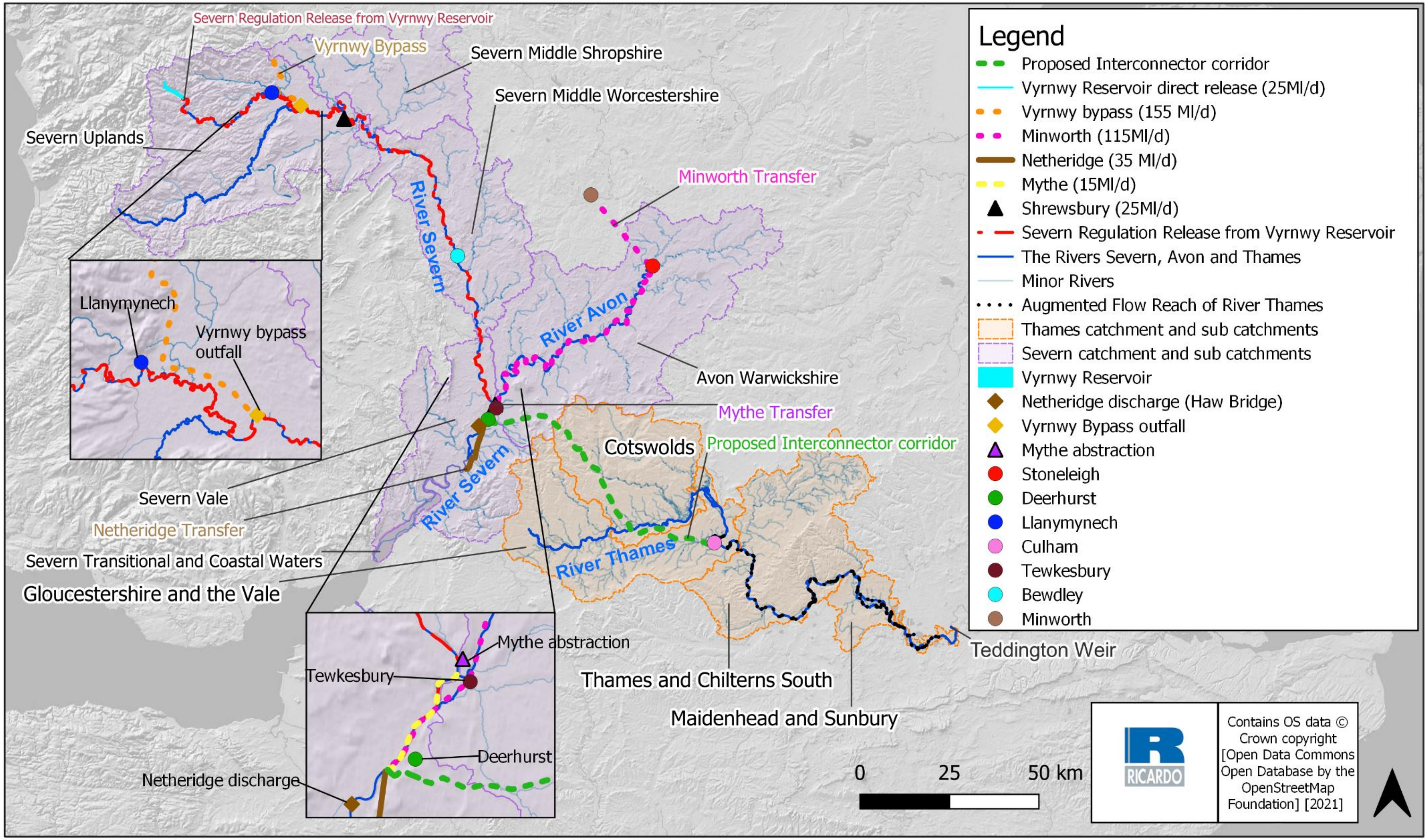

Figure 1-2 Map showing the proposed interconnector corridor

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[3]. 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[4]. 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[5] 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 a reduction in abstraction from the River Severn at Shelton WTW to remain in the River Severn for abstraction at Deerhurst;

3 STT-G2-S3-359-STT Gate 2 Design Principles

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

5 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
	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

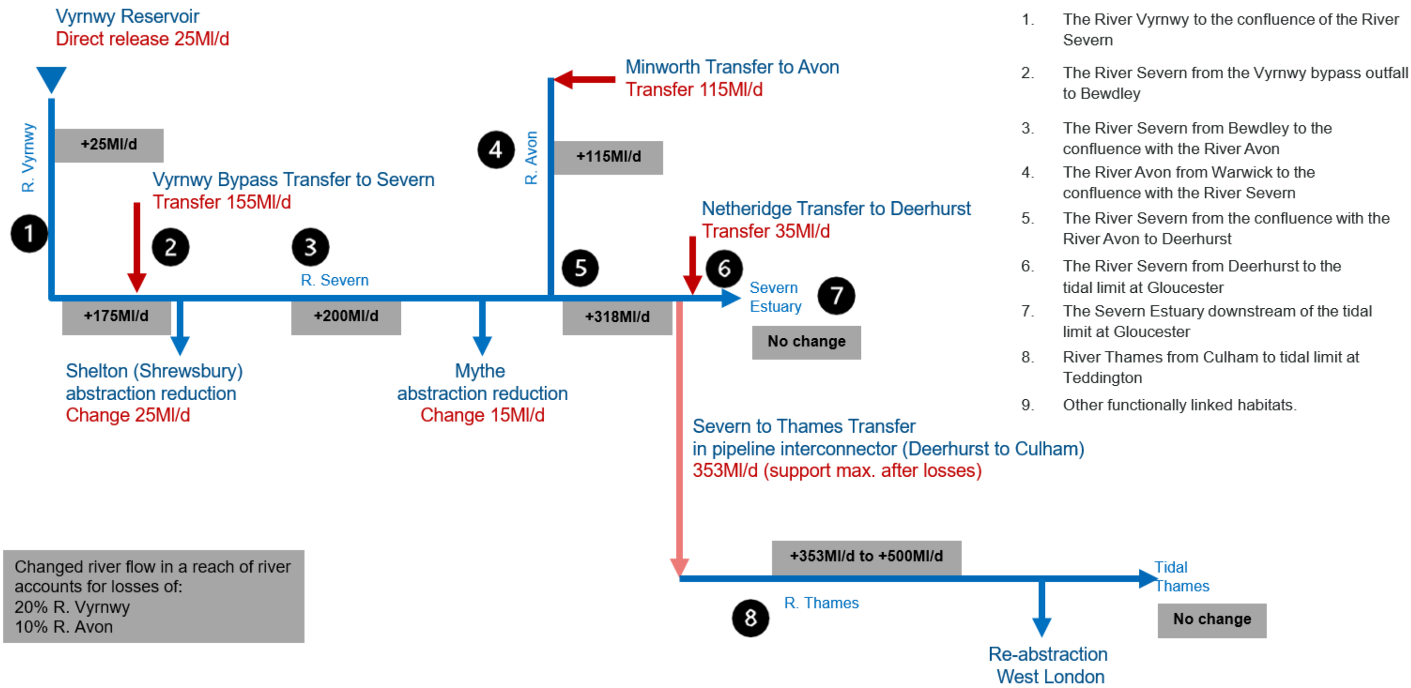

Figure 1-3 Schematic representing flow changes (accounting for losses) of STT Solution

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 represent contemporary climate conditions and provide 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[6] 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, 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.

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 show the periods when the full STT operation pattern is being deployed. The review of river flows and operating patterns for the environmental assessment has 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);
- 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.

[6] 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,

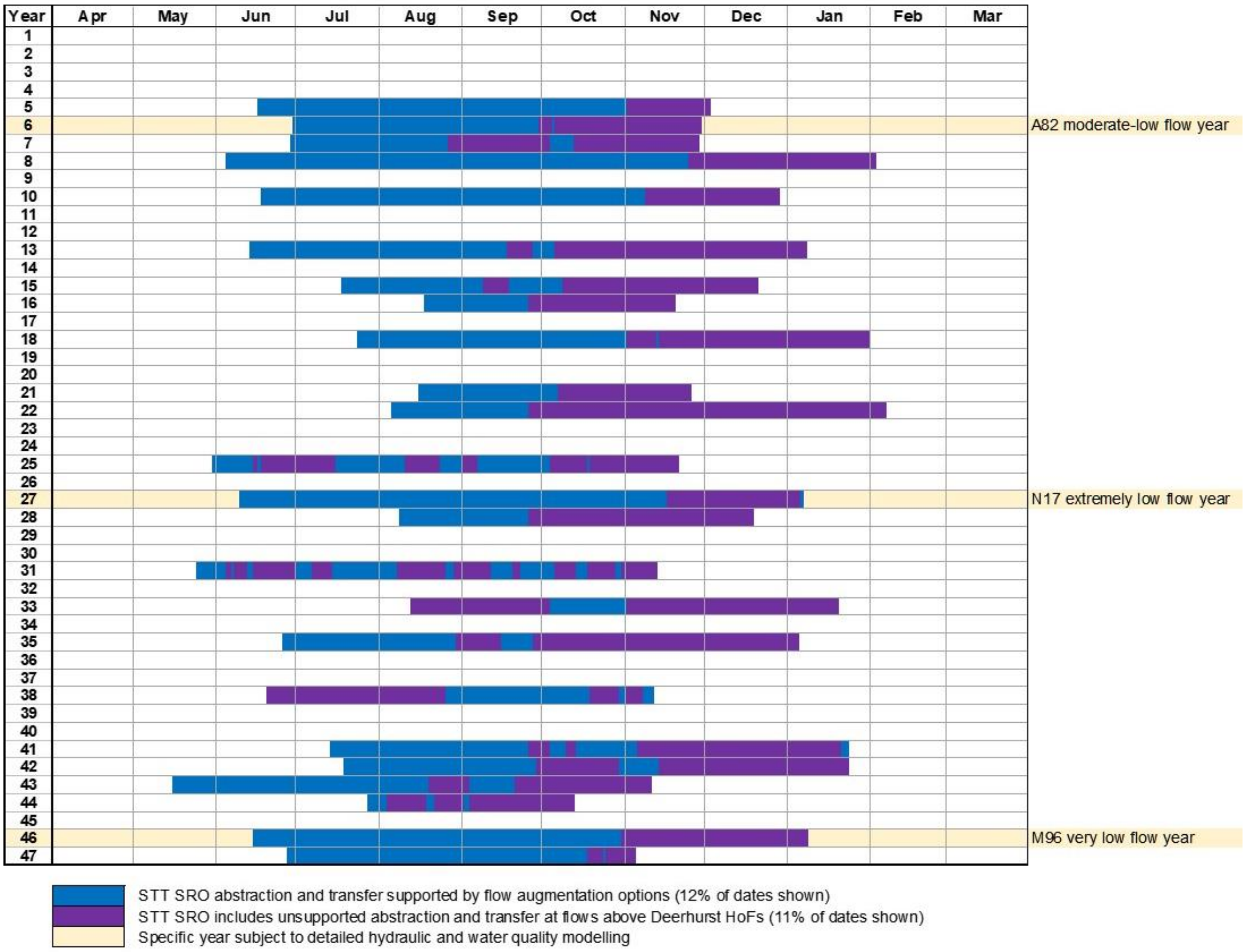

Figure 1-4 Representation of dates full STT solution would be on (for water resources purposes) as used in the environmental assessment

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

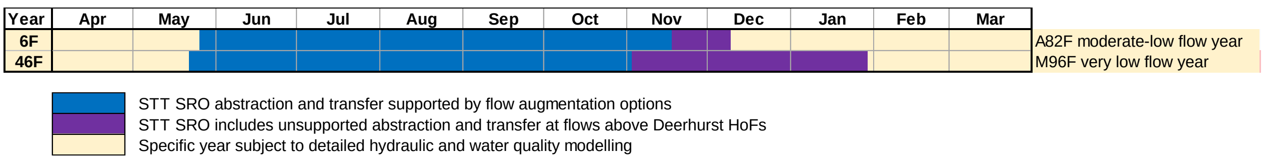

Figure 1-5 Representation of dates full STT solution would be on (for water resources purposes) for selected future scenarios as used in the environmental assessment

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 Severn Thames Transfer on the physical environment. 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 is 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 more confidence could be placed in the results, 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 Physical Environment 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 flow, water level and velocity changes. 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 in-channel aquatic physical environment effects arising from the STT solution required for Gate 2 and the approach to undertaking this assessment is described in **Table 2.1**. This table is replicated from the Gate 2 Physical Environment Evidence Report.

Table 2-1 Approach to the Gate 2 in-channel aquatic physical environment assessment

Task item	Scope of assessment	Approach to assessment
a. Flow change	• Assessment of changes in flow patterns throughout the study area (both river and pass forward flows to Severn Estuary) for the range of reference conditions and scenarios with STT solution.	• Develop and interrogate fluvial flow series at key locations for Gate 2 reference conditions and scenario sets • Develop and use a 1D hydraulic model of the River Severn and River Avon • Use outputs from the 1D hydraulic model of the River Thames
b. River wetted habitat change (River Severn and River Avon)	• Assess effects of flow change on river level, velocity and wetted habitat change	• Interrogate 1D fluvial modelling outputs together with hydromorphological survey data to describe significance of changes in flow velocity and wetted area to provide information for change for key species in the ecological assessments
c. Fish pass and barrier passability (on River Avon)	• Assess effect on passability of fish passes at weirs along the River Avon	• Confirm critical levels for fish pass operation • Review river level model outputs calculated under varying scenarios and compare these with critical levels for fish pass operation to identify any potential impacts and their magnitude
d. Weir pool wetted habitat change (selected weir pools on River Thames)	• Assess effects on level, velocity and wetted habitat change at selected weir pools on the River Thames	• Interrogate 2D fluvial modelling outputs to describe significance of changes in flow velocity and wetted area to provide information for change for key species in the ecological assessments
e. River Vyrnwy specific assessment on wetted habitat and sediment	• Understanding STT releases effects of increased flow on wetted habitat • Sediment dynamics assessment in the River Vyrnwy	• Use monitoring and modelling data to provide quantitative evidence of velocity and aquatic habitat changes at different flows, to better understand the potential effects of the operational regime of an STT release on geomorphology and wetted habitats in the middle and lower reaches of the River Vyrnwy, in the context of the Severn Regulation regime[7]
f. Future climates assessment	• Two climate change future scenarios to assist understanding of resilience	• Incorporate climate change scenarios into 1D hydraulic models for the assessment for the rivers and Severn Estuary pass-forward flows, including specification of scenarios, to quantify effects of climate change baseline changes alongside STT effects

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. The complexity of the collaborative approach is represented in **Figure 2-1**.

[7] It should be noted that discussions are taking place between water companies and the environmental regulators around the representation of Severn regulation in water company water resource models, especially releases from the Vyrnwy water bank, in the Aquator models with the aim of improving the representation in the future to more closely align with the operational decision making by the Environment Agency. The Aquator representation of the Severn Regulation Releases for the different scenarios assessment has been reviewed by the environmental regulators with agreement that they can be used for the Gate 2 submission.

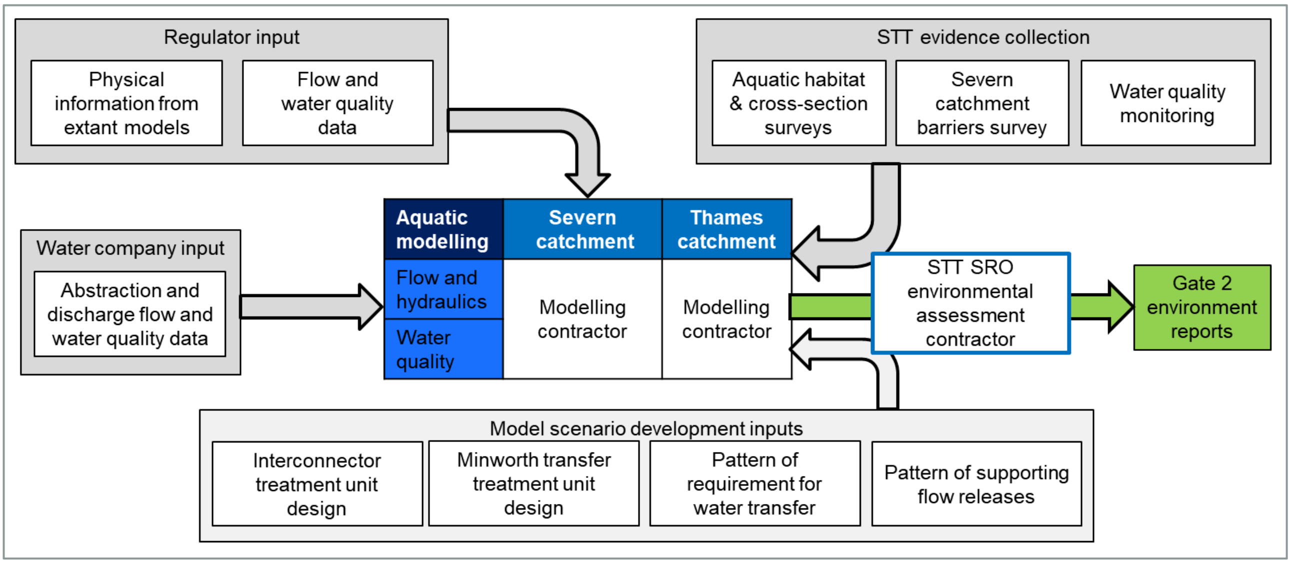

Figure 2-1 Representation of the collaborative approach to STT solution Gate 2 environmental modelling

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 Wales (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 aspects where needed in order to ensure the work undertaken is as robust as possible. They will review and provide comment on, as appropriate, 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.

2.2.2.1 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 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.

2.2.2.2 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 Vyrnwy, Severn and Avon; 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 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 STT solution operation in the following way:

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

For hydraulic and in-channel habitat 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 above. 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. The 1D hydraulic model output, available throughout the study reaches, includes location-specific daily flow, water level, wetted area and depth-average velocity. Model output locations are throughout the modelled study area of the River Vyrnwy, River Severn, River Avon, River Thames and River Severn flows to the Severn Estuary.

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

Scenario		Flow (baseline without 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	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[7]	Central to Gate 2 environmental futures assessments, IEA etc	A82F (Severn) M96F (Thames)
5	**Natural** version of "moderate-low flow"	Represents current meteorological patterns, without abstractions or discharges	Assists discussions of environmental significance with regulators	A82N

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**
A82N - ref	Moderate low flow conditions in River Severn - in **Severn model**	Scenario not considered; used as reference condition only		Scenario not considered; used as reference condition only	
	Moderate low flow conditions in River Thames - in **Thames model**				

The hydraulic model scenarios are parameterised using water resource model flows. These are taken from the GR6J stochastic flow series for the WRW regional group of companies and the WRSE regional group of companies. In each case, the stochastic flow series comprises 400 stochastic representations of 48 calendar years, which total a set of 19,200 years. From these, the modelling teams have identified characteristic patterns, for each of the return periods selected for scenario representations, at key model nodes. Representative years from the stochastic dataset have then been selected that fit well to the characteristic patterns, and as an ensemble of different return periods. Further description of the scenario selection process is provided in the STT SRO Hydraulic and Water Quality Modelling Scenarios Report.

For the River Severn catchment, the key model nodes used in the selection process were Deerhurst and Bewdley, together with information on the pattern of River Severn regulation releases. For the River Thames catchment, the key nodes used in selection were Teddington and Culham. To create flow time series for the representative years, water resources models have been used to parameterise boundary flow conditions for the 1D hydraulic models, together with flow additions from discharges and flow reductions from abstractions.

Severn Trent Water's Aquator model has been used to provide flows for the River Severn catchment 1D hydraulic model. The WRSE North pyWR model has been used to provide flows for the River Thames catchment 1D hydraulic model.

For the future flows, the environmental regulators required that their guidance on climate change is followed, as set out in the Water Resources Planning Guidelines for WRMP24, and the Welsh WRMP guidance i.e. use the RCP 8.5 Business as Usual emissions scenario. Therefore this assessment has drawn upon the selected years of the WRW and WRSE GR6J stochastic series which have been reworked as 2070s RCM8.5 futures by WRW and WRSE. 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 completely representative return frequency for the environmental assessments. As such, it is important to note that the future representation of the selected A82 1:5 return frequency year and M96 1:20 return frequency year do not necessarily retain those return frequencies in the future. The A82 Future and M96 Future years are therefore illustrative of the potential types of changes to river flows and operating patterns in the future.

2.2.4 River Severn catchment hydraulic modelling

Hydraulic model outputs including river flow, velocity and wetted depth selected for use in this assessment are catalogued in the Gate 2 Physical Environment Evidence Report. Wetted habitat model outputs are also catalogued in the Gate 2 Physical Environment Evidence Report.

2.2.5 River Thames catchment hydraulic modelling

Hydraulic model outputs including river flow, velocity and wetted depth selected for use in this assessment are catalogued in the Gate 2 Physical Environment Evidence Report.

2.2.6 River Severn catchment in-channel habitat modelling

In-channel habitat model outputs selected for use in this assessment are catalogued in the Gate 2 Physical Environment Evidence Report.

3 REACH BY REACH ASSESSMENT

3.1 INTRODUCTION

This section describes the effects of the STT Scheme on a reach by reach basis, addressing each metric of change in turn. The reaches, as shown on **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
- Other functionally linked habitats.

For each reach, an assessment is made first of the baseline conditions, before assessing the effect of the STT Scheme on current and then future flow conditions.

For each reach, an assessment is made first of the baseline conditions, before assessing the effect of the STT Scheme on current and then future flow conditions.

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

3.2.1 Overview of the reach

Based on FEH[8] data, the catchment area at the Vyrnwy Reservoir outfall is 74 km², although the flows are highly regulated by the reservoir, including some flow augmentation releases managed through the Severn Regulations[9]. The catchment area of the River Vyrnwy prior to the confluence of the River Vyrnwy with the River Severn is 881 km². The length of the River Vyrnwy in this reach is approximately 66 km.

The initial 24 km downstream of Vyrnwy Reservoir includes a flow regime heavily modified by the reservoir. This includes the reservoir itself and the managed releases from the reservoir; together with the effect of UU's catchwater abstractions on the Marchnant and Afon Cownwy. The Marchant confluences with the River Vyrnwy approximately 2 km downstream of the reservoir and the Afon Cownwy confluences with the River Vyrnwy approximately 3 km downstream. This initial part of the study reach of the middle Vyrnwy is relatively steep, falling 169m over its length, with a gradient of 0.4° and is fairly sinuous (sinuosity ratio of 1.14). River channel widths vary from ~12m at the top of the reach to ~25m at the bottom of the reach. Land cover flanking the reach is composed predominantly of improved grasslands with some natural grasslands and woodland. Riparian tree cover along the reach is continuous to semi-continuous.

The river flows through a relatively steep sided v-shaped valley for the first 20 km, which opens out after Pont Robert and towards the end of the reach around the wider floodplain of the River Vyrnwy. From the series of extended and repeated walkover hydromorphological surveys undertaken[10], the river is characterised by a broad and diverse mixture of low and high energy flow types, with runs and riffles predominating. Bed sediment is characterised by coarse sediments, dominantly cobble sized, although there is a good distribution of sizes from fine sands, gravel and pebble and some boulder. The bed substrate of the upper sections of the reach are characterised by bedrock, particularly down to 16 km. Sediment bars are abundant throughout the reach and most are unvegetated. Most banks are moderate to steep earth banks and bank erosion is occasional, particularly in the lower reaches downstream of Pont Robert. Anthropogenic features are limited mostly to

[8] CEH: Flood Estimation Handbook Web Service. https://fehweb.ceh.ac.uk/

[9] As set out in the "The River Severn Arrangements" between the Environment Agency, Natural Resources Wales and water company

[10] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 1 in in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

bridges, of which nine cross the river, although there is some spatially limited bank reinforcement in the small villages along the way, e.g. Dolanog and Pont Robert. At Dolanog, 16 km downstream, the Dolanog Falls are located on the river. These are a large area of exposed bedrock spanning the channel which have been converted to provide hydropower for Dolanog village. They are a barrier to fish passage, although field observations suggest that it does not act as a significant barrier to downstream sediment movement.

The remaining 42 km of the middle Vyrnwy from the Afon Banwy confluence includes a return to a more variable flow regime following the confluences of several larger tributaries with near-natural flow regimes. These include the 214 km^2 Afon Banwy, which confluences with the River Vyrnwy 24 km downstream of the reservoir; the 79 km^2 Afon Cain, which confluences with the River Vyrnwy a further 18 km; the 244 km^2 Afon Tanat, which confluences with the River Vyrnwy approximately 2 km downstream; and the 77 km^2 River Morda which confluences with the River Vyrnwy approximately 12 km upstream of the end of the reach. The River Morda also conveys treated wastewater effluent from Oswestry WwTW.

This reach of the middle Vyrnwy is of a very low gradient, falling 29m over its length, with a gradient of 0.04° and is very sinuous (sinuosity ratio of 1.68). River channel widths vary from ~30-35m throughout the reach. Land cover flanking the reach is composed predominantly of improved grasslands and arable. Riparian tree cover along the reach is semi-continuous to scattered trees. The river flows through a shallow valley with extensive floodplains on either side. From the series of extended and repeated walkover hydromorphological surveys undertaken[11], the river is characterised by a mixture of low and moderate energy flow types, with runs and riffles predominating and occasional glides and pools. Sediment bars are abundant throughout the reach, with particularly extensive point bars and most are unvegetated. In several areas, the bars create a wide diversity of flow habitats, while there are a number of complex side channels around several of these point bars related to channel migration and there are a number of cut-off meanders along the reach. Based on the sediment bars visible, it is highly likely that the channel bed sediment is dominated by coarse sediments, likely cobble sized. Most banks are moderate to steep earth banks and bank erosion is relatively common. Anthropogenic features are limited mostly to bridges, of which six cross the river. There are no clear bank reinforcement or re-sectioning visible along most of the reach, with some spatially limited bank reinforcement and re-sectioning noted towards the end of the reach at Melverley. There are notable areas of localised bankside poaching around some of the small villages and also adjacent to pastoral grasslands.

In total four potential barriers to fish passage are noted in the reach.

3.2.2 Baseline

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):
[V1] VyrnwyDsReservoir.xlsm - tab 'Flow_Nat'
[V2] VyrnwyDsBanwy.xlsm - tab 'Flow_Nat'
[V3] VyrnwyAtLlanymynech.xlsm – tab 'Flow_Nat'

This section describes baseline conditions and provides a comparison of the baseline to naturalised conditions.

The flow in the River Vyrnwy downstream of Vyrnwy Reservoir varies between 25 and 100 Ml/d from April to October in reference conditions in the A82 scenario [V1]. When flows are 25 Ml/d, an additional flow volume is contributed by the Afon Cownwy to make up the full compensation flow value of 45 Ml/d. The higher flows are a representation of Severn Regulation releases as suggested by EA, which totals ~1,225 Ml additional release over 31 dates in July and August. In October, the managed releases from the reservoir increase to 405 Ml/d, a flood drawdown release, which fluctuates with periods of lower release and higher release until mid-January, after which the flow reduces to between 25 and 50 Ml/d. There is a four-day duration peak flow event in December of approximately 1,500 Ml/d, which is a short duration period of overtopping of the refilled Vyrnwy Reservoir.

Comparison with the naturalised flows [V1] shows the attenuating effect of the reservoir on flow in the river downstream: a number of higher flow events do not occur in the reference scenario between April and December. Very low flows are also increased by release from the reservoir during the summer in the reference scenario.

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[11] The STT SRO Gate 2 hydromorphological survey evidence is presented in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

Downstream of the confluence with the River Banwy [V2] the flow in the River Vyrnwy takes on a more natural pattern, apart from in the summer period where the controlled flow from the reservoir is noticeable. In comparison with the naturalised flow, there is a reduction in the peak flows throughout the year, but the influence of the reservoir is reduced. The flow in spring, autumn and winter is more strongly influenced by the flow from the River Banwy and other tributaries than from the flow released from the reservoir.

The flow between Llanymynech [V3] and the confluence with the River Severn is similar to the flow series downstream of the confluence with the River Banwy. The flow in the River Vyrnwy takes on a more natural pattern, apart from in the summer period where the controlled flow from the reservoir is noticeable. The flow in spring, autumn and winter is increased due to flow from the tributaries.

In comparison with the naturalised flow [V3], there is a reduction of peak flows throughout the year, but the influence of the reservoir is reduced. The flow in spring, autumn and winter is more strongly influenced by the flow from the tributaries than from the flow that is released from the reservoir.

3.2.2.1 Differences between measured and naturalised flow

Statistical characterisation of the differences between measured flow in the River Vyrnwy at the flow gauge immediately downstream of the dam (Vyrnwy at Vyrnwy Reservoir, NRFA ID 54003) and a naturalised inflow time series to Vyrnwy Reservoir (as used in water resources modelling by UU and STW) have been calculated using the Indicators of Hydrological Alteration[12] (IHA) for years 1999 to 2017. The IHA statistics are summarised in Table 3-1.

Figure 3-1 presents a graphical comparison of key IHA flow statistics for the 1999-2017 River Vyrnwy measured and naturalised flows, namely mean monthly flows (Figure 3-1a), mean of annual minimum (MAM) 1 to 90 day flows (Figure 3-1b) and mean of annual maximum (MAMx) 1 to 90 day flows (Figure 3-1c).

Table 3-1 IHA statistics for 1999-2017 River Vyrnwy measured and naturalised flows

IHA statistics	Unit	Vyrnwy measured flow (1999-2017)	Vyrnwy naturalised flow (1999-2017)
Mean April flow	Ml/d	122	266
Mean May flow	Ml/d	113	243
Mean June flow	Ml/d	74	140
Mean July flow	Ml/d	88	178
Mean August flow	Ml/d	50	150
Mean September flow	Ml/d	99	277
Mean October flow	Ml/d	227	542
Mean November flow	Ml/d	300	544
Mean December flow	Ml/d	386	657
Mean January flow	Ml/d	431	602
Mean February flow	Ml/d	365	551
Mean March flow	Ml/d	187	341
Mean of annual minimum 1 day flow	Ml/d	16	14
Mean of annual minimum 3 day flow	Ml/d	21	15
Mean of annual minimum 7 day flow	Ml/d	25	18
Mean of annual minimum 30 day flow	Ml/d	33	44

[12] Richter, B.D., Baumgartner, J.V., Powell, J., and Braun, D.P. (1996). A Method for Assessing Hydrologic Alteration within Ecosystems. Conservation Biology, Vol. 10, No. 4. August 1996. p1163-1174.

IHA statistics	Unit	Vyrnwy measured flow (1999-2017)	Vyrnwy naturalised flow (1999-2017)
Mean of annual minimum 90 day flow	Ml/d	39	75
Mean of annual maximum 1 day flow	Ml/d	2,938	3,583
Mean of annual maximum 3 day flow	Ml/d	2,159	2,834
Mean of annual maximum 7 day flow	Ml/d	1,509	2,029
Mean of annual maximum 30 day flow	Ml/d	777	1148
Mean of annual maximum 90 day flow	Ml/d	486	709
Q95	Ml/d	25	24
Q5	Ml/d	795	1,482
Base flow index: 7 day minimum/mean annual	Ml/d	0.2	0.1
Mean Julian day of minimum flow	day	168	88
Mean number of times per year flow is less than Q75‡	count	13	16
Mean Julian day of maximum flow	day	270	245
Mean number of times per year flow exceeds Q25†	count	7	22
Mean number of flow rises	count	46	45
Mean fall rate – mean difference between falling flows	Ml/d	79	143
Mean duration of flows less than Q75‡	days	19	6
Mean duration of flows greater than Q25†	days	5	4

‡ Assessed using Q75 from the natural dataset 63.6Ml/d

† Assessed using Q25 from the natural dataset 456.9Ml/d

Figure 3-1 Graphical comparisons between key IHA flow statistics for the River Vyrnwy measured and naturalised flows over 1999-2017

Both the numerical IHA statistics and their graphical representation (**Table 3-1** and **Figure 3-1**) illustrate the differences between the measured and naturalised flows. On a monthly basis the mean naturalised flows are significantly higher than the mean measured flows, commonly by two to three times. For very short duration low flows, the mean annual minimum and the 3-day average illustrates that naturalised flows tend to be lower than the measured flows. In contrast over weekly (MAM 7) or longer, naturalised flows are higher than the measured flows. This indicates that while naturalised flows can be below the measured flows (likely at times of compensation flow), long periods of low flow associate with an average flow value which is higher than the compensation flow, suggesting greater flow variability. For the mean annual maximum flows, measured flows are lower than naturalised flows over all duration ranges assessed, particularly for the MAMx 1 (daily) to MAMx 7 (weekly) duration events. This indicates the effect of the dam and current compensation release pattern in suppressing the magnitude of peak flows, but also the fact that short, high flow periods (for example, driven by high intensity rainfall events) are also greatly attenuated in the measured dataset.

3.2.2.2 Differences between measured and naturalised flow

This analysis highlight how the release pattern of water from the reservoir does not represent or mimic a naturalised flow release pattern. A release pattern is requested that is as naturalised as possible, but which does not compromise the requirements for compensation flow and Severn River Regulation releases, and which can accommodate water to be released for the STT scheme.

When the volume of water to be released from the Reservoir is confirmed, through the further development of the scheme, post Gate 2, it will then be possible to explore what a more naturalised flow release volume could be achieved.

3.2.3 STT operation – current climate

In this reach, the STT solution would augment flows through a 25 Ml/d direct release from Vyrnwy Reservoir at selected times. The indicative system operational pattern identified from stochastic series in Section 1.3 and illustrated as the blue periods of the 47 water resources years in **Figure 1-4**, describes a typical pattern of STT solution scheme operation for river flow augmentation on the River Vyrnwy from a Vyrnwy Reservoir direct release during current climate conditions. Overall, this describes a pattern of STT solution releases only in 24 of the 47 years, and on 16% of days overall. As shown on **Figure 3-2**, flow changes in this reach would typically be in the months July to October, peaking in August at 47% of days in August. Outside this period, there would be less regular flow changes in June and November, with changes very rare in May, December and January and not anticipated in February, March or April.
The A82 scenario would include a continuous 105 day period of flow augmentation from late June to early October. The M96 scenario would include a continuous 144 day period of flow augmentation from mid-June to early November.

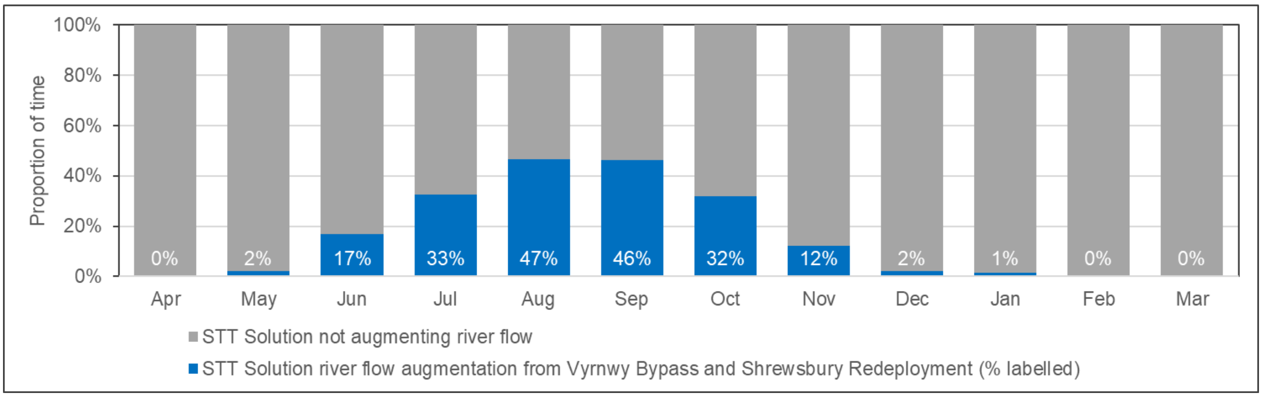


Figure 3-2 Representation of seasonality of STT solution flow changes in the River Vyrnwy from the Vyrnwy Reservoir to Llanymynech

3.2.3.1 Change to flow

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):
[V4] VyrnwyDsReservoir.xlsm – tab ‘Flow’
[V5] VyrnwyDsReservoir.xlsm – tab ‘FlowChange’
[V6] VyrnwyDsBanwy.xlsm – tab ‘Flow’
[V7] VyrnwyDsBanwy.xlsm – tab ‘FlowChange’
[V8] VyrnwyAtLlanymynech.xlsm – tab ‘Flow’
[V9] VyrnwyAtLlanymynech.xlsm – tab ‘FlowChange’
[V10] VyrnwySaxons_LongSection_flows.xlsx – tab ‘Vyrnwy_Flow’

Downstream of the reservoir, the flow is increased by 25 Ml/d from the 27th of June to the 9th of October in the A82 scenario and from the 12th of June to the 2nd of November in the M96 scenario [V4 and V5]. This is a percentage change in flow of between 25 and 100% depending on the baseline flow. The duration of the STT support changes between Scenario A82 and M96 because of when the transfer of water is required.

In A82, STT solution releases of 25 Ml/d potentially coincide with Severn Regulation releases on 31 dates in July and August, with other managed releases (compensation flow, Severn Regulation Release) up to 95 Ml/d. In M96, STT solution releases of 25 Ml/d potentially coincide with Severn Regulation releases on 115 dates between mid-June and mid-October, with other managed releases (compensation flow, Severn Regulation Release) at a higher rate in this representative very low flow year, up to 120 Ml/d.

Downstream of the confluence with the River Banwy, the absolute increase in flow with the fully supported condition is slightly reduced to ~22 Ml/d compared to immediately downstream of the reservoir due to losses [V6 and V7]. The percentage of flow due to the supported release from the reservoir reduces to 23% of the flow downstream of the River Banwy, because the River Banwy increases the reference flow in the river from 77 to 193 Ml/d on the 25th of August. The reference flow increases from 45 Ml/d to 960 Ml/d on the 5th of December. This can be seen by the step in the long profile for the River Vyrnwy at 24 km downstream of the reservoir [V8]. Note that the long profile of flow is for particular points in time - this means that there can be changes in flow rate along a reach at higher flows because the system is dynamic and the increased flow from a tributary may not have travelled along the reach. In summer, the flows are more constant along reaches between tributaries because of upstream flow regulation. In the A82 scenario, the percentage change of flow in the River Vyrnwy is significantly reduced in September and October due to the higher flow from the River Banwy. This does not occur in the lower flow scenario (M96) due to the lower flow in River Banwy under this scenario.

At Llanymynech, the flow is increased by approximately 22 Ml/d from the 28th of June to the 9th of October from the reservoir release (less the losses between the reservoir and Llanymynech) in the A82 scenario [V11 and V12]. Again, the flow increase is less than the release flow because of losses.

In the M96 scenario, the flow is increased by approximately 22 Ml/d on the 13th and 14th June, to 3rd November [V11 and V12]. This is because when the transfer of water is required, the flow in the River Severn is low and full support is required.

3.2.3.2 Change to river level, velocity and wetted habitat

Summary results showing the percentage coverage of baseline hydraulic habitat distribution and percentage change in this habitat (derived from 1D model output data) under A82 and M96 periods and releases for the reach (see Annex A), are provided below in Table 3-2.

Table 3-2 Percentage of hydraulic habitat within the reach of the River Vyrnwy from Vyrnwy Reservoir to the confluence with the River Severn

Fish	Life stage	A82 habitats (%)				M96 habitats (%)			
		Baseline	Scheme			Baseline	Scheme		
		Suitable habitat	Gain	No change	Loss	Suitable habitat	Gain	No change	Loss
Atlantic salmon	0+	31.9	0.7	97.3	2.0	35.5	0.2	97.3	2.5
	Juvenile	42.5	0.2	98.1	1.7	44.3	0.2	97.3	2.5
	Spawning	33.6	0.6	97.7	1.7	35.0	0.7	98.1	1.2
Brown trout	0+	2.6	0.0	98.5	1.5	1.8	0.0	99.1	0.9
	Juvenile	56.8	0.9	96.1	3.0	57.0	0.0	97.5	2.5
	Spawning	33.1	0.8	97.9	1.3	36.1	0.6	98.1	1.3
Lamprey sp.	Larvae	25.2	0.3	97.3	2.4	28.2	0.0	97.0	3.0
	Spawning	4.5	1.1	98.6	0.2	5.0	1.3	98.7	0.0
Chub	Juvenile	0.4	0.0	99.6	0.3	0.1	0.0	99.9	0.1
	Spawning	46.4	0.5	97.8	1.7	49.1	0.3	98.1	1.6
Roach	Juvenile	41.2	0.6	95.4	4.0	44.5	0.0	96.3	3.7
	Spawning	23.8	1.0	97.2	1.9	25.2	0.2	96.7	3.1
Eel	Juvenile	79.7	2.0	98.0	0.0	75.2	2.6	97.4	0.0

The data indicate that, on the whole there is a wide range of suitable baseline hydraulic habitat present throughout the reach during both A82 and M96 runs, notably for Atlantic salmon (all life stages), Brown trout (juvenile and spawning), Lamprey (larvae), Chub (spawning), Roach (juvenile) and European eel. There are notable variations in the presence of suitable hydraulic habitat based on fish life cycle, with Brown trout (0+), Lamprey (spawning) and Chub (juvenile) habitat indicated as being relatively rare within the reach.

Changes in the presence of suitable hydraulic habitat under the A82 and M96 flow releases show that there is limited change in this baseline habitat for most species, with 97.6% habitat remaining unchanged for the A82 flows and 97.8% for the M96 flows. Under A82 flows, habitat gains and losses average 0.7% and 1.7% respectively, while for the M96 flows, habitat gains decrease to 0.5%, while habitat losses remain at 1.7% on average.

The data show that that there is a wide range of suitable habitat present in the reach for the key fish species considered, and there are likely to be only limited and localised change in habitat as flows change during releases, with some losses and some small gains in hydraulic habitat.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. Annex A should be referred to for the full assessment, including spatial plots of hydraulic habitat distribution and changes.

3.2.3.3 Change to weir pool wetted habitat or weir passability

There are no weir pool habitats in this reach.

There are no weirs identified for review of fish passability in this reach.

3.2.4 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 extension both 35 days earlier, to include late May and all of June; and 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.

3.2.4.1 Change to flow

This section is supported by charts and data in excel workbooks: the same ones as listed in the section above for current conditions.

Downstream of the reservoir, the flow is increased by 25 Ml/d from the 23$^{rd\ of}$ May to the 20$^{th\ of}$ November in the A82 Future scenario [V3 and V4]. This is a percentage change in flow of between 10 and 100% depending on the baseline flow.

Downstream of the confluence with the River Banwy, the absolute increase in flow with the fully supported condition is slightly reduced to ~22 Ml/d compared to immediately downstream of the reservoir due to losses [V6 and V7]. The percentage of flow due to the supported release from the reservoir increases to between 5% and 35% of the flow downstream of the River Banwy, because the River Banwy increases the reference flow in the river. The long section [V10] shows that during low flows in the Future Scenario, on the 18$^{th\ of}$ October, the reference flow is only increased by 50% after the Banwy, whereas in current conditions, the flow more than doubles at low flows.

With the A82 Future flow scenario, the flow is increased by approximately 22 Ml/d from the 24$^{th\ of}$ May to the 20$^{th\ of}$ November from the reservoir release (less the losses between the reservoir and Llanymynech) at Llanymynech [V10 and 11]. The flow increase with the scheme is around 15% of the total flow in the river under Future conditions on the 18$^{th\ of}$ October. Again, the flow increase is less than the release flow because of losses.

3.2.4.2 Change to river level, velocity and wetted habitat

The baseline and scheme hydraulic habitats for fish species within the reach are briefly outlined in Section 3.2.3.2. These data show that that there is a wide range of suitable habitat present in the reach for the key fish species considered (particularly Atlantic salmon (all life stages), Brown trout (juvenile and spawning), Lamprey (larvae), Chub (spawning), Roach (juvenile) and European eel). With the A82 and M96 scenarios, hydraulic habitats remain fairly constant, although there are some losses averaging between 0.6% (A82) and 1.7% (M96) and slight gains.

With future flow changes, both an increase in flow volume and duration in the reach, it is likely that there will be an increasing loss of hydraulic habitats in response to increasing velocity and depth of flows, although, based on the current A82 and M96 data, these losses are not likely to be extensive in both magnitude and distribution. However, as noted for the current climate, there could also be some gains, which would contribute marginally to offsetting any losses as other areas of the river within the reach trend towards suitable hydraulic habitat with increasing flows.

3.2.4.3 Change to weir pool wetted habitat or weir passability

There are no weir pool habitats in this reach.

There are no weirs identified for review of fish passability in this reach.

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

3.3.1 Overview of the reach

Based on FEH[13] data, the catchment area of the River Severn after the confluence of the River Vyrnwy is 1,938 km² for both rivers combined. In terms of catchment area alone, the River Vyrnwy is 45% of the combined area at the confluence, to the River Severn's 55%. Flow in the River Severn is managed by the Severn Regulations[14] with significant flow augmentation releases from Clywedog Reservoir at times of moderate-low flows in the River Severn measured at the Bewdley river flow gauge.

The catchment area of the River Severn at Bewdley is 4,330 km². This represents a doubling of the catchment area along the 112 km of the River Severn in this reach of the study area. In this reach, there is one very large tributary, the River Tern which confluences with the River Severn 86 km downstream of the confluence of the River Vyrnwy with the River Severn, and accounts for 878 km² of the additional catchment area. There are also smaller tributaries regularly along the reach, including, in downstream order, the Weir Brook (33 km² contributing catchment area), River Perry (194 km² contributing catchment area), Rea Brook (190 km² contributing catchment area), Cound Brook (157 km² contributing catchment area), River Worfe (261 km² contributing catchment area) and Dowles Brook (46 km² contributing catchment area). The Shropshire Groundwater Scheme, operated as part of the Severn Regulations, augments flow in the River Perry and River Tern. The reach also includes direct WwTW treated effluent inputs from Shrewsbury (Monkmoor) WwTW; and Coalport WwTW. There are three public water supply abstractions in the reach, Shelton at 32 km downstream of the confluence of the River Vyrnwy with the River Severn; Hampton Loade at 97 km downstream of the confluence of the River Vyrnwy with the River Severn; and Trimpley at 106 km downstream of the confluence of the River Vyrnwy with the River Severn.

This reach of the middle Severn is of a very low gradient, falling 38m over its length, with a gradient of 0.01° and is fairly sinuous (sinuosity ratio of 1.22). River channel widths vary ~40-45m throughout the majority of the reach. In the vicinity of Ironbridge Gorge, the channel is steeper than the average values. Land cover flanking the reach is composed predominantly of improved grasslands with some natural grasslands and arable land, with occasional woodland. There are extensive urban areas at Shrewsbury (~27 km downstream), Ironbridge (~73 km downstream), Bridgnorth (~88 km downstream) and Bewdley. Riparian tree cover along the reach ranges from continuous to scattered trees, though some banks do have limited to no tree cover. The river generally flows through an extensive and wide floodplain for much of its length, though there are areas of difference, such as where the rivers flows though valley sections, for example around Ironbridge.

From extant aerial imagery and the extended and repeated walkover hydromorphological surveys undertaken[15], the river is characterised by a mixture of deep glides and runs, with occasional riffle sections, including a distinctive riffle to rapid section at Ironbridge. Sediment bars are rare throughout the reach, although there are multiple islands scattered throughout the reach. Bed sediments information from the repeated walkovers indicate a range of substrates dependent on site, including clay bed and bedrock sections, gravel dominated sections and some areas of coarser bed material and some of finer. The majority of banks outside of urban areas appear to range from moderate to steep with occasional shallow banks, and bank erosion is

[13] CEH: Flood Estimation Handbook Web Service. https://fehweb.ceh.ac.uk/

[14] As set out in the "The River Severn Arrangements" between the Environment Agency, Natural Resources Wales and water company

[15] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 2 in in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

relatively common. Within urban areas, the evidence indicates increased reinforcement and re-sectioning of banks, especially in the larger urban areas.

Approximately 48 bridges (mostly road and footbridges with occasional railway bridges) cross the channel. There are two weirs. As noted above, most bank reinforcement and re-sectioning are found within the main urban areas along the reach. There are notable areas of localised bankside poaching around some of the small villages and also adjacent to pastoral grasslands.

3.3.2 Baseline

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):
[S1] SevernDsVyrnwy.xlsm - tab 'Flow_Nat'
[S2] SevernDsVyrnwyBypass – tab 'Flow_Nat'
[S3] SevernAtBewdleyGauge.xlsm - tab 'Flow_Nat'
[V11] VyrnwySaxons_LongSection_flows.xlsx – tab 'SeverntoWroxeter_Flow'
[V12] VyrnwySaxons_LongSection_flows.xlsx – tab 'WroxetertoBewdley_Flow'

This section describes baseline conditions and provides a comparison of the baseline to naturalised conditions. The flow in the River Severn has a fluctuating natural pattern through the year, apart from in the summer period where the controlled flow from the reservoir is noticeable in July and August [S1, S2, S3 and V12]. The flow is significantly increased due to flow from the upper Severn compared to the flow in the River Vyrnwy, and the duration of the summer low flow is reduced to around 2 months.

In comparison with the naturalised flow, there is less reduction of the flow peaks throughout the year as the influence of the reservoir is reduced.

After the confluence of the River Vyrnwy and River Severn, the low summer flow on 25th August increases from 355 Ml/d to 730 Ml/d in the reference condition [S1, S2 and S3]. The long profile plots [V11 and V12] also show minor increases in flow from the Weir Brook (at 69 km) and Yealton (at 85 km) then in reference conditions a fall of 25 Ml/d at Shelton that represents the Shrewsbury abstraction (at 98 km), then a larger increase of 85 Ml/d at Hookagate (104 km). The next significant increase is at Walcot (121 km) and Boreton (125 km). Minor flow increases occur at Coalport STW (145 km) and Burcote (152 km). Significant abstractions occur at Hampton Loade (163 km) of around 165 Ml/d and around 122 Ml/d at Trimpley (172 km).

3.3.3 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); and an abstraction reduction at Shelton intake at Shrewsbury, at selected times. Accounting for flow losses in the river systems, STT solution flow augmentation in this reach would be up to 200 Ml/d. The operating pattern is shown on **Figure 3-3**.

The indicative system operation pattern identified from stochastic series in Section 1.3 and illustrated as the blue periods of the 47 water resources years in **Figure 1-4**, describes a typical pattern of the STT solution scheme operation for river flow augmentation on the River Severn from a Vyrnwy Bypass outfall during current climate conditions. Overall, this describes a pattern of the STT solution releases only in 24 of the 47 years, and on 16% of days overall. As shown on **Figure 3-3**, flow changes in this reach would typically be in the months July to October, peaking at 47% of days in August. Outside this period, there would be less regular flow changes in June and November, with changes very rare in May, December and January and not anticipated in February, March or April.

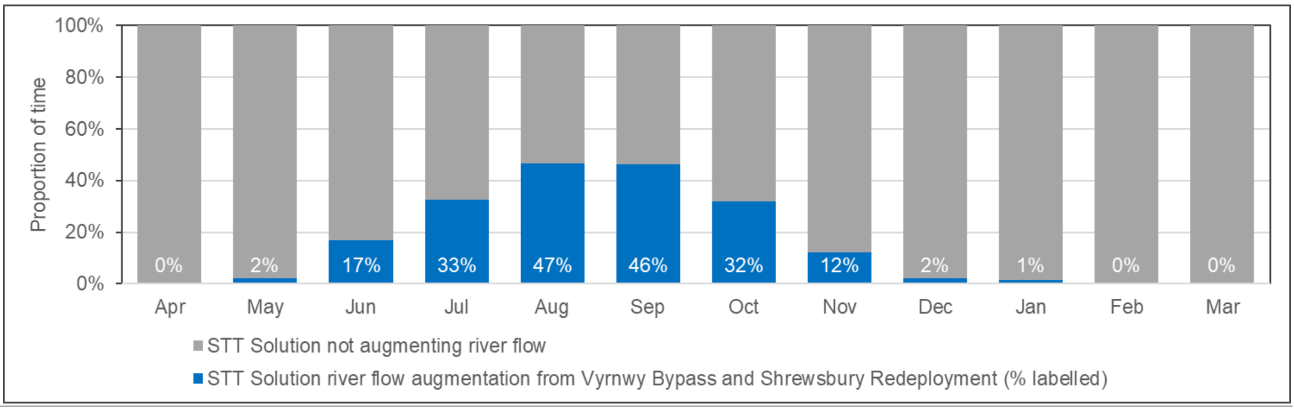


Figure 3-3 Representation of seasonality of STT solution flow changes in the River Severn from the Vyrnwy bypass outfall and Shrewsbury Redeployment

The A82 scenario would include a continuous 105 day period of flow augmentation from late June to early October. The M96 scenario would include a continuous 144 day period of flow augmentation from mid-June to early November.

3.3.3.1 Change to flow

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):
[S4] SevernDsVyrnwy.xlsm – tab 'Flow'
[S5] SevernDsVyrnwy.xlsm] – tab 'FlowChange
[S6] SevernDsVyrnwyBypass.xlsm – tab 'Flow'
[S7] SevernDsVyrnwyBypass.xlsm – tab 'FlowChange'
[S8] SevernAtBewdleyGauge.xlsm – tab 'Flow'
[S9] SevernAtBewdleyGauge.xlsm] – tab 'FlowChange'
[V11] VyrnwySaxons_LongSection_flows.xlsx – tab 'SeverntoWroxeter_Flow'
[V12] VyrnwySaxons_LongSection_flows.xlsx - tab 'WroxetertoBewdley_Flow'

On the River Severn, downstream of the confluence with the River Vyrnwy [S4 and S5], the flow is increased by approximately 20 Ml/d from the 28th of June to the 10th of October in the A82 scenario. Once the STT supported flows ramp up, the flow is increased by approximately 23% during July and August. The percentage increase is variable during September due to moderate flow events increasing the baseline flows.

In the M96 scenario the flow is increased by approximately 20 Ml/d on the 13th and 62 Ml/d on the 14th of June, then by approximately 160 Ml/d from the 16th of June to 2nd November. The low flow period is longer in the M96 scenario compared to A82, even after the confluence of the Rivers Vyrnwy and Severn. Once the STT supported flows ramp up, the flow is increased by approximately 23% during July, August, September and October.

Downstream of the Vyrnwy Bypass [S6 and S7] the flow is increased by a further 155 Ml/d which is a total increase of 175 Ml/d. In the A82 Scenario, this occurs from the 28th of June until the 9th of October and is a flow increase of around 22%, and in the M96 Scenario from the 18th of June until the 2nd of November and the flow increase is around 24%.

At Bewdley on the River Severn [S8 and S9] the flow is increased by approximately 35 Ml/d from the 28th of June then increases by approximately 201 Ml/d from the 4th of July to the 10th of October in the A82 scenario. The flow increases then reduces and drops off by the 12th of October. The timing of the flow increase is delayed compared to the locations further upstream due to the travel time along the river. The increase in flow at Bewdley is greater than at the location of the River Vyrnwy bypass outfall upstream of Montford because of the Shrewsbury component of the fully supported scheme. Once the STT supported flows ramp up the flow is increased by approximately 23% during July and August. The percentage increase is variable during September due to moderate flow events increasing the baseline flows.

In the M96 scenario, the flow is increased by approximately 20 Ml/d on the 15th to the 18th of June, then by approximately 201 Ml/d from the 20th of June to 2nd November. This is because when the transfer of water is required the flow in the River Severn is low and full support is required from both the reservoir, the reservoir bypass and Shrewsbury. Once the STT supported flows ramp up, the flow is increased by approximately 24% during July, August, September and October.

The long profile of flows on the 25th of August (low flow condition) [V11 and V12] show that after the confluence of the Vyrnwy bypass with the River Severn at 69 km, just upstream of Montford, the flow from the STT scheme is approximately 16% of the total flow. At Bewdley, the percentage of flow from the scheme increases to around 17% of the total flow, due to the flow not abstracted from Shrewsbury [V11 and V12].

3.3.3.2 Change to river level, velocity and wetted habitat

Summary results showing the percentage coverage of baseline hydraulic habitat distribution and percentage change in this habitat (derived from 1D model output data) under A82 and M96 periods and releases for the reach (see Annex A), are provided below in Table 3-3.

Table 3-3 Percentage of hydraulic habitat within the reach of the River Severn from the confluence with the River Vyrnwy to Bewdley

Fish	Life stage	A82 habitats (%)				M96 habitats (%)			
		Baseline	Scheme			Baseline	Scheme		
		Suitable habitat	Gain	No change	Loss	Suitable habitat	Gain	No change	Loss
Atlantic salmon	0+	5.0	0.1	97.6	2.3	6.5	0.1	96.5	3.4
	Juvenile	9.3	0.0	97.1	2.9	11.3	0.1	96.5	3.4
	Spawning	5.6	0.0	98.1	1.9	7.1	0.0	97.2	2.8
Brown trout	0+	0.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0
	Juvenile	49.9	0.9	93.9	5.3	53.7	0.0	94.7	5.2
	Spawning	4.6	0.1	98.1	1.8	6.1	0.2	97.0	2.9
Lamprey sp.	Larvae	3.3	0.0	98.0	2.0	4.6	0.0	97.0	3.0
	Spawning	2.1	0.3	99.6	0.1	1.6	0.4	99.6	0.0
Chub	Juvenile	0.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0
	Spawning	16.3	0.1	96.1	3.8	19.4	0.0	94.6	5.4
Roach	Juvenile	22.1	0.3	94.2	5.5	26.8	0.0	92.7	7.3
	Spawning	0.1	0.0	99.9	0.1	0.1	0.0	99.9	0.1
Eel	Juvenile	97.3	1.5	98.4	0.0	97.8	2.4	97.6	0.0

The data indicate that, on the whole there is very limited suitable baseline hydraulic habitat present throughout the reach during both A82 and M96 runs, with only Brown trout (juvenile), Chub (spawning), Roach (juvenile) and European eel (juvenile) showing notable presence of suitable hydraulic habitat.

Changes in the presence of suitable hydraulic habitat under the A82 and M96 flow releases show that there is limited change in this baseline habitat for most species, with the majority of suitable habitat remaining unchanged for the A82 and M96 flows. Under A82 flows, habitat gains and losses average 0.3% and 2.0% respectively, while for the M96 flows, habitat gains remain unchanged, while habitat losses increase up to 3% on average.

The data show that, except for a few specific fish species life stages, there is a very limited range of suitable hydraulic habitat present in the reach for the key fish species considered, and there are likely to be only very limited and localised change in habitat as flows change during releases, with losses being larger than gains.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. Annex A should be referred to for the full assessment, including spatial plots of hydraulic habitat distribution and changes.

3.3.3.3 Fish pass and barrier passability

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report:
[A] ShrewsburyRightBank.xlsm – tab 'Depth'
[B] ShrewsburyRightBank.xlsm – tab 'DepthChange'

One fish pass site in this reach has been modelled to review the changes in level associated with the STT solution. This is the 'Shrewsbury right bank' site. The level change can then be used to inform the impact on the efficacy of this fish pass (noting that there is currently insufficient information to derive the critical levels for fish passage).

For the Shrewsbury right bank, under the A82 scenario, there is an increase in level [A] between 27th June and 10th October. From the 27th of June to the 25th of August the level increases by between 1.0cm and 3.9cm [B] with a mean level of 47.50m AOD compared to the mean baseline level of 47.47m AOD over this period. Between 26th August and 10th October the level increase is more variable, fluctuating between 1.1cm and 3.6cm with a mean level of 62m AOD compared to a mean baseline level of 47.59m AOD.

Under the M96 scenario the level change is relatively consistent throughout the period from the 18th of June to 3rd November. Generally, the change in level fluctuates between 5cm and 3.9cm increase in level with the mean level over the period being 53m AOD compared to 49m AOD in the baseline.

3.3.4 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 extension both 35 days earlier, to include late May and all of June; and 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.

3.3.4.1 Change to flow

This section is supported by charts and data in excel workbooks: the same ones as listed in the section above for current conditions.

On the River Severn downstream of the confluence with the River Vyrnwy [V6 and V7], the flow is increased by approximately 20 Ml/d on from the 24th of May to the 21st of November in the A82 Future scenario. The flow is increased by approximately 3% during July to October.

Downstream of the Vyrnwy Bypass [S6 and S7] the flow is increased by a further 155 Ml/d which is a total increase of 175 Ml/d. In the A82 Future Scenario this occurs from the 25th of May until the 21st of November and is a flow increase of around 22%.

At Bewdley on the River Severn [S8 and S9] the flow in the A82 Future scenario is increased by approximately 28 Ml/d from the 24th May then increases by approximately 198 Ml/d from the 6th of May to the 22nd of November. The flow increase then reduces and drops off by the 23rd of November.

The long section [V11] shows that after the outfall from the Vyrnwy bypass pipeline at 69 km, the flow increases by 175 Ml/d or 24% of the total flow in the Future flow scenario on the 18th of October. The flow in the River Severn with the Full STT scheme in this lowest flow period is similar in magnitude to the Reference flow under A82 present day conditions.

3.3.4.2 Change to river level, velocity and wetted habitat

As a guide, the change in depth-average velocity and water depth at the Severn at Bewdley assessment point from the 1D hydraulic model has been reviewed. There are 141 days in the A82 Futures scenario with modelled river flows of less than 900 Ml/d in the reference conditions and with direct release from Vyrnwy Reservoir; Vyrnwy bypass release; and abstraction reduction at Shelton intake at Shrewsbury. On these dates, the mean change in depth-average velocity is modelled as 0.028 m/s (a 3% increase) and the mean change in water depth is modelled as 0.068 m (a 7% increase).

The baseline and scheme hydraulic habitats for fish species within the reach are briefly outlined in Section 3.3.3.2. These data show that that there is generally very limited suitable baseline hydraulic habitat present throughout the reach, with only Brown trout (juvenile), Chub (spawning), Roach (juvenile) and European eel (juvenile) showing notable presence of suitable hydraulic habitat. With the A82 and M96 scenarios, hydraulic habitats remain fairly constant, although there are some losses averaging between 0.3% (A82) and 2.0% (M96) and minimal gains.

With future flow changes, the data for the Severn at Bewdley assessment point indicates relatively small increases in velocity and depth. It is likely that there will be an increase in the loss of hydraulic habitats in response to this increase in velocity and depth of flows. However, given the relatively low magnitude of change simulated, these losses are likely to be very limited in both magnitude and distribution.

3.3.4.3 Fish pass and barrier passability

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report:
[A] ShrewsburyRightBank.xlsm – tab 'Depth'
[B] ShrewsburyRightBank.xlsm – tab 'DepthChange'

One fish pass site in this reach has been modelled to review the changes in level associated with the STT solution. This is the 'Shrewsbury right bank' site. The level change can then be used to inform the impact on the efficacy of this fish pass (noting that there is currently insufficient information to derive the critical levels for fish passage).

For the Shrewsbury right bank, under the A82 scenario, there is an increase in level [A] between 23rd May and 22nd November. For this period, the level increases by between 1cm and 4cm [B] with a mean level of 47.54m AOD compared to the mean baseline level of 47.51m AOD over this period.

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

3.4.1 Overview of the reach

Based on FEH[16] data, the catchment area of the River Severn at Bewdley is 4,330 km². The catchment area of the River Severn prior to the confluence of the River Avon with the River Severn is 6,984 km². Along the 56 km of this reach, this represents a further doubling in catchment area compared with the catchment at the River Severn after its confluence with the River Vyrnwy. In this reach, there is one very large tributary, the River Teme which confluences with the River Severn 28 km downstream of the Bewdley flow gauge, and accounts for 1,654 km² of the additional catchment area. There are also smaller tributaries regularly along the reach, including, in downstream order, the River Stour (372 km² contributing catchment area) and River Salwarpe (197 km² contributing catchment area). The reach also includes direct WwTW treated effluent inputs from Worcester WwTW. There are two public water supply abstractions in the reach, Upton at 42 km downstream of the Bewdley flow gauge; and Mythe at 54 km downstream of the Bewdley flow gauge.

The reach is of a very low gradient, falling 10m over its length, with a gradient of 0.01° and is fairly sinuous (sinuosity ratio of 1.24). River channel widths vary from ~40-45m throughout the majority of the reach from the start to south of Worcester and increases to ~60m wide to the end of the reach. Land cover flanking the reach is composed predominantly of improved grasslands with some natural grasslands and arable land, with occasional woodland. There are extensive urban areas at Bewdley, Stourport-on-Severn (~6 km downstream), Worcester (~25 km downstream) and Upton upon Severn (~42 km downstream). As with the upstream reach, riparian tree cover along the reach ranges from continuous to scattered trees, though some banks do have limited to no tree cover. The river generally flows through an extensive and wide floodplain for much of its length.

From extant aerial imagery and the extended and repeated walkover hydromorphological surveys undertaken [17], the river is characterised by deep glides. Sediment bars are rare throughout the reach, although there are multiple islands scattered throughout the reach. No information on bed sediments are available. The majority of banks outside of urban areas appear to range from moderate to steep with occasional shallow banks and bank erosion is relatively common. Within urban areas the evidence indicates increased reinforcement and re-sectioning of banks, especially in the larger urban areas.

Approximately 12 bridges (mostly road bridges) cross the channel. The river is managed for navigation from Stourport-on-Severn and there are four weir and lock combinations located on channel bifurcations round an island, with the weir and lock located on opposite arms of the bifurcation. There is a notable increase in boating activity, including moorings, towards the bottom of the reach. As noted above, most bank reinforcement and

[16] CEH: Flood Estimation Handbook Web Service. https://fehweb.ceh.ac.uk/

[17] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 3 in in the supporting Excel workbook called "*STT_Physical Environment_Workbook*".

re-sectioning are found within the main urban areas along the reach. There are notable areas of localised bankside poaching around some of the small villages and also adjacent to pastoral grasslands.

3.4.2 Baseline

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): [S3] SevernAtBewdleyGauge.xlsm - tab 'Flow_Nat' [S10] SevernPriorToConfluenceWithTheAvon.xlsm - tab 'Flow_Nat' [V13] VyrnwySaxons_LongSection_flows.xlsx - tab 'BewdleytoSaxons_Flow'

This section describes baseline conditions and provides a comparison of the baseline to naturalised conditions.

The flow in the River Severn prior to the confluence with the River Avon [S3 and S10] has a fluctuating natural pattern through the year, apart from in the summer period where the controlled flow from the reservoir is noticeable in July and August. The flow is significantly increased due to flow from the upper Severn compared to the flow in the River Vyrnwy, and the duration of the summer low flow is reduced to around 2 months in the A82 reference scenario. During winter the flow is above 5,000 Ml/d.

In comparison with the naturalised flow, there is little reduction in the flow peaks throughout the year as the influence of the Vyrnwy reservoir on flow attenuation is significantly reduced [S10].

The long profile flow plot between Bewdley and Saxons Lode [V13] shows that in the low flow summer period (25th August) the flow in the River Severn increases from approximately 800 Ml/d to 1,450 Ml/d at 206 km due to inflow from tributaries, then falls by 90 Ml/d due to abstractions at Upton. The flow in the river increases by a factor of 1.7 in this reach during the low flow period. The increase factor is similar at moderate flows (5th December) when supported flows are not required because the flow in the River Severn at Saxons Lode is above 4,500 Ml/d.

3.4.3 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); and an abstraction reduction at Shelton intake at Shrewsbury, at selected times. Accounting for flow losses in the river systems, STT solution flow augmentation in this reach would be up to 200 Ml/d. The operating pattern remains as per that described in the upstream reach in Section 3.3.3 and shown on Figure 3-3, albeit at a higher rate of flow augmentation. The A82 scenario would include a continuous 105 day period of flow augmentation from late June to early October. The M96 scenario would include a continuous 144 day period of flow augmentation from mid-June to early November.

3.4.3.1 Change to flow

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): [S11] SevernPriorToConfluenceWithTheAvon.xlsm – tab 'Flow' [S12] SevernPriorToConfluenceWithTheAvon.xlsm – tab 'FlowChange' [V13] VyrnwySaxons_LongSection_flows.xlsx – tab 'BewdleytoSaxons_Flow'

On the River Severn upstream of the confluence with the River Avon [S11 and S12] the increase in flow due to the fully supported STT scheme (direct release from Vyrnwy Reservoir, Vyrnwy Bypass and Shrewsbury Redeployment) is approximately 14% of the reference flow during the summer period in both scenarios. The flow increase due to the scheme is around 200 Ml/d.

The fully supported flow increases are noticeable between 30th June and 12th October in the A82 scenario and between 15th June and 2nd November in the M96 scenario.

The long profile [V13] shows that on the 25th of August (low flow) the proportion of the total flow contributed by the scheme is approximately 17% at Bewdley and 11% at Saxons Lode. This is because of the increase in flow in the river due to tributaries, the major ones being the River Stour (at 183 km) and River Teme (at 206 km).

3.4.3.2 Change to river level, velocity and wetted habitat

Summary results showing the percentage coverage of baseline hydraulic habitat distribution and percentage change in this habitat (derived from 1D model output data) under A82 and M96 periods and releases for the reach (see Annex A), are provided below in Table 3-4.

Table 3-4 Percentage of hydraulic habitat within the reach of the River Severn from Bewdley to the confluence with the River Avon

Fish	Life stage	A82 habitats (%)				M96 habitats (%)			
		Baseline	Scheme			Baseline	Scheme		
		Suitable habitat	Gain	No change	Loss	Suitable habitat	Gain	No change	Loss
Atlantic salmon	0+	0.4	0.0	99.8	0.2	0.5	0.0	99.7	0.3
	Juvenile	0.6	0.0	99.7	0.3	0.9	0.0	99.7	0.3
	Spawning	0.4	0.0	99.8	0.2	0.5	0.0	99.7	0.3
Brown trout	0+	0.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0
	Juvenile	33.2	1.2	94.1	4.7	37.2	1.4	93.4	5.2
	Spawning	0.4	0.0	99.8	0.2	0.5	0.0	99.7	0.3
Lamprey	Larvae	0.2	0.0	99.8	0.2	0.3	0.0	99.7	0.3
	Spawning	0.9	0.6	98.9	0.4	0.9	0.6	99.0	0.4
Chub	Juvenile	0.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0
	Spawning	2.2	0.0	99.5	0.5	2.7	0.0	99.2	0.8
Roach	Juvenile	9.9	0.3	96.0	3.7	13.1	0.3	94.2	5.5
	Spawning	0.2	0.0	99.8	0.2	0.2	0.0	99.7	0.3
Eel	Juvenile	89.5	6.3	92.5	1.2	86.4	9.4	89.3	1.3

The data indicate that, on the whole there is very limited suitable baseline hydraulic habitat present throughout the reach during both A82 and M96 runs, with only Brown trout (juvenile) and European eel (juvenile) showing notable presence of suitable hydraulic habitat.

Changes in the presence of suitable hydraulic habitat under the A82 and M96 flow releases show that there is very limited change in this baseline habitat for most species, with the already limited majority of suitable habitat remaining unchanged for the A82 and M96 flows. Under A82 flows, there are very limited gains, with Brown trout (juvenile) and European eel seeing gains of 1.2% and 6.3% and Brown trout (juvenile), Roach (juvenile) and European eel seeing losses of 4.7%, 3.7% and 1.2% respectively. For the M96 flows, gains and losses are slightly high for these species and life stages with the remaining specifies and life stages remaining relatively unchanged.

The data show that, except for a very few specific fish species life stages, there is a very limited range of suitable hydraulic habitat present in the reach for the key fish species considered, and only very limited and localised change in habitat as under the A82 and M96 flow releases.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. Annex A should be referred to for the full assessment, including spatial plots of hydraulic habitat distribution and changes.

3.4.3.3 Change to weir pool wetted habitat or weir passability

Four fish pass sites in this reach have been identified by the EA during Gate 2 and local river levels modelled to review the changes in level associated with the STT solution. The level change can then be used to inform the impact on the efficacy of these fish passes (noting that there is currently insufficient information to derive the critical levels for fish passage). Fisheries assessment is set out in the Gate 2 Fisheries Assessment Report. These sites are as follows:

- Lincomb
- Holt
- Bevere
- Diglis

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report:
[C] Lincomb – tab 'Depth'
[D] Lincomb – tab 'DepthChange'
[E] Holt – tab 'Depth'
[F] Holt – tab 'DepthChange'

[G] Bevere – tab 'Depth'
[H] Bevere – tab 'DepthChange'
[I] Diglis – tab 'Depth'
[J] Diglis – tab 'DepthChange'

For Lincomb, under the A82 scenario, there is an increase in level between 29th June and 11th October [C]. From the 2nd of July to the 28th of August the level increases by between 3.2cm and 4.7cm [D] with a mean level of 15.96m AOD compared to the mean baseline level of 15.92m AOD over this period. Between 29th August and 11th October the level increase is more variable, fluctuating between 0.6cm and 3.7cm with a mean level of 16.05m AOD compared to the baseline mean level of 16.03m AOD. Under the M96 scenario the level change is relatively consistent between 17th June to 3rd November. Generally, the change in level fluctuates between 2cm and 4cm increase in level with the mean level over the period being 15.97m AOD compared to 15.94m AOD in the baseline

For Holt, under the A82 scenario, there is an increase in level between 29th June and 11th October [E]. From the 29th of June to the 28th of August the level increases by between 2.5cm and 4.5cm [F] with a mean level of 14.05m AOD compared to the mean baseline level of 14.01m AOD over this period. Between 29th August and 11th October the level increase is more variable, fluctuating between 1.1cm and 6.2cm with a mean level of 14.19m AOD compared to the baseline mean level of 14.16m AOD. Under the M96 scenario the level change is relatively consistent between 19th June to 3rd November. Generally, the change in level fluctuates between a 3cm and 4cm increase in level with the mean level over the period being 14.08m AOD compared to 14.04m AOD in the baseline. There is one date of note in M96 (27th August) where the level increases by 5.2cm which is abnormal compared to the normal trend and associates with a short period of catchment management change associated with change in Severn Regulation release from Clywedog and Vyrnwy Reservoirs.

For Bevere, under the A82 scenario, there is an increase in level between 29th June and 11th October [G]. From the 29th of July to the 3rd of September the level increases by between 2.4cm and 4.9cm [H] with a mean level of 10.72m AOD compared to the mean baseline level of 10.68m AOD over this period. Between 4th September and 11th October the level increase is more variable, fluctuating between 1.8cm and 5.9cm with a mean level of 10.91m AOD compared to the baseline mean level of 10.87m AOD. There is one date of note in A82 (4th September) where the level increases by 7.7cm which is abnormal compared to the normal trend and associates with a catchment flow increase on that date. Under the M96 scenario the level change is relatively consistent between 19th June to 4th November. Generally, the change is an approximate increase in level of 4cm with the mean level over the period being 10.77m AOD compared to 10.73m AOD in the baseline.

For Diglis, under the A82 scenario, there is an increase in level between 29th June and 11th October [I]. From the 29th of June to the 27th of August the level increases by between 1.7cm and 3.0cm [J] with a mean level of 10.67m AOD compared to the mean baseline level of 10.64m AOD over this period. Between 28th August and 12th October the level increase is more variable, fluctuating between 0.02% and 0.33% with a mean level of 10.77m AOD compared to the baseline mean level of 10.76m AOD. There is one date of note in A82 (4th September) where the level increases by 7.7cm which is abnormal compared to the normal trend and associates with a catchment flow increase on that date. Under the M96 scenario the level change is relatively consistent between 20th June to 3rd November. Generally, the change in level fluctuates between a 2cm and 3cm increase in level with the mean level over the period being 10.69m AOD compared to 10.66m AOD in the baseline. There is one date of note in M96 (27th August) where the level increases by 3.8cm which is abnormal compared to the normal trend and associates with a short period of catchment management change associated with change in Severn Regulation release from Clywedog and Vyrnwy Reservoirs.

3.4.4 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 extension both 35 days earlier, to include late May and all of June; and 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.

3.4.4.1 Change to flow

This section is supported by charts and data in excel workbooks: the same ones as listed in the section above for current conditions.

On the River Severn upstream of the confluence with the River Avon [S11 and S12] the increase in flow due to the fully supported STT scheme (Vyrnwy Reservoir, Vyrnwy bypass, abstraction reduction at Shelton and Mythe licence transfer) is approximately 20% of the reference flow during the summer period in the A82 Future scenario at Bewdley and around 14% prior to the confluence with the Avon. The flow increase due to the scheme is around 180 Ml/d, the same as with baseline conditions.

The fully supported flow increases are noticeable between 26th May and 18th November in the A82 Future scenario which is a longer duration than in the M96 baseline scenario.

3.4.4.2 Change to river level, velocity and wetted habitat

The change in depth-average velocity and water depth at the Severn at Bewdley assessment point from the 1D hydraulic model has been reviewed. There are 141 days in the A82 Futures scenario with modelled river flows of less than 900 Ml/d in the reference conditions and with direct release from Vyrnwy Reservoir; Vyrnwy bypass release; and abstraction reduction at Shelton intake at Shrewsbury. On these dates, the mean change in depth-average velocity is modelled as 0.028 m/s (a 3% increase) and the mean change in water depth is modelled as 0.068 m (a 7% increase).

The baseline and scheme hydraulic habitats for fish species within the reach are briefly outlined in Section 3.4.3.2. The data indicate that, on the whole there is very limited suitable baseline hydraulic habitat present throughout the reach during both A82 and M96 runs, with only Brown trout (juvenile) and European eel (juvenile) showing notable presence of suitable hydraulic habitat. With the A82 and M96 scenarios, hydraulic habitats remain fairly constant, although there are some losses ranging between 1.2-4.7% for Brown trout (juvenile), Roach (juvenile) and European eel, with slight gains of 1.2-6.3% for Brown trout (juvenile) and European eel.

With future flow changes, the data for the Severn at Bewdley assessment point indicates relatively small increases in velocity and depth. It is likely that there will be an increase in the loss of hydraulic habitats in response to this increase in velocity and depth of flows. However, given the relatively low magnitude of change simulated, these losses are likely to be very limited in both magnitude and distribution and are likely only to affect those few species where suitable (but albeit greatly restricted) hydraulic habitat is present in the reach.

3.4.4.3 Fish pass and barrier passability

Four fish pass sites in this reach have been identified by the EA during Gate 2 and local river levels modelled to review the changes in level associated with the STT solution. The level change can then be used to inform the impact on the efficacy of these fish passes (noting that there is currently insufficient information to derive the critical levels for fish passage). Fisheries assessment is set out in the Gate 2 Fisheries Assessment Report. These sites are as follows:

- Lincomb
- Holt
- Bevere
- Diglis

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report:
[C] Lincomb – tab ‘Depth’
[D] Lincomb – tab ‘DepthChange’
[E] Holt – tab ‘Depth’
[F] Holt – tab ‘DepthChange’
[G] Bevere – tab ‘Depth’
[H] Bevere – tab ‘DepthChange’
[I] Diglis – tab ‘Depth’
[J] Diglis – tab ‘DepthChange’

For Lincomb, under the A82 scenario, there is an increase in level between 24th May and 23rd November [C]. This level increase is variable and below 5cm up to 16th June, where it has low variability with a level increase of approximately 4cm until 7th September. From 7th September to 23rd November, the level change is much more variable between 1cm and 6cm. Overall, the level increases by between 1cm and 6cm [D] with a mean level of 15.97m AOD compared to the mean baseline level of 15.94m AOD between 24th May and 23rd November.

For Holt, under the A82 scenario, there is an increase in level between 24th May and 23rd November [E]. This level increase is variable at the start of the scheme until 18th June, with a level increase between 1cm and 6cm

[F] and a mean level of 14.12m AOD compared to the mean baseline level of 14.09m AOD. There is subsequently low variability between 18th June and 8th September, with a mean level increase of 4cm and a mean level of 14.04m AOD compared to a mean baseline of 14.00m AOD. From 9th September to 23rd November, the level change is much more variable with a level increase ranging between 1cm and 5cm, and a mean level of 14.12m AOD compared to the mean baseline level of 14.09m AOD.

For Bevere, under the A82 scenario, there is an increase in level between 24th May and 23rd November [G]. This level increase is variable at the start of the scheme until 17th June, with a level increase between 2cm and 6cm [H]. The mean level during this period is 10.81m AOD compared to the mean baseline level of 10.78m AOD. There is subsequently low variability between 7th June and 8th September, with a mean level increase of 4cm and a mean level of 10.71m AOD compared to a mean baseline of 10.67m AOD. From 9th September to 23rd November, the level change is much more variable with a level increase ranging between 2cm and 6cm, and a mean level of 10.82m AOD compared to the mean baseline level of 10.79m AOD.

For Diglis, under the A82 scenario, there is an increase in level between 24th May and 23rd November [I]. This level increase is variable at the start of the scheme until 17th June, with a level increase between 1cm and 4cm [J]. The mean level during this period is 10.81m AOD compared to the mean baseline level of 10.78m AOD. There is subsequently low variability between 7th June and 8th September, with a mean level increase of approximately 3cm and a mean level of 10.71m AOD compared to a mean baseline of 10.67m AOD. From 9th September to 23rd November, the level change is much more variable with a level increase ranging between 1cm and 4cm, and a mean level of 10.82m AOD compared to the mean baseline level of 10.79m AOD.

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

3.5.1 Overview of the reach

Based on FEH data, the catchment area of the River Avon at Stoneleigh, near Kenilworth is 612 km², while the catchment area at the end of the reach at the confluence with the River Severn is 2,779 km². The length of the River Avon in this reach is 108 km. The reach start at Stoneleigh is just downstream of the confluence of the River Avon and the River Sowe. The upstream River Avon upstream is subject to public water supply abstractions, while the River Sowe has a significant augmented baseflow as it conveys the treated effluent from Coventry (Finham) WwTW. There are several moderate-sized tributaries regularly along the reach, including, in downstream order, the River Leam (386 km² contributing catchment area), River Dene (104 km² contributing catchment area), River Stour (323 km² contributing catchment area), River Broom (333 km² contributing catchment area), Badsey Brook (96 km² contributing catchment area), River Isbourne (96 km² contributing catchment area), Pidley Brook (106 km² contributing catchment area) and Bow Brook (164 km² contributing catchment area). The reach also includes direct WwTW treated effluent inputs from Warwick (Longbridge) WwTW; Stratford (Millcote) WwTW; Evesham WwTW; and Tewkesbury WwTW.

The reach is of a very low gradient, falling 40m over its length, with a gradient of 0.02° and is moderately sinuous (sinuosity ratio of 1.42). River channel widths vary from ~25-35m throughout the majority of the reach, with increases in width mostly associated with anthropogenic structures and urban areas. Land cover flanking the reach is composed predominantly of improved grasslands with some natural grasslands and arable land, with occasional woodland. There are extensive urban areas at Warwick (in the upper reach, ~19 km downstream of the reach start), Stratford-upon-Avon (~40 km downstream), Welford-upon-Avon (~50 km downstream), Bidford-on-Avon (~55 km downstream), Evesham (~67 km downstream), Pershore (~85 km downstream) and Tewkesbury (~108 km downstream). Riparian tree cover along the reach ranges from continuous to scattered trees, with tree cover reducing towards the end of the reach.

The river flows through an extensive and wide floodplain for its length. From extant aerial imagery and the extended and repeated walkover hydromorphological surveys undertaken [18], the river is characterised by a mixture of glides and runs, with occasional riffle sections and rapids over weirs. Sediment bars are rare, although there are multiple islands scattered throughout the reach. Based on the limited sediment bars visible it is likely that the bed substrate is dominated by coarse, likely cobble sized, sediments. The majority of banks outside of urban areas appear to range from moderate to steep with occasional shallow banks and bank erosion is relatively common. Within urban areas, the evidence indicates increased reinforcement and re-

[18] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 4 in in the supporting Excel workbook called “*STT_Physical Environment_Workbook”.*

sectioning of banks, especially in the larger urban areas. Approximately 50 bridges (mostly road and footbridges with occasional railway bridges) cross the channel. There are ~26 weirs located along the reach. Of these 26 weirs, at least 17 are located on bifurcations and have associated bypass locks for navigation purposes on the opposite bifurcation arm. There is notable boating activity throughout the reach, with a large number of moorings and marinas throughout the reach. As noted above, most bank reinforcement and re-sectioning are found within the main urban areas along the reach. There are some areas of localised bankside poaching around some of the small villages and also adjacent to pastoral grasslands.

3.5.2 Baseline

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):
[A1] AvonDsMinworthOutfall.xlsm – tab 'Flow_Nat'
[A2] AvonDsWarwickSTW.xlsm – tab 'Flow_Nat'
[A3] AvonAtEvesham.xlsm – tab 'Flow_Nat'
[A4] AvonPriorToConfluenceSevern.xlsm – tab 'Flow_Nat'
[A5] AvonSevern_LongSection_flows.xlsx – tab 'Avon_Flows'

This section describes baseline conditions and provides a comparison of the baseline to naturalised conditions.

In the River Avon downstream of the Minworth outfall [A1] the naturalised flow is around 110 Ml/d lower than the reference flow during the whole year, which is a reduction of around 50% of the flow in the summer. This is because the naturalised flow removes the inflow from Coventry STW further upstream on the River Avon.

Downstream of Warwick [A2] the summer low flow is increased by around 70 Ml/d compared to upstream. The naturalised flow is still around 50% of the reference flow during the summer.

At Evesham, the flow in summer is increased by around 200 Ml/d compared to Warwick and the winter and high flows are significantly higher [A3]. This is due to the number of tributaries that join the River Avon between Warwick and Evesham. The naturalised flow is around 30% lower than the reference in spring and around 45% lower in summer.

The long section plot [A5] shows the flow on the 25th of August 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. On the 5th of December the flows in the River Avon are similar in magnitude to those on 25th August, around 10% higher prior to the confluence with the Severn.

It should be noted that the flows on 5th December are similar to those on 25th August on the river Avon. The December date was, however, chosen for the autumn / winter period because it is relevant for the River Severn when the flow allows unsupported transfer which is required by the Thames in the M96 Scenario.

At the downstream end of the River Avon prior to the confluence with the River Severn [A4], the summer low flow is not much increased from that at Evesham. The difference between naturalised flow and reference condition is also similar to Evesham.

3.5.3 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 identified from stochastic series in Section 1.3 and illustrated as the blue periods of the 47 water resources years in **Figure 1-4**, describes a typical pattern of the STT solution scheme operation for river flow augmentation on the River Avon from a Minworth Transfer during current climate conditions. Overall, this describes a pattern of the STT solution releases only in 24 of the 47 years, and on 15% of days overall. As shown on **Figure 3-4**, flow changes in this reach would typically be in the months July to October, peaking at 46% of days in September. Outside this period, there would be less regular flow changes in June and November, with changes very rare in May, December and January and not anticipated in February, March or April.

The A82 scenario would include a continuous 99 day period of flow augmentation from early July to early October. The M96 scenario would include a continuous 138 day period of flow augmentation from mid-June to early November.

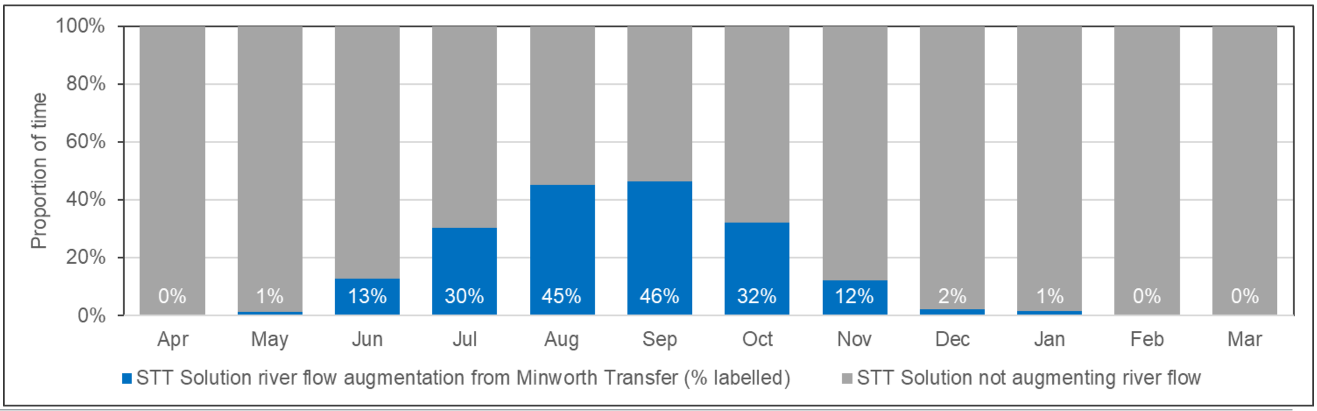


Figure 3-4 Representation of seasonality of STT solution flow changes in the River Avon from Stoneleigh to the confluence with the River Severn

3.5.3.1.1 Change to flow

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):
[A6] AvonDsMinworthOutfall.xlsm – tab 'Flow'
[A7] AvonDsMinworthOutfall.xlsm - tab 'FlowChange'
[A8] AvonDsWarwickSTW.xlsm - tab 'Flow'
[A9] AvonDsWarwickSTW.xlsm - tab 'FlowChange'
[A10] AvonAtEvesham.xlsm - tab 'Flow'
[A11] AvonAtEvesham.xlsm - tab 'FlowChange'
[A12] AvonPriorToConfluenceSevern.xlsm - tab 'Flow'
[A13] AvonPriorToConfluenceSevern.xlsm - tab 'FlowChange'
[A5] AvonSevern_LongSection_flows.xlsx – tab 'Avon_Flows'

Immediately downstream of the Minworth Transfer outfall, the flow in the River Avon is increased by 115 Ml/d due to the flow augmentation from Minworth in the fully supported STT scheme [A6], which is approximately 60% in A82 and 64% in M96 compared to the reference conditions summer flow [A7].

Downstream of Warwick [A8 and A9] the flow is increased by around 41% in A82 and 50% in M96 compared to the reference conditions, due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 113 Ml/d at Warwick due to losses.

At Evesham [A10 and A11] the flow is increased by around 25% in A82 and 28% in M96 compared to the reference conditions, due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 107 Ml/d at Evesham due to losses.

Upstream of the confluence with the River Severn [A12 and A13] the flow is increased by around 20% in A82 and 23% in M96 compared to the reference conditions due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 103 Ml/d at the downstream end of the River Avon due to losses of 10% along the River Avon.

The long section plot [A5] shows the flow on the 25th of August for the reference and the fully supported STT scheme. Initially downstream of the Minworth transfer outfall the flow is increased by 115 Ml/d. At Warwick the increase is 114 Ml/d. At Evesham the increase in flow is 107 Ml/d and 103 Ml/d at the downstream end of the River Avon due to losses of 10% spread along the length of the Avon. On the 5th of December the flows in the River Avon are similar in magnitude to those on 25th August, around 10% higher prior to the confluence with the Severn. Note that this date was chosen for the autumn / winter period because the flow in the River Severn allows unsupported abstraction at Deerhurst in the M96 Scenario.

3.5.3.1.2 Change to river level, velocity and wetted habitat

Summary results showing the percentage coverage of baseline hydraulic habitat distribution and percentage change in this habitat (derived from 1D model output data) under A82 and M96 periods and releases for the reach (see Annex A), are provided below in Table 3-5.

Table 3-5 Percentage of hydraulic habitat within the reach of the River Avon from Stoneleigh to the confluence with the River Severn

Fish	Life stage	A82 habitats (%)				M96 habitats (%)			
		Baseline	Scheme			Baseline	Scheme		
		Suitable habitat	Gain	No change	Loss	Suitable habitat	Gain	No change	Loss
Atlantic salmon	0+	9.1	0.2	96.2	3.6	10.5	0.1	96.7	3.2
	Juvenile	11.5	0.0	96.5	3.5	12.7	0.1	96.9	3.0
	Spawning	8.0	0.0	100.0	0.0	9.4	0.2	96.0	3.8
Brown trout	0+	0.0	0.0	100.0	0.0	0.0	33.1	66.9	0.0
	Juvenile	63.3	0.2	97.7	2.1	64.0	0.4	97.4	2.2
	Spawning	7.6	0.1	97.1	2.8	9.1	0.2	95.9	3.9
Lamprey sp.	Larvae	7.1	0.4	96.4	3.2	8.3	0.4	96.8	2.9
	Spawning	0.3	0.1	99.8	0.0	0.2	0.2	99.8	0.0
Chub	Juvenile	0.6	0.0	99.7	0.3	0.6	0.0	99.8	0.2
	Spawning	20.5	0.0	95.8	4.2	22.8	0.2	94.1	5.7
Roach	Juvenile	39.7	0.2	95.5	4.3	41.8	0.4	95.2	4.4
	Spawning	1.2	0.0	99.3	0.7	1.5	0.0	99.1	0.9
Eel	Juvenile	62.1	10.0	89.5	0.4	57.2	12.0	89.9	0.7

The data indicate that, on the whole there is a fairly wide range of suitable baseline hydraulic habitat present throughout the reach during both A82 and M96 runs. There is notable habitat availability for Brown trout (juvenile), Chub (spawning), Roach (juvenile) and European eel. There are notable variations in the presence of suitable hydraulic habitat based on fish life cycle, with Atlantic salmon (0+ and spawning), Brown trout (0+ and spawning), Lamprey (larvae and spawning), Chub (juvenile) and Roach (spawning) habitat indicated as being relatively rare or not present within the reach.

Changes in the presence of suitable hydraulic habitat under the A82 and M96 flow releases show that there is limited change in this baseline habitat for most species. Gains are relatively minor (generally <0.2%), though Lamprey (larvae) and European eel see gains of 0.4% and 10% for A82 runs, with that of the European eel increasing slightly for M96 runs. Notably, for M96, 0+ Brown trout hydraulic habitat sees a 33% increase. For the A82 and M96 scenarios, there are a range of losses, averaging 1.9% for the A82 scenario and increasing to an average of 2.4% for the M96 scenario, with most of these losses occurring in the upper 30km of the reach.

The data show that that there is a fairly wide range of suitable hydraulic habitat present in the reach for the key fish species considered. There are very minor gains in habitat for the A82 and M96 releases while there are some elevated losses of habitat for a range of species for both A82 and M96 scenarios.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. Annex A should be referred to for the full assessment, including spatial plots of hydraulic habitat distribution and changes.

3.5.3.1.3 Fish pass and barrier passability

Seventeen fish pass sites or barriers in this reach have been identified by the Gate 1 review of barriers in the River Avon[19]. River levels in the hydraulic model have been assessed to review the changes in level associated with the STT solution. The level change can then be used to inform the impact on barriers and the efficacy of fish passes (noting that there is currently insufficient information to derive the critical levels for fish passage) or the passability of the identified barriers. The STT fisheries assessment is set out in the Gate 2 Fisheries Assessment Report. These sites are as follows:

- Stoneleigh Abbey 2
- Warwick Castle 1
- Barford 2
- Alveston 2
- Stratford Upon Avon
- Marlcliffe Weir
- Fladbury
- Wyre Piddle
- Pershore
- Narfford
- Strensham
- Tewkesbury Marina

[19] APEM (2021). Severn Thames Transfer: River Avon Barrier Update. APEM Scientific Report P00006085. United Utilities, September 2021, 29 pp.

- Harvington
- Anchor Meadow Weir
- Evesham
- Stanchard Pit - Eel Pass
- Abbey Mill - Eel Pass

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report:
[K] StoneleighAbbey2.xlsm – tab ‘Depth’
[L] StoneleighAbbey2.xlsm – tab ‘DepthChange’
[M] WarwickCastle1.xlsm – tab ‘Depth’
[N] WarwickCastle1.xlsm – tab ‘DepthChange’
[O] Barford2.xlsm – tab ‘Depth’
[P] Barford2.xlsm – tab ‘LevelChange
[Q] Alveston2.xlsm – tab ‘Depth’’
[R] Alveston2.xlsm – tab ‘DepthChange’
[S] StratfordUponAvon.xlsm – tab ‘Depth’
[T] StratfordUponAvon.xlsm – tab ‘DepthChange’
[U] MarlcliffeWeir.xlsm – tab ‘Depth’
[V] MarlcliffeWeir.xlsm – tab ‘DepthChange’
[W] Harvington.xlsm – tab ‘Depth’
[X] Harvington.xlsm – tab ‘DepthChange’
[Y] AnchorMeadowWeir.xlsm – tab ‘Depth’
[Z] AnchorMeadowWeir.xlsm – tab ‘DepthChange’
[AA] Evesham.xlsm – tab ‘Depth’
[AB] Evesham.xlsm – tab ‘DepthChange’
[AC] Fladbury.xlsm – tab ‘Depth’
[AD] Fladbury.xlsm – tab ‘DepthChange’
[AE] WyrePiddle.xlsm – tab ‘Depth’
[AF] WyrePiddle.xlsm – tab ‘DepthChange’
[AG] Pershore.xlsm – tab ‘Depth’
[AH] Pershore.xlsm – tab ‘DepthChange’
[AI] Narfford.xlsm – tab ‘Depth’
[AJ] Narfford.xlsm – tab ‘DepthChange’
[AK] Strensham.xlsm – tab ‘Depth’
[AL] Strensham.xlsm – tab ‘DepthChange’
[AM] TewkesburyMarina – tab ‘Depth’
[AN] TewkesburyMarina – tab ‘DepthChange’
[AO] StanchardPit-EelPass.xlsm – tab ‘Depth’
[AP] StanchardPit-EelPass.xlsm – tab ‘DepthChange’
[AQ] AbbeyMill-EelPass.xlsm – tab ‘DepthChange’

For the barriers between Stoneleigh Abbey and Strensham there is a general pattern of water level increase with operation of the STT solution. The STT solution changes at these sites are summarised in Table 3-6. In the A82 scenario the change in water level would be for the indicative 99 day period of Minworth Transfer support between 3rd July and 9th October. These changes would be indicative of the normal pattern of changes associated with the STT solution, noting the Minworth Transfer would only augment flows in the River Avon once every two years, on average. Less often changes would be as indicated by the 1:20 year return frequency M96 scenario. In the M96 scenario the change in water level would be for the indicative 139 day period of Minworth Transfer support between 18th June to 3rd November.

Differences in water level associated with the STT solution would be small; an increase not a decrease; and within normal patterns of level. Typically, the increase in water level modelled at lowest water levels associated with the STT solution would, during the period of operation, be 3-5cm. Notable exceptions are modelled at Stoneleigh Abbey 2 at the beginning of the reach, where an increase of 17.2cm is modelled at lowest water levels; Harvington where an increase of 14.4cm is recorded, and nearer to the River Severn confluence at Wyre Piddle and Pershore where an increase of 10.7cm and 13.2cm are recorded from the model respectively.

For the barriers in the lowest part of the River Avon, there is more complex influence on water levels associated with the STT solution. This is due to the very low gradient of the River Severn and the influence of the normal tidal limit weir at Maisemore on water levels as far upstream as the next weir on the Severn at Saxons Lode. Tidal influence on water level is observed throughout that reach of the River Severn although that is too complex an interaction to include in the hydraulic modelling. The hydraulic modelling does show that the increase in River Severn low flows from the STT solution flow augmentation releases for supported STT raise water levels in the River Severn around the River Avon confluence. The hydraulic modelling also shows that during periods of unsupported STT, where there would be up to 500 Ml/d abstraction from the River Severn at Deerhurst 3.8km downstream of the River Avon confluence, abstraction would lower water levels in the River Severn around the River Avon confluence.

Table 3-6 Changes in water level at barriers and fish passes in the River Avon associated with STT solution

Barrier/ fish pass	Minworth Transfer operational period during A82 scenario			Minworth Transfer operational period during M96 scenario		
	Reference conditions water level	Water level with STT solution	Water level increase with STT solution (cm)	Reference conditions water level	Water level with STT solution	Water level increase with STT solution (cm)
Stoneleigh Abbey 2 [K and L]	52.97m - 53.19m mean 53.02m AOD	53.15m - 53.27m mean 53.17m AOD	8.6 – 17.2	52.96m - 53.35m mean 52.97m AOD	53.14m - 53.41m mean 53.15m AOD	6.5 – 17.8
Warwick Castle 1 [M and N]	44.96m - 45.17m mean 44.98m AOD	45.01m - 45.08m mean 45.03m AOD	0.7 – 4.4	44.96m - 45.09m mean 44.97m AOD.	45.00m - 45.13m mean 45.01m AOD	0.9 – 4.5
Barford 2 [O and P]	43.10m - 43.16m mean 43.12m AOD	43.14m - 43.19m mean 43.15m AOD	2.0 – 3.5	43.10m - 43.19m mean 43.11m AOD	43.13m - 43.21m mean 43.14m AOD	0.7 – 3.6
Alveston 2 [Q and R]	36.41m - 36.61m mean 36.43m AOD	36.45m - 36.63m mean 36.47m AOD	1.4 – 4.4	36.41m - 36.75m mean 36.42m AOD	36.45m - 36.78m mean 36.46m AOD	1.2 – 4.5
Stratford Upon Avon [S and T]	34.48m - 34.59m mean 34.50m AOD	34.51m - 34.60m mean 34.52m AOD	0.9 – 2.6	34.48m - 34.67m mean 34.49m AOD	34.50m - 34.69m mean 34.51m AOD	0.8 – 2.6
Marlcliffe Weir [U and V]	25.52m - 25.62m mean 25.53m AOD	25.54m - 25.64m mean 25.56m AOD	0.5 – 2.7	25.51m - 25.73m mean 25.52m AOD	25.54m - 25.75m mean 25.55m AOD	0.9 – 2.8
Harvington [W and X]	23.85m - 24.29m mean 23.93m AOD	23.99m - 24.30m mean 24.06m AOD	1.1 – 14.4	23.83m - 24.40m mean 23.89m AOD	23.98m - 24.41m mean 24.02m AOD	0.6 – 15.0
Anchor Meadow Weir [Y and Z]	22.72m - 22.89m mean 22.75m AOD	22.76m - 22.92m mean 22.79m AOD	2.7 – 4.5	22.71m - 23.16m mean 22.74m AOD.	22.76m - 23.18m mean 22.78m AOD	1.7 – 5.5
Evesham [AA and AB]	21.94m - 21.98m mean 21.94m AOD	21.95m - 21.99m mean 21.95m AOD	0.8 – 1.1	21.93m - 22.05m mean 21.94m AOD	21.95m - 22.06m mean 21.95m AOD	0.7 – 1.4
Fladbury [AC and AD]	18.41m - 18.48m mean 18.42m AOD	18.43m - 18.50m mean 18.44m AOD	1.8 – 2.2	18.40m - 18.63m mean 18.42m AOD	18.43m - 18.64m mean 18.44m AOD	0.9 – 2.6
Wyre Piddle [AD and AE]	14.97m - 15.23m mean 15.03m AOD	15.06m - 15.33m mean 15.11m AOD	7.2 – 10.7	14.96m - 16.05m mean 15.01m AOD	15.05m - 16.10m mean 15.10m AOD	4.8 – 10.3
Pershore [AF and AG]	13.00m - 13.29m mean 13.06m AOD	13.10m - 13.42m mean 13.17m AOD	8.2 – 13.2	12.99m - 14.39m mean 13.05m AOD	13.09m - 14.43m mean 13.15m AOD	4.3 – 12.0
Narfford [AH and AI]	12.31m - 12.39m mean 12.33m AOD	12.34m - 12.43m mean 12.37m AOD	2.4 – 4.0	12.30m - 12.71m mean 12.32m AOD	12.34m - 12.72m mean 12.36m AOD	1.1 – 3.7
Strensham [AJ and AK}	10.83m - 10.92m mean 10.86m AOD	10.87m - 10.97m mean 10.90m AOD	2.6 – 4.9	10.82m - 11.24m mean 10.84m AOD	10.87m - 11.25m mean 10.89m AOD	0.9 – 4.9

For Tewkesbury Marina, water level varies across the whole annual period [AL] due to a range of complex factors affecting the level at this site. Under the full STT A82 scenario, between, roughly, the 1st of April and 20th June the level reduces by a range of 0.4cm and 0.6cm [AM] compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly the 24th of June), the level no longer varies from the baseline until the full STT support commences. When the full support commences (late June) there is a variation in level ranging between a 0.9cm reduction and a 3.1cm increase compared to the reference condition over a seven day period before the level returns to being similar to the reference level whilst the STT abstraction is fully supported. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 30th August) there is a decrease in water level until the STT is turned off in late November. Over this unsupported period, the level ranges from an increase of 0.4cm to a reduction of 12.8cm with the level ranging between 6.71m AOD and 10.53m AOD (with a mean level of 7.62m AOD) compared to the reference levels which range between 6.71m AOD and 10.58m AOD (with a mean level of 7.68m AOD). The level change in the unsupported STT A82 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer.

Under the full STT M96 scenario, between, roughly, the 1st of April and 9th May the level reduces by a range of 0.4cm to 0.5cm compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly the 10th of May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (roughly 15th June) there is a variation in level ranging between a 0.9cm reduction and a 3.5cm increase compared to the reference condition over an eight day period before the level returns to being similar to the reference level whilst the STT abstraction is fully supported. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 28th October) there is a decrease in water level until the STT is turned off in early January. Over this unsupported period, the level reduces by 0.3cm to 11.4cm with the level ranging between 6.79m AOD and 11.40m AOD (with a mean level of 9.08m AOD) compared to the reference levels which range between 6.79m AOD and 11.44m AOD (with a mean level of 9.15m AOD). The level change in the unsupported STT M96 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer. Overall these changes in water level associated with the STT solution would be very small, in the order of 1cm, at times of low water levels and within normal patterns of level.

For Stanchard Pit – Eel Pass, water level varies across the whole annual period [AO] due to a range of complex factors affecting the level at this site. Under the full STT A82 scenario, between, roughly, the 1st of April and 20th June the level reduces by a range of 0.4cm and 0.6cm [AP] compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly the 24th of June), the level no longer varies from the baseline until the full STT support commences. When the full support commences (late June) there is a variation in level ranging between a 0.9cm reduction and a 3.0cm increase compared to the reference condition over a 10 day period before the level returns to being similar to the reference level whilst the STT abstraction is fully supported. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 30th August) there is a decrease in water level until the STT is turned off in late November. Over this unsupported period, the level ranges from a reduction of 0.7cm to 12.8cm with the level ranging between 6.92m AOD and 10.53m AOD (with a mean level of 7.99m AOD) compared to the reference levels which range between 6.94m AOD and 10.58m AOD (with a mean level of 8.08m AOD). The level change in the unsupported STT A82 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer.

Under the full STT M96 scenario, between, roughly, the 1st of April and 9th May the level reduces by a range of 0.4cm to 0.6cm compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly the 10th of May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (roughly 15th June) there is a variation in level ranging between a 0.9cm reduction and a 3.4cm increase compared to the reference condition over an eight day period before the level returns to being similar to the reference level whilst the STT abstraction is fully supported. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 28th October) there is a decrease in water level until the STT is turned off in early January. Over this unsupported period, the level reduces by 0.5cm to 11.4cm with the level ranging between 6.78m AOD and 11.40m AOD (with a mean level of 9.07m AOD) compared to the reference levels which range between 6.79m AOD and 11.44m AOD (with a mean level of 9.15m AOD). The level change in the unsupported STT M96 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer. Overall these changes in water level associated with the STT solution would be very small, in the order of 1cm, at times of low water levels and within normal patterns of level.

For Abbey Mill – Eel Pass, water level varies across the whole annual period [AQ] due to a range of complex factors affecting the level at this site. Under the full STT A82 scenario, between, roughly, the 1st of April and 20th June the level reduces by a range of 0.4cm and 0.6cm compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly the 24th of June), the level no longer varies from the baseline until the full STT support commences. When the full support commences (late June) there is a variation in level ranging between a 0.9cm reduction and a 2.9cm increase compared to the reference condition over a 17 day period before the level returns to being similar to the reference level whilst the STT abstraction is fully supported. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 30th August) there is a decrease in water level until the STT is turned off in late November. Over this unsupported period, the level ranges from an increase of 0.2cm to a reduction of 12.9cm with the level ranging between 6.70m AOD and 10.53m AOD (with a mean level of 7.62m AOD) compared to the reference levels which range between 6.94m AOD and 10.58m AOD (with a mean level of 8.08m AOD). The level change in the unsupported STT A82 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer.

Under the full STT M96 scenario, between, roughly, the 1st of April and 9th May the level reduces by a range of 0.4cm to 0.6cm compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly the 10th of May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (roughly 15th June) there is a variation in level ranging between a 0.9cm reduction and a 3.3cm increase compared to the reference condition over an eight day period before the level returns to being similar to the reference level whilst the STT abstraction is fully supported. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 28th October) there is a decrease in water level until the STT is turned off in early January. Over this unsupported period, the level reduces by 0.5cm to 11.4cm with the level ranging between 6.78m AOD and 11.39m AOD (with a mean level of 9.07m AOD) compared to the reference levels which range between 6.79m AOD and 11.44m AOD (with a mean level of 9.15m AOD). The level change in the unsupported STT M96 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer. Overall these changes in water level associated with the STT solution would be very small, in the order of 1cm, at times of low water levels and within normal patterns of level.

3.5.4 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 extension both 35 days earlier, to include late May and all of June; and 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.

3.5.4.1.1 Change to flow

This section is supported by charts and data in excel workbooks: the same ones as listed in the section above for current conditions.

Immediately downstream of the Minworth Transfer outfall, the flow in the River Avon is increased by 115 Ml/d due to the flow augmentation from Minworth in the fully supported STT scheme [A6], which is approximately 64% in A82 Future compared to the reference conditions summer flow [A7]. The scheme runs from the 25th of May to the 21st of November in the A82 Future climate.

Downstream of Warwick [S22 and S23] the flow is increased by around 50% in A82 Future climate (similar to M96 present day) compared to the reference conditions, due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 113 Ml/d at Warwick due to losses.

At Evesham [A10 and A11] the flow is increased by around 28% in A82 Future climate compared to the reference conditions, due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 107 Ml/d at Evesham due to losses.

Upstream of the confluence with the River Severn [A12 and A13] the flow is increased by around 24% in the A82 Future climate compared to the reference conditions due to the flow from Minworth in the fully supported STT scheme. The increase in the flow is approximately 103 Ml/d (the same as in baseline climate) at the downstream end of the River Avon due to losses of 10% along the River Avon.

The long section plot [A5] shows the flow on the 18th of October for the reference and the fully supported STT scheme from the A82 Future scenario. Initially downstream of the Minworth transfer outfall the flow is increased by 115 Ml/d. At Warwick, the increase is 114 Ml/d. At Evesham, the increase in flow is 107 Ml/d and 103 Ml/d at the downstream end of the River Avon due to losses of 10% spread along the length of the Avon. In the future scenario, the flows are approximately 10% lower than the low flow in present conditions.

3.5.4.1.2 Change to river level, velocity and wetted habitat

As a guide, the change in depth-average velocity and water depth on the River Avon Immediately downstream of the Minworth Transfer outfall assessment point from the 1D hydraulic model has been reviewed. There are 176 days in the A82 Futures scenario with effluent transfer from Minworth WwTW. On these dates, mean modelled flow in the reference conditions is 185 Ml/d; the mean change in depth-average velocity is modelled as 0.024 m/s (a 5% increase in very low reference condition velocities); and the mean change in water depth is modelled as 0.11 m (a 27% increase).

The baseline and scheme hydraulic habitats for fish species within the reach are briefly outlined in Section 3.5.3.1.2. These data show that that there is a fairly wide range of suitable habitat present in the reach, particularly for Brown trout (juvenile), Chub (spawning), Roach (juvenile) and European eel. There is indicated to be minimal change in baseline habitat for the A82 and M96 flows, though there are some gains and losses averaging 1.9% for A82 and increasing to 2.4% for the M96 scenario, with most losses concentrated in the upper 30km of the reach.

With future flow changes, the data for the River Avon Immediately downstream of the Minworth Transfer outfall assessment point indicates a small increase in flow velocity but a relatively large increase in flow depth. It is likely that the increase in depth could lead to increasing loss of hydraulic flow habitats, particularly in the upper reaches of the river, as seen for the increasing hydraulic habitat losses for the A82 and M96 scenarios.

3.5.4.1.3 Fish pass and barrier passability

Seventeen fish pass sites or barriers in this reach have been identified by the Gate 1 review of barriers in the River Avon[20]. River levels in the hydraulic model have been assessed to review the changes in level associated with the STT solution. The level change can then be used to inform the impact on barriers and the efficacy of fish passes (noting that there is currently insufficient information to derive the critical levels for fish passage) or the passability of the identified barriers. The STT fisheries assessment is set out in the Gate 2 Fisheries Assessment Report. These sites are as follows:

- Stoneleigh Abbey 2
- Warwick Castle 1
- Barford 2
- Alveston 2
- Stratford Upon Avon
- Marlcliffe Weir
- Harvington
- Anchor Meadow Weir
- Evesham
- Fladbury
- Wyre Piddle
- Pershore
- Narfford
- Strensham
- Tewkesbury Marina
- Stanchard Pit - Eel Pass
- Abbey Mill - Eel Pass

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report:

[K] StoneleighAbbey2.xlsm – tab ‘Depth’
[L] StoneleighAbbey2.xlsm – tab ‘DepthChange’
[M] WarwickCastle1.xlsm – tab ‘Depth’
[N] WarwickCastle1.xlsm – tab ‘DepthChange’
[O] Barford2.xlsm – tab ‘Depth’
[P] Barford2.xlsm – tab ‘LevelChange
[Q] Alveston2.xlsm – tab ‘Depth’’
[R] Alveston2.xlsm – tab ‘DepthChange’
[S] StratfordUponAvon.xlsm – tab ‘Depth’
[T] StratfordUponAvon.xlsm – tab ‘DepthChange’
[U] MarlcliffeWeir.xlsm – tab ‘Depth’
[V] MarlcliffeWeir.xlsm – tab ‘DepthChange’
[W] Harvington.xlsm – tab ‘Depth’
[X] Harvington.xlsm – tab ‘DepthChange’
[Y] AnchorMeadowWeir.xlsm – tab ‘Depth’
[Z] AnchorMeadowWeir.xlsm – tab ‘DepthChange’
[AA] Evesham.xlsm – tab ‘Depth’
[AB] Evesham.xlsm – tab ‘DepthChange’
[AC] Fladbury.xlsm – tab ‘Depth’
[AD] Fladbury.xlsm – tab ‘DepthChange’
[AE] WyrePiddle.xlsm – tab ‘Depth’
[AF] WyrePiddle.xlsm – tab ‘DepthChange’
[AG] Pershore.xlsm – tab ‘Depth’
[AH] Pershore.xlsm – tab ‘DepthChange’
[AI] Narfford.xlsm – tab ‘Depth’
[AJ] Narfford.xlsm – tab ‘DepthChange’
[AK] Strensham.xlsm – tab ‘Depth’
[AL] Strensham.xlsm – tab ‘DepthChange’
[AM] TewkesburyMarina – tab ‘Depth’
[AN] TewkesburyMarina – tab ‘DepthChange’
[AO] StanchardPit-EelPass.xlsm – tab ‘Depth’
[AP] StanchardPit-EelPass.xlsm – tab ‘DepthChange’
[AQ] AbbeyMill-EelPass.xlsm – tab ‘DepthChange’

[20] APEM (2021). Severn Thames Transfer: River Avon Barrier Update. APEM Scientific Report P00006085. United Utilities, September 2021, 29 pp.

For the barriers between Stoneleigh Abbey and Strensham there is a general pattern of water level increase with operation of the STT solution. The STT solution changes at these sites are summarised in Table 3-7. In the A82 scenario the change in water level would be for the indicative 99 day period of Minworth Transfer support between 30th May and 22nd November. These changes would be indicative of the normal pattern of changes associated with the STT solution, noting the Minworth Transfer would only augment flows in the River Avon once every two years, on average.

Differences in water level associated with the STT solution would be small; an increase not a decrease; and within normal patterns of level. Typically, the increase in water level modelled at lowest water levels associated with the STT solution would, during the period of operation, be 3-5cm. Notable exceptions are modelled at Stoneleigh Abbey 2 at the beginning of the reach, where an increase of 17cm is modelled at lowest water levels; and nearer to the River Severn confluence at Wyre Piddle and Pershore where an increase of 9-10cm is modelled at lowest water levels.

For the barriers in the lowest part of the River Avon, there is more complex influence on water levels associated with the STT solution. This is due to the very low gradient of the River Severn and the influence of the normal tidal limit weir at Maisemore on water levels as far upstream as the next weir on the Severn at Saxons Lode. Tidal influence on water level is observed throughout that reach of the River Severn although that is too complex an interaction to include in the hydraulic modelling. The hydraulic modelling does show that the increase in River Severn low flows from the STT solution flow augmentation releases for supported STT raise water levels in the River Severn around the River Avon confluence. The hydraulic modelling also shows that during periods of unsupported STT, where there would be up to 500 Ml/d abstraction from the River Severn at Deerhurst 3.8km downstream of the River Avon confluence, abstraction would lower water levels in the River Severn around the River Avon confluence.

Table 3-7 Changes in water level at barriers and fish passes in the River Avon associated with STT solution

Barrier/ fish pass	Minworth Transfer operational period during A82 scenario		
	Reference conditions water level	Water level with STT solution	Water level increase with STT solution (cm)
Stoneleigh Abbey 2 [K and L]	52.96m - 53.18m mean 52.98m AOD	53.11m - 53.27m mean 53.15m AOD	9.0 – 17.9
Warwick Castle 1 [M and N]	44.96m - 45.05m mean 44.97m AOD	45.00m - 45.07m mean 45.01m AOD	1.1 – 4.5
Barford 2 [O and P]	43.10m - 43.15m mean 43.11m AOD	43.14m - 43.18m mean 43.14m AOD	1.0 – 3.6
Alveston 2 [Q and R]	36.40m - 36.63m mean 36.42m AOD	36.45m - 36.66m mean 36.47m AOD	1.6 – 4.5
Stratford Upon Avon [S and T]	34.48m - 34.61m mean 34.49m AOD	34.51m - 34.63m mean 34.52m AOD	0.9 – 2.6
Marlcliffe Weir [U and V]	25.51m - 25.66m mean 25.52m AOD	25.54m - 25.68m mean 25.55m AOD	0.5 – 2.8
Harvington [W and X]	23.82m - 24.34m mean 23.90m AOD	24.04m - 24.36m mean 23.97m AOD	1.0 – 15.2
Anchor Meadow Weir [Y and Z]	22.71m – 23.01m mean 22.74m AOD	22.76m – 23.04m mean 22.78m AOD	0.4 – 4.5
Evesham [AA and AB]	21.93m – 22.01m mean 21.94m AOD	21.94m – 22.02m mean 21.95m AOD	0.6 – 1.1
Fladbury [AC and AD]	18.40m - 18.56m mean 18.42m AOD	18.43m - 18.57m mean 18.44m AOD	1.1 – 2.3
Wyre Piddle [AD and AE]	14.95m - 15.60m mean 15.01m AOD	15.05m - 15.67m mean 15.10m AOD	0.6 – 9.5
Pershore [AF and AG]	12.98m - 13.80m mean 13.05m AOD	13.08m - 13.89m mean 13.15m AOD	0.8 – 11.2

Barrier/ fish pass	Minworth Transfer operational period during A82 scenario		
	Reference conditions water level	Water level with STT solution	Water level increase with STT solution (cm)
Narfford [AH and AI]	12.30m - 12.57m mean 12.32m AOD	12.34m - 12.59m mean 12.36m AOD	0.4 – 3.7
Strensham [AJ and AK}	10.81m - 11.13m mean 10.84m AOD	10.86m – 11.14m mean 10.89m AOD	0.6 – 5.0

For Tewkesbury Marina, water level varies across the whole annual period [AL] due to a range of complex factors affecting the level at this site. Under the full STT A82 scenario, between, roughly, the 1st of April and 14th May, the level varies from a reduction of 0.4cm to 0.5cm compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly 15th May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (early June) there is a variation in level ranging between a -0.1cm and 0.3cm change compared to the reference conditions until mid-November. From mid-November, the STT scheme is stopped and the abstraction is unsupported until Mid-December. Over this unsupported period, the level varies from +1.8cm to -12.8cm compared to the reference level, which corresponds to the level ranging between 6.79m AOD and 9.72m AOD (with a mean level of 8.03m AOD) compared to the reference levels which range between 6.78m AOD and 9.79m AOD (with a mean level of 8.09m AOD).

For Stanchard Pit, water level varies across the whole annual period [AL] due to a range of complex factors affecting the level at this site. Under the full STT A82 scenario, between, roughly, the 1st of April and 14th May, the level varies from a reduction of 0.4cm to 0.5cm compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly 15th May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (early June) there is a variation in level ranging between a reduction of 1.3cm and an increase of 2.7cm compared to the reference conditions until mid-November. From mid-November, the STT scheme is stopped and the abstraction is unsupported until Mid-December. Over this unsupported period, the level varies from +1.8cm to -12.9cm compared to the reference level, which corresponds to the level ranging between 6.79m AOD and 9.72m AOD (with a mean level of 8.03m AOD) compared to the reference levels which range between 6.74m AOD and 9.79m AOD (with a mean level of 8.04m AOD).

For Abbey Mill, water level varies across the whole annual period [AL] due to a range of complex factors affecting the level at this site. Under the full STT A82 scenario, between, roughly, the 1st of April and 14th May, the level varies from a reduction of 0.4cm to 0.5cm compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly 15th May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (early June) there is a variation in level ranging between a reduction of 1.4cm and an increase of 2.6cm compared to the reference conditions until mid-November. From mid-November, the STT scheme is stopped and the abstraction is unsupported until Mid-December. Over this unsupported period, the level varies from +1.8cm to -12.9cm compared to the reference level, which corresponds to the level ranging between 6.79m AOD and 9.72m AOD (with a mean level of 7.98m AOD) compared to the reference levels which range between 6.74m AOD and 9.79m AOD (with a mean level of 8.04m AOD).

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

3.6.1 Overview of the reach

Based on FEH data, the catchment area at the Avon-Severn confluence is 9,763 km². The catchment area at Deerhurst is 9,866 km². The length of the River Severn in this reach is 2.6 km. This reach is included to characterise the flow changes associated with the STT solution support options in total, prior to re-abstraction at Deerhurst. From extant aerial imagery and the extended and repeated walkover hydromorphological surveys undertaken [21], the river is characterised by deep glides.

3.6.2 Baseline

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):
[S13] SevernAtDeerhurstUsOfftake.xlsm – tab 'Flow_Nat'
[S14] SevernAtDeerhurstUsOfftake.xlsm – tab 'FlowChange'

This section describes baseline conditions and provides a comparison of the baseline to naturalised conditions. Upstream of the Deerhurst transfer location [S13] the low flow period occurs in July and August with flows of approximately 1,700 Ml/d and winter flows are above 5,000 Ml/d in the A82 Scenario. In July, the naturalised flows are around 20% lower than the reference condition which reflects the influence of Vyrnwy Reservoir [S14], reservoirs on the Upper Severn, the Shropshire Groundwater Scheme and the STW releases on the River Avon during the low flow period. In May, August and September there is suppression of flow peaks in the reference condition due to the upstream reservoirs.

3.6.3 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); and an abstraction reduction at 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 318 Ml/d. The operating pattern remains as per that described in the upstream reach in Section 3.5.3 and shown on **Figure 3-3**, albeit at a higher rate of flow augmentation. The A82 scenario would include a continuous 105 day period of flow augmentation from late June to early October. The M96 scenario would include a continuous 144 day period of flow augmentation from mid-June to early November.

3.6.3.1 Change to flow

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):
[S15] SevernAtDeerhurstUsOfftake.xlsm – tab 'Flow'
[S16] SevernAtDeerhurstUsOfftake.xlsm – tab 'FlowChange'

The increase in flow upstream of Deerhurst [S15 and S16], due to the fully supported STT scheme is around 15% in the A82 scenario and 17% in the M96 scenario. The period of the scheme is 30th June to the 12th of October in the A82 scenario and from 15th June to 2nd November in the M96 scenario [S15 and S16]. The flow increase during the summer period is around 309 Ml/d.

3.6.3.2 Change to river level, velocity and wetted habitat

Summary results showing the percentage coverage of baseline hydraulic habitat distribution and percentage change in this habitat (derived from 1D model output data) under A82 and M96 periods and releases for the reach (see Annex A), are provided below in Table 3-8. It should be noted that this is a relatively short reach of around 3km in length.

Table 3-8 Percentage of hydraulic habitat within the reach of the River Severn from the confluence with the River Avon to Deerhurst

Fish	Life stage	A82 habitats (%)				M96 habitats (%)			
		Baseline	Scheme			Baseline	Scheme		
		Suitable habitat	Gain	No change	Loss	Suitable habitat	Gain	No change	Loss
	0+	0	0	100	0	0	0	100	0

[21] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 5 in in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

		A82 habitats (%)				M96 habitats (%)			
Atlantic salmon	Juvenile	0	0	100	0	0	0	100	0
	Spawning	0	0	100	0	0	0	100	0
Brown trout	0+	0	0	100	0	0	0	100	0
	Juvenile	0	0	100	0	0	0	100	0
	Spawning	0	0	100	0	0	0	100	0
Lamprey sp.	Larvae	0	0	100	0	0	0	100	0
	Spawning	0	0	100	0	0	0	100	0
Chub	Juvenile	0	0	100	0	0	0	100	0
	Spawning	0	0	100	0	0	0	100	0
Roach	Juvenile	0	0	100	0	0	0	100	0
	Spawning	0	0	100	0	0	0	100	0
Eel	Juvenile	75	11	83	6	47	11	80	10

The data indicate that, apart from European eel, there is no suitable hydraulic habitat for the fish species and life stages considered in this assessment, though this is variable for the A82 and M96 scenarios (75% available hydraulic habitat for the A82 reducing to 47% for the M96 scenarios).

Only European eel shows changes in habitat with the A82 and M96 flows, with a gain of 11% for the A82 flows, increasing marginally for the M96 flows, and a loss of 6% hydraulic habitat for A82 flows, increasing to 10% for M96 flows.

The data show that, except for European eel, there is no suitable hydraulic habitat in the reach. For eel, gains in hydraulic habitat are relatively similar for A82 and M96 flows, with increasing habitat losses for M96 over the A82 flows.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. Annex A should be referred to for the full assessment, including spatial plots of hydraulic habitat distribution and changes.

3.6.3.3 Change to weir pool wetted habitat or weir passability

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report:
[AR] UpperLodeLeftBank.xlsm – tab 'Depth'
[AS] UpperLodeLeftBank.xlsm – tab 'DepthChange'

One fish pass site in this reach has been identified by the EA during Gate 2 and local river levels modelled to review the changes in level associated with the STT solution. This is Saxons Lode the 'Upper Lode left bank' site. The level change can then be used to inform the impact on the efficacy of this fish pass (noting that there is currently insufficient information to derive the critical levels for fish passage). Fisheries assessment is set out in the Gate 2 Fisheries Assessment Report. Tidal influence on water level is observed throughout that reach of the River Severn although that is too complex an interaction to include in the hydraulic modelling. Below Saxons Weir there is a complex influence on water levels associated with the STT solution. This is due to the very low gradient of the River Severn and the influence of the normal tidal limit weir at Maisemore on water levels as far upstream as Saxons Lode which is the next weir upstream.

For this site, the level varies across the whole annual period [AR] due to a range of complex factors affecting the level at this site. Under the full STT A82 scenario, between, roughly, the 1st of April and 20th June the level reduces by a range of 0.4cm and 0.6cm [AS] compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly the 24th of June), the level no longer varies from the baseline until the full STT support commences. When the full support commences (late June) there is a variation in level ranging between a reduction of 0.9cm and an increase of 3.0cm compared to the reference condition over an 18 day period before the level returns to being slightly below the reference level whilst the STT abstraction is fully supported. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 30th August) there is a decrease in water level until the STT is turned off in late November. Over this unsupported period, the level changes from an increase of 0.2cm to a reduction of 12.8cm, with the level ranging between 6.70m AOD and 10.54m AOD (with a mean level of 7.63m AOD) compared to the reference levels which range between 6.71m AOD and 10.60m AOD (with a mean level of

7.69m AOD). The level change in the unsupported STT A82 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer.

Under the full STT M96 scenario, between, roughly, the 1st of April and 9th May the level reduces by a range of 0.4cm and 0.6cm compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly the 10th of May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (roughly 15th June) there is a variation in level ranging between a 0.9cm reduction to a 3.3cm increase compared to the reference conditions over an eight day period before the level returns to being similar to the reference level whilst the STT abstraction is fully supported. Once the flow is sufficient at Deerhurst for the full abstraction to be achieved whilst unsupported (roughly 27th October) there is a decrease in water level until the STT is turned off in early January. Over this unsupported period, the level reduces by between 0.5cm and 11.3cm with the level ranging between 6.78m AOD and 11.41m AOD (with a mean level of 9.09m AOD) compared to the reference levels which range between 6.79m AOD and 11.45m AOD (with a mean level of 9.16m AOD). The level change in the unsupported STT M96 scenario is similar to the full STT scenario except from the level variation associated with the commencement of the support from Minworth Transfer.

3.6.4 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 extension both 35 days earlier, to include late May and all of June; and 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.

3.6.4.1 Change to flow

This section is supported by charts and data in excel workbooks: the same ones as listed in the section above for current conditions.

The increase in flow upstream of Deerhurst [S15 and S16], due to the fully supported STT scheme is around 17% in the A82 Future climate scenario. The period of the scheme is 28th May to the 20th of November in the A82 Future scenario, which is longer than in the M96 baseline scenario [S18]. The flow increase during the summer period is around 283 Ml/d.

The low flow in the future scenario is around 30% less than the low flow in present conditions.

3.6.4.2 Change to river level, velocity and wetted habitat

As a guide, the change in depth-average velocity and water depth at the Severn at Deerhurst upstream offtake assessment point from the 1D hydraulic model has been reviewed. There are 166 days in the A82 Futures scenario with modelled river flows of less than the HoF2 value of 3,333 Ml/d in the reference conditions and with direct release from Vyrnwy Reservoir; Vyrnwy bypass release; abstraction reduction at Shelton intake at Shrewsbury; and effluent transfer from Minworth WwTW. On these dates, the mean change in depth-average velocity is modelled as 0.016 m/s (a 18% increase in very low reference condition velocities) and the mean change in water depth is modelled as 0 m.

The baseline and scheme hydraulic habitats for fish species within the reach are briefly outlined in Section 3.6.3.2. The data indicate that, apart from European eel, there is no other suitable hydraulic habitat present in the reach for the fish species and life cycles considered in the assessment. For the A82 and M96 flows, hydraulic habitat for European eel show gains of ~11% and losses of between 5.9% (A82) to 9.6% (M96).

With future flow changes, the data for the Severn at Deerhurst assessment point indicates small increases in velocity and depth. Given the nature of the channel and the limited hydraulic habitat potential identified here, these changes are not likely to lead to any significant change in available hydraulic habitat in the reach.

3.6.4.3 Change to weir pool wetted habitat or weir passability

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report: [AR] UpperLodeLeftBank.xlsm – tab 'Depth' [AS] UpperLodeLeftBank.xlsm – tab 'DepthChange'

One fish pass site in this reach has been identified by the EA during Gate 2 and local river levels modelled to review the changes in level associated with the STT solution. This is Saxons Lode the 'Upper Lode left bank' site. The level change can then be used to inform the impact on the efficacy of this fish pass (noting that there is currently insufficient information to derive the critical levels for fish passage). Fisheries assessment is set out in the Gate 2 Fisheries Assessment Report. Tidal influence on water level is observed throughout that reach of the River Severn although that is too complex an interaction to include in the hydraulic modelling. Below Saxons Weir there is a complex influence on water levels associated with the STT solution. This is due to the very low gradient of the River Severn and the influence of the normal tidal limit weir at Maisemore on water levels as far upstream as Saxons Lode which is the next weir upstream.

For this site, water level varies across the whole annual period [AL] due to a range of complex factors affecting the level at this site. Under the full STT A82 scenario, between, roughly, the 1$^{st\ of}$ April and 14th May, the level varies from a reduction of 3.0cm to 7.8cm compared to the reference level, driven by unsupported interconnector pipeline maintenance abstraction at Deerhurst. When the Netheridge release is required to support the maintenance abstraction at Deerhurst (roughly 17th May), the level no longer varies from the baseline until the full STT support commences. When the full support commences (early June) there is a variation in level ranging between a reduction of 20.2cm and an increase of 40.6cm compared to the reference conditions until mid-November. From mid-November, the STT scheme is stopped and the abstraction is unsupported until mid-December. Over this unsupported period, the level varies from +0.258m to -1.757m compared to the reference level, which corresponds to the level ranging between 6.79m AOD and 9.74m AOD (with a mean level of 8.26m AOD) compared to the reference levels which range between 6.74m AOD and 9.80m AOD (with a mean level of 8.26m AOD).

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

3.7.1 Overview of the reach

Based on FEH data, the catchment area at Deerhurst is 9,866 km^2. The catchment area at the normal tidal limit of the River Severn is 10,070 km^2, including the main channel with its normal tidal limit at Maisemore Weir and the catchment area draining to the Eastern Channel between Upper Parting and Llanthony Weir. The length of the River Severn in this reach, to Maisemore Weir, is 12.5 km.

The reach is of a very low gradient, falling <1m over its length and is fairly straight (sinuosity ratio of 1.11). River channel widths vary from ~50-65m throughout the majority of the reach. Land cover flanking the reach is composed predominantly of improved grasslands with some natural grasslands and arable land, with occasional woodland. There are few extensive urban areas along the reach. Riparian tree cover along the reach ranges from continuous to scattered trees. The river flows through an extensive and wide floodplain for its length. From extant aerial imagery and the extended and repeated walkover hydromorphological surveys undertaken [22], the river is characterised mostly by deep glides and runs with occasional rapids over weirs. No sediment bars are present within the reach, although there are several small lateral accumulations of sediment. There is limited information on which to characterise the channel bed substrate, however it is likely to be dominated by coarse material based on the upstream reaches. The majority of banks appear to range from moderate to steep with occasional shallow banks. Bank erosion is present but is not common. There is only one road bridge crossing the reach. There are two weirs at the end of the reach delineating the normal tidal limit. There is notable boating activity, with several moorings along the reach. There is limited bank reinforcement and re-sectioning along the reach, with some limited and localised bankside poaching.

3.7.2 Baseline

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):
[S17] SevernAtDeerhurstDsOfftake.xlsm – tab 'Flow_Nat'
[S18] SevernAtDeerhurstDsOfftake.xlsm – tab 'FlowChange'
[S19] AvonSevern_LongSection_flows.xlsx – tab 'Severn_Flows'

[22] The STT SRO Gate 2 hydromorphological survey evidence is presented for this reach as Extended Reach 6 in in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

This section describes baseline conditions and provides a comparison of the baseline to naturalised conditions.

Downstream of the Deerhurst transfer location, the flow pattern is the same as that described for upstream of Deerhurst [S17]. The low flow period occurs in July and August with flows of approximately 1,700 Ml/d and winter flows are above 5,000 Ml/d in the A82 scenario. In July, the naturalised flows are around 20% lower than the reference condition [S18].

At Gate 1 the EA advised that the Hands-off Flow (HOF) for the River Severn at Deerhurst flow gauge had two levels:

- HOF 1 No flow abstracted without support when the flow is below 2,568 Ml/d, above this level 172 Ml/d can be abstracted without support,
- HOF 2 Maximum of 527 Ml/d could be abstracted without support when the flow is greater than 3,333 Ml/d.

The long profiles [S19] and time series [S17] show that the flow is below HOF 1 in the summer period in Scenario A82, and above HOF2 in late autumn and winter in both Scenarios.

3.7.3 STT operation – current climate

In this reach, the STT solution would abstract flow for transfer in the STT interconnector. The abstraction regime is dependent on the maturity of the STT solution.

For the early phase STT, abstraction would be unsupported up to 500Ml/d at selected times, subject to hands-off flow conditions identified by EA. The indicative system operation pattern identified from stochastic series in Section 1.3 and illustrated as the purple periods of the 47 water resources years in **Figure 1-4**, describes a typical pattern of early phase STT scheme operation during current climate conditions. Overall, this describes a pattern of the STT solution abstraction only in 24 of the 47 years, and on 11% of days overall.

As shown on **Figure 3-5**, flow changes in this reach would typically be in the months October to December, peaking at 35% of days in November. Outside this period, there would be less regular flow changes in August, September and January, with changes very rare in June, July and February and not anticipated in March, April or May. As well as this pattern, there would be a continuous abstraction of 20 Ml/d at Deerhurst to maintain a constant minimum flow and maintain water quality in the interconnector pipeline at all other times. As well as these patterns of abstraction, there would be flow augmentation releases from advanced treated wastewater transfer from Netheridge WwTW to the River Severn upstream Haw Bridge. These Netheridge Transfers would enable a pipeline maintenance flow to continue to be abstracted at Deerhurst, some 2km upstream, when River Severn flows are less than hands-off flow conditions. The controls on this part-time transfer are not well understood at Gate 2 but could be in the order of an additional 17% of time, including parts of most years, typically in the months May to November, at times when river flows are low.

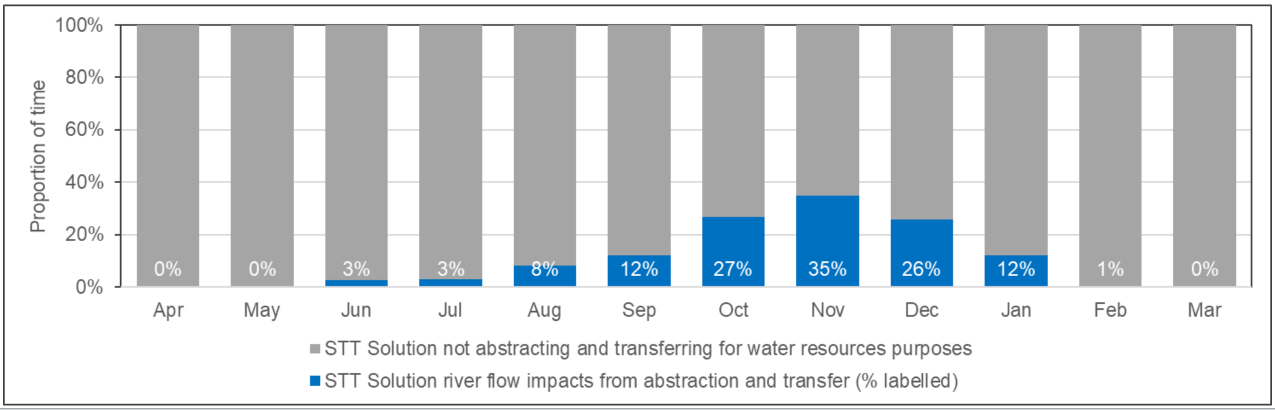


Figure 3-5 Representation of seasonality of early phase STT solution flow changes in the River Severn from Deerhurst to the tidal limit at Gloucester

The A82 scenario would include a period of unsupported abstraction for 60 days from late September to late November, including 25,400 Ml abstracted; at peak rate of 500 Ml/d for 53, non-continuous days. The M96 scenario would include a period of unsupported abstraction for 70 days from late September to early January, including 32,900 Ml abstracted; at peak rate of 500 Ml/d for 64, non-continuous days.

For the full STT, abstraction would be unsupported up to 500 Ml/d at selected times, subject to hands-off flow conditions identified by EA, and supplemented by flow augmentation releases at additional times. The indicative system operation pattern identified from stochastic series in Section 1.3 and illustrated as the purple and blue periods of the 47 water resources years in **Figure 1-4**, describes a typical pattern of full STT scheme operation during current climate conditions. Overall, this describes a pattern of the STT solution abstraction only in 24 of the 47 years, and on 23% of days overall. As shown on **Figure 3-6**, flow changes in this reach would typically be in the months June to January, peaking at 51% of days in September. Outside this period, changes would be very rare in May and February and not anticipated in March or May. It is recognised that within this pattern is the unsupported abstraction shown on **Figure 3-5**, and outside those times there would only be a flow reduction associated with the Netheridge Transfer and Mythe licence transfer. The Netheridge Transfer would result in a 2km reach of the River Severn with 35 Ml/d lower flow until the augmenting release from the transfer is discharged. The Mythe licence transfer would see a 15 Ml/d flow reduction throughout the reach. As well as this pattern there would be a continuous abstraction of 20 Ml/d at Deerhurst to maintain a constant minimum flow and maintain water quality in the interconnector pipeline at all other times. As well as these patterns of abstraction, there would be flow augmentation releases from advanced treated wastewater transfer from Netheridge WwTW to the River Severn upstream of Haw Bridge. These Netheridge Transfers would enable a pipeline maintenance flow to continue to be abstracted at Deerhurst when River Severn flows are less than hands-off flow conditions. The controls on this part-time transfer for supporting pipeline maintenance flows are not well understood at Gate 2 but could be in the order of an additional 5% of time, including parts of most years, typically in the months May to November, at times when river flows are low.

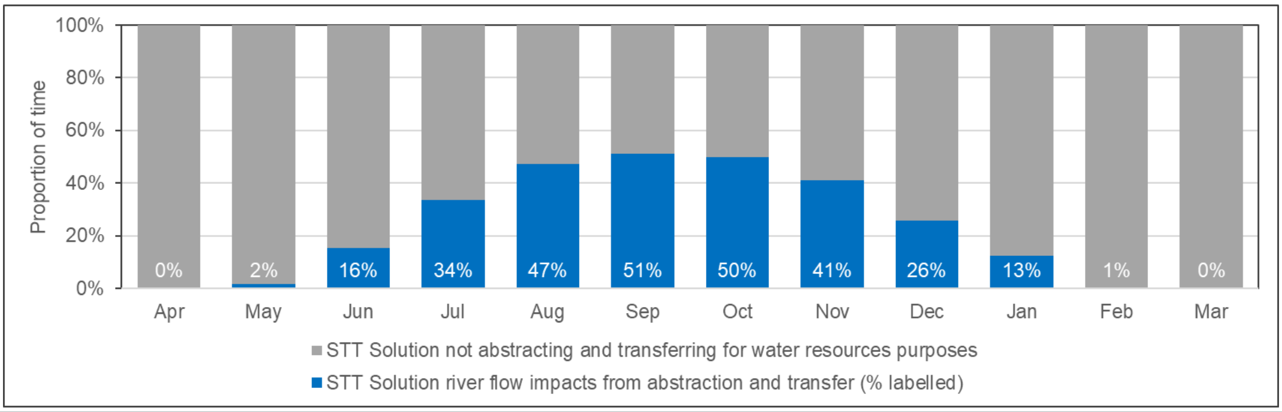


Figure 3-6 Representation of seasonality of full STT solution flow changes in the River Severn from Deerhurst to the tidal limit at Gloucester

The A82 scenario would see abstraction for transfer on 153 continuous days between the end of June and late November. That period includes unsupported abstraction for 60 days from late September to late November, including 25,400 Ml abstracted; at peak rate of 500Ml/d for 53, non-continuous days. Supported abstraction would take place between end of June and late September, with supported transfers maintained until river flows significantly increase in early October in the scenario year.

The M96 scenario would see abstraction for transfer on 208 days from mid-June to early January. That period includes unsupported abstraction for 70 days from late September to early January, including 32,900 Ml abstracted; at peak rate of 500Ml/d for 64, non-continuous days. Supported abstraction would take place between mid-June and late September, with supported transfers maintained until river flows significantly increase in early November in the scenario year.

3.7.3.1 Change to flow

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):
[S20] SevernAtDeerhurstDsOfftake.xlsm – tab 'Flow'
[S21] SevernAtDeerhurstDsOfftake.xlsm – tab 'FlowChange'
[S19] AvonSevern_LongSection_flows.xlsx - tab 'Severn_Flows'

Early phase (Unsupported)

Flow is abstracted at Deerhurst in the unsupported STT scheme when the flow in the River Severn is above the HOF and water is required for the River Thames. In scenario A82, this occurs from the 30th of September to the 30th of November, and in Scenario M96 from the 31st of October to the 9th of January [S20]. This leads to a reduction in the flow in the River Severn downstream of Deerhurst by 5 to 15% depending on the flow in the river [S21].

The long profile of flow [S19] on the 5th of December shows that the flow is above HOF 2 and there is unsupported abstraction at Deerhurst of 500 Ml/d. This is approximately 10% of the total flow in the river. These proportions are maintained to the normal tidal limit at Gloucester.

Full STT

In the fully supported STT scheme, there is a flow reduction of approximately 1.5% during the summer [S20 and 34]. This is due to the Mythe licence transfer of 15 Ml/d. In the autumn and early winter when flow is abstracted without support, the reduction in flow is similar to the unsupported STT scheme.

The long profile of flow [S19] on the 25th of August shows that the flow is below HOF 1 and there is fully supported abstraction at Deerhurst of 353 Ml/d. After the Netheridge outfall, the flow in the river with the fully supported STT scheme is slightly lower than in reference condition due to the Mythe licence transfer.

3.7.3.2 Change to river level, velocity and wetted habitat

Summary results showing the percentage coverage of baseline hydraulic habitat distribution and percentage change in this habitat (derived from 1D model output data) under A82 and M96 periods and releases for the reach (see Annex A), are provided below in Table 3-9. It should be noted that this is a relatively short reach of around 13km in length.

Table 3-9 Percentage of hydraulic habitat within the reach of the River Severn from Deerhurst to the tidal limit at Gloucester

		A82 habitats (%)				M96 habitats (%)			
		Baseline	Scheme			Baseline	Scheme		
Fish	**Life stage**	Suitable habitat	Gain	No change	Loss	Suitable habitat	Gain	No change	Loss
Atlantic salmon	0+	0	0	100	0	0	0	100	0
	Juvenile	0	0	100	0	0	0	100	0
	Spawning	0	0	100	0	0	0	100	0
Brown trout	0+	0	0	100	0	0	0	100	0
	Juvenile	4	0.2	100	0	7	0.2	100	0.1
	Spawning	0	0	100	0	0	0	100	0
Lamprey sp.	Larvae	0	0	100	0	0	0	100	0
	Spawning	0	0	100	0	0	0	100	0
Chub	Juvenile	0	0	100	0	0	0	100	0
	Spawning	0	0	100	0	0	0	100	0
Roach	Juvenile	0	0	100	0	0	0	100	0
	Spawning	0	0	100	0	0	0	100	0
Eel	Juvenile	97	9	89	2.1	93	17	79	4

The data indicate that, apart from Brown trout (juvenile) and European eel, there is no suitable hydraulic habitat for any of the other fish species and life stages considered in this assessment. Habitat for eel is extensive at 97% for the A82 scenario and 93% for the M96 scenario. Hydraulic habitat for juvenile Brown trout is very limited at 4.4% for the A82 scenario and 7% for the M96 scenario.

For European eel, hydraulic habitat remains relatively similar, though there are gains of 9% and 17% under A82 and M96 flows respectively, with small losses of 2% and 4% under A82 and M96 flows respectively. The small amount of juvenile Brown trout hydraulic habitat remains relatively invariant, with some marginal gains of 0.2% under A82 and M96 flows and only a slight loss of 0.1% under M96 flows.

The data show that, except for European eel and limited juvenile Brown trout, there is no suitable hydraulic habitat in the reach. For eel, gains in hydraulic habitat for M96 are nearly double those for A82. Gains and losses for Juvenile Brown trout hydraulic habitat are marginal for releases under A82 and M96 scenarios.

Due to the complexity and volume of data, this is a brief overview of the potential changes only. Annex A should be referred to for the full assessment, including spatial plots of hydraulic habitat distribution and changes.

3.7.3.3 Change to weir pool wetted habitat or weir passability

There are no weir pool habitats in this reach. There are no weirs identified for review of fish passability in this reach.

3.7.4 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 extension both 35 days earlier, to include late May and all of June; and 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. In the A82 Future reference conditions River Severn flows are below hands-off flow conditions for later in the autumn which drives the need to augmentation releases later in the autumn. Noting that in the A82 Future scenario abstraction from the River Severn for transfer to the River Thames would be required for 10 days later into autumn, the total period of unsupported abstraction would reduce from 60 days by 38 days to only 22 days. The 22 days of unsupported abstraction would be in the mid-November to early December period.

3.7.4.1 Change to flow

This section is supported by charts and data in excel workbooks: the same ones as listed in the section above for current conditions.

In the fully supported STT scheme, there is a flow reduction of approximately 1.5% during the summer [S17 and S18]. This is due to the Mythe licence transfer of 15 Ml/d. In the autumn and early winter when flow is abstracted without support, the reduction in flow is similar to the unsupported STT scheme.

The long profile of flow [S19] on the 18th of October shows that the flow is below HOF 1 and there is fully supported abstraction at Deerhurst of 330 Ml/d. After the Netheridge outfall, the flow in the river with the fully supported STT scheme is slightly lower than in reference condition due to the Mythe licence transfer.

3.7.4.2 Change to river level, velocity and wetted habitat

As a guide, the change in depth-average velocity and water depth at the Severn at Deerhurst downstream offtake assessment point from the 1D hydraulic model has been reviewed. There are 22 days in the A82 Futures scenario with unsupported abstraction above HoF conditions. On these dates, mean modelled flow in the reference conditions is 7,940 Ml/d; the mean change in depth-average velocity is modelled as 0.009 m/s (a 0.0002% reduction); and the mean change in water depth is modelled as 0.07 m (a 1.6% reduction).

The baseline and scheme hydraulic habitats for fish species within the reach are briefly outlined in Section 3.7.3.2. The data indicate that, apart from Brown Trout (juvenile) (only very limited at 4.4%) and European eel (extensive habitat pf ~96%), there is no other suitable hydraulic habitat present in the reach for the fish species and life cycles considered in the assessment. For the A82 and M96 flows, hydraulic habitat for European eel show small gains (of ~9-17%) and marginal losses (of ~2-4%), while juvenile Brown trout shows only limited marginal losses (0.1%) and gains (0.2%).

With future flow changes, the data for the Severn at Deerhurst assessment point indicates small increases in velocity and depth. Given the nature of the channel and the limited hydraulic habitat potential identified here, these changes are not likely to lead to any significant change in available hydraulic habitat in the reach.

3.7.4.3 Change to weir pool wetted habitat or weir passability

There are no weir pool habitats in this reach.

There are no weirs identified for review of fish passability in this reach.

3.8 THE SEVERN ESTUARY DOWNSTREAM OF THE TIDAL LIMIT AT GLOUCESTER

3.8.1 Overview of the reach

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 input become dominant i.e. oligohaline.

Downstream of the normal tidal limit of the main River Severn at Maisemore Weir and the Eastern Channel at Llanthony Weir, the channel sees normal tidal estuarine hydrodynamics, with a pattern of twice-daily high-low-high tides. The main freshwater flow contribution from the River Severn to the Severn Estuary is over Maisemore Weir, with the Eastern Channel providing further freshwater input at the Lower Parting, some 2.3 km seawards. Between these two channels of the freshwater Severn, the River Leadon confluences with the tidal channel, with an additional catchment area of 328km^2. The tidal channel continues as a narrow constrained upper estuary, or tideway, for approximately 14 km to around Waterend before the estuary widens.

3.8.2 Baseline

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): [S22] SevernAtModelEnd.xlsm – tab 'Flow_Nat' [S23] SevernAtModelEnd.xlsm – tab 'FlowChange'

This section describes baseline conditions and provides a comparison of the baseline to naturalised conditions.

The flow pattern at the normal tidal limit in Gloucester is the same as that described for upstream of Deerhurst [S22]. The low flow period occurs in July and August with flows of approximately 1,750 Ml/d and winter flows are above 7,000 Ml/d in the A82 Scenario. In July the naturalised flows are around 20% lower than the reference condition [S23].

The River Leadon is not specifically included in the STT solution assessment. Gauged flows at Wedderburn Bridge[23] (gauging 90% of the catchment area) describe low flow Q_{95} as 27 Ml/d (1962-2020).

3.8.3 STT operation – current climate

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): [S24] SevernAtModelEnd.xlsm - tab 'Flow' [S25] SevernAtModelEnd.xlsm – tab 'FlowChange'

The pass-forward flow to the Severn Estuary from the freshwater River Severn would be amended by unsupported STT abstraction. The daily pattern of unsupported STT solution abstraction rates – either early phase STT or full STT are illustrated as the purple periods of the 47 water resources years in Figure 1-4. Overall, this describes a pattern of unsupported STT solution abstraction only in 24 of the 47 years, and on 11% of days overall.

[23] https://nrfa.ceh.ac.uk/data/station/meanflow/54017 accessed 13 May 2022.

In environmental terms, unsupported STT abstraction would specifically be protected by licence hands-off flow conditions as set out in Table 1-2. Following these conditions, the greatest impact on pass forward flows would either be at the lowest remaining flow conditions, or highest abstraction rate. The greatest STT solution impact under lowest remaining flow conditions would be abstraction of 172 Ml/d at river flows at Deerhurst of 2,740 Ml/d, reducing flow at Deerhurst to 2,568 Ml/d. The greatest STT solution impact under highest abstraction rates would be abstraction of 500 Ml/d at river flows at Deerhurst of 3,661 Ml/d, reducing flow at Deerhurst to 3,161 Ml/d. These changes from the STT solution are set against a dynamic flow regime in the River Severn. Flows in the River Severn at this part of the flow regime are not stable day-on-day flows [S24], those stable conditions only exist under very low flow conditions, which are less than the hands-off flow condition and unsupported abstraction does not take place. Thus dates with significant flow change [S25] are on higher flow days.

As shown on Figure 3-7, pass forward flow changes would typically be in the months October to December, peaking at 35% of days in November. Outside this period, there would be less regular flow changes in August, September and January, with changes very rare in June, July and February and not anticipated in March, April or May.

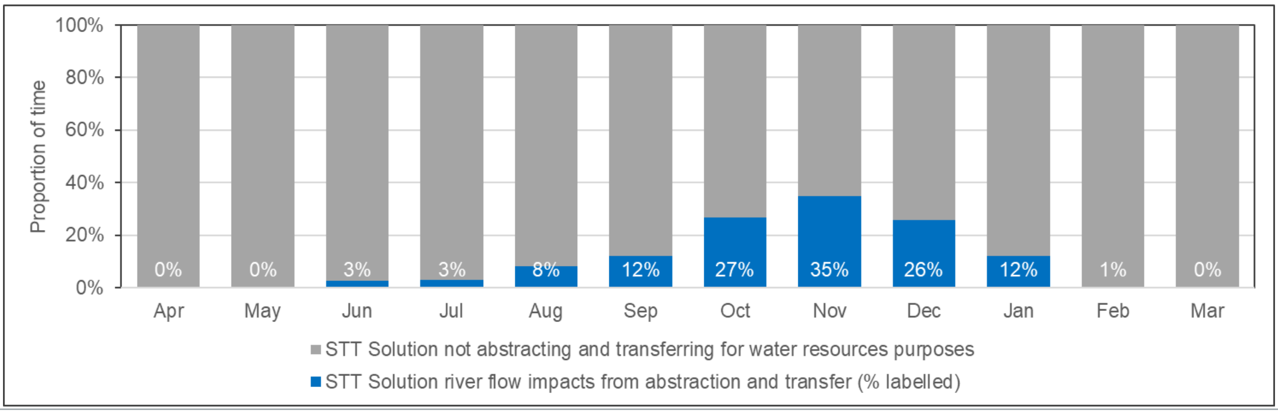


Figure 3-7 Representation of seasonality of unsupported STT solution abstraction for water resources transfer amending River Severn flows to the Severn Estuary

The A82 scenario would include a period of unsupported abstraction for 60 days from late September to late November, including 25,400 Ml abstracted; at peak rate of 500 Ml/d for 53, non-continuous days. The M96 scenario would include a period of unsupported abstraction for 70 days from late September to early January, including 32,900 Ml abstracted; at peak rate of 500 Ml/d for 64, non-continuous days.

There are other minor reductions in pass-forward flow to the Severn Estuary associated with the STT solution. These are the periods when abstraction at Deerhurst to provide the 20 Ml/d interconnector pipeline maintenance flow is unsupported. These are outside the times that the STT solution would be in use for water resources transfer purposes, at times when river flows at Deerhurst are above hands-off flow conditions. The gold periods on Figure 3-8 shows that these circumstances are routine and represent the most common effect of the STT solution.

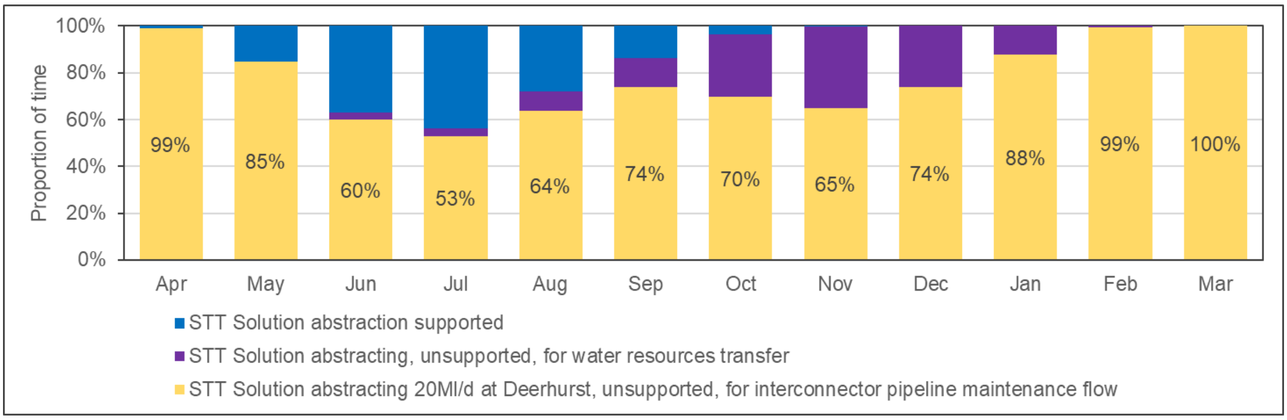


Figure 3-8 Representation of seasonality of unsupported STT solution abstraction for interconnector maintenance flow amending River Severn flows to the Severn Estuary

In addition, the Mythe temporary licence transfer is considered likely to reduce flows into the Severn Estuary. Severn Trent Water's Mythe licence is accounted for within the hands-off flow conditions and as such the full licence abstraction rate can be abstracted without constraint from the hands-off flow conditions. In the modelling it is noted that the abstraction rate attributed to the Mythe intake in the reference conditions for A82 and M96 affords for 15 Ml/d additional abstraction at Deerhurst in the full STT model scenarios, without the need to reduce the abstraction rate at Mythe. As such there is 15 Ml/d additional abstraction modelled at Deerhurst at times of supported STT abstraction. At these times the pass-forward flow modelled to the Severn Estuary reduces by 15 Ml/d. These are analogous to the blue periods shown on Figure 3-4.

Overall, the effect on pass-forward flows to the Severn Estuary from the STT solution is shown on the flow duration curve for the full 47 year representative period on Figure 3-9. In terms of the overall pattern of changes to pass-forward flow of freshwater from the River Severn to the Severn Estuary, the effects of the STT solution are neither distinct or substantially different from the reference conditions pattern without the STT solution. For example, at Q95, Full STT flows passed forward to the Severn Estuary would be 0.05% lower than reference conditions.

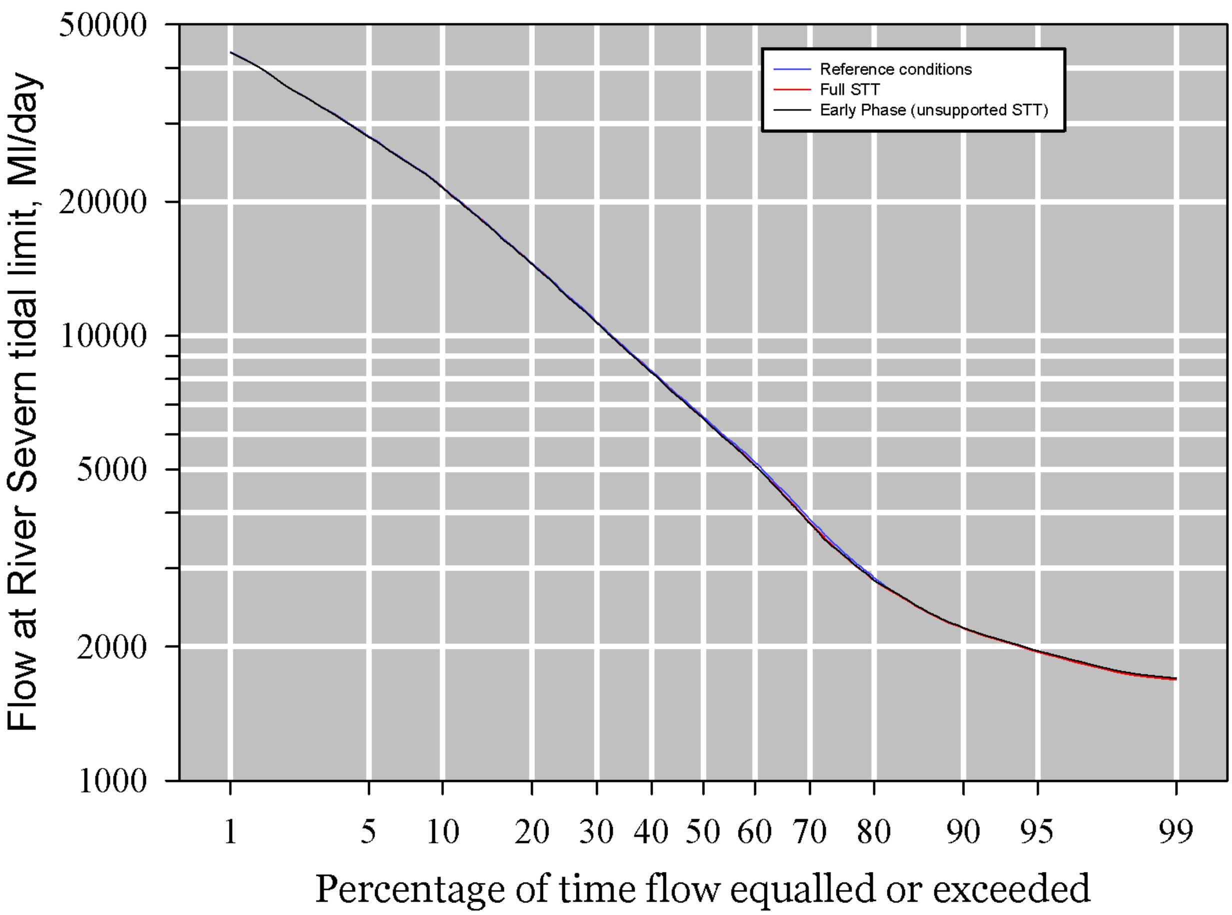


Figure 3-9 Flow duration curve representing 47-year pattern of flow change into the Severn Estuary from either early phase STT or full STT

3.8.4 STT operation - future climate

As noted above, the pass-forward flow to the Severn Estuary from the freshwater River Severn would be amended by unsupported STT abstraction. The daily pattern of unsupported STT solution abstraction rates – are illustrated as the purple periods for A82 Future and M96 Future in Figure 1-5. Overall, this describes a pattern of unsupported STT solution abstraction only for 22 days in A82 Future in the mid-November to early December period; and 88 days in M96 Future in November, December and January.

Although a fuller context of future operating patterns and flows are not currently available from modelling, review of A82 Future identifies a reduction of 0.7% in the flows passed forward to the Severn Estuary compared with reference conditions. The M96 Future, for which a flow series is only currently available for the River Thames, identifies a pattern of unsupported abstraction in Figure 1-5 which is longer than in the current climate, and this later seasonal trend may a feature of future operating patterns.

3.9 THE RIVER THAMES FROM CULHAM TO THE TIDAL LIMIT AT TEDDINGTON

3.9.1 Overview of the reach

3.9.1.1 Middle Thames from Culham to Windsor

Based on FEH data, the catchment area at Thames Culham where the interconnectors would discharge to the River Thames is 3,373 km². The catchment area at Thames in Windsor (located just upstream of the River Thames at Royal Windsor Park flow gauge) is 7,125 km². The length of the River Thames in this reach is approximately 96 km.

The reach is of a very low gradient, falling 35m over its length, with a gradient of 0.02° and is fairly sinuous (sinuosity ratio of 1.28). River channel widths vary from ~25-30m at the start of the reach, increasing to around 50m in the middle of the reach and increasing again to 50-60m at the end of the reach, with localised widths around impounding structures being well over 60m. Land cover flanking the reach is composed predominantly of improved grasslands with some natural grasslands in the upper portions of the reach, increasing to more arable and woodland in the middle of the reach, along with an increasing dominance of urban areas from the middle to the end of the reach. There is occasional open water, mostly located towards the end of the reach (Dorney Lake etc.). There are extensive urban areas at Wallingford (~18 km downstream), Goring (~27 km downstream), Reading (~39 km downstream), Henley-on-Thames (~60 km downstream), Marlow (~73 km downstream), Maidenhead (~84 km downstream) and Windsor (~92 km downstream). Riparian tree cover along the reach is highly variable, ranging from continuous to scattered and no trees depending on land cover. Where land cover is dominated by grassland or urban areas there tend to be fewer trees. Generally, tree cover declines with distance along the reach. The river flows predominantly through an extensive and wide floodplain throughout the reach, though this changes somewhat around 27 km downstream as the river flows through Goring Gap.

From extant aerial imagery, the river is characterised by a mixture of deep glides and runs, with occasional rapids over weirs. No sediment bars are visible, although there are multiple islands scattered throughout the reach with the channel bifurcating around these. There is no information to classify the sediment size composing the bed substrate. The majority of banks outside of urban areas appear to range from moderate to steep with occasional shallow banks and bank erosion is not common. Within and between urban areas aerial imagery appears to indicate reinforcement and re-sectioning of banks, especially in the larger urban areas where this modification appears to be dominant.

Approximately 34 bridges (mostly road and footbridges with occasional railway bridges) cross the channel. Some 26 weirs are located along the reach. Of these 19 are located on bifurcations and have associated bypass locks for navigation purposes on the opposite bifurcation arm. Features of note are Days Weir (~10 km downstream), Benson Lock and Weir (~17 km downstream), Goring Lock (~28 km downstream), Pangbourne Lock (~35 km downstream), Mapledurham Lock (~39 km downstream), Sonning Lock (~50 km downstream), Hambleden Lock (~65 km downstream), Hurley Lock (~70 km downstream), Taplow Lock (~85 km downstream and Boveney Lock (~94 km downstream). These bifurcation channels, below weirs prior to reconnection with the navigable channel, are referred to as weir pools in the scope of the Gate 2 assessment. As well as the main channel and associated bifurcations, a large side channel, the Jubilee River splits from the reach at ~84 km downstream, re-joining the reach in the next study reach. There is notable boating activity throughout the reach, with a large number of moorings and marinas throughout the reach. As noted above, most bank reinforcement and re-sectioning are found within the main urban areas along the reach. There are some areas of localised bankside poaching around some of the urban areas at tourist hotspots and also adjacent to pastoral grasslands.

3.9.1.2 Lower Thames from Windsor to the tidal limit at Teddington

Based on FEH data, the catchment area at Thames in Windsor (located just upstream of the River Thames at Royal Windsor Park flow gauge) is 7,125 km. The catchment area of the River Thames at Teddington lock is 9,938 km². The length of the River Thames in this reach is approximately 44.6 km.

The reach is of a very low gradient, falling 13m over its length, with a gradient of 0.03° and is fairly sinuous. River channel widths vary from ~50-65m across the reach, however localised widths can be much larger (up to ~80m) around islands and impounding structures. Land cover flanking the reach is composed predominantly of urban and suburban areas (as the reach flows through the outer extents of London) and park land, with occasional improved grasslands, arable land (towards the top of the reach) and open water. Riparian tree cover along the reach is highly variable, ranging from continuous to scattered and no trees depending on land cover. Where land cover is dominated by urban areas tree coverage tends to decline. The river flows predominantly through an extensive and wide urbanised floodplain throughout the reach.

From extant aerial imagery, the river is characterised by a mixture of deep glides and runs, with occasional rapids over weirs. No sediment bars are visible, although there are multiple islands scattered throughout the reach with the channel bifurcating around these, e.g. Penton Hook (~18 km downstream) and Platt's Eyot (~33 km downstream). There is no information to classify the sediment size composing the bed substrate. For riverbanks outside of urban areas these appear to range from moderate to steep with occasional shallow banks and bank erosion is not common. Within urban areas aerial imagery indicates dominant reinforcement and re-sectioning of banks.

Approximately 15 bridges (mostly road and footbridges with occasional railway bridges) cross the channel. Some 15 weirs are located in the reach. Of these, nine (though these are frequently groups of one or more weir across the channel) are located on the main stem of the river and have associated bypass locks for navigation purposes, commonly on the opposite bifurcation arm. Features of note are Romney Lock (~1.4 km downstream), Windsor Cut and Old Windsor Lock (~6 km downstream), Bell Weir Lock (~13 km downstream), Penton Hook Lock (~18 km downstream), Chertsey Lock (~21 km downstream), Shepperton Lock (~24 km downstream), Sunbury Lock (~30 km downstream), Molesey Lock (~35 km downstream) and Teddington Lock at the end of the reach. As well as the main channel and associated bifurcations, a large side channel, the Jubilee River re-joins the river at ~3 km downstream. There is significant boating activity throughout the reach, with a large number of moorings and marinas throughout the reach. As noted above, bank reinforcement and re-sectioning is dominant within urban areas. There are some areas of localised bankside poaching around some of the urban areas at tourist hotspots.

3.9.2 Baseline

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):
[TH1] ThamesAtCulhamDsOutfall.xlsm – tab 'Flow_Nat'
[TH2] ThamesUsPang.xlsm – tab 'Flow_Nat'
[TH3] ThamesUsDatchetIntake.xlsm – tab 'Flow_Nat'
[TH4] Thames_LongSection_flows.xlsx – tab 'Thames_Flows'‘

This section describes baseline conditions and provides a comparison of the baseline to naturalised conditions.

In the River Thames downstream of the Culham outfall location [TH1] the naturalised flow shows the distinctive pattern of a baseflow dominated river with a steady receding limb from 15th April until a return to higher flows on 4th October and a stepping up in magnitude of flow peaks in the winter period. Lowest flows, in the August and September period, are ~420 Ml/d. At Culham there are few differences between the reference conditions, which include abstractions to Thames Water's Farmoor Reservoir upstream, and natural conditions.

Upstream of the confluence with the River Pang [TH2], some 38km downstream of Culham, the Culham flow pattern is retained, but with a mean 46% increase in flow across the year. Lowest flows, in the August and September period, are ~770 Ml/d, 84% higher than at Culham in this period. As at Culham, there are few differences between the reference conditions and natural conditions.

Upstream of Thames Water's Datchet intake [TH3], some 64km downstream of Culham, the Culham flow pattern is retained, but with a mean 120% increase in flow across the year. Lowest flows, in the August and September period, are ~1,300 Ml/d, 210% higher than at Culham in this period. As at Culham, there are few differences between the reference conditions and natural conditions.

The long profile flow plot between Culham and Teddington [TH4] shows that in the low flow summer period (7th August) the flow in the River Thames increases from approximately 500 Ml/d to 1,500 Ml/d at ~100 km due to inflow from tributaries, then falls by a net of 1,000 Ml/d due to Thames Water and Affinity Water's abstractions despite further flow addition from tributaries. The flow in the river increases by a factor of 3 in this reach during the low flow period. The increase factor is smaller at moderate flows (30th November) although abstraction reduces flows by Walton to a value similar to that at Culham – but with additional flow inputs from the River Mole and Hogsmill River greater than Thames Water's abstraction rates at Walton, Hampton and Surbiton intakes on that modelled date. As such under moderate flow conditions flows at Teddington are modelled higher than at Culham. It is noted that although the WRSE water resources model is effective at describing the total potable supply abstraction rate from intakes in the lower Thames and the flows at Teddington Weir, it is not specifically designed to represent abstraction rates at individual Thames Water' intakes and as such it is not a precise tool for describing River Thames flows downstream of the Datchet intake. As such, location downstream of the Datchet intake are only shown for reference on the long profile flow plots.

3.9.3 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 EA. The indicative system operation pattern identified from stochastic series in Section 1.3 and illustrated as the purple periods of the 47 water resources years in **Figure 1-4**, describes a typical pattern of early phase STT scheme operation during current climate conditions. Overall, this describes a pattern of the STT solution flow augmentation only in 24 of the 47 years, and on 11% of days overall.

The seasonality of flow changes in the River Thames for the early phase STT mirror those in the River Severn at point of abstraction as shown on **Figure 3-5** and described in Section 3.7.3. Outside of these operating periods, the pipeline maintenance flow of 35 Ml/d would be discharged to the River Thames at all other times. The A82 scenario would include a period of flow augmentation for 60 days from late September to late November, including flow augmentation at peak rate of 500 Ml/d for 53, non-continuous days. The M96 scenario would include a period of flow augmentation for 70 days from late September to early January, including flow augmentation at peak rate of 500 Ml/d for 64, non-continuous days.

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 EA, and supplemented by flow augmentation of the River Severn at additional times. The indicative system operation pattern identified from stochastic series in Section 1.3 and illustrated as the purple and blue periods of the 47 water resources years in **Figure 1-4**, describes a typical pattern of full STT scheme operation during current climate conditions. Overall, this describes a pattern of the STT solution abstraction only in 24 of the 47 years, and on 23% of days overall.

The seasonality of flow changes in the River Thames for the early phase STT mirror those in the River Severn at point of abstraction as shown on **Figure 3-6** and described in Section 3.7.3. Outside of these operating periods, the pipeline maintenance flow of 35 Ml/d would be discharged to the River Thames at all other times. The A82 scenario would include a period of flow augmentation for 153 continuous days between the end of June and late November, including flow augmentation at peak rate of 500Ml/d for 53, non-continuous days from late September. Between the end of June and late September, flow augmentation would be at the supported rate of 353 Ml/d. The M96 scenario would include a period of flow augmentation for 208 days from mid-June to early January, including flow augmentation at peak rate of 500Ml/d for 64, non-continuous days from late September. Between mid -June and late September flow augmentation would be at the supported rate of 353 Ml/d.

3.9.3.1 Change to flow

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):
[TH5] ThamesAtCulhamDsOutfall.xlsm – tab 'Flow'
[TH6] ThamesAtCulhamDsOutfall.xlsm – tab 'FlowChange'
[TH7] ThamesUsPang.xlsm – tab 'Flow'
[TH8] ThamesUsPang.xlsm – tab 'FlowChange'
[TH9] ThamesUsDatchetIntake.xlsm – tab 'Flow'
[TH10] ThamesUsDatchetIntake.xlsm – tab 'FlowChange'

[TH11] Thames_LongSection_flows.xlsx – tab 'Thames_Flows''

Early phase (Unsupported)

Flow augmentation at Culham in the early phase STT scheme is when the flow in the River Severn is above the HOF and water is required for the River Thames. In scenario A82, this occurs from the 30th of September to the 30th of November, and in Scenario M96 from the 31st of October to the 9th of January [TH5]. In both of these scenarios flows have also begun to increase in the River Thames at time of unsupported transfer and the higher rate of flow augmentation of 500 Ml/d does not coincide with periods of lowest river flow in the River Thames. As such, there is no other pattern of introduced flow peaks in the River Thames in either scenario, with the reference condition patterns of flow increases and decreases retained. Flow augmentation leads to an increase in the flow in the River Thames downstream of Culham typically around 20-25%, but by up to 40% depending on the flow in the river [TH6]. Upstream of the confluence with the River Pang [TH7] the increase in the flow in the River Thames is lower as a proportion of river flow, typically 20%, but by up to 34% depending on the flow in the river [TH8]. Upstream of the Datchet intake [TH9] the increase in the flow in the River Thames is lower still as a proportion of river flow, typically 10-15%, but by up to 32% depending on the flow in the river [TH10]. Outside of these operating periods the pipeline maintenance flow of 20 Ml/d or a Netheridge Transfer supported rate of 35 Ml/d would be discharged to the River Thames at all other times, both of which are small proportion (less than 10%) flow increases at Culham.

The long profile of flow [TH11] for A82 on the 23rd of October shows a 25% increase in river flow at Culham from 500 Ml/d flow augmentation with that flow increase held to upstream of the Datchet intake ~100km downstream and then re-abstracted. The long profile of flow [TH11] for M96 on the 5th of December shows a 20% increase in river flow at Culham from 500 Ml/d flow augmentation with that flow increase again held to upstream of the Datchet intake ~100km downstream and then re-abstracted.

Full STT

Flow augmentation at Culham in the Full STT scheme is more frequent than the Early Phase STT. In scenario A82, this occurs from the 30th of June to the 30th of November, and in Scenario M96 from the 15th of June to the 9th of January [TH5]. The supported period of abstraction (in the modelled scenario this is a 330 Ml/d flow increase) this leads to a steady increase in the flow in the River Thames downstream of Culham by 60-86% in A82, depending on the flow in the river, and in the lower flow year M96 an increase of 65-103% depending on flow in the river [TH6]. Apart from the initial flow increase when flow augmentation commences, there are no other patterns of introduced flow peaks in the River Thames in either scenario, with the reference condition patterns of flow increases and decreases retained. Upstream of the confluence with the River Pang [TH7] the increase in the flow in the River Thames is lower as a proportion of river flow, typically 33-48% for the A82 scenario and 35-45% for the M96 scenario depending on the flow in the river [TH8]. Upstream of the Datchet intake [TH9] the increase in the flow in the River Thames is lower still as a proportion of river flow, typically 22-33% for both the A82 and M96 scenarios depending on the flow in the river [TH10]. Outside of these operating periods the pipeline maintenance flow of 20 Ml/d would be discharged to the River Thames at all other times which are small proportion (less than 5%) flow increases at Culham.

The long profile of flow [TH11] for the A82 scenario on the representative low flow date 18th July shows a 67% increase in river flow at Culham from 330 Ml/d flow augmentation with that flow increase again held to upstream of the Datchet intake ~100km downstream and then re-abstracted.

3.9.3.2 Change to river level and velocity

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): [TH12] ThamesAtCulhamDsOutfall.xlsm – tab 'Depth' [TH13] ThamesAtCulhamDsOutfall.xlsm – tab 'Velocity' [TH14] ThamesUsPang.xlsm – tab 'Depth' [TH15] ThamesUsPang.xlsm – tab 'Velocity' [TH16] ThamesUsDatchetIntake.xlsm – tab 'Depth' [TH17] ThamesUsDatchetIntake.xlsm – tab 'Velocity'

The 1D hydraulic model output for water depth variability in the River Thames has not been used in this assessment. This is because water levels in the River Thames are managed for navigation, with the normal operating level varying within one metre. For example at Culham Lock 90% of gauged river levels in the last year have varied within in a 0.26m range; at Whitchurch Lock (local to the River Pang confluence) by 0.22m; at Romney Lock (local to the Datchet intake) by 0.4m. This is in contrast to the differences in water depth which have been greater than one metre during the scenario periods reported for the River Thames at Culham [TH12]; upstream of the River Pang [TH14]; and upstream of the Datchet intake [TH16].

The 1D hydraulic model output for depth-average velocity variability in the River Thames is considered more reliable. The key summary of the modelled velocity change is that the STT solution would reduce the extent of average velocity reduction within the channel during summer periods of low flow in the River Thames. With the STT solution, average velocity at Culham would not fall below 0.2 m/s [TH13]; and upstream of the River Pang [TH15] and upstream of the Datchet intake [TH17] average velocity would not fall below 0.25 m/s at times of operation of the STT solution.

3.9.3.3 Change to weir pool wetted habitat or weir passability

An assessment is required of the potential effects from STT solution flow augmentation effects on level, velocity and wetted habitat change at selected weir pool reaches on the River Thames. Weir pool reaches are a feature of the navigation infrastructure of the River Thames, and are that part of the river at a lock, between the weir and the reconnection with the navigable channel. Weir pool reaches represent zones of hydraulic heterogeneity within the otherwise level controlled River Thames. At Gate 1 SESRO identified the first three weir pool reaches downstream of a Culham outfall (same location as the STT Solution outfall) for review: Culham Weir, Clifton Hampden Weir and Days Weir.

A screening review has been undertaken at the weir pools of these prior to the collection of bathymetry and hydraulic data under suitable flow conditions for inclusion in a 2D model. Those flow conditions were not present in the River Thames during the Gate 2 survey season. The screening identified there could be velocity increases within each of the weir pools from flow augmentation, but was not able to provide context around the reference condition velocities in a A82 moderate-low flow year or a M96 very low flow year or the seasonal differences from the augmentation pattern.

3.9.4 STT operation - future climate

In comparison with the M96 scenario the M96 Future scenario 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 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.

3.9.4.1 Change to flow

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): [TH18] ThamesAtCulhamDsOutfall.xlsm – tab 'Flow_M96_Future' [TH19] ThamesUsPang.xlsm – tab 'Flow_M96_Future' [TH20] ThamesUsDatchetIntake.xlsm – tab 'Flow_M96_Future'

Flow augmentation at Culham in the M96 Future scenario would occur from the 22nd of May to the 29th of January [TH18]. This leads to an increase in the flow in the River Thames downstream of Culham by 16% to 132% depending on the flow in the river [TH18]. Apart from the initial flow increase when flow augmentation commences, there is no other pattern of introduced flow peaks in the River Thames, with the reference condition pattern of flow increases and decreases retained. Upstream of the confluence with the River Pang [TH20] the increase in the flow in the River Thames is lower as a proportion of river flow, typically 10-61% depending on the flow in the river [TH19]. Upstream of the Datchet intake [TH20] the increase in the flow in the River Thames is lower still as a proportion of river flow, typically 5-40% depending on the flow in the river [TH20]. Outside of these operating periods, the pipeline maintenance flow of 20 Ml/d would be discharged to the River Thames at all other times: this is a small proportion (less than 5%) of the flow increase at Culham.

3.9.4.2 Change to river level and velocity

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):
[TH12] ThamesAtCulhamDsOutfall.xlsm – tab 'Depth'
[TH13] ThamesAtCulhamDsOutfall.xlsm – tab 'Velocity'
[TH14] ThamesUsPang.xlsm – tab 'Depth'
[TH15] ThamesUsPang.xlsm – tab 'Velocity'
[TH16] ThamesUsDatchetIntake.xlsm – tab 'Depth'
[TH17] ThamesUsDatchetIntake.xlsm – tab 'Velocity'

As explained in **Section 3.9.3.2**, the 1D hydraulic model output for water depth variability in the River Thames has not been used in this assessment. The 1D hydraulic model output for depth-average velocity variability in the River Thames is considered more reliable. The key summary of the modelled velocity change is that the STT solution would reduce the extent of average velocity reduction within the channel during summer periods of low flow in the River Thames. With the STT solution, average velocity at Culham would not fall below 0.25 m/s [TH13]; and upstream of the River Pang [TH15] and upstream of the Datchet intake [TH17] average velocity would not fall below 0.3 m/s at times of operation of the STT solution.

3.9.4.3 Change to weir pool wetted habitat or weir passability

The assessment of effects on weir pool reaches under future scenarios has not been specifically undertaken at Gate 2 due to the limitations noted in **Section 3.9.3.3**.

3.10 OTHER FUNCTIONALLY LINKED HABITATS

Gate 1 review identified a number of specific sites within the study area in the Severn catchment for detailed review of habitat and ecological change. These seven sites have been modelled to understand the depth and velocity changes as a result of the STT solution to help inform the impacts on other functionally linked habitat. The ecological assessment is set out in the Gate 2 Fisheries and Protected Habitats Assessment Report. These sites are as follows:

- River Vyrnwy U/S Cownwy
- River Vyrnwy at Dolanog - Mill Lane
- River Vyrnwy D/S Meifod
- River Vyrnwy U/S Llanymynech
- River Vyrnwy near Melverley Green
- River Severn at Montford SSSI
- River Severn near Upton Ham SSSI

This section is supported by charts and data in the following excel workbooks, part of the Evidence Report:
[AT] RiverVyrnwyUsCownwy.xlsm – tab 'Depth'
[AU] RiverVyrnwyUsCownwy.xlsm – tab 'DepthChange'
[AV] RiverVyrnwyUsCownwy.xlsm – tab 'Velocity'
[AW] RiverVyrnwyUsCownwy.xlsm – tab 'VelocityChange'
[AX] RiverVyrnwyAtDolanog-MillLane.xlsm – tab 'Depth'
[AY] RiverVyrnwyAtDolanog-MillLane.xlsm – tab 'DepthChange'
[AZ] RiverVyrnwyAtDolanog-MillLane.xlsm – tab 'Velocity'
[BA] RiverVyrnwyAtDolanog-MillLane.xlsm – tab 'VelocityChange'
[BB] RiverVyrnwyDsMeifod.xlsm – tab 'Depth'
[BC] RiverVyrnwyDsMeifod.xlsm – tab 'DepthChange'
[BD] RiverVyrnwyDsMeifod.xlsm – tab 'Velocity'
[BE] RiverVyrnwyDsMeifod.xlsm – tab 'VelocityChange'
[BF] RiverVyrnwyUsLlanymynech.xlsm – tab 'Depth'
[BG] RiverVyrnwyUsLlanymynech.xlsm – tab 'DepthChange'
[BH] RiverVyrnwyUsLlanymynech.xlsm – tab 'Velocity'
[BI] RiverVyrnwyUsLlanymynech.xlsm – tab 'VelocityChange'
[BJ] RiverVyrnwyNearMelverleyGreen.xlsm – tab 'Depth'
[BK] RiverVyrnwyNearMelverleyGreen.xlsm – tab 'DepthChange'
[BL] RiverVyrnwyNearMelverleyGreen.xlsm – tab 'Velocity'
[BM] RiverVyrnwyNearMelverleyGreen.xlsm – tab 'VelocityChange'
[BN] RiverSevernAtMontfordSSSI.xlsm – tab 'Depth'
[BO] RiverSevernAtMontfordSSSI.xlsm – tab 'DepthChange'

[BP] RiverSevernAtMontfordSSSI.xlsm – tab 'Velocity'
[BQ] RiverSevernAtMontfordSSSI.xlsm – tab 'VelocityChange'
[BR] RiverSevernNearUptonHamSSSI.xlsm – tab 'Depth'
[BS] RiverSevernNearUptonHamSSSI.xlsm – tab 'DepthChange'
[BT] RiverSevernNearUptonHamSSSI.xlsm – tab 'Velocity'
[BU] RiverSevernNearUptonHamSSSI.xlsm – tab 'VelocityChange'

3.10.1 River Vyrnwy U/S Cownwy

At the River Vyrnwy U/S Cownwy site, under the A82 scenario, there is an increase in depth between 27th June and 9th October [AT]. Over this period the depth increases by between 10.3% and 34.0% [AU] with the depth ranging between 0.29m and 0.42m (with a mean depth of 0.34m compared to the reference which ranged between 0.22m and 0.38m (with a mean depth of 0.29m).

Similarly, the velocity in this period increases under this scenario [AV]. The range in percentage increase compared to the reference is between 4.4% and 14.8% [AW] with the scenario velocities ranging between 0.85m/s and 1.00m/s (with a mean velocity of 0.92m/s) compared to the reference which ranged between 0.74m/s and 0.96m/s (with a mean velocity of 0.84m/s).

Under the M96 scenario, there is an increase in depth between 12th June and 2nd November. Over this period the depth increases by between 8.2% and 34.2% with the depth ranging between 0.29m and 0.46m (with a mean depth of 0.39m) compared to the reference which ranged between 0.21m and 0.42m (with a mean depth of 0.34m AOD).

Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 3.5% and 14.9% with the scenario velocities ranging between 0.82m/s and 1.04m/s (with a mean velocity of 0.96m/s) compared to the reference which ranged between 0.74m/s and 1.00m/s (with a mean velocity of 0.91m/s).

3.10.2 River Vyrnwy at Dolanog - Mill Lane

At the River Vyrnwy at Dolanog – Mill Lane site, under the A82 scenario, there is an increase in depth between 27th June and 9th October [AX]. Over this period the depth increases by between 6.9% and 19.1% [AY] with the depth ranging between 0.25m and 0.33m (with a mean depth of 0.28m) compared to the reference which ranged between 0.21m and 0.31m (with a mean depth of 0.25m).

Similarly, the velocity in this period increases under this scenario [AZ]. The range in percentage increase compared to the reference is between 7.2% and 21.2% [BA] with the scenario velocities ranging between 0.63m/s and 0.86m/s (with a mean velocity of 0.73m/s) compared to the reference which ranged between 0.52m/s and 0.80m/s (with a mean velocity of 0.65m/s).

Under the M96 scenario, there is an increase in depth between 12th June and 2nd November. Over this period the depth increases by between 5.3% and 18.5% with the depth ranging between 0.24m and 0.35m (with a mean depth of 0.30) compared to the reference which ranged between 0.21m and 0.34m (with a mean depth of 0.28m AOD).

Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 5.5% and 20.6% with the scenario velocities ranging between 0.62m/s and 0.93m/s (with a mean velocity of 0.79m/s) compared to the reference which ranged between 0.53m/s and 0.89m/s (with a mean velocity of 0.72m/s).

3.10.3 River Vyrnwy D/S Meifod

At the River Vyrnwy D/S Meifod – Mill Lane site, under the A82 scenario, there is an increase in depth between 28th June and 10th October [BB]. Over this period the depth increases by between 0.2% and 3.0% [BC] with the depth ranging between 1.53m and 2.34m (with a mean depth of 1.71m) compared to the reference which ranged between 1.49m and 2.30m (with a mean depth of 1.7m).

Similarly, the velocity in this period increases under this scenario [BD]. The range in percentage increase compared to the reference is between 0.9% and 32.2% [BE] with the scenario velocities ranging between

0.04m/s and 0.44m/s (with a mean velocity of 0.11m/s) compared to the reference which ranged between 0.03m/s and 0.43m/s (with a mean velocity of 0.10m/s).

Under the M96 scenario, there is an increase in depth between 13th June and 3rd November. Over this period the depth increases by between 0.1% and 2.5% with the depth ranging between 1.54m and 3.12m (with a mean depth of 1.65m) compared to the reference which ranged between 1.51m and 3.12m (with a mean depth of 1.62m AOD).

Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 0.2% and 25.5% with the scenario velocities ranging between 0.04m/s and 0.83m/s (with a mean velocity of 0.08m/s) compared to the reference which ranged between 0.03m/s and 0.83m/s (with a mean velocity of 0.07m/s).

3.10.4 River Vyrnwy U/S Llanymynech

At the River Vyrnwy U/S Llanymynech site, under the A82 scenario, there is an increase in depth between 28th June and 10th October [BF]. Over this period the depth increases by between 0.3% and 2.1% [BG] with the depth ranging between 0.85m and 1.65m (with a mean depth of 1.02m) compared to the reference which ranged between 0.84m and 1.64m (with a mean depth of 1.01m).

Similarly, the velocity in this period increases under this scenario [BH]. The range in percentage increase compared to the reference is between 0.5% and 14.3% [BI] with the scenario velocities ranging between 0.10m/s and 0.63m/s (with a mean velocity of 0.23m/s) compared to the reference which ranged between 0.09m/s and 0.63m/s (with a mean velocity of 0.22m/s).

Under the M96 scenario, there is an increase in depth between 13th June and 3rd November. Over this period the depth increases by between 0.1% and 2.1% with the depth ranging between 0.84m and 2.51m (with a mean depth of 0.94m) compared to the reference which ranged between 0.83m and 2.51m (with a mean depth of 0.93m).

Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 0.1% and 15.4% with the scenario velocities ranging between 0.10m/s and 1.01m/s (with a mean velocity of 0.17m/s) compared to the reference which ranged between 0.09m/s and 1.01m/s (with a mean velocity of 0.16m/s).

3.10.5 River Vyrnwy near Melverley Green

At the River Vyrnwy near Melverley Green site, under the A82 scenario, there is an increase in depth between 28th June and 10th October [BJ]. Over this period the depth increases by between 0.6% and 4.3% [BK] with the depth ranging between 0.91m and 2.69m (with a mean depth of 1.27m) compared to the reference which ranged between 0.88m and 2.67m (with a mean depth of 1.25m).

Similarly, the velocity in this period increases under this scenario [BL]. The range in percentage change compared to the reference is between -0.4% and 13.4% [BM] with the scenario velocities ranging between 0.15m/s and 0.62m/s (with a mean velocity of 0.27m/s) compared to the reference which ranged between 0.13m/s and 0.62m/s (with a mean velocity of 0.27m/s).

Under the M96 scenario, there is an increase in depth between 13th June and 30th October. Over this period the depth increases by between 0.6% and 5% with the depth ranging between 0.88m and 1.82m (with a mean depth of 1.01m) compared to the reference which ranged between 0.85m and 1.79m (with a mean depth of 0.98m).

Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 1.2% and 13.2% with the scenario velocities ranging between 0.13m/s and 0.47m/s (with a mean velocity of 0.19m/s) compared to the reference which ranged between 0.12m/s and 0.47m/s (with a mean velocity of 0.18m/s).

3.10.6 River Severn at Montford SSSI

At the River Severn at Montford SSSI site, under the A82 scenario, there is an increase in depth between 28th June and 10th October [BN]. Over this period the depth increases by between 0.6% and 15.5% [BO] with the depth ranging between 0.68m and 2.28m (with a mean depth of 0.97m) compared to the reference which ranged between 0.59m and 2.26m (with a mean depth of 0.91m).

Similarly, the velocity in this period increases under this scenario [BP]. The range in percentage increase compared to the reference is between 0.2% and 2.1% [BQ] with the scenario velocities ranging between 0.55m/s and 0.70m/s (with a mean velocity of 0.57m/s) compared to the reference which ranged between 0.54m/s and 0.69m/s (with a mean velocity of 0.57m/s).

Under the M96 scenario, there is an increase in depth between 13th June and 30th October. Over this period the depth increases by between 0.4% and 17.3% with the depth ranging between 0.64m and 1.26m (with a mean depth of 0.80m) compared to the reference which ranged between 0.58m and 1.19m (with a mean depth of 0.71m).

Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 0.2% and 2.5% with the scenario velocities ranging between 0.55m/s and 0.59m/s (with a mean velocity of 0.56m/s) compared to the reference which ranged between 0.53m/s and 0.59m/s (with a mean velocity of 0.55m/s).

3.10.7 River Severn near Upton Ham SSSI

At the River Severn near Upton Ham SSSI site, under the A82 scenario, there is an increase in depth between 1st July and 12th October [BR]. Over this period the depth increases by between 0.3% and 4.7% [BS] with the depth ranging between 1.72m and 2.73m (with a mean depth of 1.88m) compared to the reference which ranged between 1,.65m and 2.72m (with a mean depth of 1.83m).

Similarly, the velocity in this period increases under this scenario [BT]. The range in percentage increase compared to the reference is between 0.4% and 6.6% [BU] with the scenario velocities ranging between 0.41m/s and 0.73m/s (with a mean velocity of 0.46m/s) compared to the reference which ranged between 0.39m/s and 0.72m/s (with a mean velocity of 0.44m/s).

Under the M96 scenario, there is an increase in depth between 16th June and 1st November. Over this period the depth increases by between 0.9% and 5.5% with the depth ranging between 1.67m and 2.77m (with a mean depth of 1.75m) compared to the reference which ranged between 1.60m and 2.74m (with a mean depth of 1.68m).

Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 1.3% and 7.9% with the scenario velocities ranging between 0.40m/s and 0.52m/s (with a mean velocity of 0.42m/s) compared to the reference which ranged between 0.37m/s and 0.74m/s (with a mean velocity of 0.40m/s).

4 CONCLUSIONS

The potential effects of the STT solution have been considered in the context of the current and potential future in-channel physical environment, and with reference to natural conditions. The outputs from the 1D hydraulic models developed for use in Gate 2, throughout 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 Physical Environment Evidence Report. That includes the physical environment survey work undertaken bespoke to the STT solution; a catalogue of hydraulic model output including flows, and where appropriate averaged water depth, average flow velocity, water level; habitat modelling output.

4.1 SUMMARY OF THE EFFECTS UNDER CURRENT CLIMATE

The assessment of the potential effects of the STT solution on the in-channel physical environment has included the full study area associated with the scheme. This includes the River Severn catchment and the River Thames catchment, from the point of flow addition to the tidal limits and pass-forward flows 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 the in-channel physical environment is made in support of other assessments. The scope of the Gate 2 physical environment assessment has been informed by the Gate 1 assessment and feedback. It is noted that the Gate 2 physical environment assessment is not final, and represents only a position of knowledge at Gate 2. Also the assessment of effects on the physical environment is not definitive – it is used to support the development of water quality assessments; 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 Initial Environmental Assessment.

All of the in-channel Gate 2 STT solution assessment reports document effects on the same river reach basis. These reaches have been selected to cover the full study area and are divided either at point of change from STT STO scheme operation, or at key points in the river network.

In the 74 km of the River Vyrnwy from Vyrnwy Reservoir to the confluence with the River Severn, the STT solution would episodically augment flow to a total of 25 Ml/d. These flow changes would be minor in the context of the range of normal flows in the River Vyrnwy but need further consideration in the context of Severn Regulation releases which also exert a managed flow regime on the River Vyrnwy. The changes in flow would not result in significant change to wetted habitat, although there would likely be some very localised losses, particularly in the upper sections of the reach. The extent of these physical environment changes are considered further in the ecological assessments.

In the 112 km of the River Severn from the confluence of the River Vyrnwy to Bewdley, the STT solution would episodically augment flow to a total of 180 Ml/d including from the Vyrnwy Bypass outfall located at the start of this reach, and in addition a part-time abstraction reduction of 25 Ml/d at Severn Trent Water's Shelton intake upstream of Shrewsbury. These flow changes would be minor in the context of the range of normal and regulated flows in the River Severn and would not result in significant change to wetted habitat or water level at locally important hydraulic features. The extent of these physical environment changes are considered further in the ecological assessments.

In the 56 km of the River Severn from Bewdley to the confluence with the River Avon, the STT solution would episodically augment flow to a total of 205 Ml/d. These flow changes would be minor in the context of the range of normal and regulated flows in the River Severn and would not result in significant change to wetted habitat or water level at locally important hydraulic features. The extent of these physical environment changes is considered further in the ecological assessments.

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. These flow changes would be large compared to the already significantly augmented baseflow of the River Avon. However, in the context of the range of wetted habitat present in the River Avon, habitat changes would be small. The extent of these physical environment changes is considered further in the ecological assessments. At certain hydraulic features modelling indicates water level change that requires further consideration: notably Stoneleigh Abbey 2 at the beginning of the reach, where an increase of 18 cm is modelled at lowest water levels; and in the lower reach at Wyre Piddle and Pershore where an increase of 9-10 cm is modelled at lowest water levels. Elsewhere in the reach, water level changes are modelled typically 2-5 cm at lowest water levels and always within normal ranges.

In the 2.6 km of the River Severn from the confluence with the River Avon to Deerhurst flow augmentation from a fully supported STT solution would be at its maximum, up to 287 Ml/d flow increase at times of low to very low river flows. These flow changes would be minor in the context of the range of normal and regulated flows in the River Severn and would not result in significant change to wetted habitat or water level at locally important hydraulic features. The extent of these physical environment changes is considered further in the ecological assessments.

In the 12.5 km of the River Severn from Deerhurst to the normal tidal limit at Gloucester, the STT solution would lead to a range of flow changes. These are associated with the STT interconnector abstraction at Deerhurst, episodically up to 500 Ml/d unsupported, 350 Ml/d supported, or 20 Ml/d for pipeline maintenance. Flow augmentation from the Netheridge Transfer – either 20 Ml/d or 35 Ml/d would be transferred, some 3.9 km downstream of Deerhurst. As unsupported abstractions would be subject to hands-off low conditions they would not affect the lowest flows and would not result in significant change to wetted habitat or water level at locally important hydraulic features. The flow effect of net supported abstractions and unsupported pipeline maintenance flows would be very small. The extent of these physical environment changes is considered further in the ecological assessments.

The effect of the STT solution on pass-forward flows of freshwater into the Severn Estuary downstream of the tidal limit at Gloucester has also been assessed. Review of the 47 year long term pattern identifies the effects of the STT solution as neither distinct or substantially different from the reference conditions pattern without the STT solution.

In the 102 km of the River Thames, from Culham to upstream of Thames Water’s intake at Datchet near Windsor, the STT solution would episodically augment flow via up to 500 Ml/d unsupported, 353 Ml/d supported, or 20 Ml/d for pipeline maintenance. These flow changes would be large when augmenting low flow periods in the River Thames, and would occur for long durations when in use. Within the main channel of the River Thames, which is level managed for navigation, flow augmentation would maintain depth average velocities such that these do not reduce below 0.2 m/s (Culham) and 0.25 m/s (upstream River Pang; upstream Datchet intake). The assessment of wetted habitat change within the weir pools of the River Thames, particularly those with highest proportion flow increase, has not been completed during Gate 2. From Datchet, for the remaining 37 km of the freshwater River Thames to Teddington Weir, already licenced public water supply abstraction by Thames Water and Affinity Water reduces flow, and the STT solution flow augmentation would also be re-abstracted in this reach. Specific flow changes from the STT solution in the reach from the Datchet intake to Teddington Weir cannot be isolated from available tools that describe operational controls.

4.2 SUMMARY OF THE EFFECTS UNDER FUTURE CONDITIONS

Future physical environment conditions have been included in the assessment to support the Initial Environmental Assessment. The future scenario requested is the RCP 8.5 Business As Usual emissions scenario. Extensive water resources modelling has been used to define potential future operating patterns of the STT solution and future river flows.

In comparison with the A82 scenario, the A82 Future scenario would include a 40% longer period of flow augmentation releases from support elements of a STT solution. This amends the seasonality of the potential need for STT support options in late spring, early summer and later into autumn which is considered to be a significant change. The magnitude of change in flows is not significantly greater than for current climate scenarios, but the regularity and duration of effects are most likely to drive habitat change. As most of the differences for the Future Scenario relate to the use of support options there would remain insignificant change to the pass-forward flow regime to the Severn Estuary.

4.3 UNCERTAINTY AND CONFIDENCE DATA GAPS

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

The Severn catchment hydraulic model is built from EA flood models from 2009 to 2010 on the Vyrnwy and Avon. The age of the cross-section survey data is likely to be older than these dates. There is likely to be more uncertainty in the cross-section geometry on the River Vyrnwy than the Avon due to the nature of the local river morphology.

There are a number of locks and weirs with moveable gates between Evesham and the River Severn. The positions of sluice gates in hydraulic structures are not known for the probabilistically derived scenario years. It has been assumed that sluice gates on hydraulic structures are in the closed position because this is most likely to be the case at low flow when the STT supported scheme is operating, and hence when differences between the scheme and reference conditions occur.

The final reach on the River Avon below Tewkesbury weir was modelled in a simplified way with all the flow joining the River Severn at a single location. This was because the operation of the gates that control the split of flow between the two channels is not known for the probabilistic derived scenario years. Excluding the structure means that the flow is not separated downstream of the structure and that the water level and depth results in the reach between Bredon weir and the River Severn should be treated with caution.

The model calibration and validation has identified that river water levels are not well simulated at low flows at Montford and Buildwas on the River Severn. This is likely due to local impact of channel geometry or hydraulic structures near the gauges. At Montford, branch channels and islands are present a few hundred metres downstream of the gauge, and so the lack of detail on the bed geometry in this area is likely to explain the lower water levels in the model compared to the gauge at low flow. Thus, caution should be placed on the direct use of the hydraulic model outputs, other than flow, in this reach. It should be noted that the assessment of physical habitat uses recent local topographic and flow surveys alongside the model outputs of the change in flow, average velocity and water depth, so this uncertainty in the model outputs in this reach do not impact the assessment.

The habitat modelling has linked the field surveys with the model output. The level of coverage of sites in the Severn catchment is considered very good for Gate 2. However, there is always an opportunity to increase the detail of the spatial representation: the ecological assessment results may recommend further detailed data capture with which to incorporate into habitat modelling in the future.

The assessment of impact on barriers, particularly in the River Avon is at an early stage in Gate 2. The modelling of water level changes associated with the STT solution has highlighted that further survey of three structures: Stoneleigh Abbey 2, Wyre Piddle and Pershore and more detailed representation within the hydraulic model may be appropriate.

Hydraulic modelling of the River Thames at Gate 2 is of limited reliability. The specific scenario flow series for A82 and M96 at Culham do not match those identified as representative of 1:5 and 1:20 returns frequencies from the stochastic flow series modelling. Although the hydraulic modelled scenarios include suitable low flow magnitudes, the seasonality of the 1:5 and 1:20 return frequencies identified from water resources modelling included low flows later into the autumn. Therefore, the hydraulic modelled scenarios include STT solution flow augmentation at times when flows in the River Thames have recovered and there would be no water resources benefit from flow augmentation. The hydraulic model has output water depth changes in the mainstem River Thames which are outwith measured ranges. The range of modelled depth-average velocity outputs under low river flow conditions are considered more useful. The hydraulic model itself requires further work for use in Gate 3 and further flow scenarios will be required.

Habitat modelling of the River Thames at Sutton Pools (Culham Lock), Clifton Lock weir pool and Day's Lock weir pool has not been possible in Gate 2 due to unsuitable flows for repeat ADCP survey to validate 2D hydraulic models.

4.4 RECOMMENDATIONS FOR GATE 3

1D modelling: River Severn catchment

In order to reduce remaining gaps in understanding the possible scheme operation, further scenario modelling is recommended using the 1D hydraulic models to assess alternative STT operating regimes, and cumulative assessments with other water resources options.

The Severn catchment hydraulic model is built from EA flood models from 2009 to 2010 on the Vyrnwy and Avon. Given that the age of the cross-section survey will predate the models, it is recommended that cross-section geometry measurements are taken to improve the representation of the model, particularly for the River Vyrnwy, and Montford and Buildwas on the River Severn. Knowledge of the likely setting of the numerous locks and weirs with moveable gates between Evesham and the River Severn will also help improve the presentation of the river environment in future modelling activities. Further to this, surveys of three structures: Stoneleigh Abbey 2, Wyre Piddle and Pershore to enable a more detailed representation within the hydraulic model is recommended.

Further to this, it is recommended that the existing model is expanded to include barriers and fish passage structures, or localised models created for those reaches with these infrastructure in order to ascertain the effect of the STT Solution upon them. This includes a review with Regulators on those barriers and fish passage structures that warrant enhanced assessment in the context of the Gate 2 findings.

1D modelling: River Thames catchment

In order to reduce remaining gaps in understanding the possible scheme operation, further scenario modelling is recommended using the 1D hydraulic models to assess alternative STT operating regimes, and cumulative assessments with other water resources options.

The hydraulic model of the river Thames needs further development to increase confidence in its outputs for Gate 3.

2D modelling

Further ADCP data capture in the River Thames of Sutton Pools (Culham Lock), Clifton Lock weir pool and Day's Lock weir pool is also recommended to complete build and validation of 2D hydraulic models and undertake habitat modelling for Gate 3.

Flow release from Vyrnwy Reservoir

The current release from Vyrnwy Reservoir follows an artificial pattern and Regulator feedback on the ST Solution has identified that ideally the current release regime should be modified to be more natural. It is recommended, that when the volume of water to be released from the Reservoir for the STT Scheme is confirmed in Gate 3, a study is undertaken to explore what changes can be made to adopt a more naturalised regime which incorporates the need to make releases for compensation, Severn Regulation and STT scheme releases. This will require collaborative working between Natural Resources Wales, Environment Agency, Natural England and the STT Group.

In-channel habitat assessment

The habitat assessment work is based on ADCP data and the application of fish habitat preference hydraulic data to the outputs of a 1D model. It is acknowledged that the 1D model is not entirely suitable for this application due to the nature of its single point hydraulic outputs. Therefore, the following recommendations are made for Gate 3 in order to further bolster the habitat assessment and to provide this with a more robust empirical framework where review with Regulators warrants enhanced assessment in the context of the Gate 2 findings:

- Undertake more ADCP measurements at a larger number of sites on the middle River Vyrnwy (notably Vyrnwy Reservoir to the Afon Banwy confluence) and middle River Avon (from the River Sowe confluence to the River Leam confluence). Additional sites will be reviewed with Regulators in the context of the Gate 2 findings and may require additional walkover fish habitat mapping survey of the whole of these reaches prior to agreeing sites.
- Undertaken an increased number of repeat surveys at these sites which capture a much wider range of flows, including the magnitude of flows which would be expected during a release. This will provide empirical evidence of the degree of flow habitat changes expected. Coverage of a wider range of flow habitats, e.g. at more runs, riffles and pools will allow increased quantification of potential changes at these areas.
- If possible, use a more detailed model to provide higher resolution outputs at sections of velocity and depth. This would be beneficial in broadening the hydraulic information available to characterise the simulated range of changes at each cross-section within a channel and allow development of a better

understanding of these changes, particularly in areas important for fish habitat, e.g. channel margins and side channels.

Other recommendations

As the engineering design and operational triggers of the STT Solution is progressed in Gate 3, further specificity can be added to the Gate 2 assessments.

The use of water resources modelling at Gate 2 has provided the best available information on likely patterns of STT Solution use available at the time. However, with WRSE and other Regional Groups WRMP24 Plan reconciliation, the pattern of use of STT Solution and other SROs will develop. New variants on operating patterns and cumulatives can be readily tested through scenarios using the Gate 2 river modelling tools. These include variants in standby and ramp-up/ ramp-down patterns within the 1D model of the River Severn catchment and River Thames. Further future scenarios will be agreed with Regulators for assessment through modelling in Gate 3.

Annex A: in-channel habitat assessment

A.1 INTRODUCTION

The in-channel habitat assessment is specifically focussed on the potential changes in the distribution of fish habitat through the study system of the River Vyrnwy, River Severn and River Avon with respect to the proposed releases on the River Vyrnwy and River Avon.

Annex A provides a review of the approach taken to assess the fish habitats present in these rivers and how the potential releases could affect the distribution of these habitats using a combination of measured hydraulic data and modelled hydraulic data. The methodology takes the following approach:

1. Identification of suitable hydraulic survey data.
2. Analysis of fish count data to identify most common fish species within the study area.
3. Selection of appropriate fish species and their respective habitat preferences.
4. Identify habitat preferences of selected hydraulic survey sites under varying flow conditions.
5. Assess suitability of 1D hydraulic modelling for extrapolating habitat preferences throughout study area.
6. If suitable, extrapolate the habitat assessment throughout the study reach using the 1D hydraulic model data.

Each of the stages of the approach, and the results, are detailed below.

A.2 IN-CHANNEL HYDRAULICS SURVEYS

A.2.1 SURVEY SITES AND SITES SELECTED FOR HABITAT ASSESSMENT

A key part of the habitat assessment was the collection of measured hydraulics data at key reaches throughout the study area under a range of flow conditions representative of those expected during the scheme release periods (expected to be June to November). A wide range of data was collected by Ricardo during the 2021 monitoring season, including hydraulic data collected at 19 different sites over multiple repeat cross-sections using an RS5 Acoustic Doppler Current Profiler (ADCP) and flow habitat survey mapping at each of these sites (**Figure A 1**).

A review of the survey sites providing details on the dates of survey and the flow habitat types at the sites is provided in **Table A 1**.

For the purposes of the assessment, only five sites were selected for further analysis **(Table A 2**). These sites have been identified as those closest to the proposed scheme release points and which are likely to see the most significant changes in habitats due to these changes in flow.

Where repeat hydraulic surveys of either of the five sites was undertaken, only the hydraulic data for the lowest and highest measured flows during the surveys have been selected in order to provide an understanding of the magnitude of habitat changes at these sites under the widest range of flows measured.

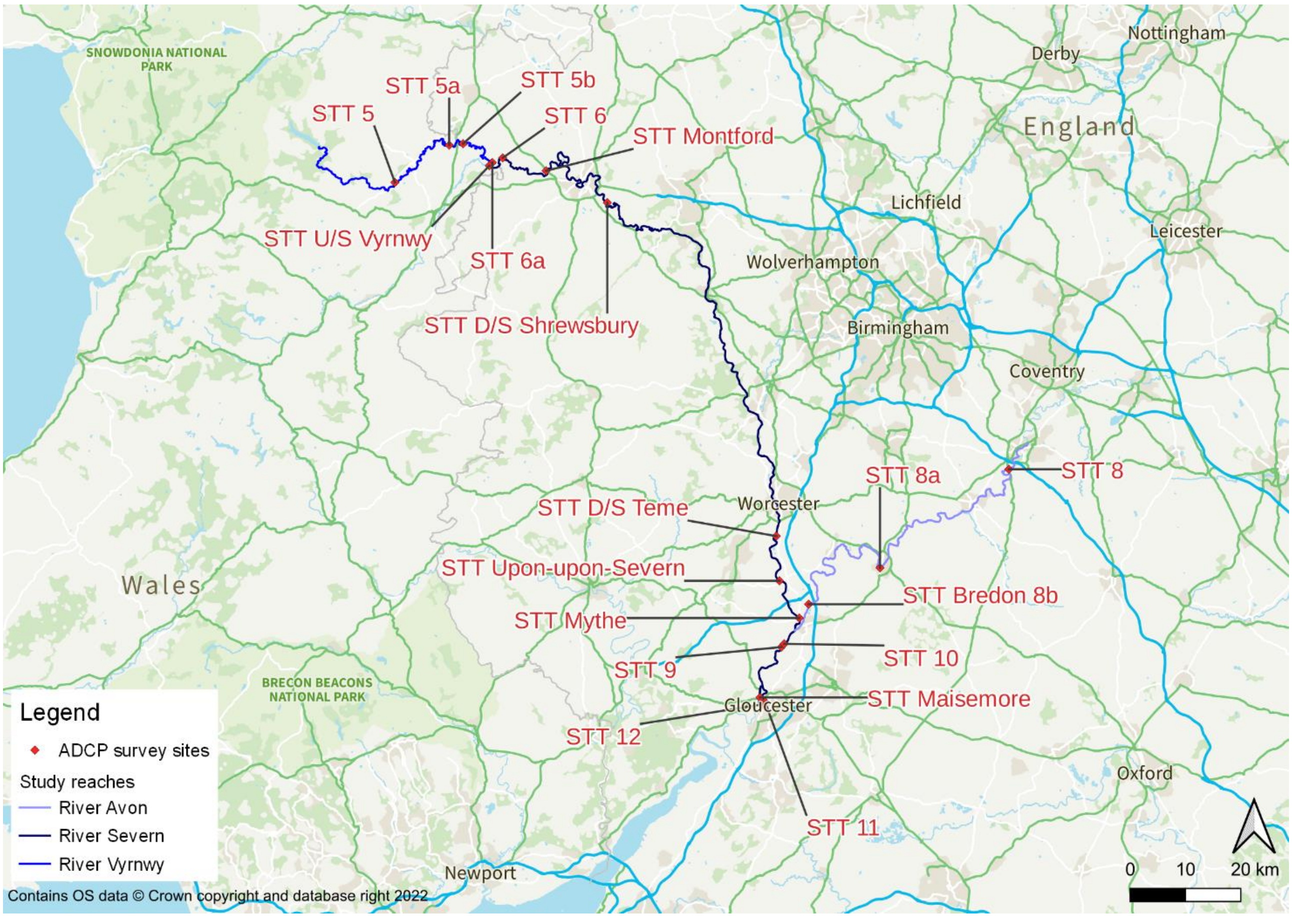


Figure A 1 ADCP survey site locations

Table A 1 ADCP survey site survey details

ADCP site ID	River	No of surveys	Date range of surveys	General flow habitat at site at lowest measured flows	General flow habitat at site at highest measured flows
STT 5	Vyrnwy	2	16 Jun 2021, 17 Sept 2021	Glide (dominant), U/S riffle and bar	Glide (dominant), U/S riffle and bar
STT 5a	Vyrnwy	2	16 Jun 2021, 17 Sept 2021	Glide with run	Glide with run
STT 5b	Vyrnwy	2	16 Jun 2021, 17 Sept 2021	Glide	Glide
STT 6a	Vyrnwy	2	16 Jun 2021, 17 Sept 2021	Glide-run with pool	Glide-run
US_Vyrnwy	Severn	2	16 Jun 2021, 14 Oct 2021	Glide	Glide
STT 6	Severn	2	15 Jun 2021, 14 Oct 2021	Glide-run	Run
STT Montford	Severn	2	15 Jun 2021, 14 Oct 2021	Glide	Glide
STT_DS_Shrewsbury	Severn	2	15 Jun 2021, 14 Oct 2021	Riffle-glide	Glide-pool
STT_DS_Teme	Severn	3	14 Jul 2021 – 15 Oct 2021	Glide	Glide
STT_Upon-upon-Severn	Severn	2	15 Oct 2021, 18 Oct 2021	Glide	Glide
STT Mythe	Severn	3	14 Jul 2021 – 15 Oct 2021	Glide	Glide
STT 10	Severn	4	15 Jul 2021 – 28 Oct 2021	Glide	Glide
STT 9	Severn	3	14 Jul 2021 – 28 Oct 2021	Glide	Glide
STT Maisemore	Severn	3	15 Jul 2021 – 28 Oct 2021	Glide	Glide
STT 11	Severn	4	15 Jul 2021 – 28 Oct 2021	Glide	Glide
STT 12	Severn	4	15 Jul 2021 – 28 Oct 2021	Run	Run
STT 8	Avon	4	14 Jun 2021 – 26 Oct 2021	Run	Run - with marginal glide
STT 8a	Avon	4	16 Jul 2021 – 19 Sept 2021	Glide	Glide
STT Bredon 8b	Avon	5	15 Jul 2021 – 15 Oct 2021	Glide	Glide

Table A 2 Selected ADCP sites for habitat analysis

ADCP site ID	River	Lowest measured flow date	Lowest measured flow (m3/s / Ml/d)	Highest measured flow date	Highest measured flow (m3/s / Ml/d)
STT 5a	Vyrnwy	7 Sept 2021	1.82 / 157	16 Jun 2021	3.40 / 294
STT 5b	Vyrnwy	7 Sept 2021	1.72 / 149	16 Jun 2021	3.48 / 301
STT Montford	Severn	15 Jun 2021	8.07 / 697	14 Oct 2021	10.97 / 948
STT 10	Severn	15 and 21 Jul 2021	22.29 / 1,926	28 Oct 2021	38.97 / 3,367
STT 8	Avon	16 and 20 Jul 2021	2.65 / 229	26 Oct 2021	4.41 / 381

A.3 SELECTION OF FISH SPECIES AND HABITAT THRESHOLDS

A.3.1 FISH COUNT DATA

In order to identify the range of fish species present within the study area Environment Agency (EA) fish count data was compared to all of the 19 ADCP sites within the entire survey area (River Vyrnwy, River Severn and River Avon) (**Table A 1**). For each ADCP site, the closest EA fish monitoring site(s) were selected and relevant data extracted. These sites are detailed in **Table A 3**.

The selected fish count data was then aggregated on a per river basis and analysed across its entire temporal range to identify the relevant dominance (using numerical counts) of all the fish species within the study area.

Table A 3 EA fish survey points used in relation to ADCP survey sites

ADCP site ID	River	EA fish survey site and ID	Date range of fish data used
STT 5	Vyrnwy	Carreghofa (1127)	2003 and 2021
STT 5a		Carreghofa (1127)	2003 and 2021
STT 5b		Carreghofa (1127)	2003 and 2021
STT 6a		Pentre (1155)	2003 - 2015
US_Vyrnwy	Severn	Pentre (1155)	2003 - 2015
STT 6		Pentre *(1155)*	2003 – 2015
STT Montford		Montford *(1424)* Montford Bridge *(39910)*	2011 *(39910)* 2003 – 2008 *(1424)*
STT_DS_Shrewsbury		Atcham *(1428)*	2003 – 2019
STT_DS_Teme		Kempsey U/S weir *(27837)* Kempsey D/S ford *(27838)* Pitchcroft *(1437)*	2007 *(27837)* 2007*(27838)* 2003 – 2006 *(1437)*
STT_Upon-upon-Severn		Upton Marina Basin EQSD *(66883)* Upton Upon Severn to Tewkesbury EQSD *(66884)* Upton *(7165)* Upton on Severn fry site *(39908)*	2016 – 2019 *(66883)* 2016 *(66884)* 2002 *(7165)* 2011-2019 *(39908)*
STT Mythe		Upton Marina Basin EQSD *(66883)* Upton Upon Severn to Tewkesbury EQSD *(66884)* Upton *(7165)* Upton on Severn fry site *(39908)* Haw bridge fry site *(39907)*	2016 – 2019 *(66883)* 2016 *(66884)* 2002 *(7165)* 2011 – 2019 *(39908)* 2011 *(39907)*
STT 10		Haw bridge fry site *(39907)* Wainlodes fry site *(607383)*	2011 *(39907)* 2014 – 2016 *(60783)*
STT 9		Haw bridge fry site *(39907)* Wainlodes fry site *(607383)*	2011 *(39907)* 2014 – 2016 *(60783)*
STT Maisemore		No adjacent sites	No adjacent sites
STT 11		No adjacent sites	No adjacent sites
STT 12		No adjacent sites	No adjacent sites
STT 8	Avon	U/S Stratford – netting *(70304)*	2017
STT 8a		Hampton Ferry *(13222)* Evesham Sports Ground fry site *(60803)*	2017 *(13222)* 2014 – 2017 *(60803)*
STT Bredon 8b		Twyning Green fry site *(44521)*	2012 – 2017

A.3.2 SELECTED FISH SPECIES AND HABITAT THRESHOLDS

Based on the analysis of fish count data and along with expert input from a fish specialist, a range of fish species and their relevant life stages were selected (**Table A 4**) for subsequent habitat analysis. These fish cover a range of species of differing sensitivities and represent a wide range of flow conditions within a watercourse. For each fish species and life cycle, suitable flow velocity and depth criteria were taken from Environment Agency data[24]. The velocity and depth data are based on the full range of preferences and not the optimal range of preferences as this provides a wider understanding of all the potential range of conditions suitable to fish and how these could be impacted by flow changes.

Table A 4 Selected fish species and their range of habitat preferences

Species	FCS2 tolerance	Life stage	Depth (m)		Velocity (m/s)	
			Min	Max	Min	Max
Atlantic salmon (*Salmo salar*)	Low	0+	0	<1	0.05	0.65
		Juvenile	0.05	1	0	<1
		Spawning	<0.2	0.91	>0.15	0.9
Brown / sea trout (*Salmo trutta*)	Low	0+	<0.2	0.3	<0.1	0.5
		Juvenile	0.05	2.4	0	0.44
		Spawning	0.06	0.91	0.108	0.81
Lamprey sp. ammocoetes	Low	Larvae	0	1	0.01	0.5
		Spawning	0.2	1.5	1	2
Chub (*Leuciscus cephalus*)	Medium	Juvenile	<0.2	<1	0	<0.05
		Spawning	>0	1.28	<0.05	0.75
Roach (*Rutilus rutilus*)	High	Juvenile	0.2	1.75	0	0.4
		Spawning	0.15	0.45	---	>0.2
European eel (*Anguilla anguilla*)	High	Juvenile	0	<6	>0.1	---

The selected fish habitat preferences were then applied to the in-channel hydraulics data collected by ADCP at each of the 20 survey reaches on the River Vyrnwy, River Severn and River Avon in order to categorise the habitat availability under the different flow conditions measured.

A.4 SCHEME FLOW RELEASES

A.4.1 OVERVIEW OF 1D MODEL RUNS USED

The hydraulic data is derived from the STT 1D hydraulic model. This model provides only a single value for flow velocity and water depth (among other variables) averaged across a single cross-section represented as a model node. There are 2,347 nodes in the model and these are spaced on average 250m apart, though this spacing varies based on in-channel features of hydraulic importance such as bridges, weirs, locks and channel bifurcations.

A number of flow scenarios have been used within the 1D model simulations. Of these, two are central to the investigation: A82 which represents a moderate-low flow (1:5 to 1:10 return period); and M96 which represents a very low flow (1:20 return period). The model outputs from the A82 and M96 runs are used throughout the

[24] Cowx, I.G., Noble, R.A., Nunn, A.D., Harvey, J.P., Welcomme, R.L. and Halls A.S. (2004). Flow and Level Criteria for Coarse Fish and Conservation Species. Environment Agency Science Report SC020112/SR. 173pp.

habitat assessment. Further details on the STT 1D hydraulic model and the flow scenarios is provided in Section 2.2 of the main STT Gate 2 Physical Environment Assessment Report[25].

A.4.2 ADCP – 1D MODEL FLOW COMPARISON

A comparison between the discharge measured at the five ADCP survey sites and the respective 1D model predictions taken at the closest node to the survey site on the day of the survey is presented in **Table A 5**.

Table A 5 Comparison between measured discharges and modelled discharges (with schemes operating) at the same date for each ADCP site

ADCP site ID	ID of closest node to ADCP site	Date of ADCP measurement	Measured discharge (Ml/d)	A82 model discharge (Ml/d)	M96 model discharge (Ml/d)
STT 5a	18502	7 Sept 2021 16 Jun 2021	157 294	797 502	242 226
STT 5b	13602	7 Sept 2021 16 Jun 2021	157 294	906 504	346 331
STT Montford	RS_234424	15 Jun 2021 14 Oct 2021	697 948	1,441 2,821	673 921
STT 10	RS_82369	15 and 21 Jul 2021 28 Oct 2021	1,926 3,367	1,698 – 1,638 10,099	1,640 – 1,611 2,115
STT 8	A1530	16 and 20 Jul 2021 26 Oct 2021	229 381	390 – 384 360	369 – 365 342

The data in **Table A 5** show that the ADCP surveys were undertaken during discharges similar to the M96 model runs, while the A82 runs have much higher discharges. These sites are incorporated into the ADCP – 1D model comparison in Section A.6.

A.5 HYDRAULICS SITES FISH HABITAT ASSESSMENT

The fish flow habitat assessment based around the ADCP hydraulic data has been undertaken by plotting up individual measurements of flow depth and mean average velocity. The relevant fish habitat thresholds for the selected fish species (**Table A 43**) are then applied to these data. Where the velocity and depth of a measurement point lies within the selected habitat threshold this point is designated as being suitable habitat. If the measurement lies outside of the selected threshold then it is designated as unsuitable habitat. There are a number of caveats applicable to the methodology:

- The use of depth average velocity means that the methodology does not explicitly account for habitat distribution across the full 2D flow cross-section, e.g. habitat at shallower flow depths in the thalweg. However, the data are taken to provide representative coverage of the broad hydraulic conditions expected over the cross-section area, and these are likely to be much more representative in the margins where flow depths are low and fish habitat is more likely to occur.
- Only flow depth and velocity are considered as drivers of change in fish habitat. There are a number of other drivers not considered, e.g. bed substrate, in-channel and marginal features, riparian vegetation and tree cover, water quality etc. It is likely that these will have a bearing on the distribution and quality of habitats, however flow hydraulics are taken to be a predominant driver of habitat.
- Only narrow windows of flow and in-channel conditions suitable for flow monitoring have been considered. Higher flows and more complex areas of channel morphology are likely to impact on the quality and distribution of fish habitat and more data would be required to better understand these impacts within the study reaches.

With these caveats in mind, it is considered that the methodology provides a broad indication of potential changes in fish habitats with changes in flow. It should also be noted that fish are sentient and mobile organisms and therefore can adapt to changes in flow by moving to other parts of the river where conditions

[25] Ricardo E&E, (2022). Severn Thames Transfer SRO. Physical Environmental Assessment Report. ED15323.

are more favourable. Exceeding a flow threshold is not likely to be instantly detrimental for the species in question. Breaching of the threshold, while not ideal, places a fish outside of its optimal envelope and it is likely the fish will respond to this by moving, however, it is only under constant change throughout a system (e.g. sustained flow rates) where species will potentially be impacted.

A.5.1 STT 5A – RIVER VYRNWY

For site STT 5a, ADCP data was used to understand the gross changes in fish habitat at two different flows, 157Ml/d measured on 7 September 2021 and 294Ml/d measured on 16 June 2021, a difference of 137Ml/d (1.58m^3/s). A review of habitat changes per selected fish lifecycle stage are presented below.

Atlantic salmon

Habitat changes for Atlantic salmon for the 0+, juvenile and spawning life stages during the 157Ml/d and 294Ml/d flows are presented in **Figure A 2**.

For each of the Atlantic salmon life stages, the habitat data indicate:

- **0+** – The data indicates that suitable 0+ habitat is very limited and confined to the slow and shallow margins. Under lower flows in September only 4% of the data indicates suitable habitat, reducing to 1% under the higher flows in June.
- **Juvenile** – The data indicates that there is some suitable juvenile habitat available at the section. Under lower flows in September, 19% of the data indicates suitable habitat, reducing to 10% under the higher flows in June.
- **Spawning** – No suitable spawning habitat is indicated at the site by the ADCP data.

At site STT 5a, the hydraulic data indicates that there is only a limited amount of suitable flow habitat for juveniles only, 0+ is very limited and there is no spawning habitat. The data show that the lowest and highest measured flows do not indicate any significant changes in flow habitat availability with increasing flow within this survey reach.

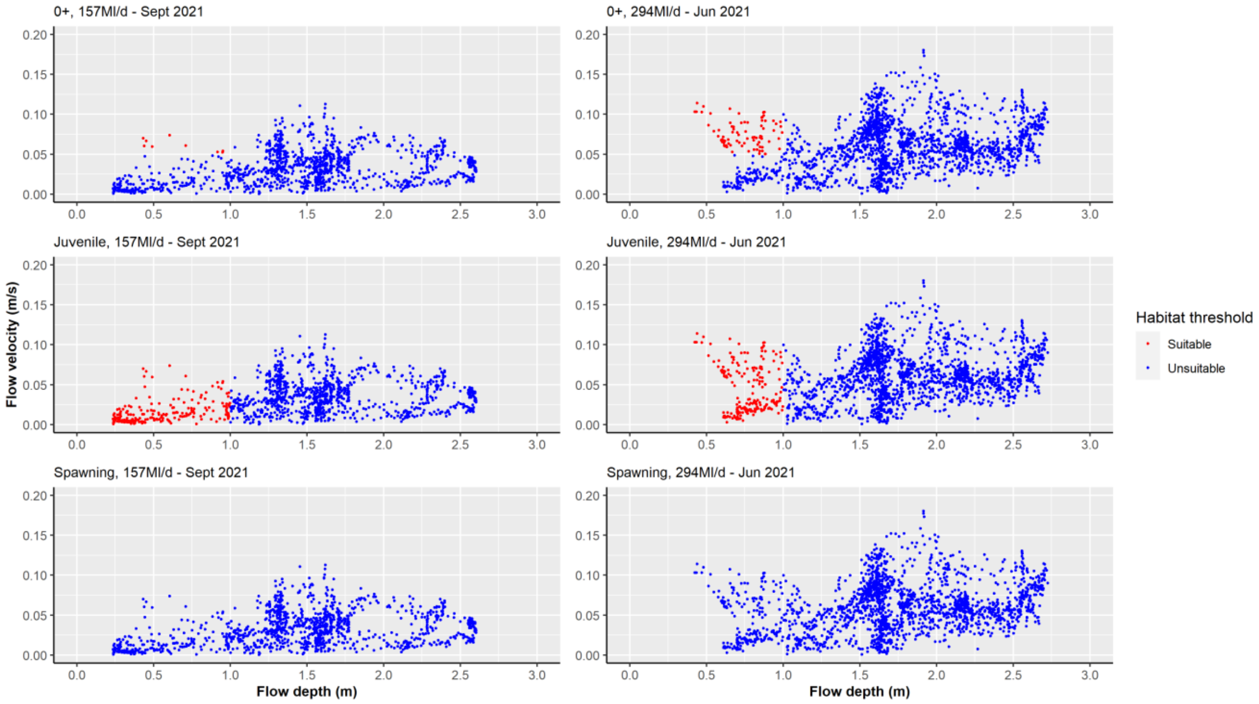


Figure A 2 Atlantic salmon habitat variability at Site STT 5a

Brown / sea trout

Habitat changes for Brown / sea trout for the 0+, juvenile and spawning life stages during the 157Ml/d and 294Ml/d flows are presented in **Figure A 3**

For each of the Brown / sea trout life stages, the habitat data indicate:

- **0+** – The data indicates that suitable 0+ habitat is very limited. Under lower flows in September only 3% of the data indicates suitable habitat, reducing to 0% under the higher flows in June.
- **Juvenile** – The data indicates that there is abundant suitable juvenile habitat available at the section. Under lower flows in September, 93% of the data indicates suitable habitat, reducing slightly to 87% under the higher flows in June.
- **Spawning** – No suitable spawning habitat is indicated at the site by the ADCP data.

At site STT 5a, the hydraulic data indicates that there is abundant suitable flow habitat for juveniles only, 0+ is very limited and there is no spawning habitat. The data show that the change from the lowest to highest measured flows do not indicate any significant changes in flow habitat availability with increasing flow within this survey reach.

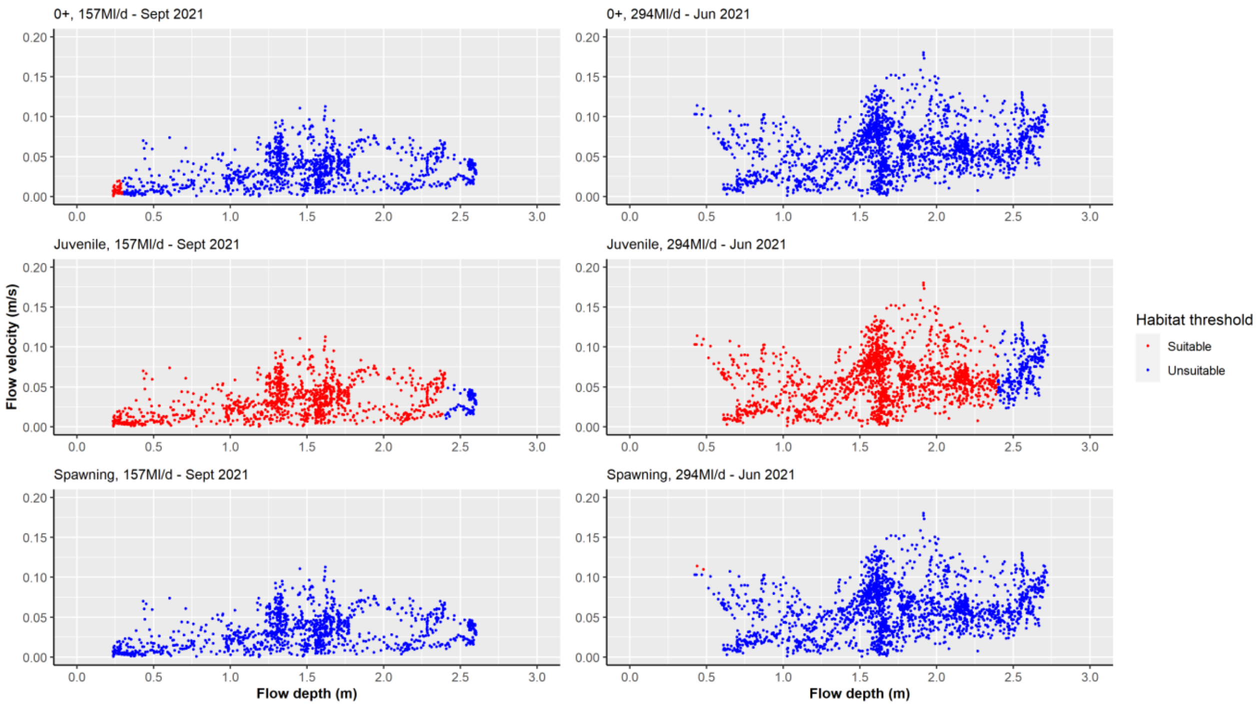


Figure A 3 Brown / sea trout habitat variability at Site STT 5a

Lamprey sp. Ammocoetes

Habitat changes for Lamprey for the larvae and spawning life stages during the 157Ml/d and 294Ml/d flows are presented in **Figure A 4.**

For each of the Lamprey life stages, the habitat data indicate:

- **Larvae** – The data indicates that suitable 0+ habitat is very limited and likely confined to marginal areas. Under lower flows in September only 10% of the data indicates suitable habitat, reducing to 9% under the higher flows in June.
- **Spawning** – No suitable spawning habitat is indicated at the site by the ADCP data.

At site STT 5a, the hydraulic data indicates that there is very limited suitable flow habitat for larvae only and there is no spawning habitat. The data show that the change from the lowest to highest measured flows do not indicate any significant changes in flow habitat availability with increasing flow within this survey reach.

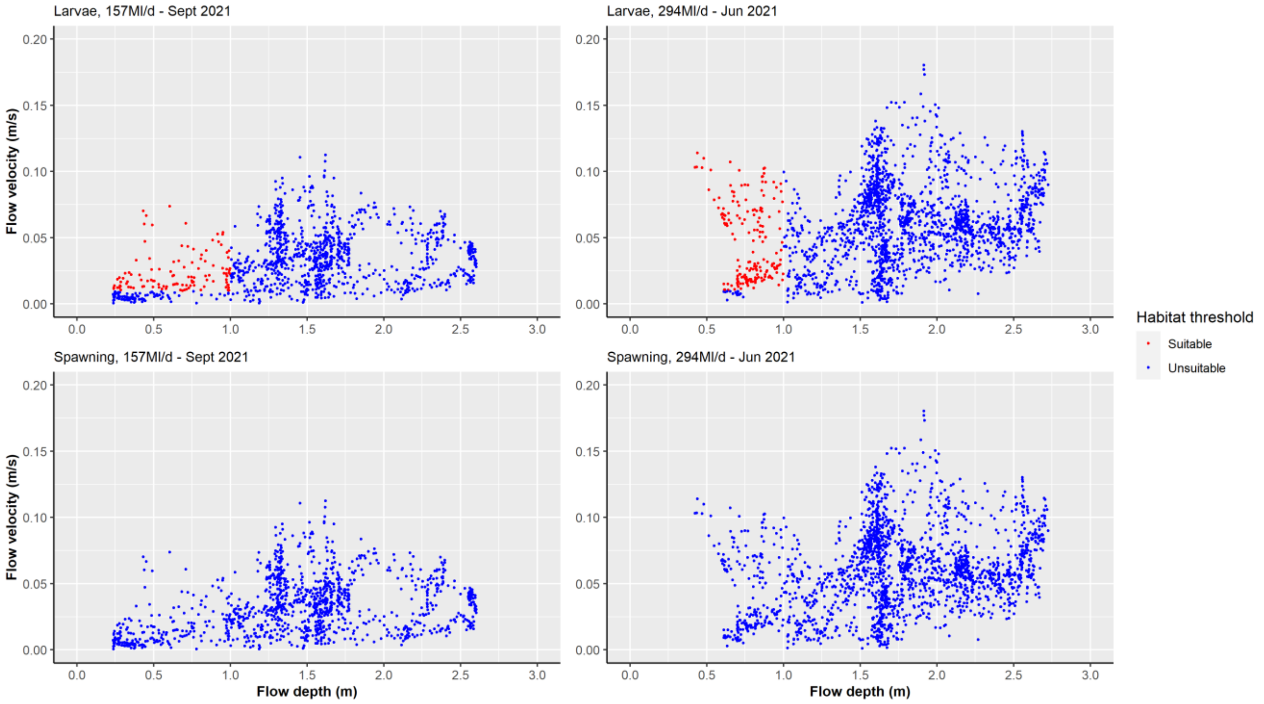


Figure A 4 Lamprey habitat variability at Site STT 5a

Chub

Habitat changes for Chub for the juvenile and spawning life stages during the 157Ml/d and 294Ml/d flows are presented in **Figure A 5.**

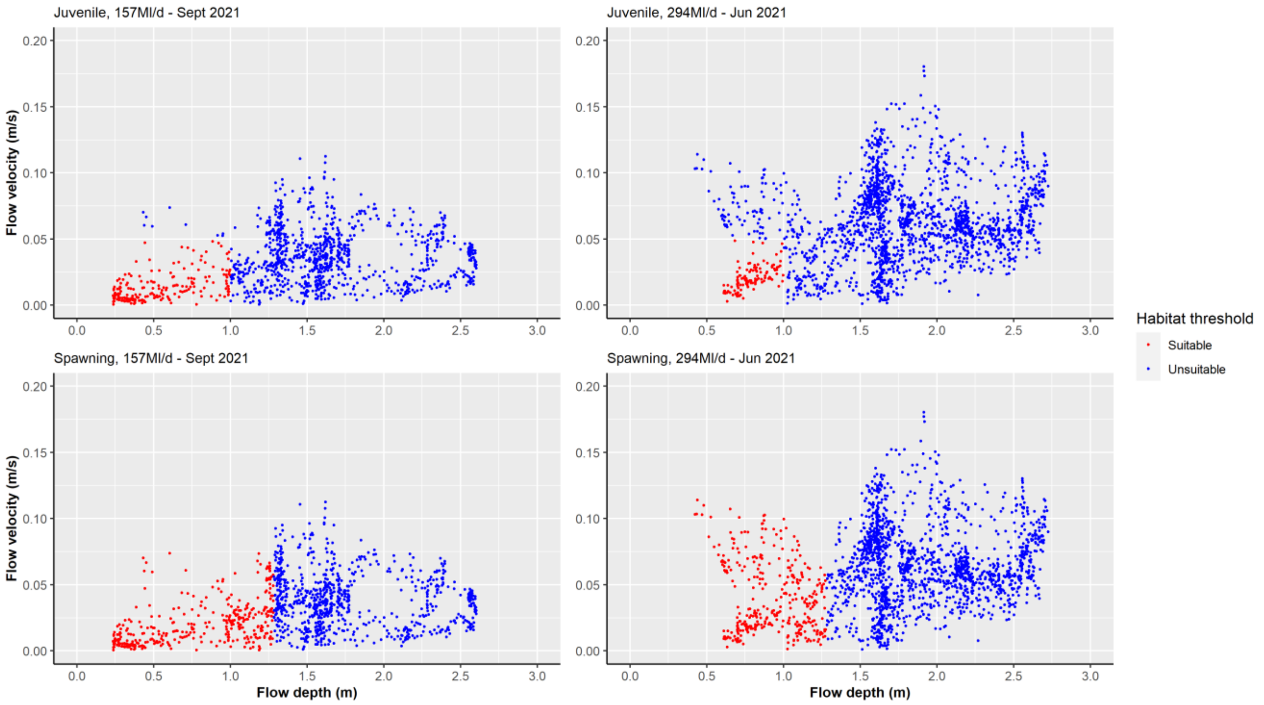


Figure A 5 Chub habitat variability at Site STT 5a

For each of the Chub life stages, the habitat data indicate:

- **Juvenile** – The data indicates that suitable juvenile is present, although is limited. Under lower flows in September only 18% of the data indicates suitable habitat, reducing significantly to 6% under the higher flows in June due to increasing flow depth and velocity.
- **Spawning** – The data indicates that suitable spawning habitat is present. Under lower flows in September, 31% of the data indicates suitable habitat, although this reduces by nearly half to 17% under the higher flows in June, driven predominantly by the increase in flow depth.

At site STT 5a, the hydraulic data indicates that there is limited suitable flow habitat for juveniles and spawning, 0+ is very limited and there is no spawning habitat. The data show that the change from the lowest to highest measured flows lead to marked reductions in habitat availability for Chub, mostly driven by increases in flow depth.

Roach

Habitat changes for Roach for the juvenile and spawning life stages during the 157Ml/d and 294Ml/d flows are presented in **Figure A 6.**

For each of the Roach life stages, the habitat data indicate:

- **Juvenile** – The data indicates that suitable 0+ habitat is common. Under lower flows in September, 76% of the data indicates suitable habitat, reducing to 54% under the higher flows in June.
- **Spawning** – No suitable spawning habitat is indicated at the site by the ADCP data.

At site STT 5a, the hydraulic data indicates that there is abundant suitable flow habitat for juveniles only and there is no spawning habitat. The data show that for juvenile habitat, the increase in flow leads to a decline in suitable habitat, mostly driven by increases in flow depth.

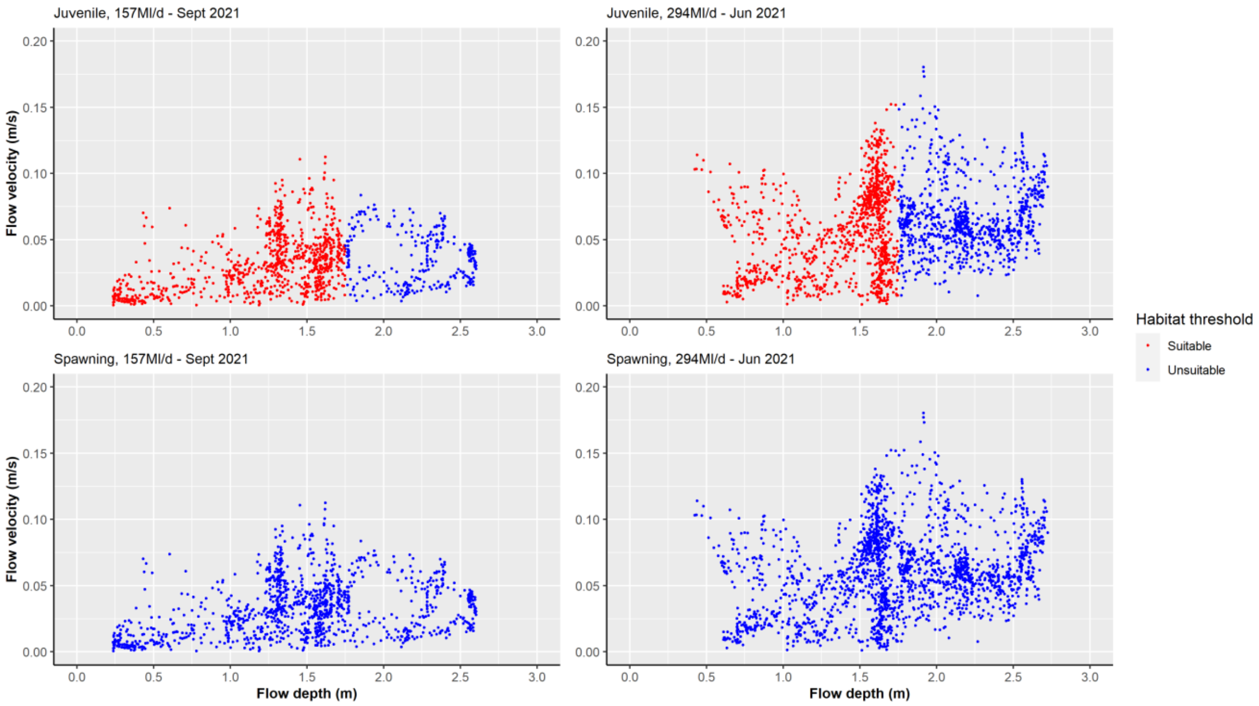


Figure A 6 Roach habitat variability at Site STT 5a

European eel

Habitat changes for European eel for the juvenile life stage during the 157Ml/d and 294Ml/d flows are presented in **Figure A 7**.

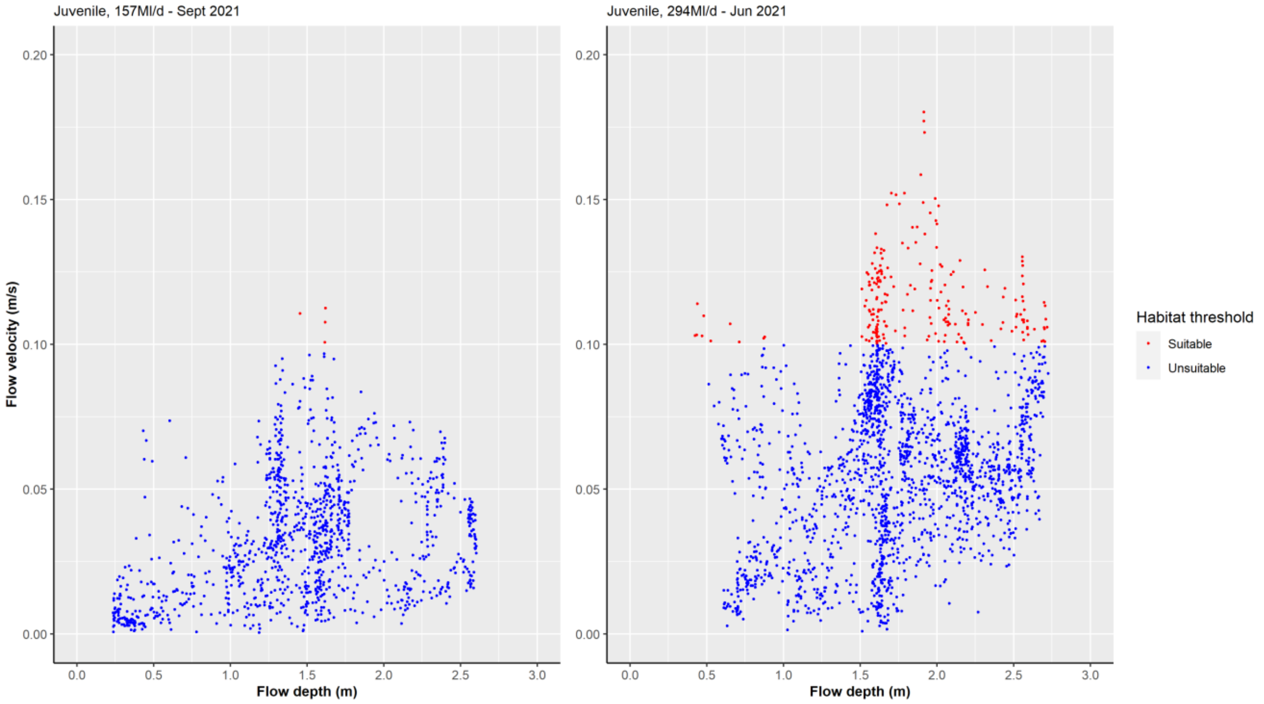


Figure A 7 European eel habitat variability at Site STT 5a

For the juvenile European eel life stage, the habitat data indicate that there is very limited suitable habitat. Under lower flows in September, <1% of the data indicates suitable habitat, increasing to 11% under the higher flows in June.

At site STT 5a, the hydraulic data indicates that there is limited suitable flow habitat available for juveniles due to the low velocities measured at the site. The increase in available habitat under the higher flows is driven by the shift towards higher flow velocities.

A.5.2 STT 5B – RIVER VYRNWY

For site STT 5b, ADCP data was used to understand the gross changes in fish habitat at two different flows, 157Ml/d measured on 7 September 2021 and 294Ml/d measured on 16 June 2021, a difference of 137Ml/d (1.58m^3/s). A review of habitat changes per selected fish lifecycle stage are presented below.

Atlantic salmon

Habitat changes for Atlantic salmon for the 0+, juvenile and spawning life stages during the 157Ml/d and 294Ml/d flows are presented in **Figure A .**

For each of the Atlantic salmon life stages, the habitat data indicate:

- **0+** – The data indicates that suitable 0+ habitat is limited, likely confined to the slow and shallower areas of the reach. Under lower flows in September only 31% of the data indicates suitable habitat, reducing to 21% under the higher flows in June.
- **Juvenile** – The data indicates that there is suitable juvenile habitat available at the section. Under lower flows in September, 54% of the data indicates suitable habitat, reducing to 33% under the higher flows in June.
- **Spawning** – Only very limited spawning habitat is noted at the section. Under lower flows in September, 6% of the data indicates suitable habitat, reducing to 1% under the higher flows in June.

At site STT 5b, the hydraulic data indicates that there is some suitable flow habitat for 0+, with a range of habitat available for juveniles and near to no spawning habitat. The data show that for the lowest and highest measured flows habitat does reduce for 0+ and juveniles as flow increases, driven by increasing depths and an increase in flow velocities at depths around 1m.

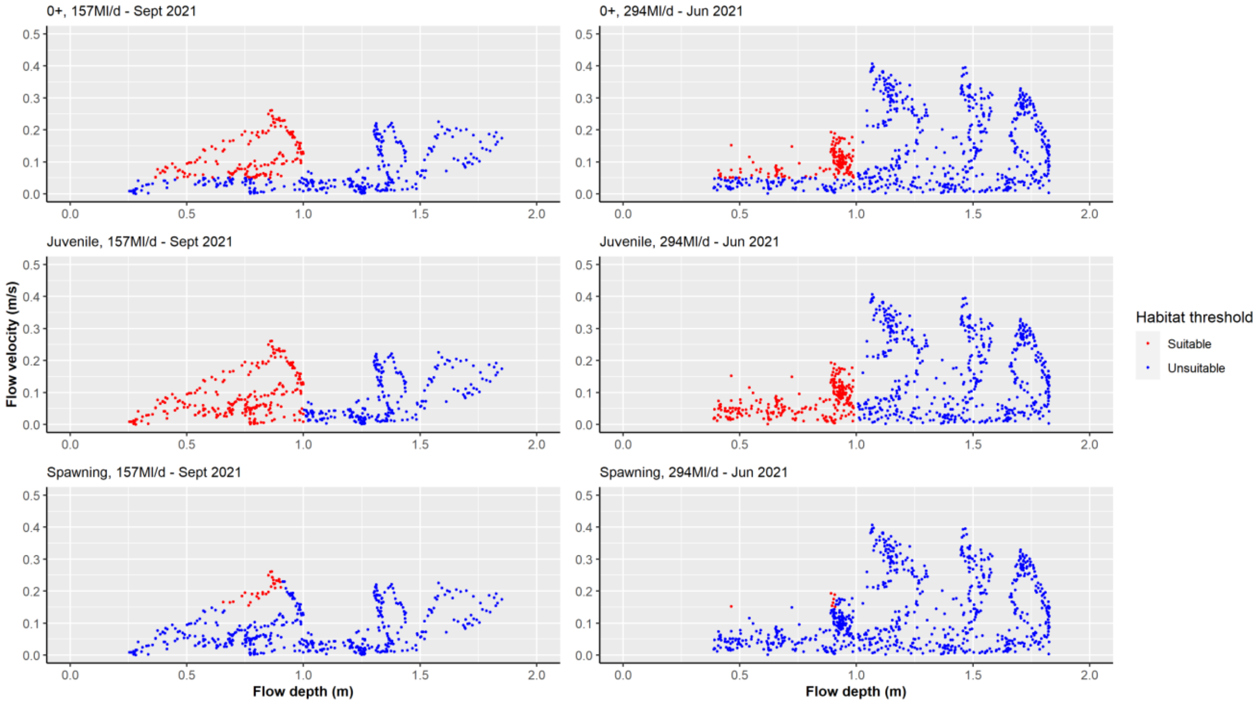


Figure A 8 Atlantic salmon habitat variability at Site STT 5b

Brown / sea trout

Habitat changes for Brown / sea trout for the 0+, juvenile and spawning life stages during the 157Ml/d and 294Ml/d flows are presented in **Figure A 9.**

For each of the Brown / sea trout life stages, the habitat data indicate:

- **0+** – The data indicates that suitable 0+ habitat is very limited. Under lower flows in September only 2% of the data indicates suitable habitat, reducing to 0% under the higher flows in June.
- **Juvenile** – The data indicates that the entire reach is suitable for juvenile habitat. This does not change with the increased flows in June when compared to the lower flow September measurements.
- **Spawning** – The data indicates that suitable spawning habitat is very limited. Under lower flows in September only 8% of the data indicates suitable habitat, reducing to 3% under the higher flows in June.

At site STT 5b, the hydraulic data indicates that there is very limited 0+ and spawning habitat. The data indicates the entire reach is suitable for spawning under both measured flow conditions. The data show that the change from the lowest to highest measured flows do not indicate any significant changes in flow habitat availability with increasing flow within this survey reach.

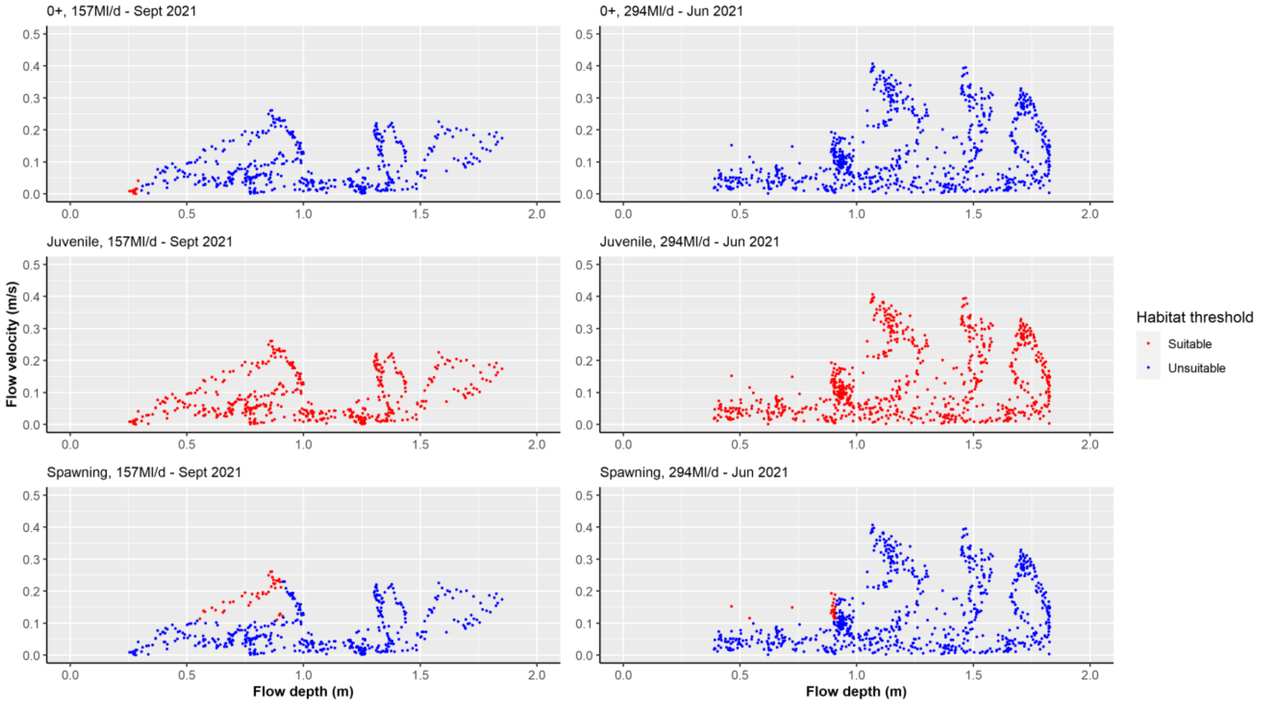


Figure A 9 Brown / sea trout habitat variability at Site STT 5b

Lamprey sp. Ammocoetes

Habitat changes for Lamprey for the larvae and spawning life stages during the 157Ml/d and 294Ml/d flows are presented in **Figure A 10.**

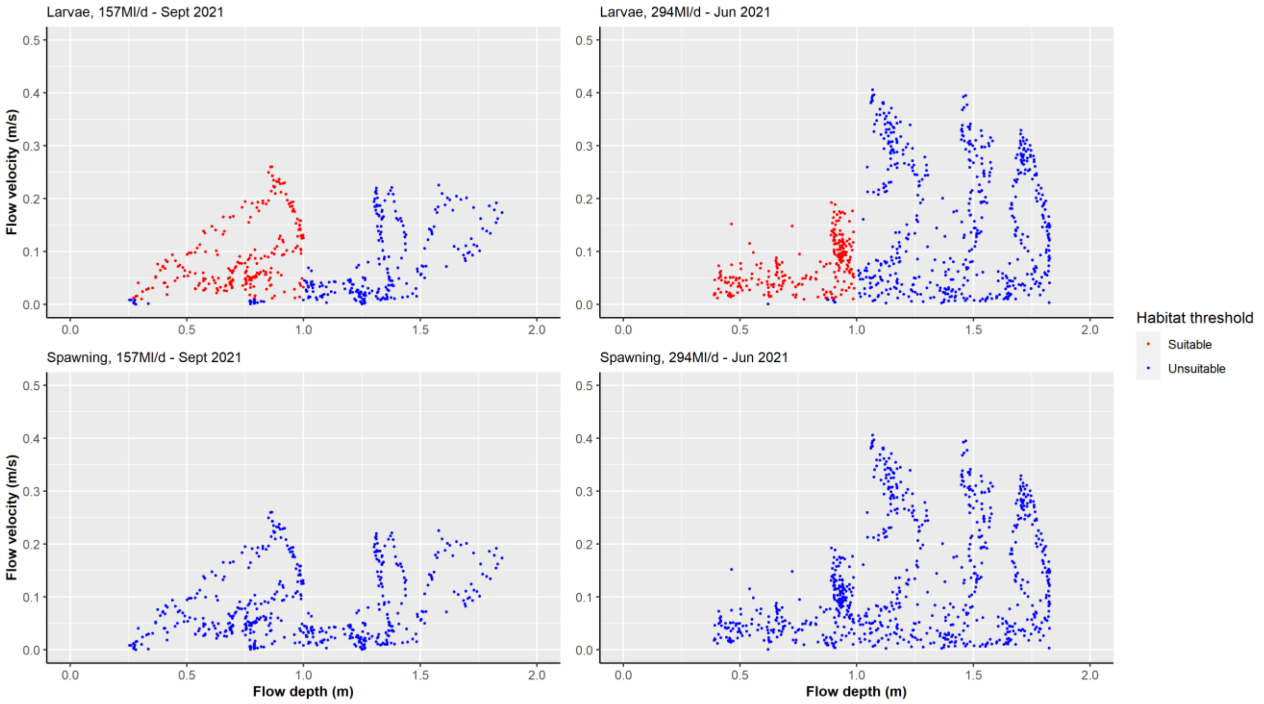


Figure A 10 Lamprey habitat variability at Site STT 5b

For each of the Lamprey life stages, the habitat data indicate:

- **Larvae** – The data indicates that there is a range of suitable larvae habitat. Under lower flows in September, 48% of the data indicates suitable habitat, reducing to 33% under the higher flows in June.
- **Spawning** – No suitable spawning habitat is indicated at the site by the ADCP data.

At site STT 5b, the hydraulic data indicates that there is available suitable flow habitat for larvae only and there is no spawning habitat. The data show that the change from the lowest to highest measured flows suggest that there is a small decline in flow habitat availability with increasing flow within this survey reach, mostly driving by increasing depths.

Chub

Habitat changes for Chub for the juvenile and spawning life stages during the 157Ml/d and 294Ml/d flows are presented in **Figure A 11**.

For each of the Chub life stages, the habitat data indicate:

- **Juvenile** – The data indicates that suitable juvenile habitat is limited. Under lower flows in September only 23% of the data indicates suitable habitat, reducing to 13% under the higher flows in June due to increasing flow depth and velocity.
- **Spawning** – The data indicates that suitable spawning habitat is abundant. Under lower flows in September, 71% of the data indicates suitable habitat, although this reduces to 57% under the higher flows in June, driven predominantly by the increase in flow depth.

At site STT 5b, the hydraulic data indicates that there is limited suitable flow habitat for juveniles but abundant spawning habitat. The data show that the change from the lowest to highest measured flows lead to a reduction in juvenile and spawning habitat availability for Chub, mostly driven by increases in flow depth.

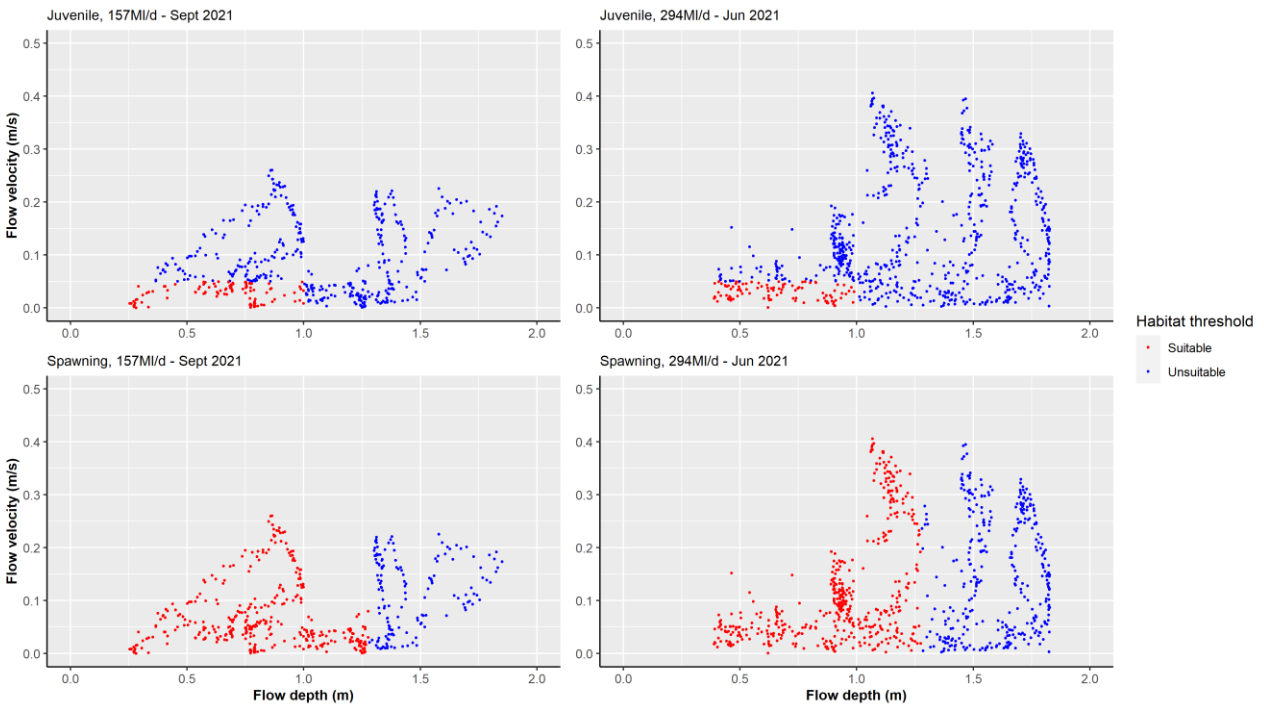


Figure A 11 Chub habitat variability at Site STT 5b

Roach

Habitat changes for Roach for the juvenile and spawning life stages during the 157Ml/d and 294Ml/d flows are presented in **Figure A 12.**

For each of the Roach life stages, the habitat data indicate:

- **Juvenile** – The data indicates that suitable juvenile habitat is abundant. Under lower flows in September, 98% of the data indicates suitable habitat, reducing to 91% under the higher flows in June.
- **Spawning** – No suitable spawning habitat is indicated at the site by the ADCP data.

At site STT 5b, the hydraulic data indicates that there is abundant suitable flow habitat for juveniles only and there is no spawning habitat. The data show that for juvenile habitat, the increase in flow leads to a very small decline in suitable habitat, driven by increases in flow depth.

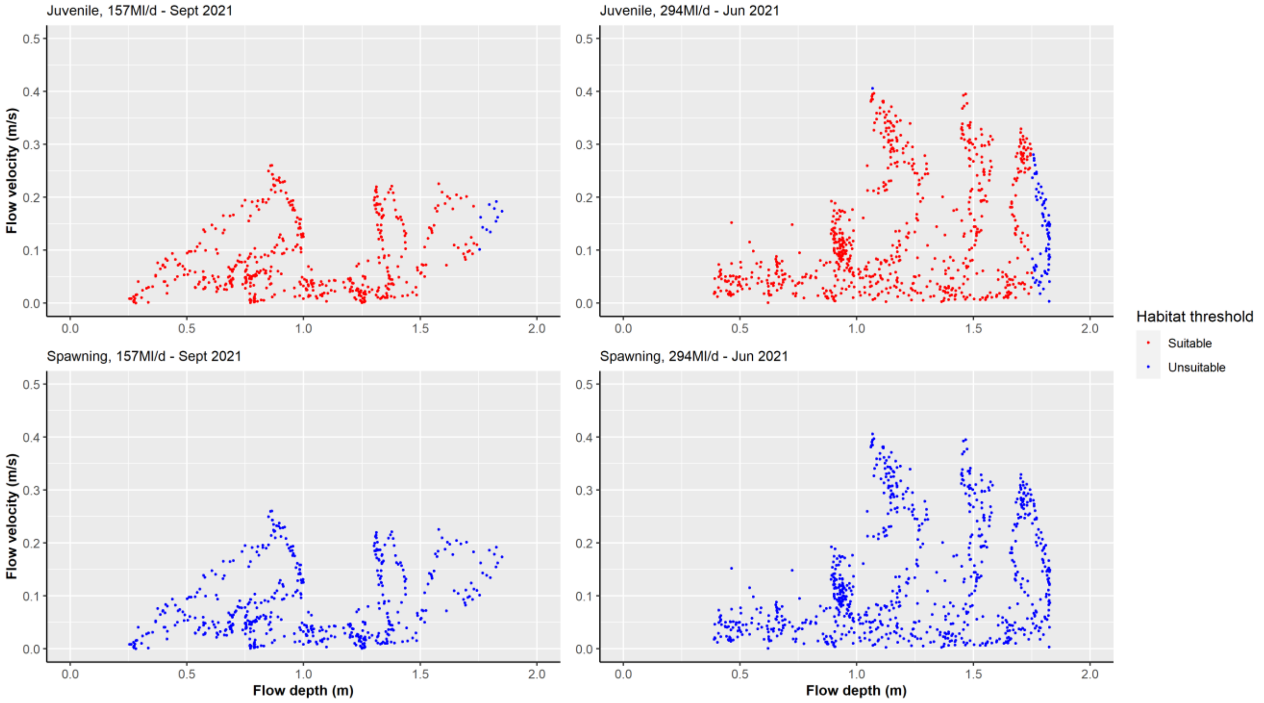


Figure A 12 Roach habitat variability at Site STT 5b

European eel

Habitat changes for European eel for the juvenile life stage during the 157Ml/d and 294Ml/d flows are presented in **Figure A 13.**

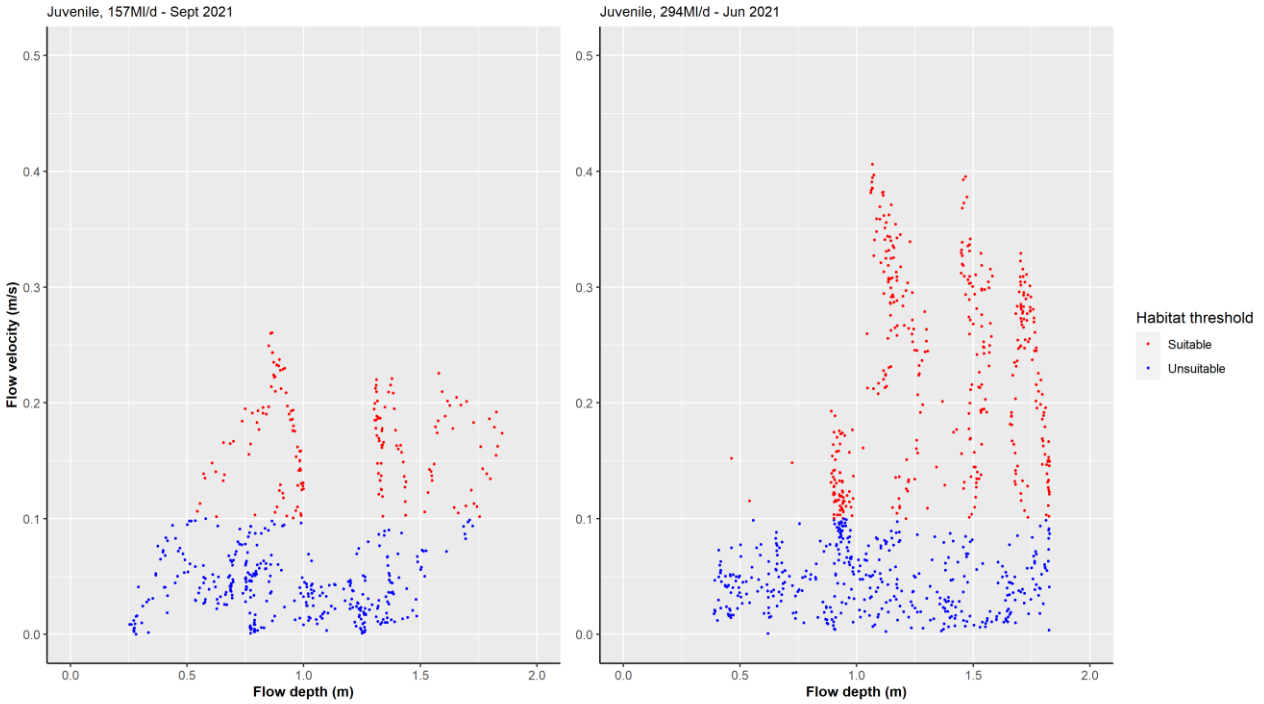


Figure A 13 European eel habitat variability at Site STT 5b

For the juvenile European eel life stage, the habitat data indicate that there is some suitable habitat available. Under lower flows in September, 33% of the data indicates suitable habitat, increasing to 49% under the higher flows in June. The increase in available habitat under the higher flows is driven by the shift towards higher flow velocities.

A.5.3 STT MONTFORD – RIVER SEVERN

For site STT Montford, ADCP data was used to understand the gross changes in fish habitat at two different flows, 697Ml/d measured on 15 June 2021 and 948Ml/d measured on 14 October 2021, a difference of 251Ml/d (2.91m^3/s). A review of habitat changes per selected fish lifecycle stage are presented below.

Atlantic salmon

Habitat changes for Atlantic salmon for the 0+, juvenile and spawning life stages during the 697Ml/d and 948Ml/d flows are presented in **Figure A 14.**

For each of the Atlantic salmon life stages, the habitat data indicate:

- **0+** – The data indicates that suitable 0+ habitat is very limited and confined to the slow and shallow margins. Under lower flows in June only 4% of the data indicates suitable habitat, increasing slightly to 10% under the higher flows in October.
- **Juvenile** – The data indicates that suitable juvenile habitat is very limited at the section. Under lower flows in June, 5% of the data indicates suitable habitat, increasing slightly to 13% under the higher flows in October.
- **Spawning** – The data indicates that suitable spawning habitat is very limited at the section. Under lower flows in June and higher flows in October suitable habitat is unchanged at 1% of the data.

At site STT Montford, the hydraulic data indicates that there is a very limited amount of suitable flow habitat for 0+, juveniles and spawning. The slight increase in habitat under higher flows are likely reflective of the greater hydraulic radius, leading to an increase in slower and deeper flows at inundated margins. Regardless, the data shows that there is very limited suitable habitat at this site under the range of flows measured.

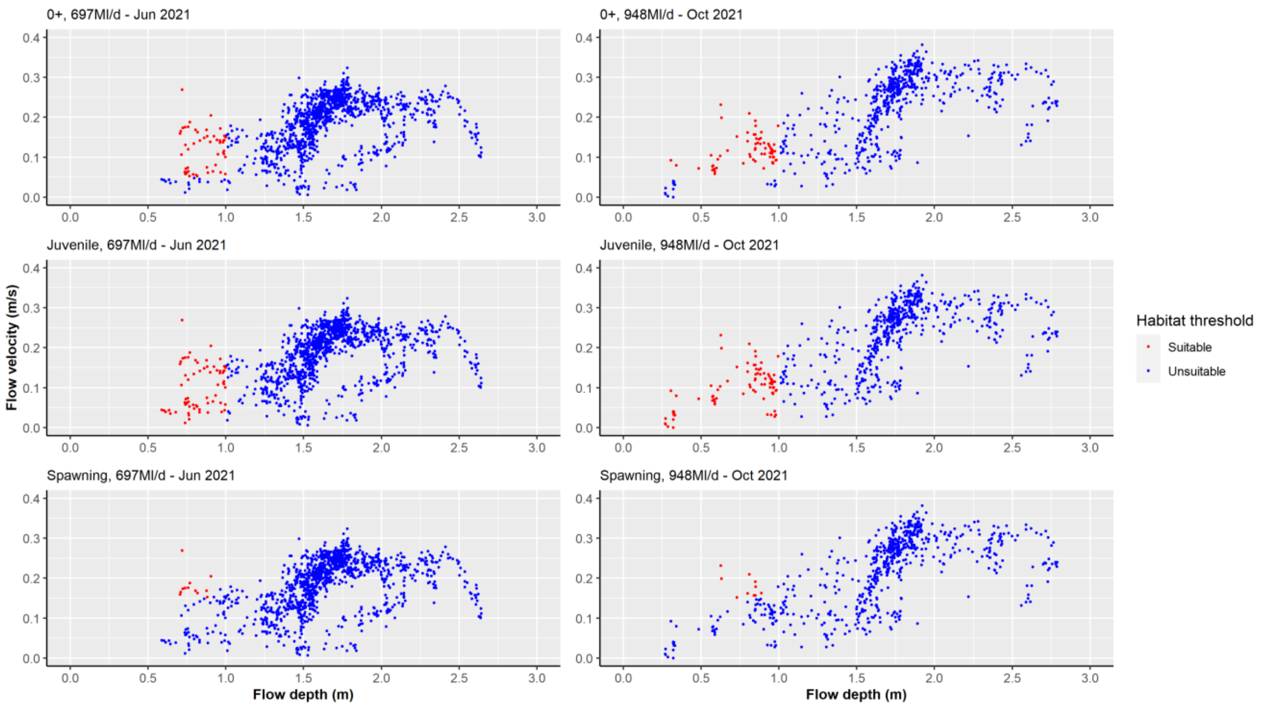


Figure A 14 Atlantic salmon habitat variability at Site STT Montford

Brown / sea trout

Habitat changes for Brown / sea trout for the 0+, juvenile and spawning life stages during the 697Ml/d and 948Ml/d flows are presented in **Figure A 15.**

For each of the Brown / sea trout life stages, the habitat data indicate:

- **0+** – The data indicates that suitable 0+ habitat is very limited. Under lower flows in June there is no habitat, while under higher flows in October suitable habitat increases only to 1%.
- **Juvenile** – The data indicates that there is abundant suitable juvenile habitat available at the section. Under lower flows in June, 98% of the data indicates suitable habitat, reducing slightly to 93% under the higher flows in October.
- **Spawning** – The data indicates that suitable spawning habitat is very limited at the section. Under lower flows in June habitat is around 1%, which increases to 3% under the higher flows in October.

At site STT Montford, the hydraulic data indicates that there is abundant suitable flow habitat for juveniles only, with very limited 0+ and spawning habitat is available. The slight increases seen in habitat under higher flows are likely reflective of the greater hydraulic radius, leading to an increase in slower and deeper flows at inundated margins. Regardless, the data shows that there is very limited suitable 0+ and spawning habitat at this site under the range of flows measured, although juvenile habitat is abundant.

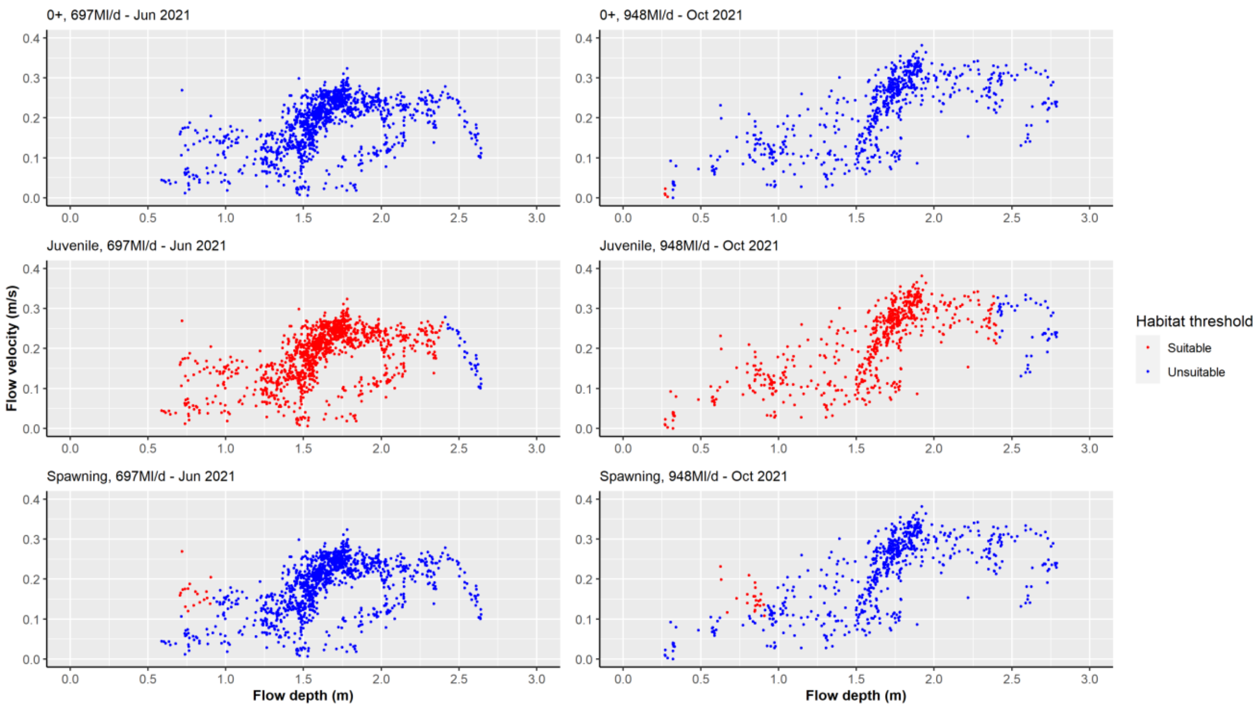


Figure A 15 Brown / sea trout habitat variability at Site STT Montford

Lamprey sp. Ammocoetes

Habitat changes for Lamprey for the larvae and spawning life stages during the 697Ml/d and 948Ml/d flows are presented in **Figure A 16.**

For each of the Lamprey life stages, the habitat data indicate:

- **Larvae** – The data indicates that suitable 0+ habitat is very limited. Under lower flows in June only 5% of the data indicates suitable habitat, increase to 12% under the higher flows in October.
- **Spawning** – No suitable spawning habitat is indicated at the site by the ADCP data.

At site STT Montford, the hydraulic data indicates that there is very limited suitable flow habitat for larvae only and there is no spawning habitat. The slight increases seen in habitat under higher flows are likely reflective of the greater hydraulic radius, leading to an increase in slower and deeper flows at inundated margins. Regardless, the data shows that there is very limited suitable larvae and spawning habitat at this site under the range of flows measured.

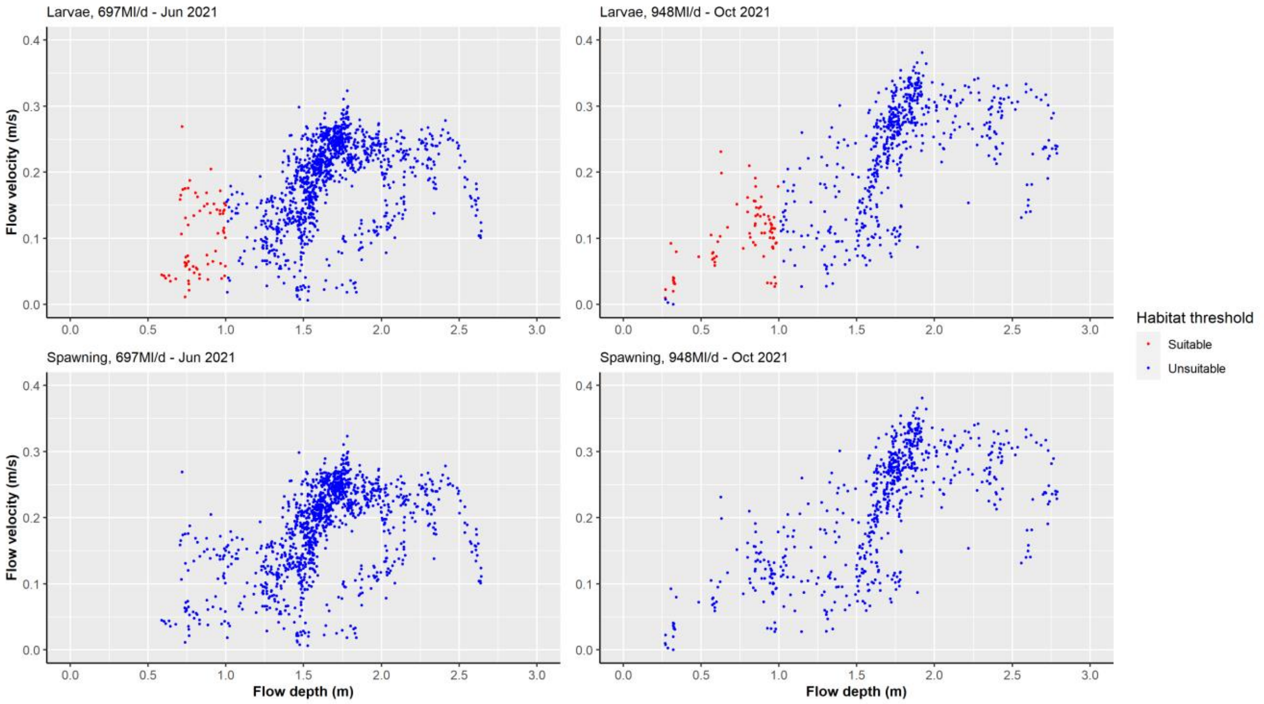


Figure A 16 Lamprey habitat variability at Site STT Montford

Chub

Habitat changes for Chub for the juvenile and spawning life stages during the 697Ml/d and 948Ml/d flows are presented in **Figure A 17**.

For each of the Chub life stages, the habitat data indicate:

- **Juvenile** – The data indicates that very limited suitable juvenile is present. Under lower flows in June only 1% of the data indicates suitable habitat, increasing slightly to 3% under the higher flows in October.
- **Spawning** – The data indicates that limited suitable spawning habitat is present. Under lower flows in June, 11% of the data indicates suitable habitat, increasing to 18% under the higher flows in October.

At site STT Montford, the hydraulic data indicates that there is very limited suitable flow habitat for juveniles and limited suitable flow habitat for and spawning. The slight increases seen in habitat under higher flows are likely reflective of the greater hydraulic radius, leading to an increase in slower and deeper flows at inundated margins.

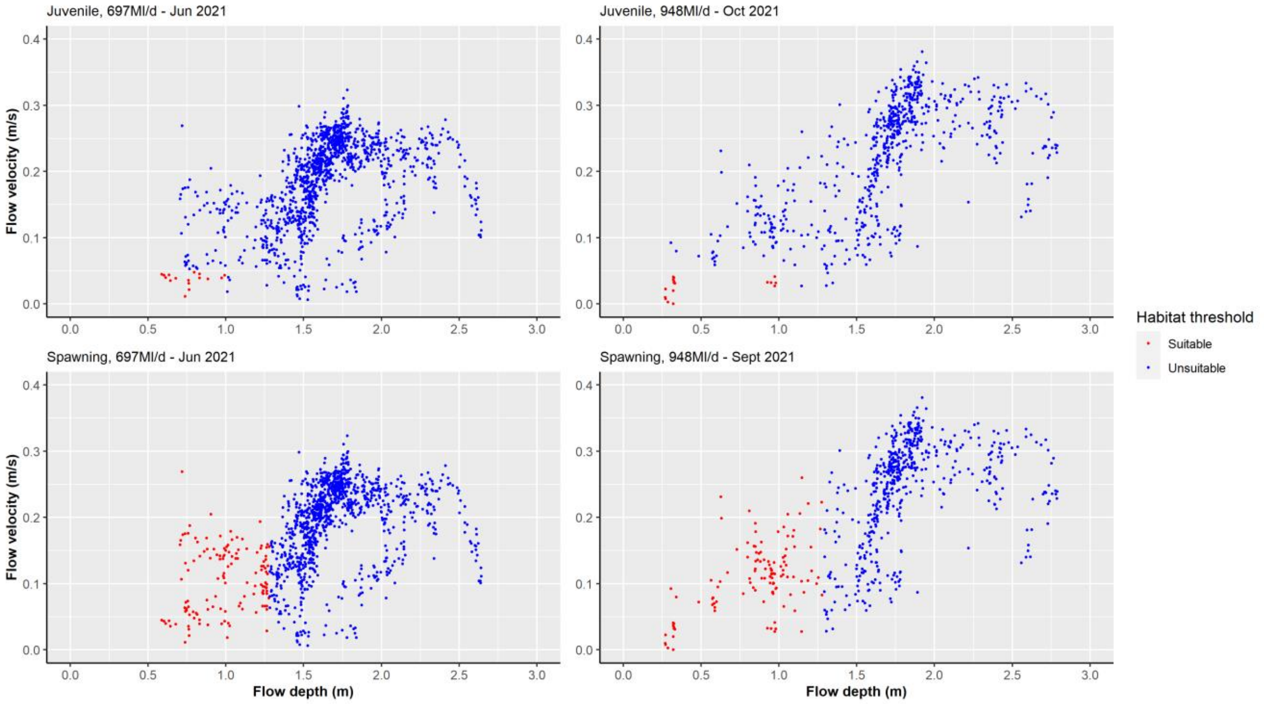


Figure A 17 Chub habitat variability at Site STT Montford

Roach

Habitat changes for Roach for the juvenile and spawning life stages during the 697Ml/d and 948Ml/d flows are presented in **Figure A 18.**

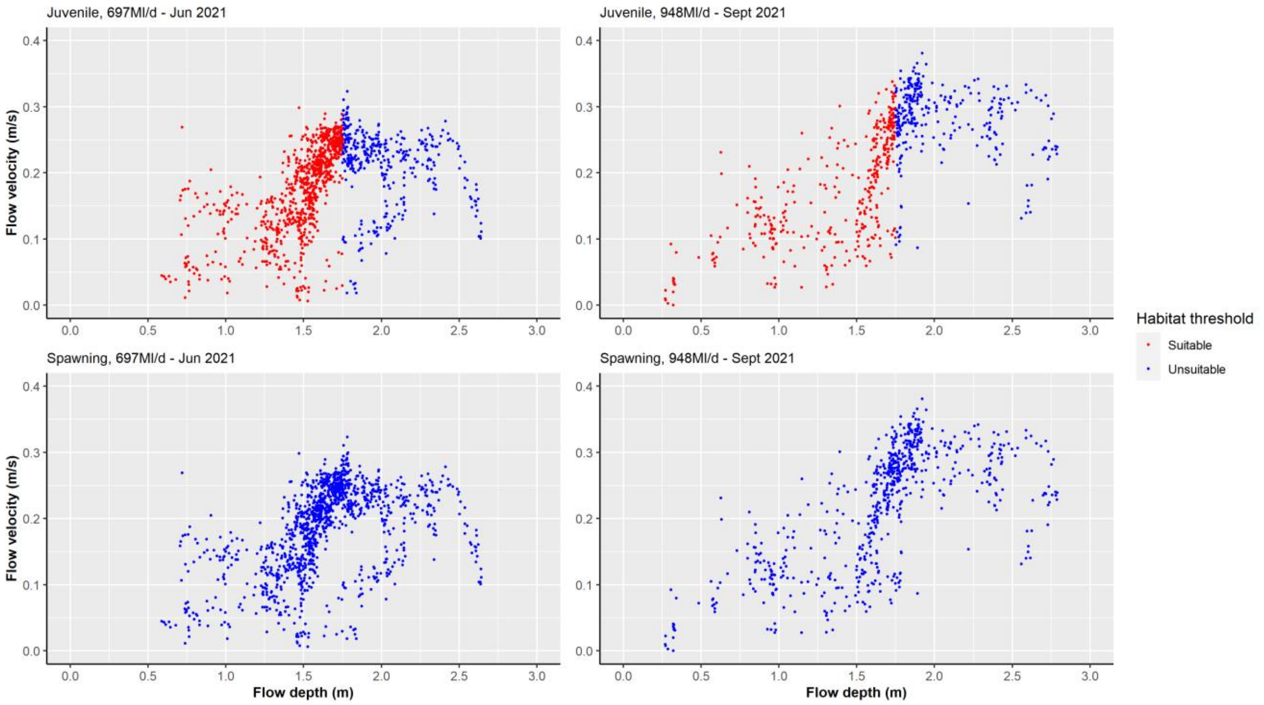


Figure A 18 Roach habitat variability at Site STT Montford

For each of the Roach life stages, the habitat data indicate:

- **Juvenile** – The data indicates that suitable 0+ habitat is common. Under lower flows in June, 71% of the data indicates suitable habitat, reducing to 55% under the higher flows in October.
- **Spawning** – No suitable spawning habitat is indicated at the site by the ADCP data.

At site STT Montford, the hydraulic data indicates that there is abundant suitable flow habitat for juveniles only and there is no spawning habitat. The data show that for juvenile habitat, the increase in flow leads to a decline in suitable habitat, mostly driven by increases in flow velocity.

European eel

Habitat changes for European eel for the juvenile life stage during the 697Ml/d and 948Ml/d flows are presented in **Figure A 19.**

For the juvenile European eel life stage, the habitat data indicate that there is abundant habitat, with 88% of all measurements indicating suitable habitat under both low and high flows.

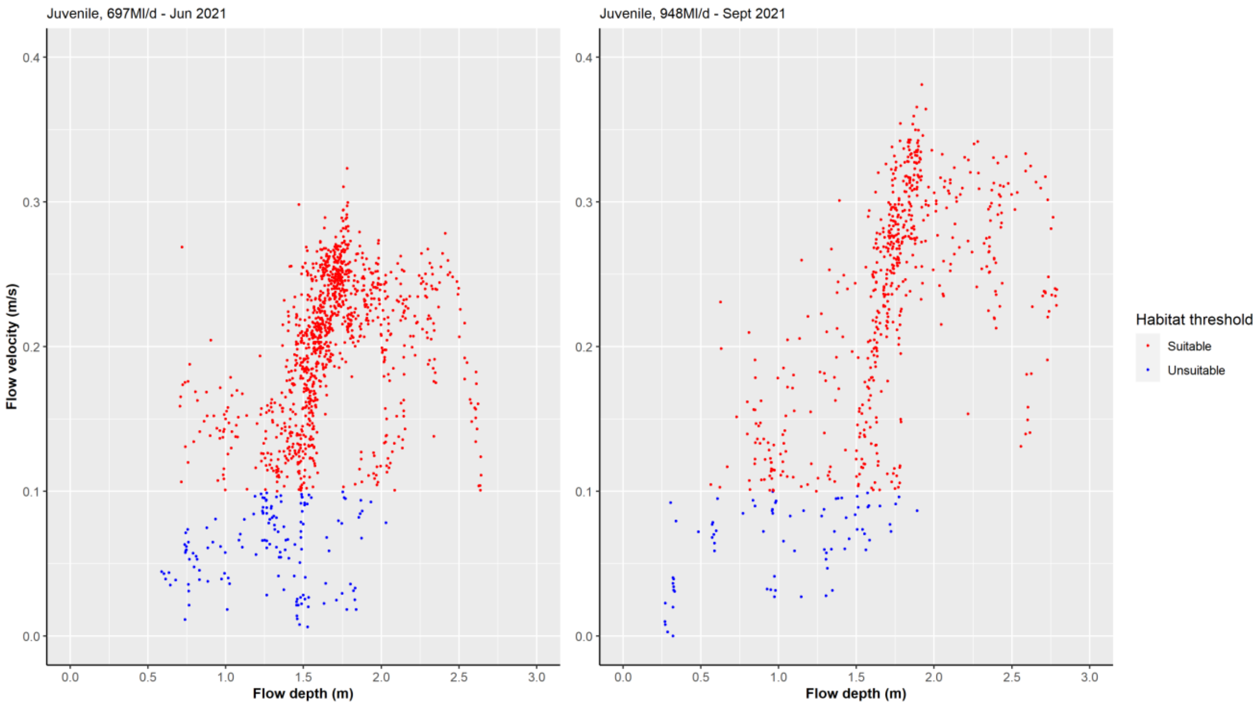


Figure A 19 European eel habitat variability at Site STT Montford

A.5.4 STT 10 – RIVER SEVERN

For site STT 10, ADCP data was used to understand the gross changes in fish habitat at two different flows, 1,926Ml/d measured on 15 and 21 July 2021 and 3,367Ml/d measured on 28 October 2021, a difference of 1,441Ml/d (16.68m³/s). A review of habitat changes per selected fish lifecycle stage are presented below.

Atlantic salmon

Habitat changes for Atlantic salmon for the 0+, juvenile and spawning life stages during the 1,926Ml/d and 3,367Ml/d flows are presented in **Figure A 20.**

For each of the Atlantic salmon life stages, the habitat data indicate:

- **0+** – The data indicates that suitable 0+ habitat is very limited and confined to the slow and shallow margins. Under lower flows in July only 5% of the data indicates suitable habitat, although this increases to 12% under the higher flows in October.

- **Juvenile** – The data indicates that suitable juvenile habitat is very limited and confined to the slow and shallow margins. Under lower flows in July, 13% of the data indicates suitable habitat, increasing to 18% under the higher flows in October.
- **Spawning** – Suitable spawning habitat is very limited, remaining around 1% during both the low flows in July and higher flows in October.

At site STT 10, the hydraulic data indicates that there is only a very limited amount of suitable flow habitat for juveniles, 0+ and spawning. The data show slight increases in available habitat with increasing flow and these are likely reflective of the greater hydraulic radius, leading to an increase in slower and deeper flows at inundated margins.

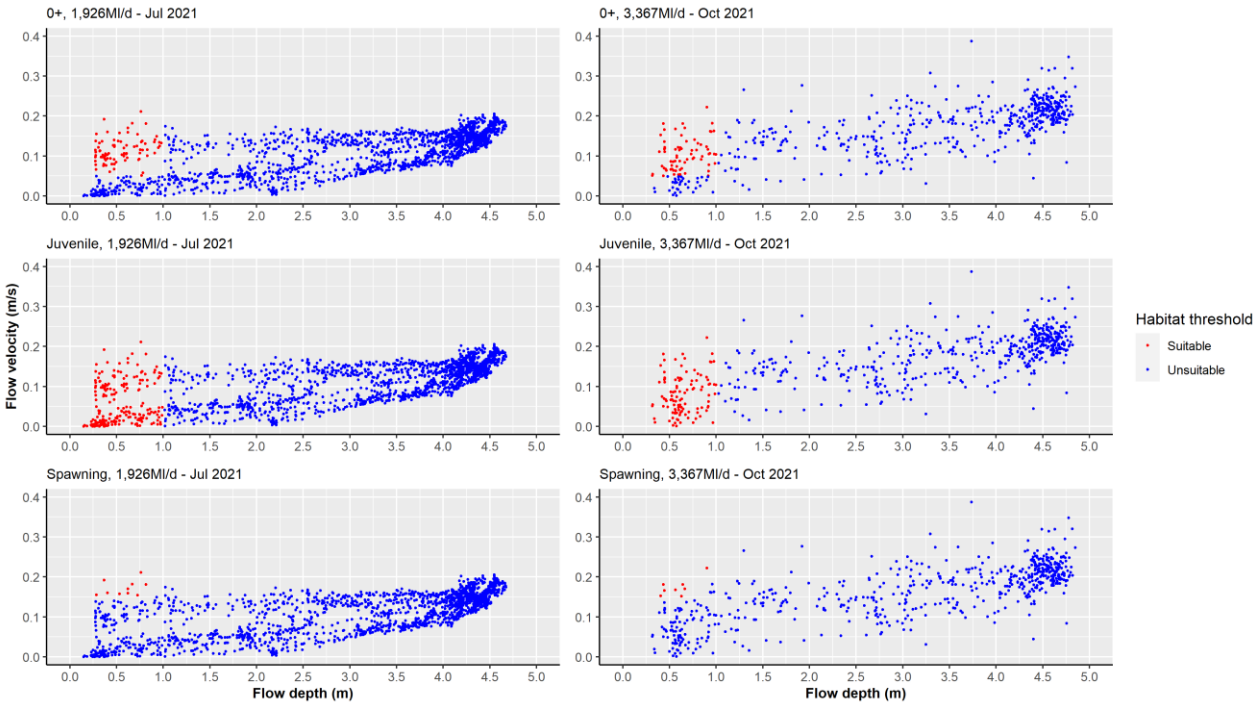


Figure A 20 Atlantic salmon habitat variability at Site STT 10

Brown / sea trout

Habitat changes for Brown / sea trout for the 0+, juvenile and spawning life stages during the 1,926Ml/d and 3,367Ml/d flows are presented in **Figure A 21.**

For each of the Brown / sea trout life stages, the habitat data indicate:

- **0+** – The data indicates that suitable 0+ habitat is very limited. Under lower flows in July only 3% of the data indicates suitable habitat, reducing to 0% under the higher flows in October.
- **Juvenile** – The data indicates that there is frequent suitable juvenile habitat available at the section. Under lower flows in July, 30% of the data indicates suitable habitat, remaining largely unchanged at 31% under the higher flows in October.
- **Spawning** – The data indicates that suitable 0+ habitat is very limited. Under lower flows in July only 2% of the data indicates suitable habitat, increasing very slightly to 4% under the higher flows in October.

At site STT 10, the hydraulic data indicates that there is very limited suitable flow habitat for juveniles, 0+ and spawning at the site. The data show that the change from the lowest to highest measured flows do not indicate any significant changes in flow habitat availability with increasing flow within this survey reach.

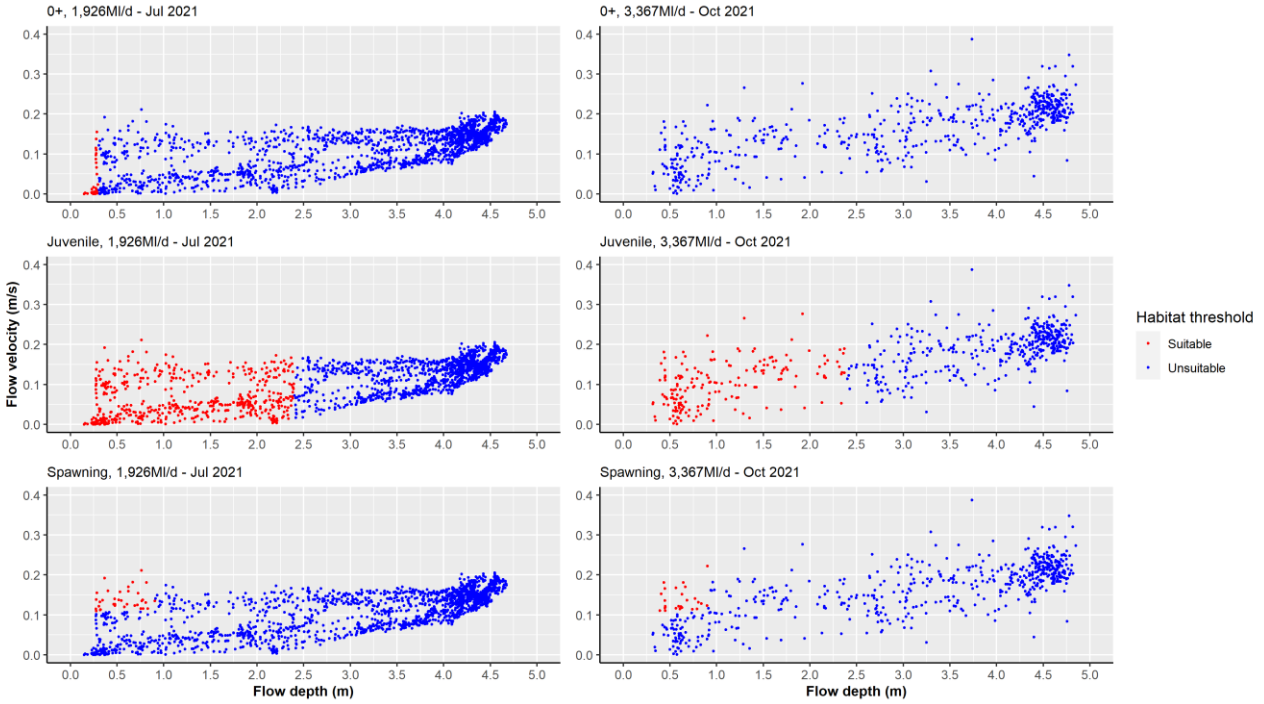


Figure A 21 Brown / sea trout habitat variability at Site STT 10

Lamprey sp. Ammocoetes

Habitat changes for Lamprey for the larvae and spawning life stages during the 1,926Ml/d and 3,367Ml/d flows are presented in **Figure A 22.**

For each of the Lamprey life stages, the habitat data indicate:

- **Larvae** – The data indicates that suitable 0+ habitat is limited. Under lower flows in July only 9% of the data indicates suitable habitat, increasing to 17% under the higher flows in October, likely in response to increasing hydraulic radius and increasing marginal inundation.
- **Spawning** – No suitable spawning habitat is indicated at the site by the ADCP data.

At site STT 10, the hydraulic data indicates that there is limited suitable flow habitat for larvae only and there is no spawning habitat. Although there is a slight increase in larvae habitat with increasing flows, the data on the whole the data indicate no significant changes in flow habitat availability with increasing flow within this survey reach.

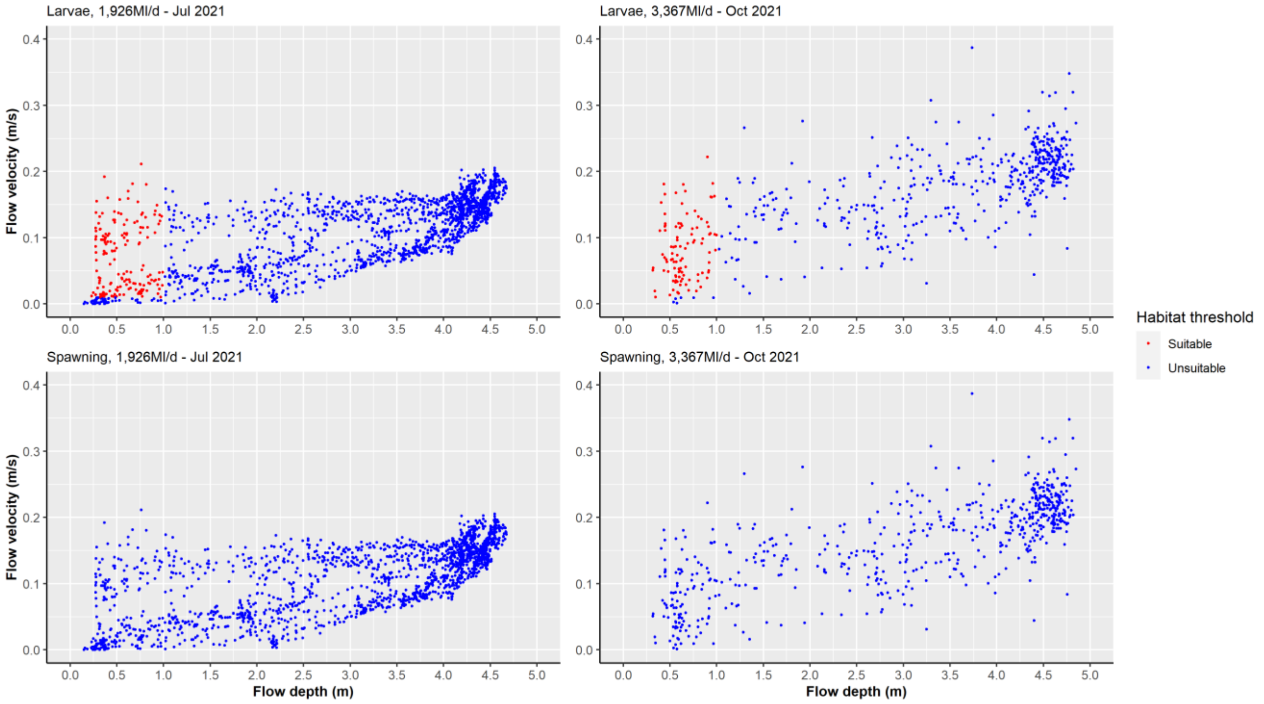


Figure A 22 Lamprey habitat variability at Site STT 10

Chub

Habitat changes for Chub for the juvenile and spawning life stages during the 1,926Ml/d and 3,367Ml/d flows are presented in **Figure A 23.**

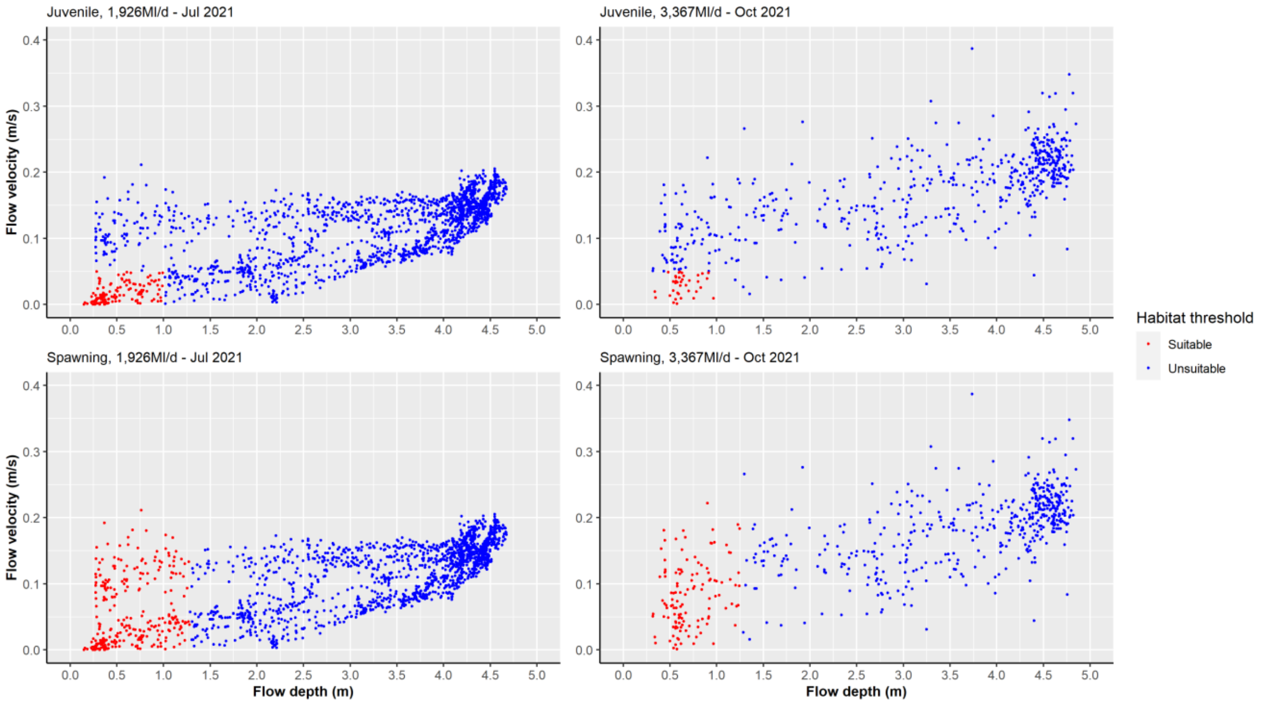


Figure A 23 Chub habitat variability at Site STT 10

For each of the Chub life stages, the habitat data indicate:

- **Juvenile** – The data indicates that suitable juvenile is present, although is limited. Under lower flows in July only 8% of the data indicates suitable habitat, reducing to 6% under the higher flows in October, mostly due to increasing flow velocities.
- **Spawning** – The data indicates that suitable spawning habitat is present. Under lower flows in July, 16% of the data indicates suitable habitat, increasing to 21% under the higher flows in June, likely in response to increasing hydraulic radius and increasing marginal inundation.

At site STT 10, the hydraulic data indicates that there is limited suitable flow habitat for juvenile and spawning and that increases in flows lead to no significant changes in flow habitat availability within this survey reach.

Roach

Habitat changes for Roach for the juvenile and spawning life stages during the 1,926Ml/d and 3,367Ml/d flows are presented in **Figure A 24.**

For each of the Roach life stages, the habitat data indicate:

- **Juvenile** – The data indicates that there is available suitable juvenile habitat. Under lower flows in July, 20% of the data indicates suitable habitat, increasing to 27% under the higher flows in October.
- **Spawning** – No suitable spawning habitat is indicated at the site by the ADCP data.

At site STT 10, the hydraulic data indicates that there is relatively limited suitable flow habitat for juveniles only and there is no spawning habitat. Increasing juvenile habitat availability under increasing flows are likely in response to increasing hydraulic radius and increasing marginal inundation.

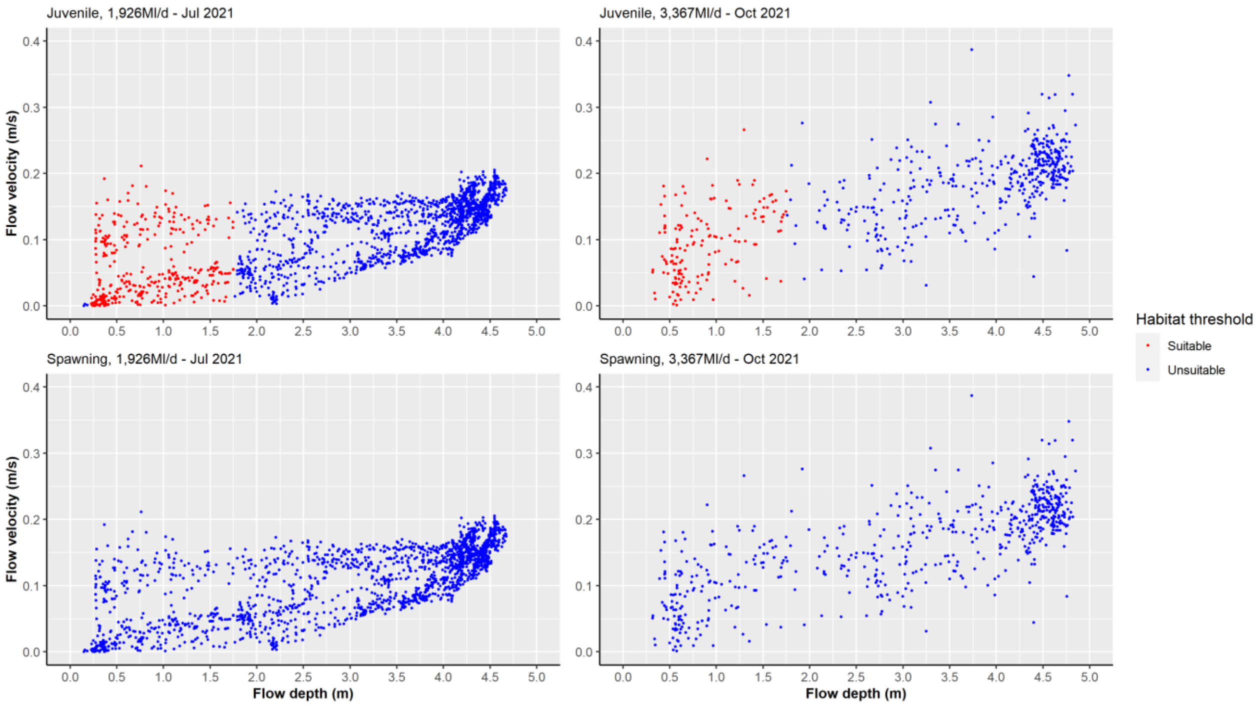


Figure A 24 Roach habitat variability at Site STT 10

European eel

Habitat changes for European eel for the juvenile life stage during the 1,926Ml/d and 3,367Ml/d flows are presented in **Figure A 25.**

For the juvenile European eel life stage, the habitat data indicate that there is available suitable habitat. Under lower flows in July, 63% of the data indicates suitable habitat, increasing slightly to 81% under the higher flows in October. This increase is driven by the shift towards higher flow velocities.

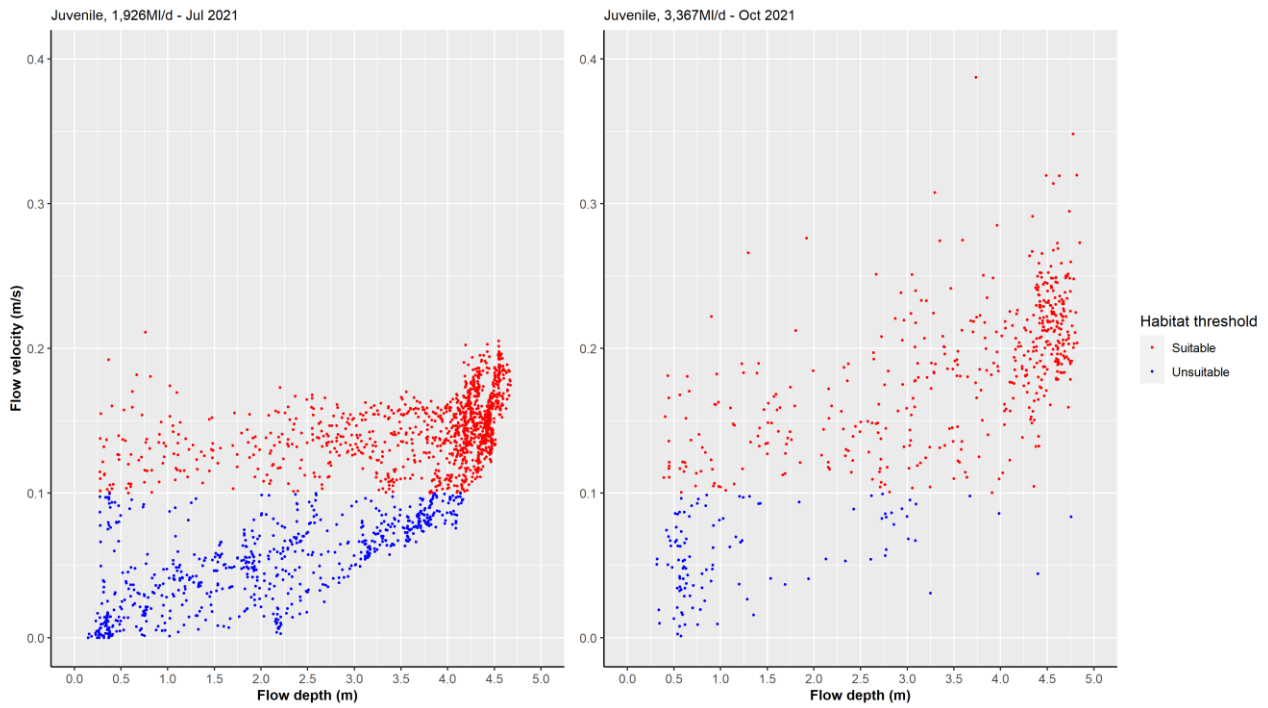


Figure A 25 European eel habitat variability at Site STT 10

A.5.5 STT 8 – RIVER AVON

For site STT 8, ADCP data was used to understand the gross changes in fish habitat at two different flows, 229Ml/d measured on 16 and 20 July 2021 and 381Ml/d measured on 26 October 2021, a difference of 152Ml/d (1.76m^3/s). A review of habitat changes per selected fish lifecycle stage are presented below.

Atlantic salmon

Habitat changes for Atlantic salmon for the 0+, juvenile and spawning life stages during the 229Ml/d and 381Ml/d flows are presented in **Figure A 26.**

For each of the Atlantic salmon life stages, the habitat data indicate:

- **0+** – The data indicates that suitable 0+ habitat is frequent. Under lower flows in July, 51% of the data indicates suitable habitat, increasing very slightly to 52% under the higher flows in October.
- **Juvenile** – The data indicates that there is abundant suitable juvenile habitat available at the section. Under lower flows in July, 63% of the data indicates suitable habitat, increasing to 82% under the higher flows in October.
- **Spawning** – The data indicates that suitable spawning habitat is frequent. Under lower flows in July, 38% of the data indicates suitable habitat, increasing to 56% under the higher flows in October.

At site STT 8, the hydraulic data indicates that there is abundant suitable flow habitat for 0+, juveniles and spawning. In contrast to other sites, increasing flow appears to lead to increased habitat availability, at least for the range of flows measured. This is likely in response to increasing hydraulic radius and increasing marginal inundation.

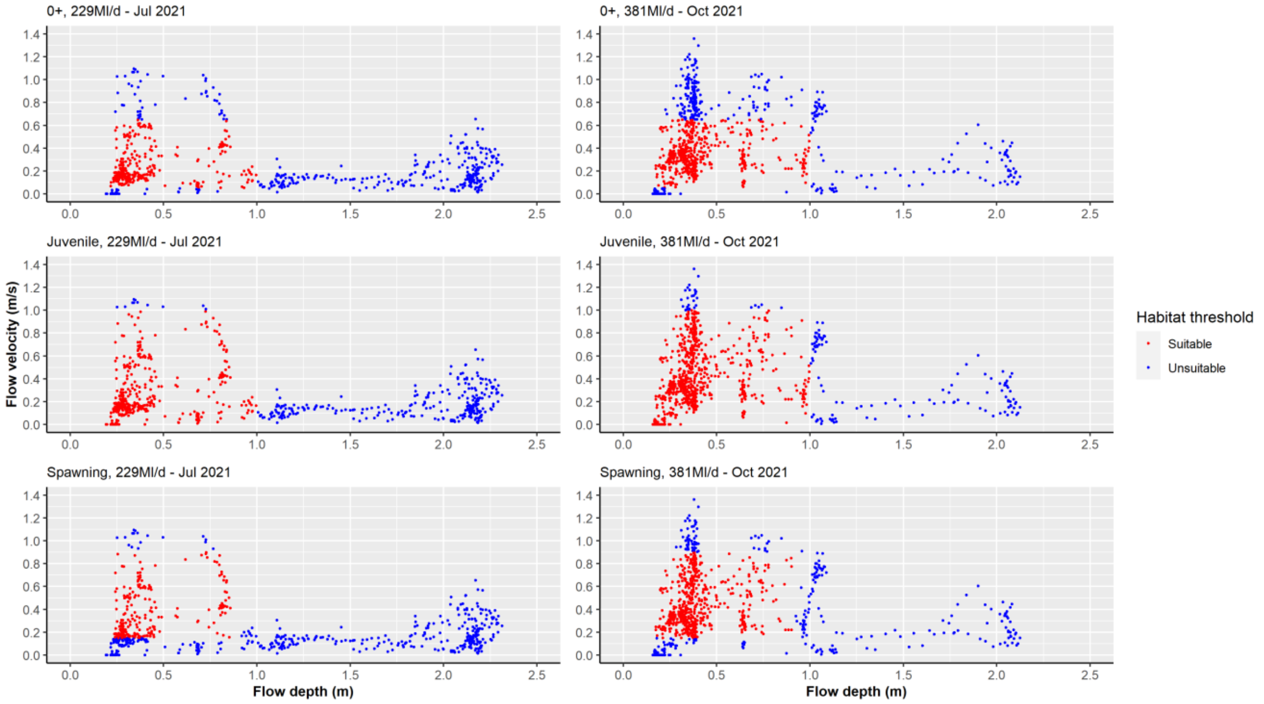


Figure A 26 Atlantic salmon habitat variability at Site STT 8

Brown / sea trout

Habitat changes for Atlantic salmon for the 0+, juvenile and spawning life stages during the 229Ml/d and 381Ml/d flows are presented in **Figure A 27.**

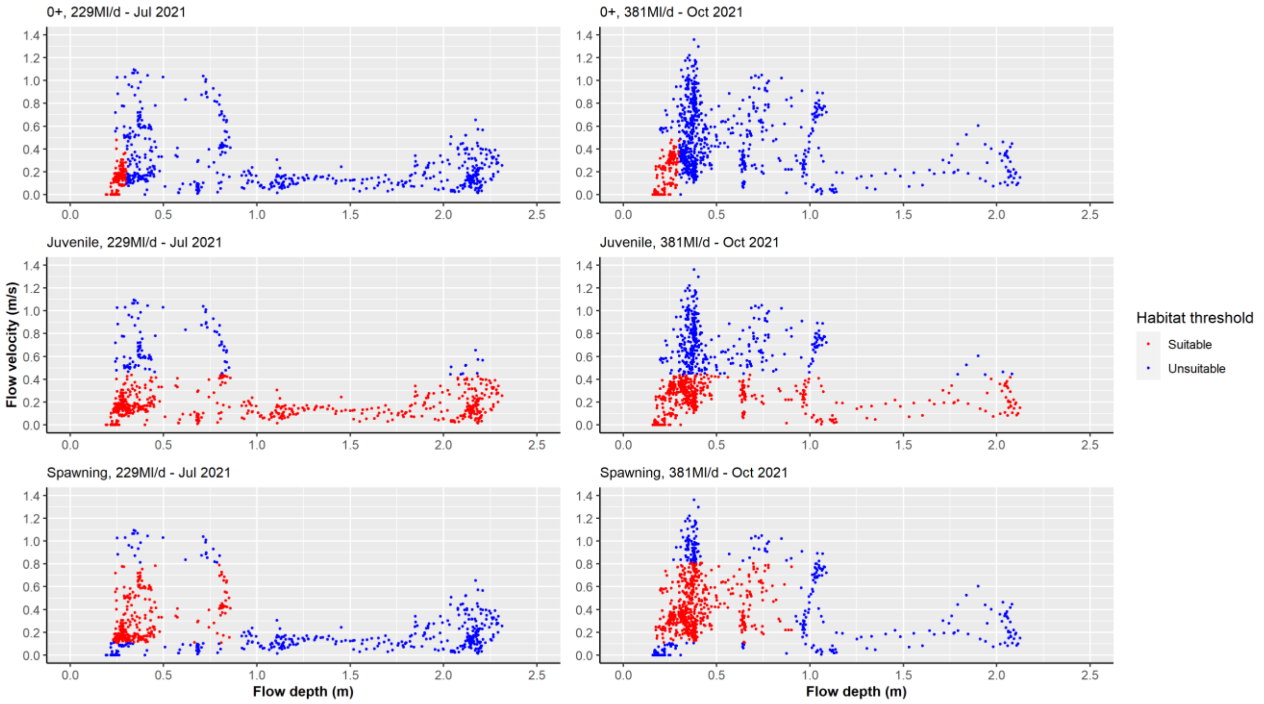


Figure A 27 Brown / sea trout habitat variability at Site STT 8

For each of the Brown / sea trout life stages, the habitat data indicate:

- **0+** – The data indicates that suitable 0+ habitat is limited. Under lower flows in July, 25% of the data indicates suitable habitat, reducing slightly to 23% under the higher flows in October.
- **Juvenile** – The data indicates that there is abundant suitable juvenile habitat available at the section. Under lower flows in July, 84% of the data indicates suitable habitat, reducing to 59% under the higher flows in October.
- **Spawning** – The data indicates that suitable spawning habitat is frequent. Under lower flows in July, 47% of the data indicates suitable habitat, increasing to 54% under the higher flows in October.

At site STT 8, the hydraulic data indicates that there is limited suitable flow habitat for 0+, abundant habitat for juveniles and frequent habitat for spawning. Although there is relatively limited change in habitat with increasing flows for 0+ and spawning habitat, there is a large increase in juvenile habitat with increasing flows. This increase is likely in response to increasing hydraulic radius and increasing marginal inundation.

Lamprey sp. Ammocoetes

Habitat changes for Lamprey for the larvae and spawning life stages during the 229Ml/d and 381Ml/d flows are presented in **Figure A 28.**.

For each of the Lamprey life stages, the habitat data indicate:

- **Larvae** – The data indicates that suitable 0+ habitat is frequent. Under both lower flows of July and the higher flows of October 2021, suitable habitat was around 50%.
- **Spawning** – In contrast to other sites, some very limited suitable spawning habitat is indicated at the site by the ADCP data, around 2% during the lower flows in July and increasing to just over 3% for the higher flows in October. This is driven predominantly by increases in velocity.

At site STT 8, the hydraulic data indicates that there is frequent suitable flow habitat for larvae and only very limited suitable habitat for spawning (noting this is the first such suitable flow habitat noted at any of the five study sites). The data show that there are no significant changes in flow habitat availability with increasing flow within this survey reach.

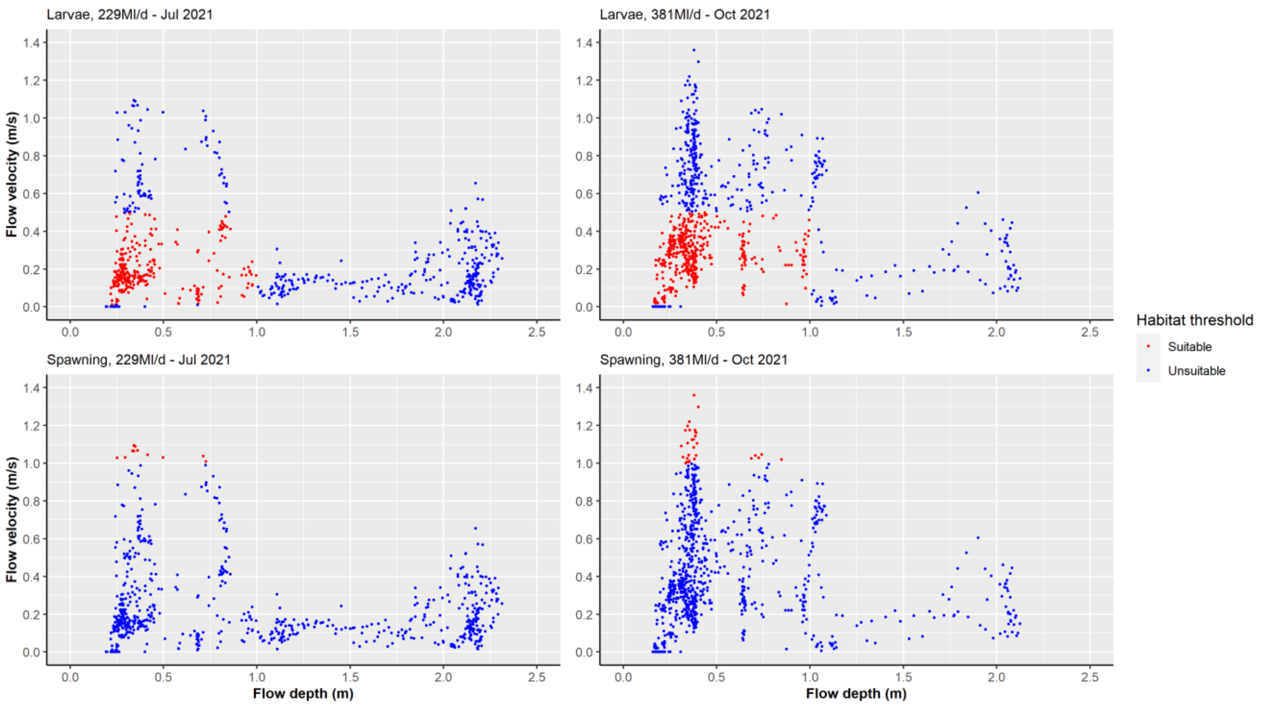


Figure A 28 Lamprey habitat variability at Site STT 8

Chub

Habitat changes for Chub for the juvenile and spawning life stages during the 229Ml/d and 381Ml/d flows are presented in **Figure A 29.**

For each of the Chub life stages, the habitat data indicate:

- **Juvenile** – The data indicates that suitable juvenile is present, although is very limited. Under lower flows in July only 6% of the data indicates suitable habitat, although this increases to 14% under the higher flows in October.
- **Spawning** – The data indicates that suitable spawning habitat is abundant. Under lower flows in July, 67% of the data indicates suitable habitat, increasing to 77% under the higher flows in October.

At site STT 8, the hydraulic data indicates that there is very limited suitable flow habitat for juveniles and abundant spawning habitat. The data show that the change from the lowest to highest measured flows lead to increases in suitable habitat, likely in response to increasing hydraulic radius and increasing marginal inundation.

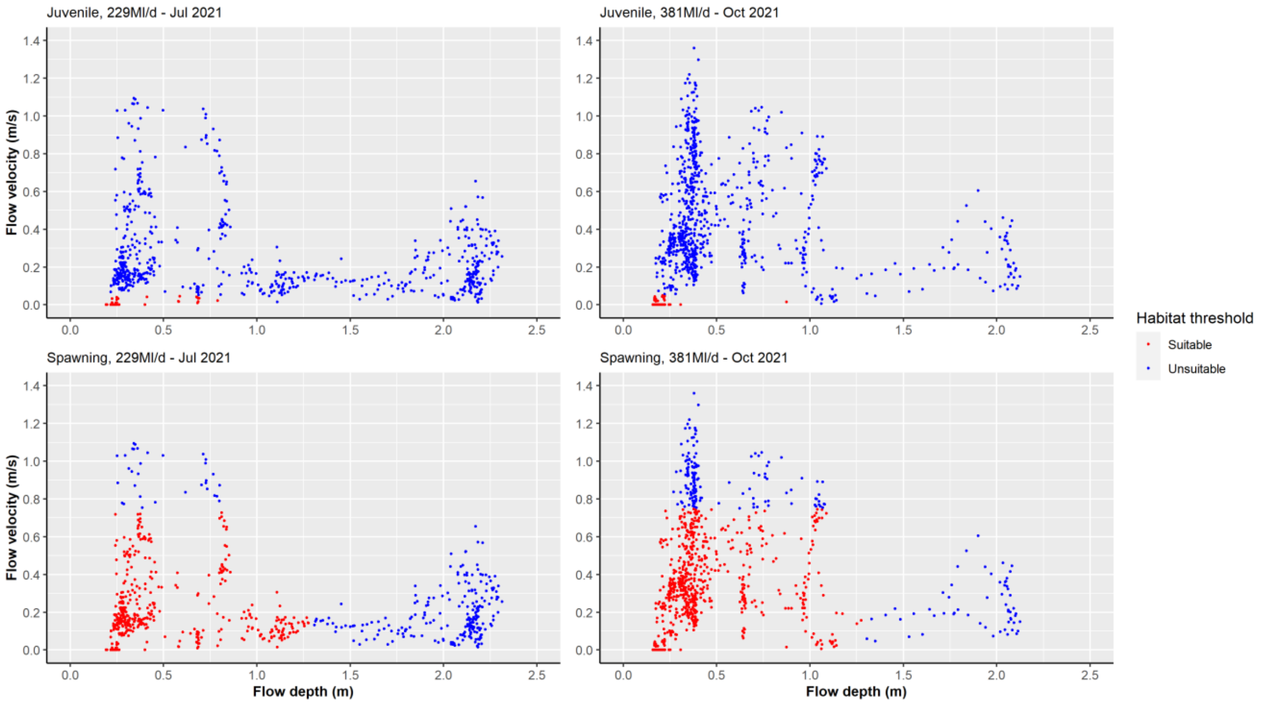


Figure A 29 Chub habitat variability at Site STT 8

Roach

Habitat changes for Roach for the juvenile and spawning life stages during the 229Ml/d and 381Ml/d flows are presented in **Figure A 30**.

For each of the Roach life stages, the habitat data indicate:

- **Juvenile** – The data indicates that there is frequent available suitable juvenile habitat. Under lower flows in July, 59% of the data indicates suitable habitat, declining to 41% under the higher flows in October.
- **Spawning** – The data indicates that suitable spawning habitat is present. Under lower flows in July, 22% of the data indicates suitable habitat, this increases markedly to 45% under the higher flows in October.

At site STT 8, the hydraulic data indicates that there is frequent suitable flow habitat for juveniles, which declines with increasing flow. Spawning habitat is found to increase in occurrence with increasing flows.

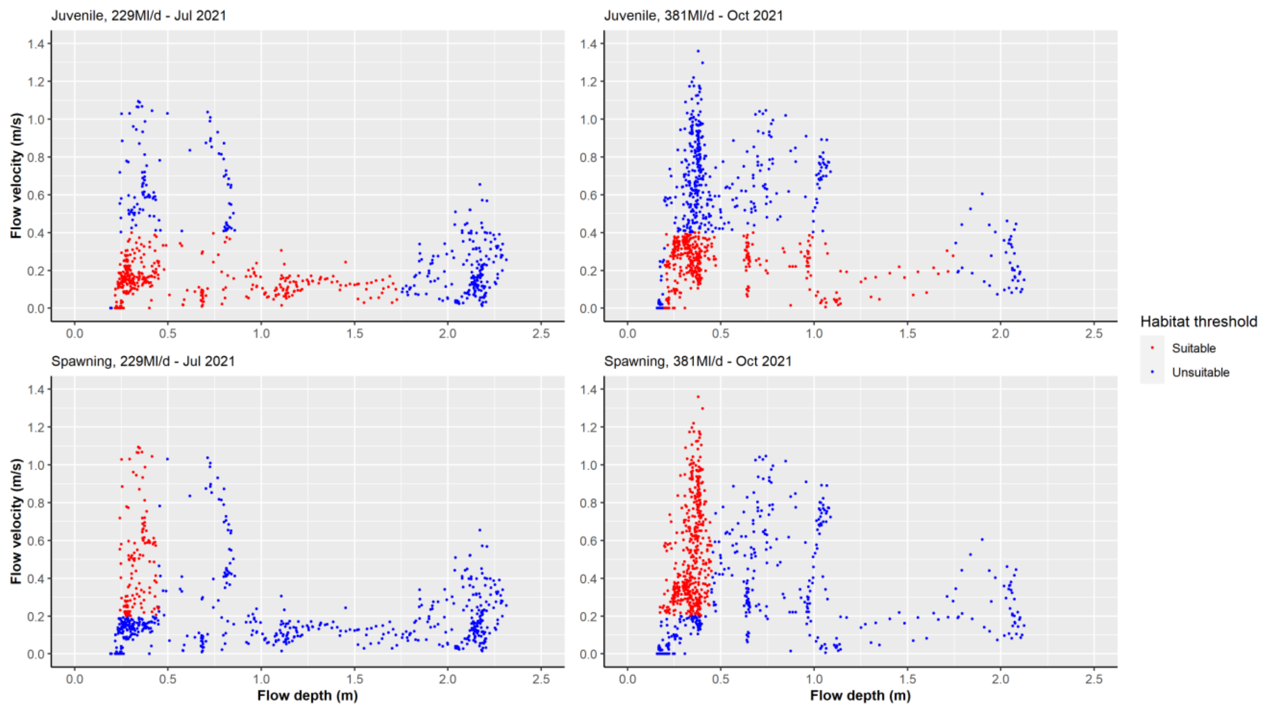


Figure A 30 Roach habitat variability at Site STT 8

European eel

Habitat changes for European eel for the juvenile and spawning life stages during the 229Ml/d and 381Ml/d flows are presented in **Figure A 31**.

For the juvenile European eel life stage, the habitat data indicate that there is abundant suitable habitat. Under lower flows in July, 80% of the data indicates suitable habitat, increasing slightly to 82% under the higher flows in October. This increase is driven by the shift towards higher flow velocities.

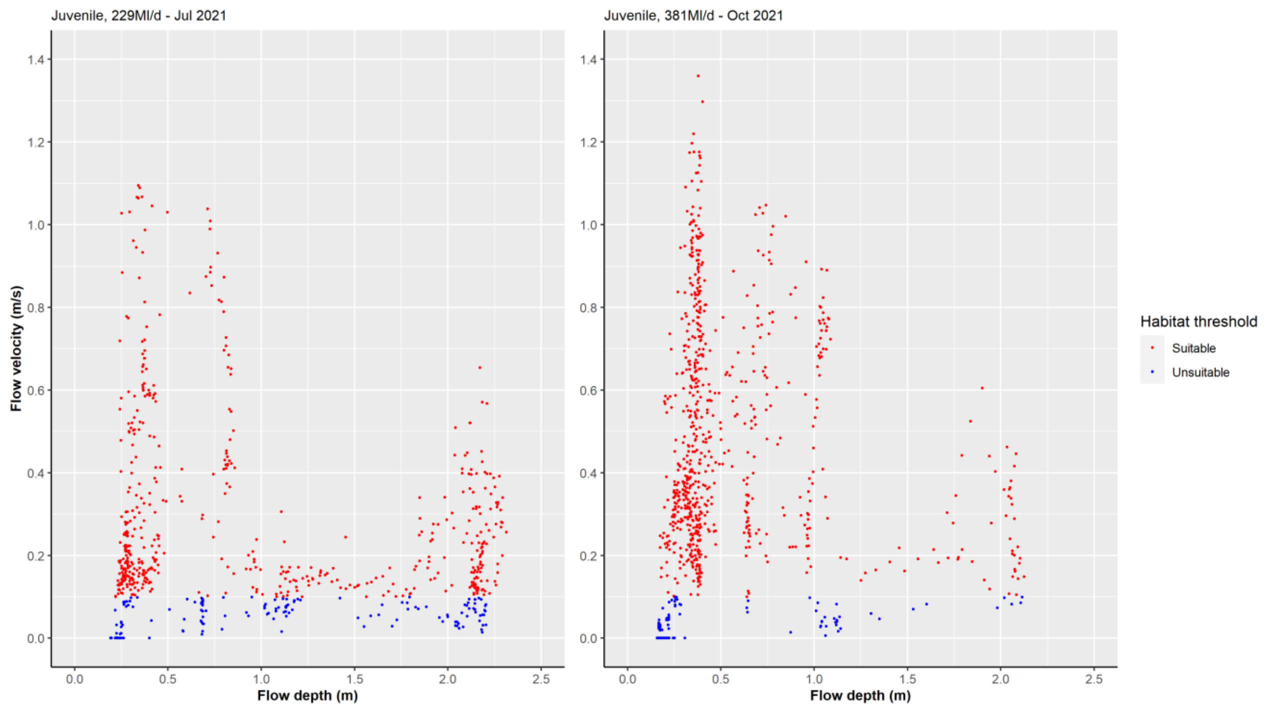


Figure A 31 European eel habitat variability at Site STT 8

A.6 HYDRAULICS SURVEY - 1D MODEL COMPARISON

In order to extend the assessment across the study reaches the output modelled hydraulic data from the 1D STT hydraulic model have been used. Prior to its application, there is a need to understand how the model predictions compare with the measured ADCP data in order to provide some degree of confidence in the applicability of the model outputs for this task. This is performed briefly as a graphical comparison in this section. It is intended as a guide only and is not intended as a direct validation of the measured ADCP and 1D model hydraulic data.

A.6.1 COMPARISON OF HYDRAULICS DATA AND 1D MODEL NODE OUTPUTS

To enable a comparison between ADCP and 1D model data a number of model nodes have been selected for each of the five ADCP sites. An attempt was made to select at least three nodes per site but this has not been possible at STT Montford due to the node spacing. Nodes which lay closest to the ADCP site (either at the site or immediately upstream or downstream of the site) and which were not representing flow changes due to any structure which exerted hydraulic control (e.g. a bridge, weir, lock or channel bifurcation) were selected. **Table A 63** indicates which model nodes have been selected per ADCP site in order to undertake the comparison between observed ADCP hydraulic data and predicted 1D model hydraulic data.

Table A 6 Selected model nodes per ADCP survey site

ADCP site ID	Model node ID	Distance of node from ADCP site (m, -ve: upstream, +ve downstream)
STT 5a	18512 18502 18402	-20 -6 +70
STT 5b	13802 13602 13402	-217 -16 +153
STT Montford	RS_234424 RS_234632	+51 +264
STT 10	RS_82570 RS_82369 RS_82171 RS_81972	-244 -42 +98 +298
STT 8	A1510 A1520 A1530 A1540	-77 -49 0 +24

The comparison involves comparing the 2D ADCP with 1D model data. Given the larger volumes of data associated with the ADCP data and the limited cross-section averaged velocity and depth predictions for the 1D model only a simple visual comparison is undertaken. Comparisons for each of the five sites are detailed, briefly, below.

STT 5a – River Vyrnwy

Figure A 32 provides a comparison between ADCP and 1D hydraulic data at STT 5a.

There are three model nodes displayed on **Figure A 32**, two of these (18512 and 18502) have very similar predicted flow and depths so lie over each other. The comparison data show that:

- **157Ml/d flow** - The M96 model runs fall within the spread of ADCP hydraulic data. The A82 model runs lie above the ADCP data by ~0.1m/s, suggesting that the A82 runs are of a higher flow velocity, however the flow depths appear to be within the ranges of the ADCP data.
- **294Ml/d flow** - The M96 model runs fall within the spread of ADCP hydraulic data. As the A82 model runs simulate higher flows, the model predictions begin to fall within the range of the ADCP data, although the nodes (closest to the ADCP site, 18502 and 18402) show higher predicted velocities than the ADCP data.

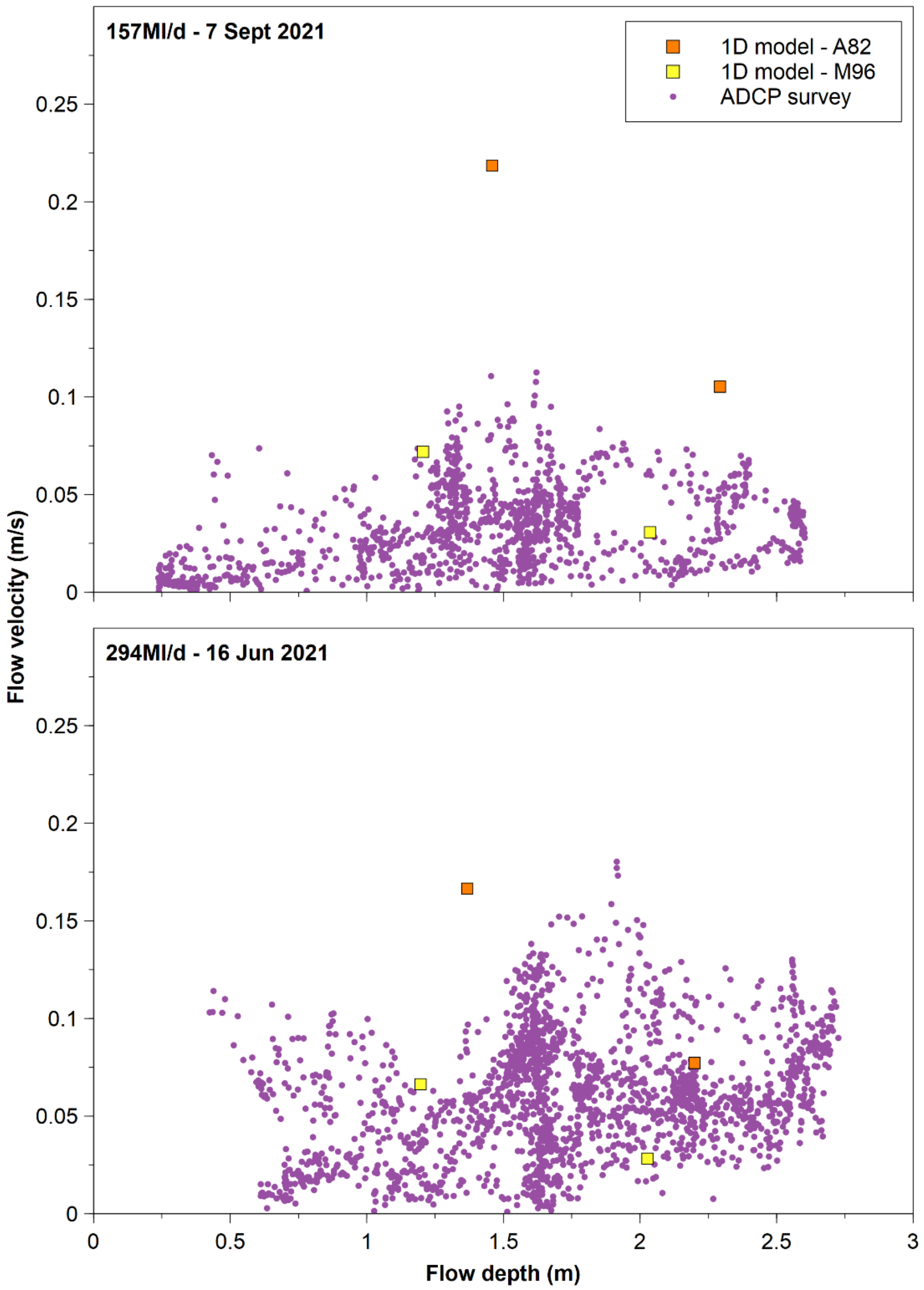


Figure A 32 STT 5a ADCP and 1D model hydraulic data comparison

STT 5b – River Vyrnwy

Figure A 33 provides a comparison between ADCP and 1D hydraulic data at STT 5b.

The comparison data show that:

- **157Ml/d flow** - The M96 model runs mostly fall within the spread of ADCP hydraulic data, although node 13402 (located 153m downstream of the ADCP site), falls outside of the range of the ADCP data, driven by higher predicted flow velocities. The A82 model runs mostly lie on the upper edge of the ADCP data, whit by ~0.1m/s, suggesting that the A82 runs are of a higher flow velocity, however the flow depths appear to be within the ranges of the ADCP data.
- **294Ml/d flow** - The M96 model runs fall within the spread of ADCP hydraulic data. As the A82 model runs simulate higher flows, the model predictions begin to fall within the range of the ADCP data, although the node 13402 lies well above the ADCP data, again driven by higher predicted flow velocities.

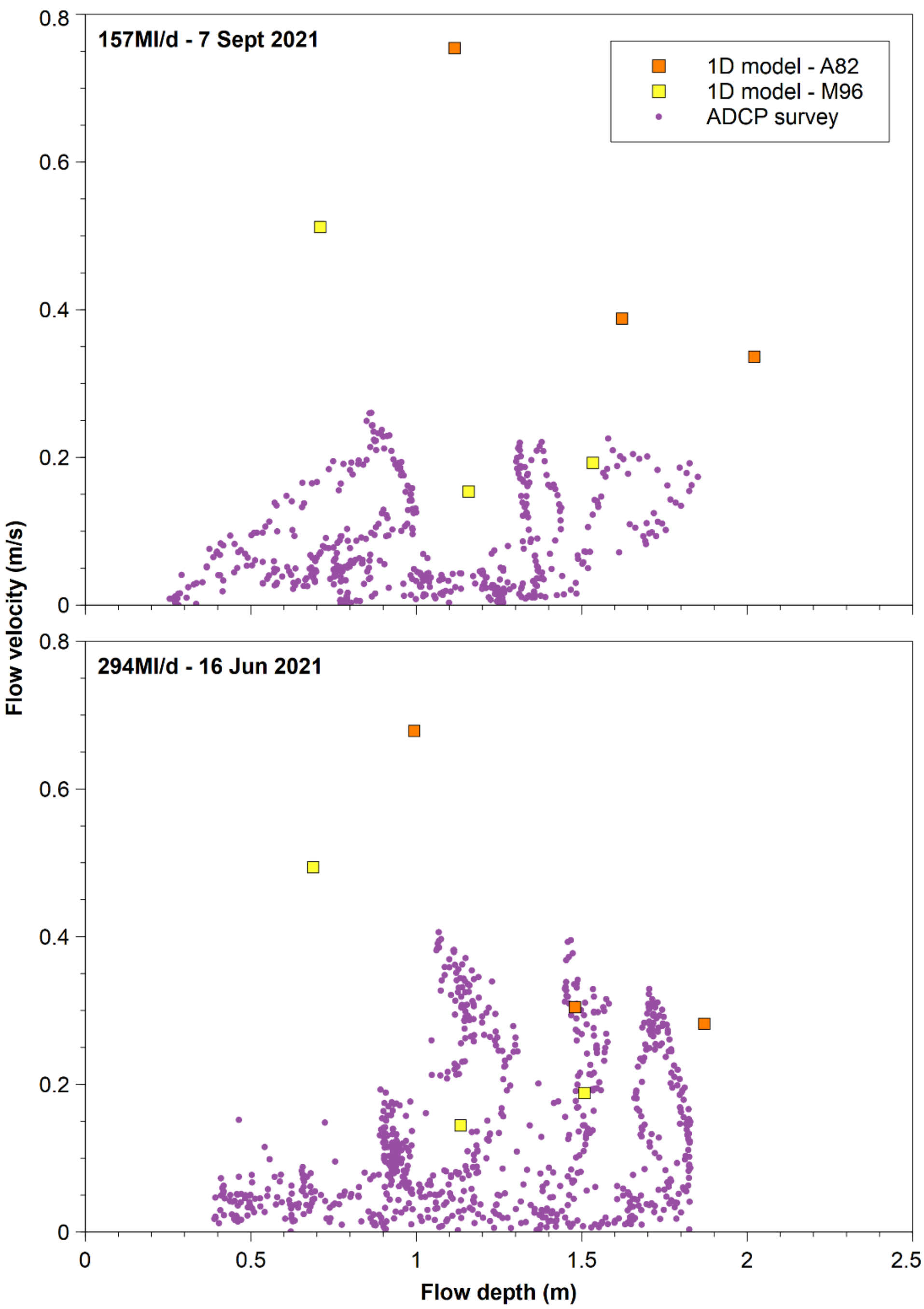


Figure A 33 STT 5b ADCP and 1D model hydraulic data comparison

STT Montford – River Severn

Figure A 34 provides a comparison between ADCP and 1D hydraulic data at STT Montford. The comparison data show that:

- **697Ml/d flow** – Node RS_234424 (51m downstream of the ADCP survey reach) falls within the spread of the ADCP data for both the A82 and M96 runs, while node RS_234632 (264m downstream of the ADCP survey reach) falls outside of the data for both runs. The latter node may be positioned too far downstream to be representative for the comparison.
- **948Ml/d flow -** Node RS_234424 falls within the spread of the ADCP data for the A82 run, while node RS_234632 falls just outside of the data, likely due to higher flow velocity predictions. Both M96 nodes lie above the ADCP data, driven by higher flow velocities, ~0.2m/s higher than measured by the ADCP.

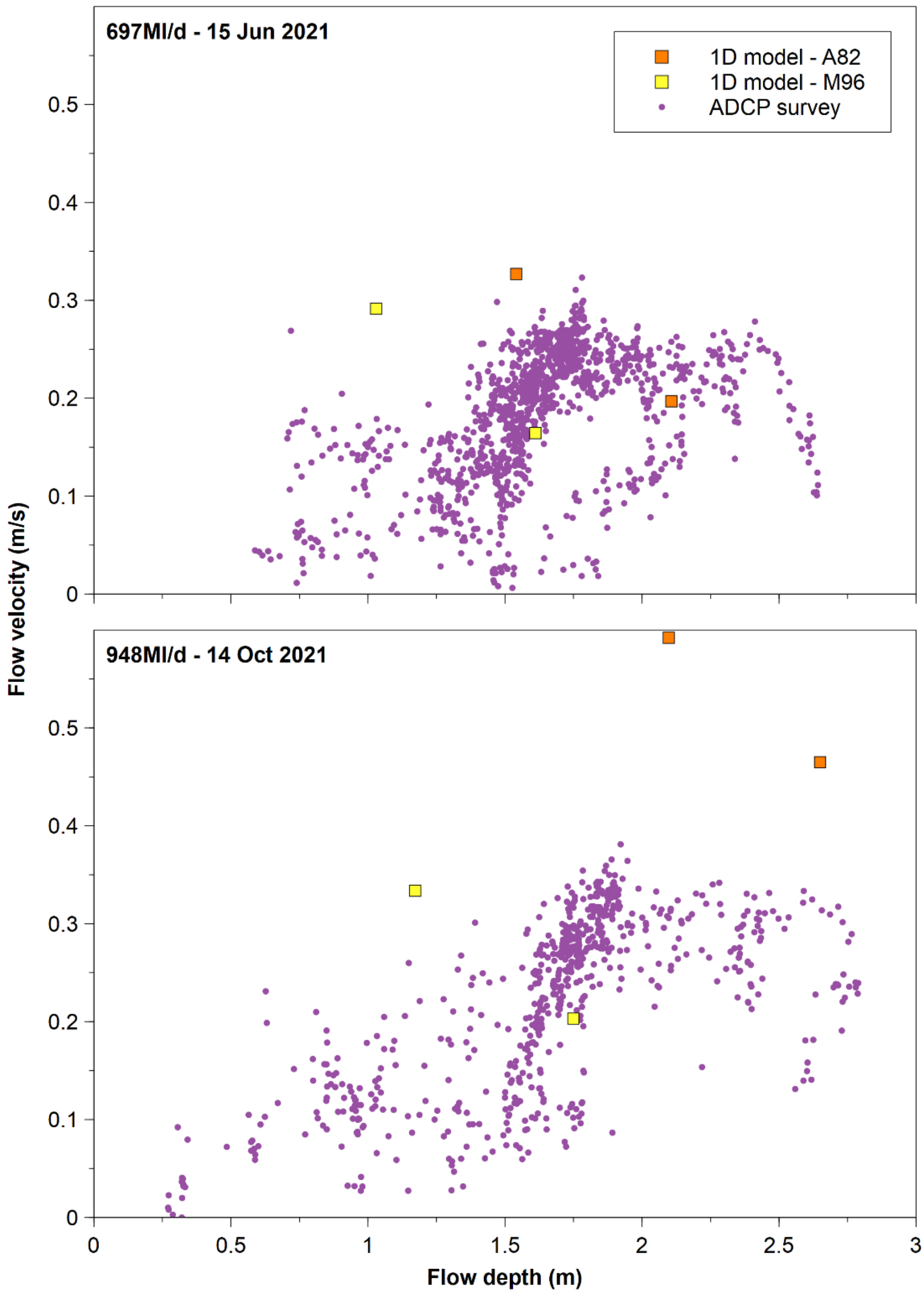


Figure A 34 Montford ADCP and 1D model hydraulic data comparison

STT 10 – River Severn

Figure A 35 provides a comparison between ADCP and 1D hydraulic data at STT 10. There are more modelled v-d values than selected 1D model sites (**Table A 6**) as these cover the range of dates over which the ADCP data was collected (**Table A2**). For A82 and M96 nodes for the STT 10 1,926Ml/d run comparison there are four nodes but eight individual flow and depth measurements representing the range of dates (15 and 21 July) under which ADCP data was captured. The comparison data show that:

- **1,926Ml/d flow** – Both the A82 and M96 model runs fall within the spread of ADCP hydraulic data, although they are located towards the deeper flow measurements.
- **3,367Ml/d flow** - The M96 model runs fall within the spread of ADCP hydraulic data, however they represent an underprediction in depth and flow velocity when compared to the ADCP data. As the A82 model runs simulate much higher flows (**Table A 5**), the model predicts higher depths and flow velocities which fall outside the upper ranges of the ADCP data.

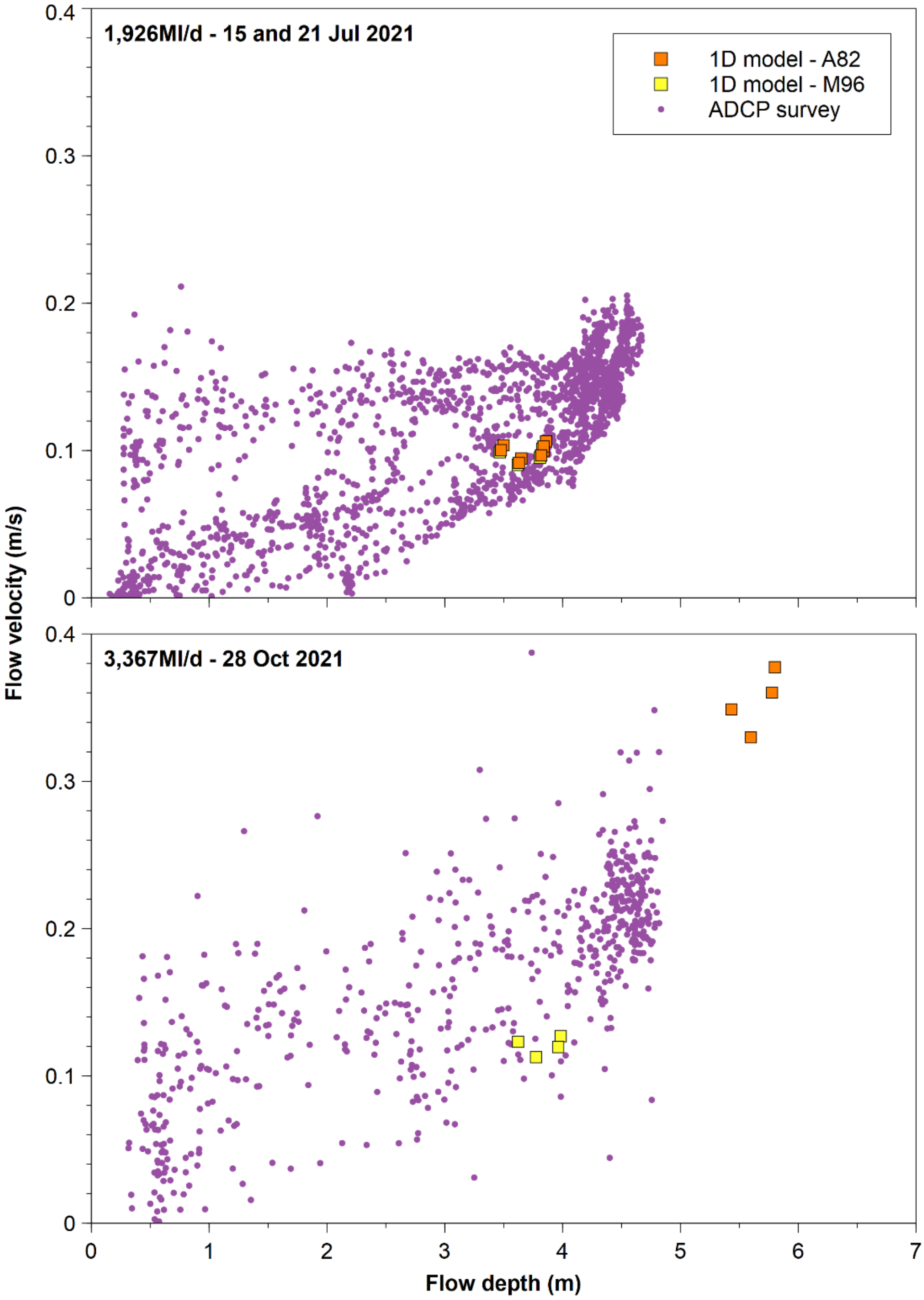


Figure A 35 STT 10 ADCP and 1D model hydraulic data comparison

A.6.2 STT8 – RIVER AVON

Figure A 36 provides a comparison between ADCP and 1D hydraulic data at STT 8. There are more modelled v-d values than selected 1D model sites (**Table A 6**) as these cover the range of dates over which the ADCP data was collected (**Table A 2**).

For A82 and M96 nodes for the STT 8 1,926Ml/d run comparison there are four nodes but eight individual flow and depth measurements representing the range of dates (16 and 20 July) under which ADCP data was captured. The comparison data show that:

- **229Ml/d flow** – All four nodes fall within the spread of ADPC data for the A82 and M96 runs, however node A1530, which lies towards the centre of the ADCP survey site lies along the upper edge of the ADCP data.
- **381Ml/d flow -** All four nodes fall within the spread of ADPC data for the A82 and M96 runs, with the M96 nodes predicting slightly higher flow velocities and depths than the A82 runs.

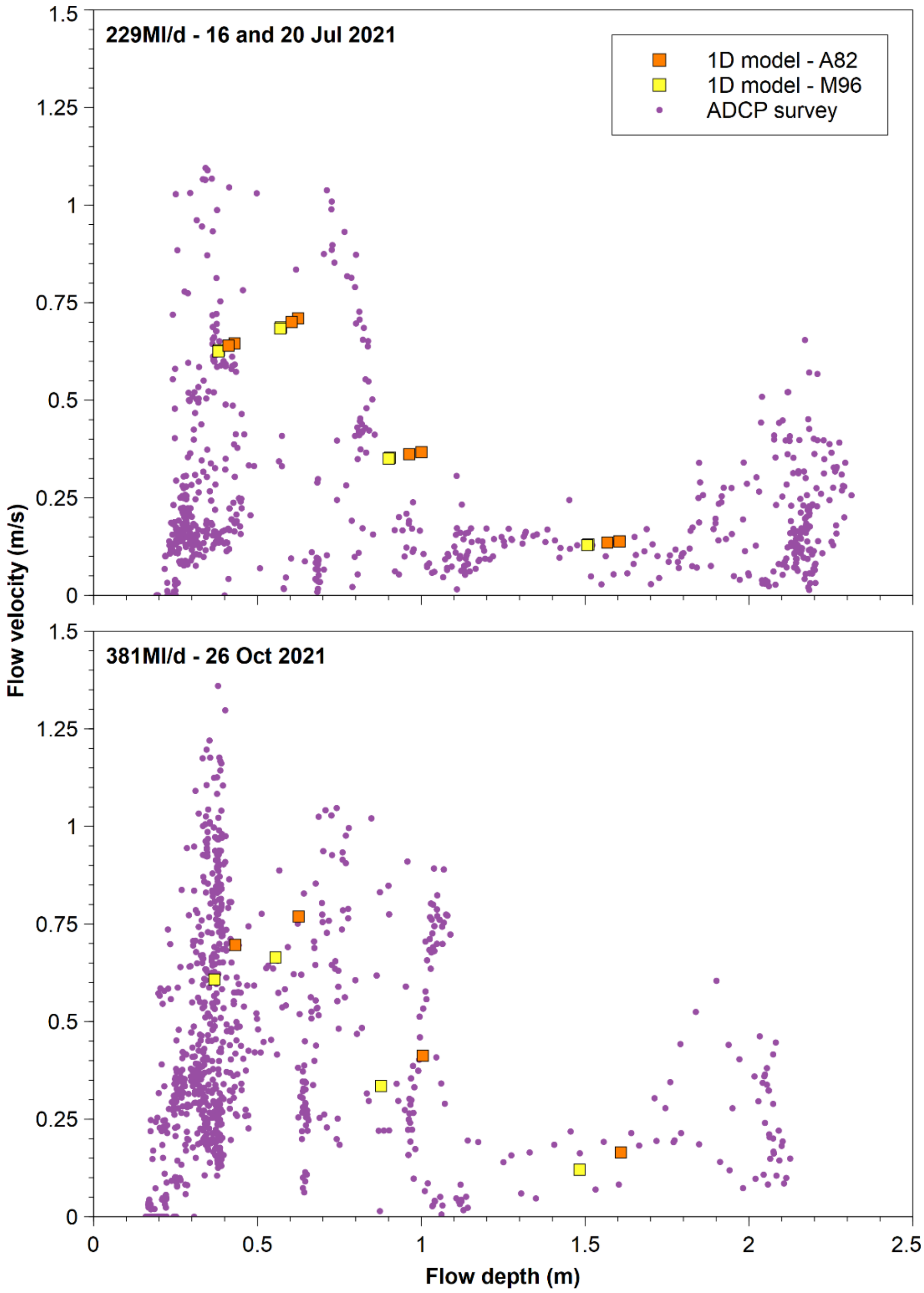


Figure A 36 STT8 ADCP and 1D model hydraulic data comparison

A.6.3 EXTENDING HABITAT ASSESSMENT USING 1D MODELLING

As noted above, this is a simple visual comparison between the measured ADCP hydraulic data and the 1D modelled hydraulic data in order to provide a degree of confidence in the application of the 1D model data to predicting habitat changes over the entire study reach.

The comparison indicates that it is not possible to use the ADCP data extrapolated across the entire study area solely for understanding changes in habitat, a wider range of measured flows (similar to those expected during releases) would be required to accomplish this. However, the ADCP data does highlight the important variability in habitats under different flows which the 1D model data is unlikely to capture.

The key issue with the 1D model data is that it is a single value representing average flow velocity and flow depth at a cross-section, rather than a range of velocities and depths. This means that the 1D data lack granularity in understanding the spatial variability of habitat within a reach and therefore how this changes as flows change. It is expected that this would lead to a potential underestimation of available habitat when using the 1D data to predict habitats. The limited range of flows measured by the ADCP cannot be used to better quantify this and this remains an uncertainty in the use of the 1D model data.

In conclusion, the comparison between the ADCP data and the 1D model data indicates a relatively good agreement, particularly with the M96 flows which are somewhat similar to the measured flows (**Table A 5**). The modelled A82 flow data is sometimes higher than those measured by the ADCP, however this most likely due to the higher modelled flows when compared to those flows measured by the ADCP data (**Table A 5**). The relatively good agreement between the modelled flows with the ADCP data suggest that the 1D model outputs are applicable to use for predicting gross habitat changes across the different survey reaches.

A.7 STUDY AREA HABITAT ASSESSMENT

In order to gain a general understanding of the potential impact of the releases across the model period, the 1D modelled data was processed to extract the flow velocity and flow depth data for each of the model nodes for the A82 and M96 reference and full model runs (discussed in Section A.4.1). Data was extracted from each of the model nodes to create two study reaches (**Figure A 37**) to understand the potential impacts on fish habitat for the Vyrnwy and Minworth releases:

- **Vyrnwy release** – ~246km reach between Vyrnwy Reservoir and the tidal limit of the River Severn.
- **Minworth release** – ~124km reach commencing in the River Avon at the River Sowe confluence and extending to the tidal limit of the River Severn.

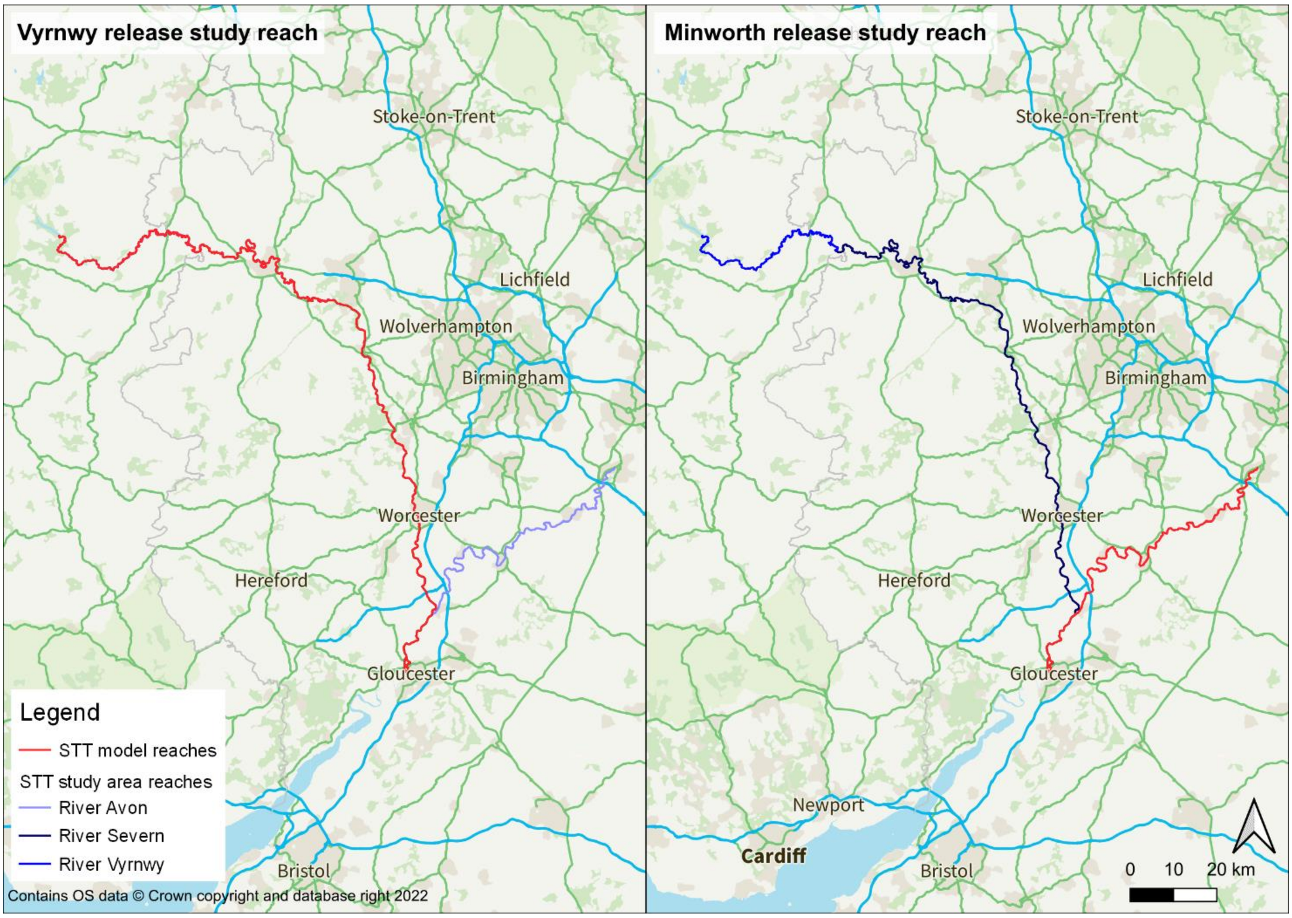


Figure A 37 Model release study reaches

Out of the 2,347 model nodes, the Vyrnwy release study reach contains 1,355 nodes while the Minworth release study reach contains 705 nodes. The time periods of the releases are outlined in **Table A 7** and are discussed further in Section 3 of the main STT Gate 2 Physical Environment Assessment Report[26].

Table A 7 Operational periods for release schemes

Model run	Release	Date turned on (day number)	Date turned off (day number)
A82	Vyrnwy Direct	27-Jun (178)	09-Oct (282)
	Vyrnwy Bypass	30-Jun (181)	09-Oct (282)
	Minworth	03-Jul (184)	09-Oct (282)
M96	Vyrnwy Direct	12-Jun (163)	02-Nov (306)
	Vyrnwy Bypass	15-Jun (166)	02-Nov (306)
	Minworth	18-Jun (169)	02-Nov (306)

Fish habitat hydraulic preferences outlined in Section A.3.2 and **Table A 4** were applied to the flow velocity and flow depth data for each model node of the A82 and M96 reference and full runs to create a fish habitat preference value. The reference runs were used to generate the habitat baselines in both study reaches while the difference between the calculated habitats for the full and reference A82 and M96 model runs were used to generate habitat change data to understand how habitat varied under release periods when compared to non-release periods.

[26] Ricardo E&E, (2022). Severn Thames Transfer SRO. Physical Environmental Assessment Report. ED15323.

Baseline and habitat change data were then visualised as matrices showing study reach length on the y-axis against date (as a day number, **Table A 7**) on the x-axis (effectively change along each study reach chainage as a function of time) for each fish species and its life stage. Percentage change values are indicative numbers used to quantify general change. These are calculated against the total number of nodes used in each matrix and do not represent changes in habitat area.

A.7.1 VYRNWY RELEASE

To analyse any potential changes in habitat due to the Vyrnwy release, a study reach of ~246km in length has been used, beginning immediately below Vyrnwy Reservoir, continuing downstream in the River Vyrnwy until the confluence with the River Severn at 66km and ending at the tidal limit of the River Severn (**Figure A 37**).

Atlantic salmon

The down reach baseline Atlantic salmon habitat for the reference conditions are presented in **Figure A 38**.

For each the Atlantic salmon life stages, the data indicate the following baseline habitat presence and distribution:

- **0+** – For the A82 model runs, 10% of the study reach contains suitable flow habitat, while for the M96 run this increases to 12% of the study reach. There is temporal variability in habitat from around 240 to 280 days, and this is related to changes in river flow. Most habitat is distributed over the first 180km, although there is a concentration in the first 30km at the head of the reach in the River Vyrnwy.
- **Juvenile** – For the A82 model runs, 14% of the study reach contains suitable flow habitat, while for the M96 run this increases to 16% of the study reach. There is temporal variability in habitat from around 240 to 280 days, and this is related to changes in river flow. Habitat distribution and temporal variability is relatively unchanged from 0+ habitat.
- **Spawning** – For the A82 model runs, 11% of the study reach contains suitable flow habitat, while for the M96 run this increases to 12% of the study reach. Habitat distribution and temporal variability is relatively unchanged from to 0+ and juvenile habitat.

The down reach change in Atlantic salmon habitat between the modelled reference conditions and when the release is operating is presented in **Figure A 39**.

For each of the Atlantic salmon life stages, when compared to the model habitat baseline, the habitat data indicate:

- **0+** – For the A82 and M96 model runs, ~98% of the habitat remains unchanged, with around a 2% loss in habitat and a gain of 0.2-0.1% for A82 and M96 runs respectively.
- **Juvenile** – For the A82 and M96 model runs, ~98% of the habitat remains unchanged, with around a 2% loss in habitat and a gain of 0.1% for A82 run only (there is no gain in habitat for M96).
- **Spawning** – For the A82 and M96 model runs, ~98% of the habitat remains unchanged, with around a 1.5% loss for both A82 and M96 runs and a 0.2% gain for both A82 and M96 runs.

For the A82 and M96 runs, there is indicated to be relatively minor and local changes from the baseline habitat condition, with much of the changes concentrated in the 80-120km section of the reach while the release is in operation.

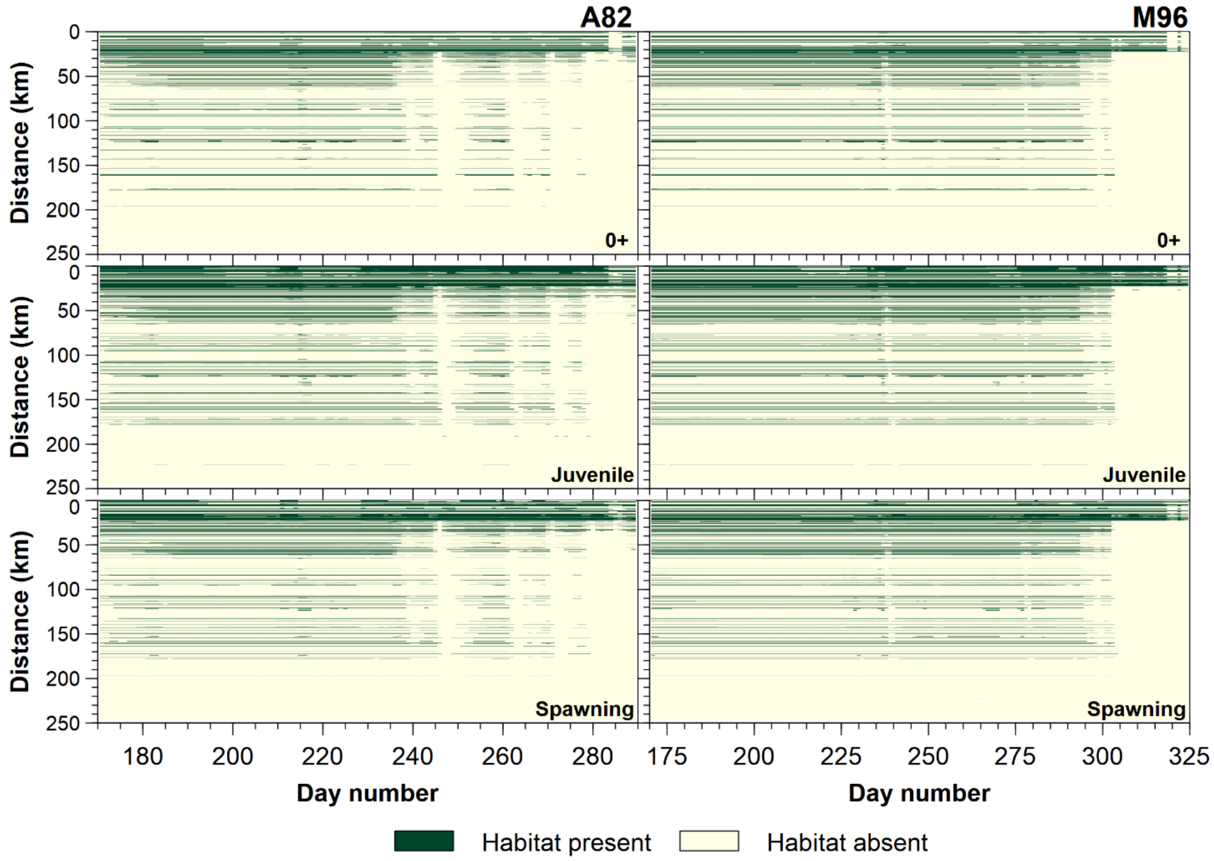


Figure A 38 Down reach baseline Atlantic salmon habitats

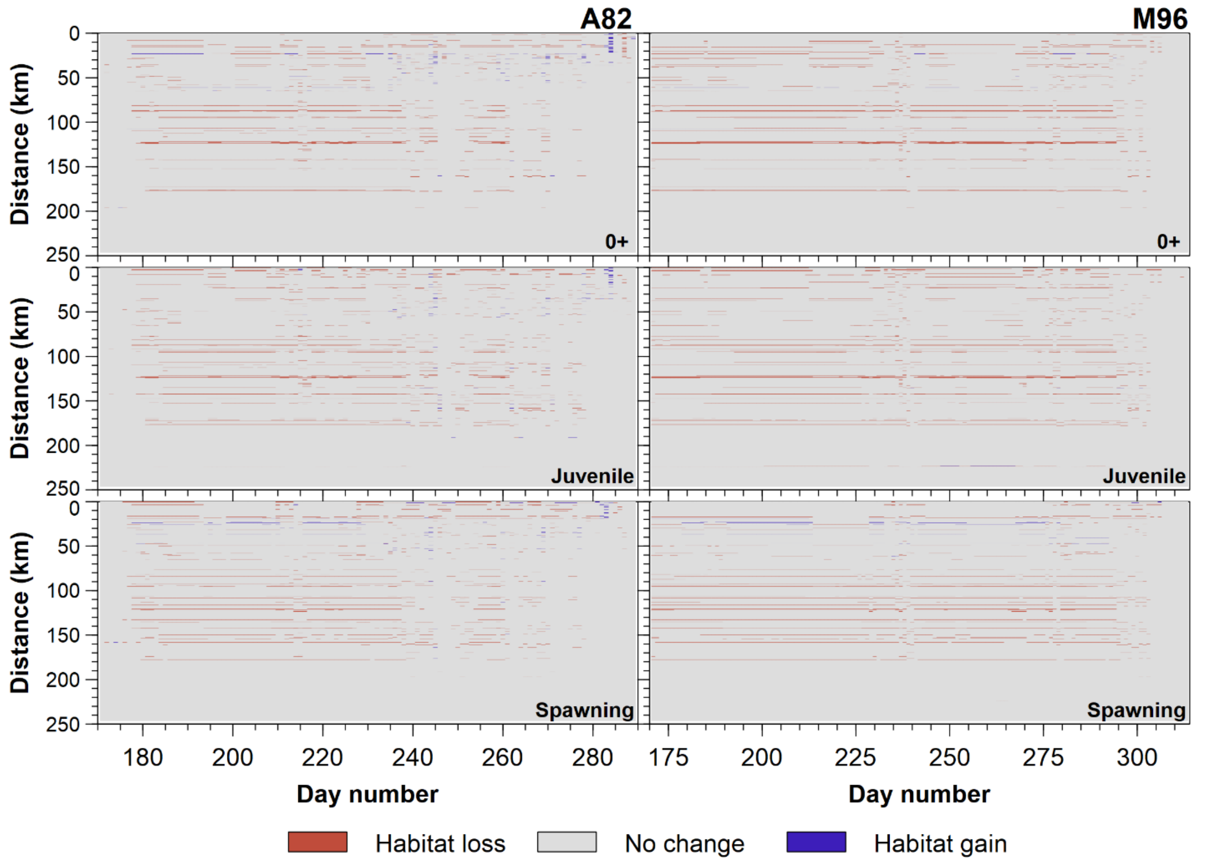


Figure A 39 Down reach changes in Atlantic salmon habitats between reference conditions and release

Brown / sea trout

The down reach baseline Brown / sea trout habitat for the reference conditions are presented in **Figure A 40**.

For each of the Brown / sea trout life stages, the data indicate the following baseline habitat presence and distribution:

- **0+** – There is limited habitat, with only 0.6% and 0.4% habitat present for the A82 and M96 runs respectively. Most of this is concentrated in the initial 30km of the River Vyrnwy.
- **Juvenile** – For both model runs, much of the study reach contains suitable juvenile habitat, with 44% for the A82 run and 47% for the M96 run. There is temporal variability in habitat from around 245 to 280 days, and this is related to changes in river flow, although these are ameliorated somewhat for the M96 runs suggesting these are related to low flows. The suitable habitat is fairly evenly spread from the start of the reach to ~220km downstream.
- **Spawning** – For the A82 model runs, 10% of the study reach contains suitable flow habitat, while for the M96 run this increases slightly to 11% of the study reach. Temporal variability in habitat distribution is relatively similar to that for juvenile habitat, however the habitat is distributed over 180km, with a higher concentration in the initial 50km.

The down reach change in Brown / sea trout habitat between the modelled reference conditions and when the release is operating is presented in **Figure A 41**.

For each of the Brown / sea trout life stages, when compared to the model habitat baseline, the habitat data indicate:

- **0+** – For the model runs, >99% of the habitat remains unchanged, with around 0.2-0.4% loss in habitat and no gain in habitat. All of the habitat loss is focussed in the upper 30km of the River Vyrnwy.
- **Juvenile** – For the A82 and M96 model runs, ~95% of the habitat remains unchanged, with around a 4% loss in habitat and a gain of 0.9% and 0.4% for the A82 and M96 run respectively. Most habitat loss is spread over ~220km of the reach. There are some gains in habitat between 7 September 2022 (day 250) and 17 October 2022 (day 290).
- **Spawning** – For spawning habitat 98.6% and 98.2% of the habitat remains unchanged for the A82 and M96 runs respectively. There is a 1.1% and 1.6% loss for the A82 and M96 runs respectively, while there is only 0.2% gain for both runs. Most habitat loss occurs around 90-150km downstream. There are some temporally limited gains in habitat, these seem to occur over the model period around 20-50km downstream.

The model data indicate that there could be some limited loss of 0+ habitat in the upper reaches of the River Vyrnwy down to around 30km, with losses of juvenile and spawning habitat are spread throughout 220km of the reach.

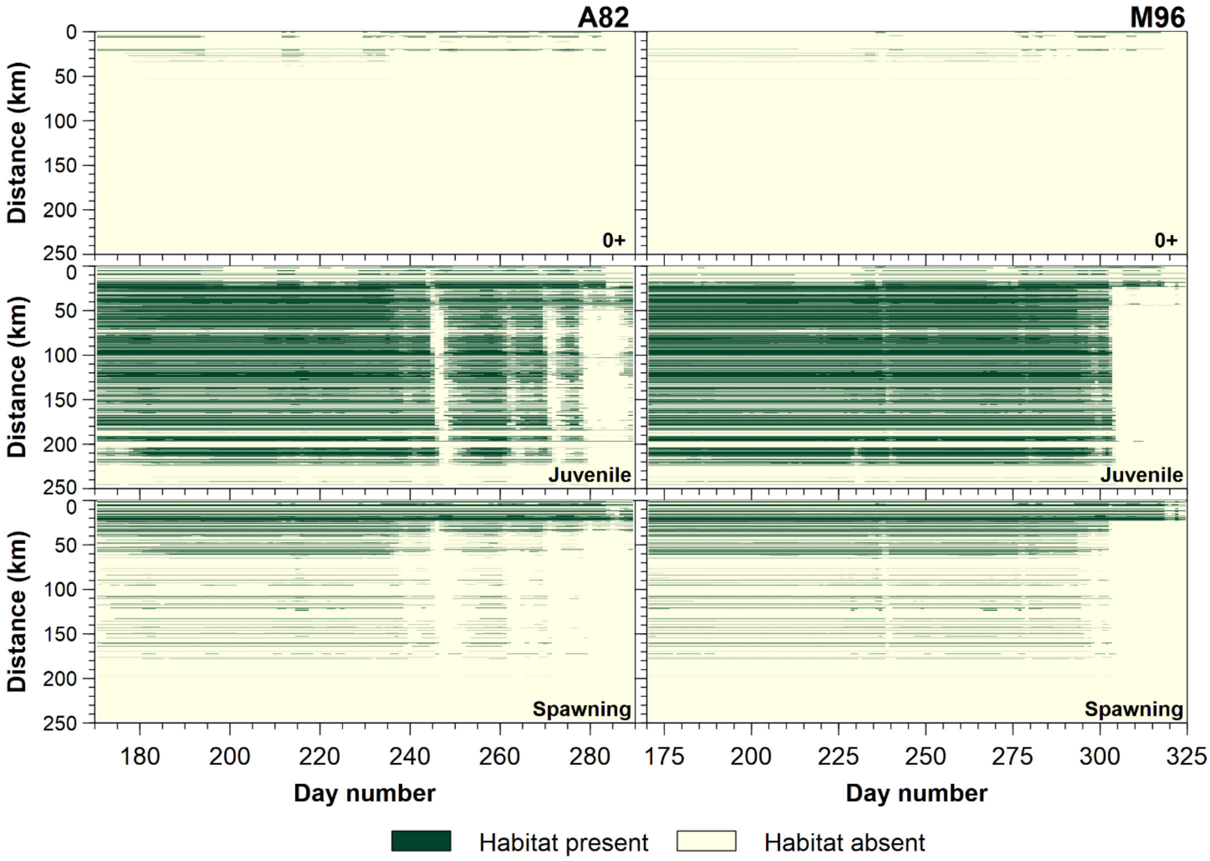


Figure A 40 Down reach baseline Brown / sea trout habitats

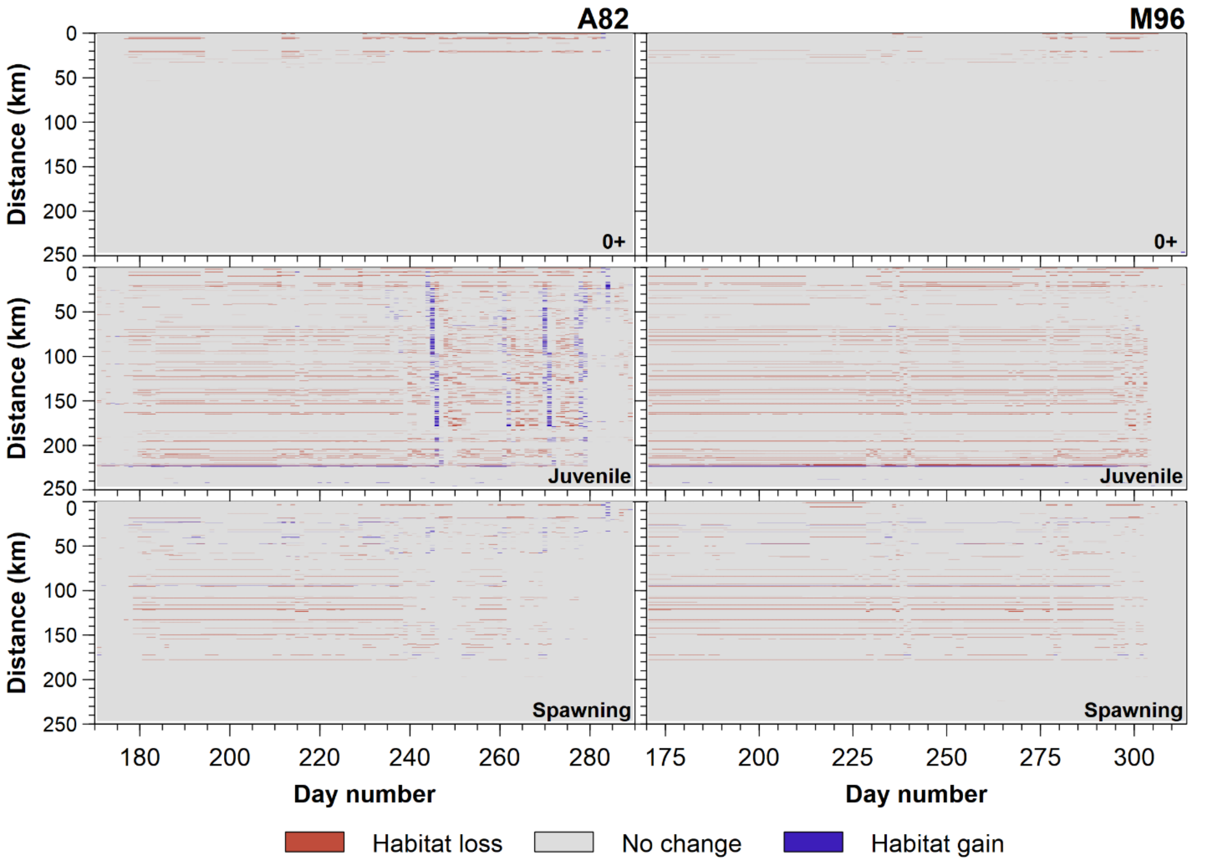


Figure A 41 Down reach changes in Brown / sea trout habitats between reference conditions and release

Lamprey sp. Ammocoetes

The down reach baseline Lamprey habitat for the reference conditions is presented in **Figure A 42**.

For each of the Lamprey life stages, when compared to the model habitat baseline, the data indicate the following baseline habitat presence and distribution:

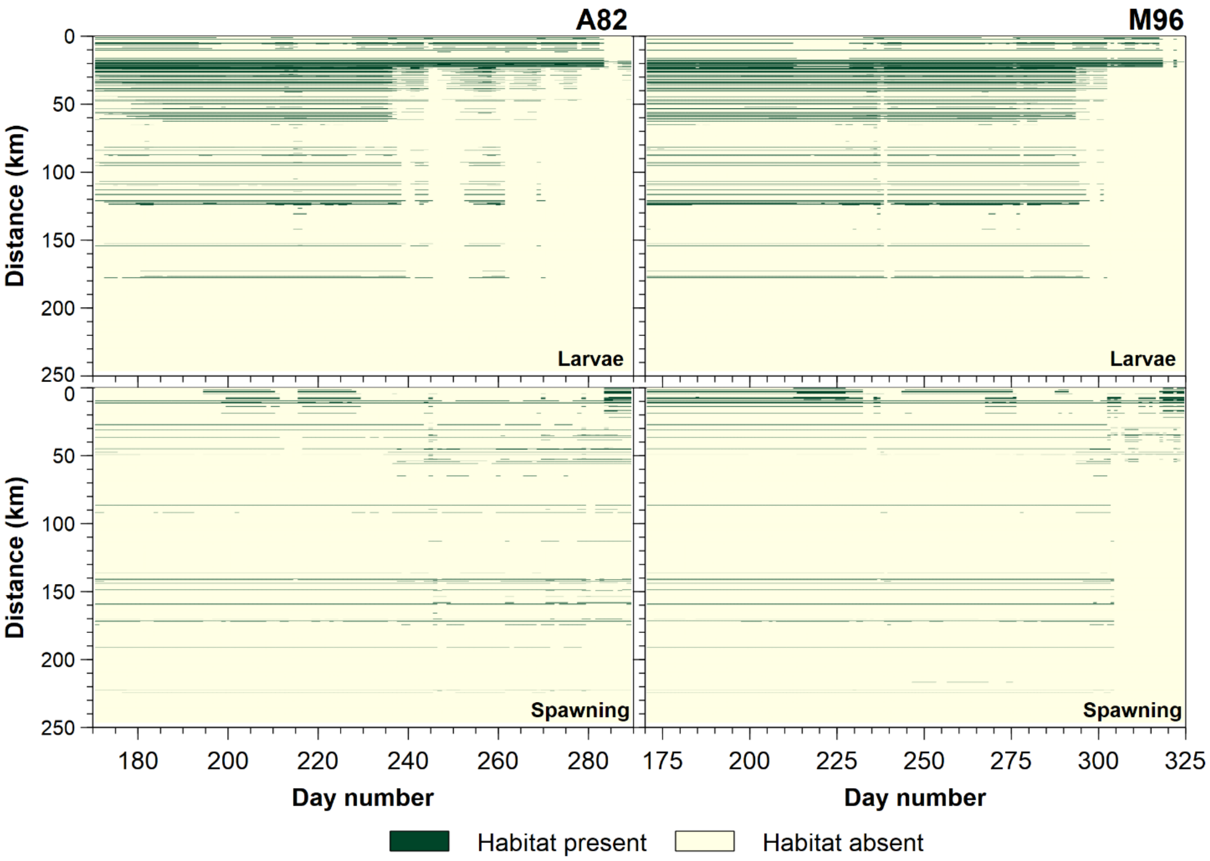
- **Larvae** – For both model runs, there is limited suitable larvae flow habitat, with 8% for the A82 run and 9% for the M96 run. There is temporal variability in habitat from around day 245 to day 280, and this is related to changes in river flow, although these changes are ameliorated somewhat for the M96 runs suggesting these are related to low flows. The suitable habitat is mostly concentrated in the initial 60km of the reach, although there is some between 100-120km downstream.
- **Spawning** – For both the A82 and M96 model runs, there is very limited suitable habitat present, covering only ~2% of the reach. This is sparsely distributed through the reach, although there is more habitat in the initial 50km, particularly for the M96 run.

The down reach change in Lamprey habitat between the modelled reference conditions and when the release is operating is presented in **A 43**.

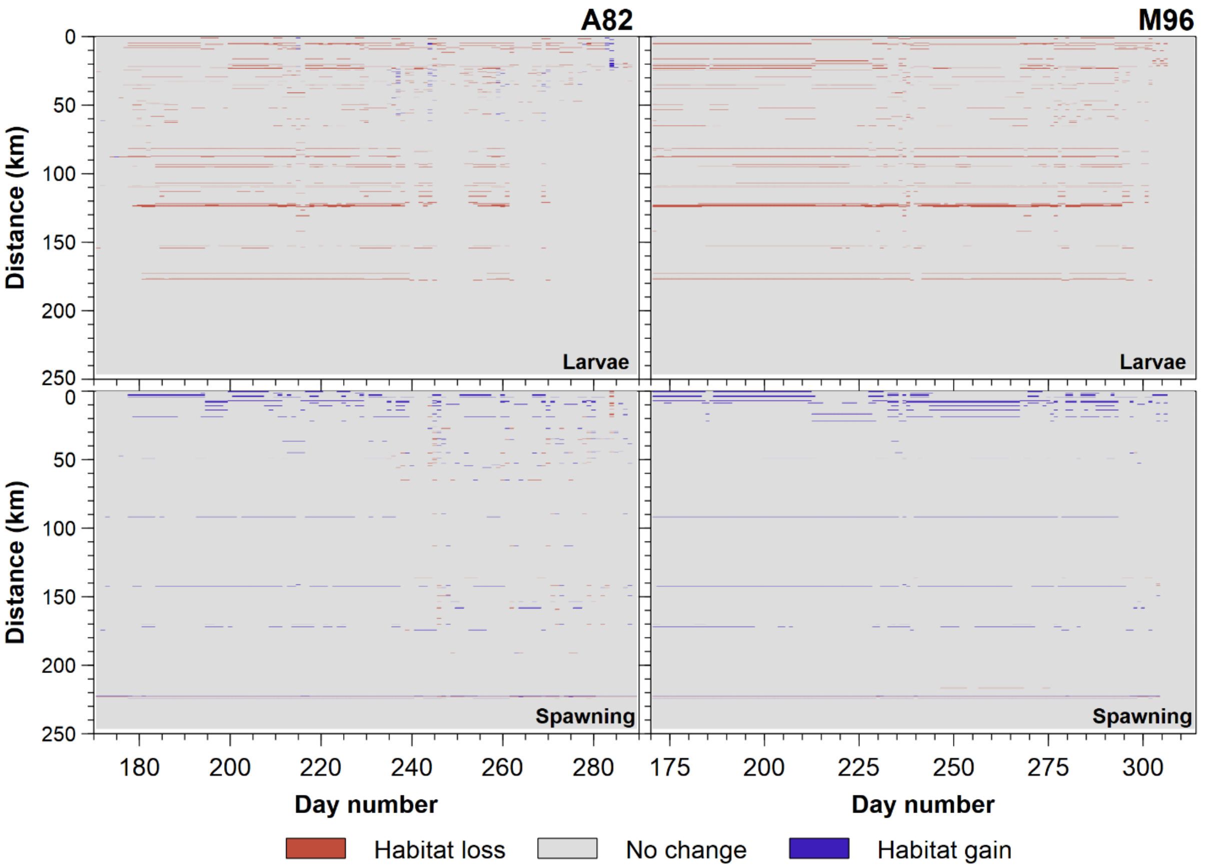
For each of the Lamprey life stages, when compared to the model habitat baseline, the habitat data indicate:

- **Larvae** – For the A82 and M96 model runs, ~98% of the habitat remains unchanged, with around a 1.5-2.0% loss in habitat and a gain of only 0.1% for the A82 run, and no gains for the M96 run. Most habitat loss is spread over the initial 120km of the reach, although there are areas of increased loss in the initial 20km and between 100-120km downstream.
- **Spawning** – For spawning habitat 99% of the habitat remains unchanged for the A82 and M96 runs respectively. However, there is 0.6% (A82) and 0.7% (M96) gain in habitat for both runs and only 0.2% (A82) and 0.1% (M96) habitat loss. The gain in habitat is concentrated in the initial 20km of the River Vyrnwy, although there are some very localised gains further downstream.

The model data indicate that there could be limited loss of Lamprey larvae habitat, mostly spread over the initial 120km of the reach, and a potential for some limited, localised gains in spawning habitat in the initial 20km.



A 42 Down reach baseline Lamprey habitats



A 43 Down reach changes in Lamprey habitats between reference conditions and release

Chub

The down reach baseline Chub habitat for the reference conditions are presented in **A 44**.

For each of the Chub life stages, when compared to the model habitat baseline, the data indicate the following baseline habitat presence and distribution:

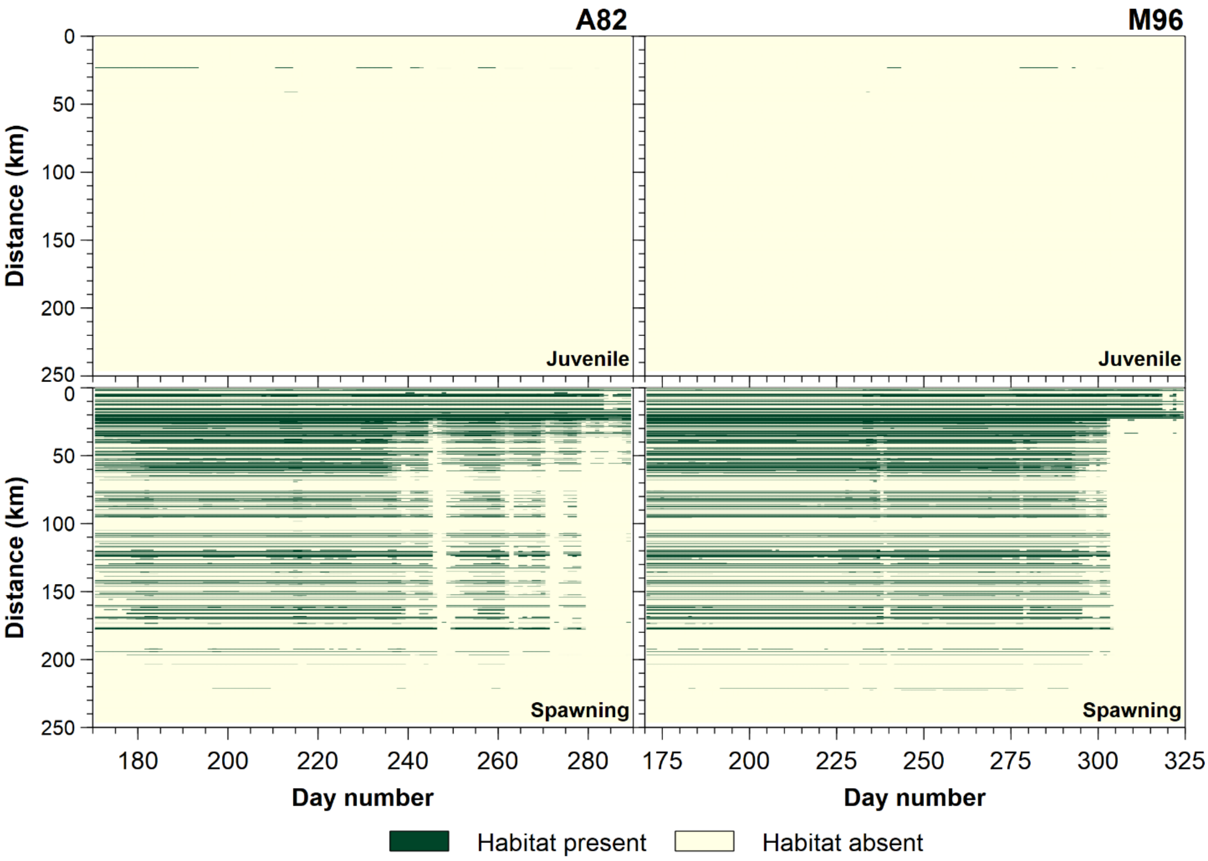
- **Juvenile** – For both model runs, juvenile habitat covers only 0.1% of the reach for the A82 model run and is absent completely for the M96 run.
- **Spawning** – For both the A82 and M96 model runs there is some suitable spawning habitat present. For the A82 run, 19% of the reach is covered by suitable habitat, increasing to 21% for the M96 runs. There is temporal variability in habitat from around day 245 to day 280, and this is related to changes in river flow, although these are ameliorated somewhat for the M96 runs suggesting these are related to low flows. Suitable habitat is fairly evenly spread from the start of the reach to ~180km downstream, although there is a higher concentration in the initial 50km.

The down reach change in Chub habitat between the modelled reference conditions and when the release is operating is presented in **A 45**.

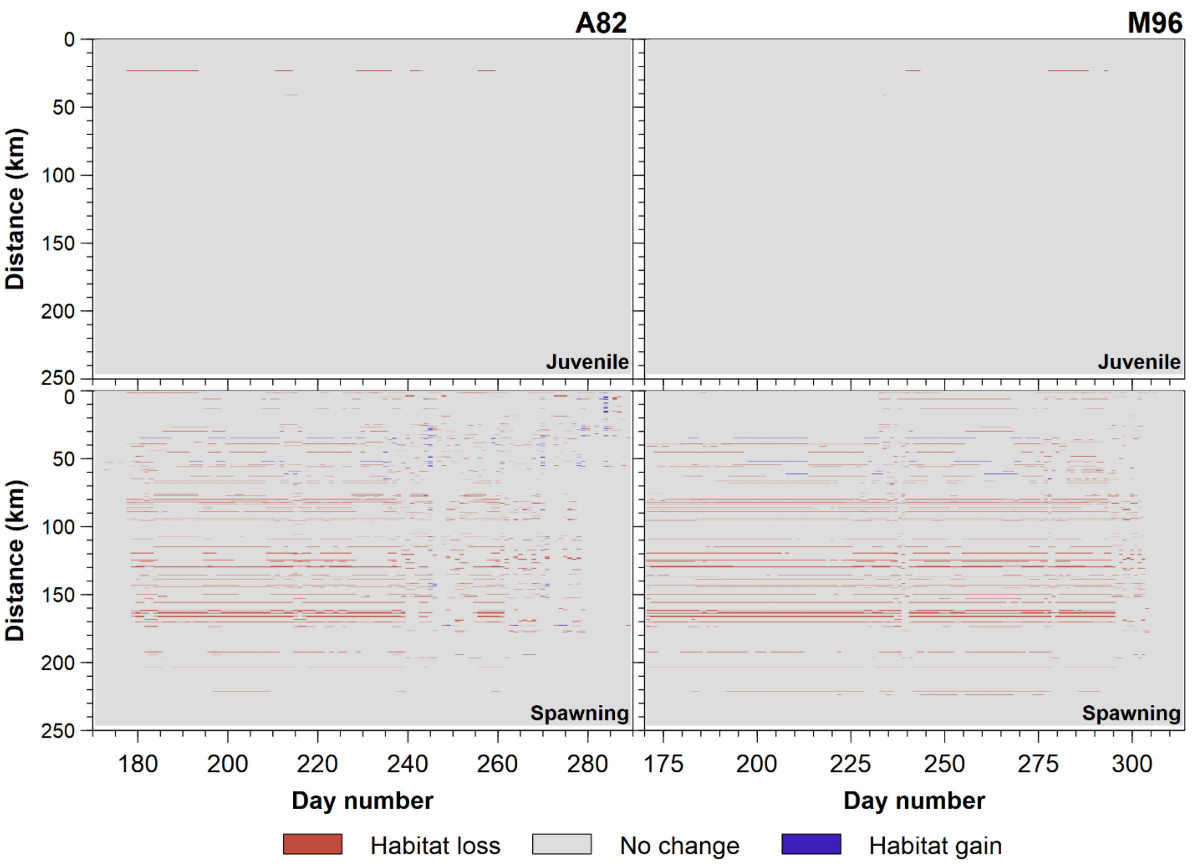
For each of the Chub life stages, when compared to the model habitat baseline, the habitat data indicate:

- **Juvenile** – For the A82 and M96 model runs, there is essentially no change in habitat, with only 0.1% loss for the A82 run and no loss indicated for the M96 run.
- **Spawning** – For spawning habitat 98% and 97% remains unchanged for the A82 and M96 runs respectively. There is however a 2.2% and 2.9% loss for the A82 and M96 runs respectively, with only 0.1% habitat gain for both. Losses are spread throughout 200km of the reach, although concentrations of loss increase between 30-70km and 160-170km downstream.

For the A82 and M96 runs, juvenile habitat remains essentially unchanged, although there is increased spawning habitat loss.



A 44 Down reach baseline Chub habitats



A 45 Down reach changes in Chub habitats between reference conditions and release

Roach

The down reach baseline Roach habitat for the reference conditions are presented in **A 46**.

For each of the Roach life stages, when compared to the model habitat baseline, the data indicate the following baseline habitat presence and distribution:

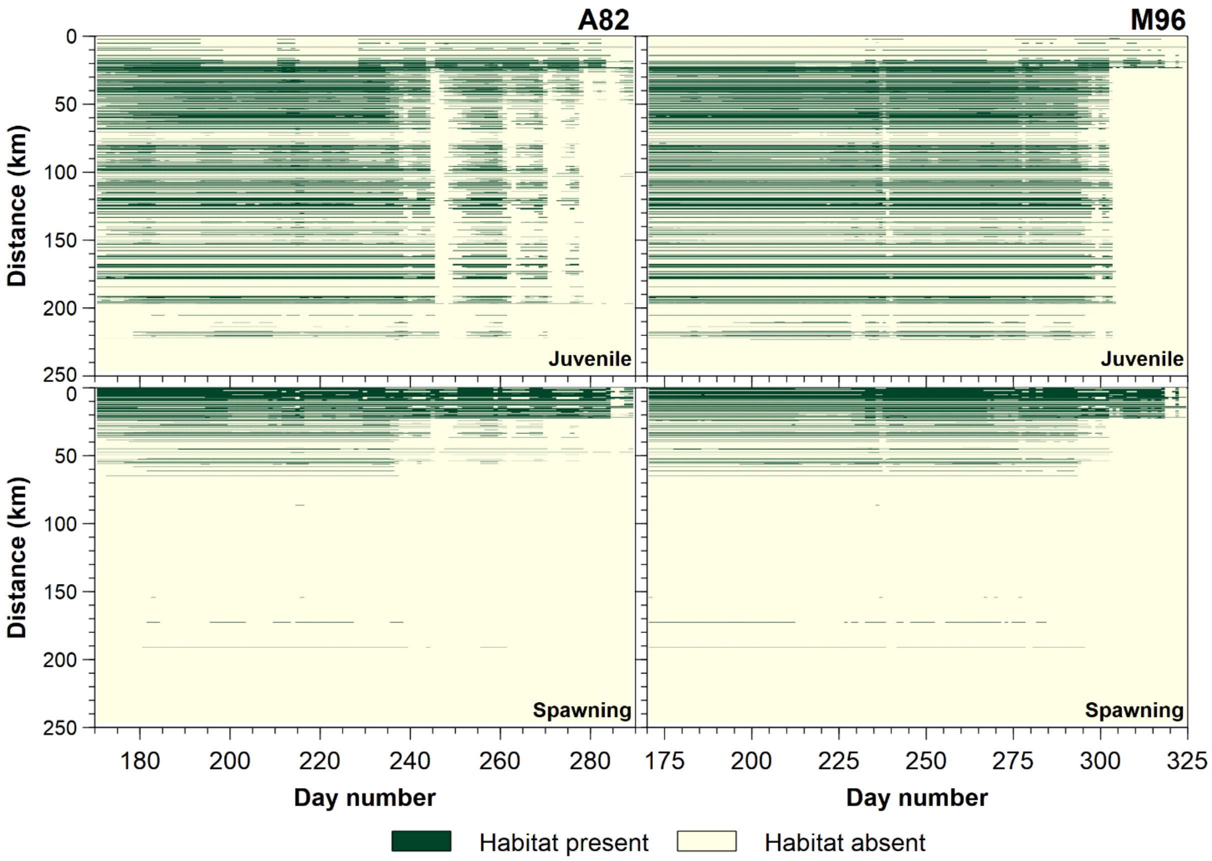
- **Juvenile** – For both the A82 and M96 model runs, there is suitable spawning habitat present. For the A82 run, 22% of the reach is covered by suitable habitat, increasing to 26% for the M96 runs. There is temporal variability in habitat from around day 245 to day 280, and this is related to changes in river flow, although these are ameliorated somewhat for the M96 runs suggesting these are related to low flows. Suitable habitat is fairly evenly spread from the start of the reach to ~200km downstream, although there is a higher concentration in the initial 70km.
- **Spawning** – For both the A82 and M96 model runs, there is very limited suitable spawning habitat present in the reach, at ~6% for both the A82 and M96 runs. The majority of the suitable habitat is concentrated in the upper River Vyrnwy between 0-30km downstream.

The down reach change in Roach habitat between the modelled reference conditions and when the release is operating is presented in **A 47.**

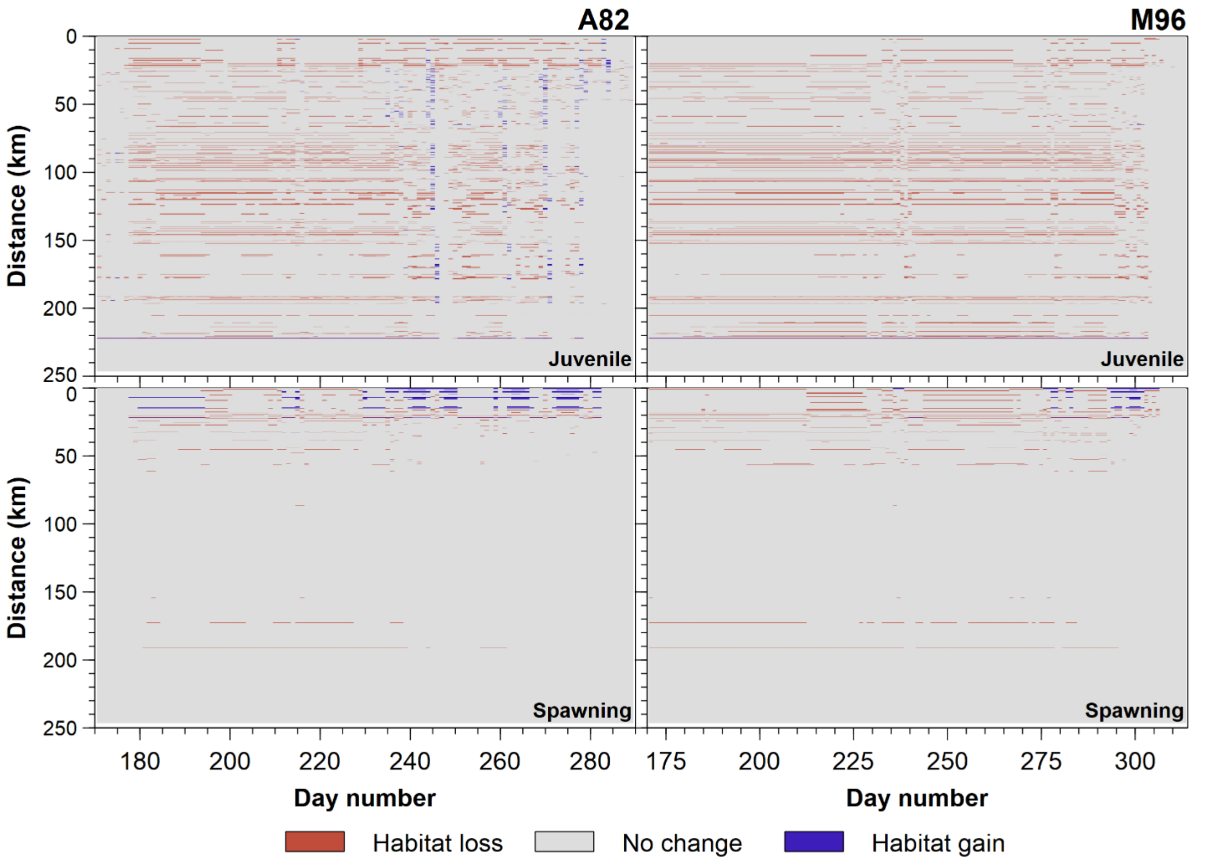
For each of the Roach life stages, when compared to the model habitat baseline, the habitat data indicate:

- **Juvenile** – For the A82 and M96 model runs, there is a habitat loss of 4.3% for the A82 run and 5.5% for the M96 run. There is 0.1% (M96) and 0.4% (A82) gain. 95.4% (A82) and 94.5% (M96) of the habitat remains unchanged. The loss of habitat is distributed relatively evenly across the initial 150km of the reach, with an area of loss around 200-220km. Most gains seem to be focussed around specific periods between day 250 and day 280 (September to October 2022) for the A82 run.
- **Spawning** – For spawning habitat 99% remains unchanged for both runs. There is however a 0.5% and 0.9% loss for the A82 and M96 runs respectively, accompanied by a 0.2% and 0.1% habitat gain for A82 and M96 runs respectively. Losses are mostly concentrated in the first 30km downstream. The habitat gains are spatially limited to around 20km downstream and occur sporadically between day 210 to day 280 for the A82 run (August to October 2022) and day 275 to day 305 for the M96 run (October to November 2022).

For the A82 and M96 runs losses in habitat are noted to occur, with juvenile habitat losses distributed over the initial 150km, and juvenile losses focussed around the initial 30km. There are some habitat gains, however the losses for juvenile are notably higher than for the other fish species under the model runs.



A 46 Down reach baseline Roach habitats



A 47 Down reach changes in Roach habitats between reference conditions and release

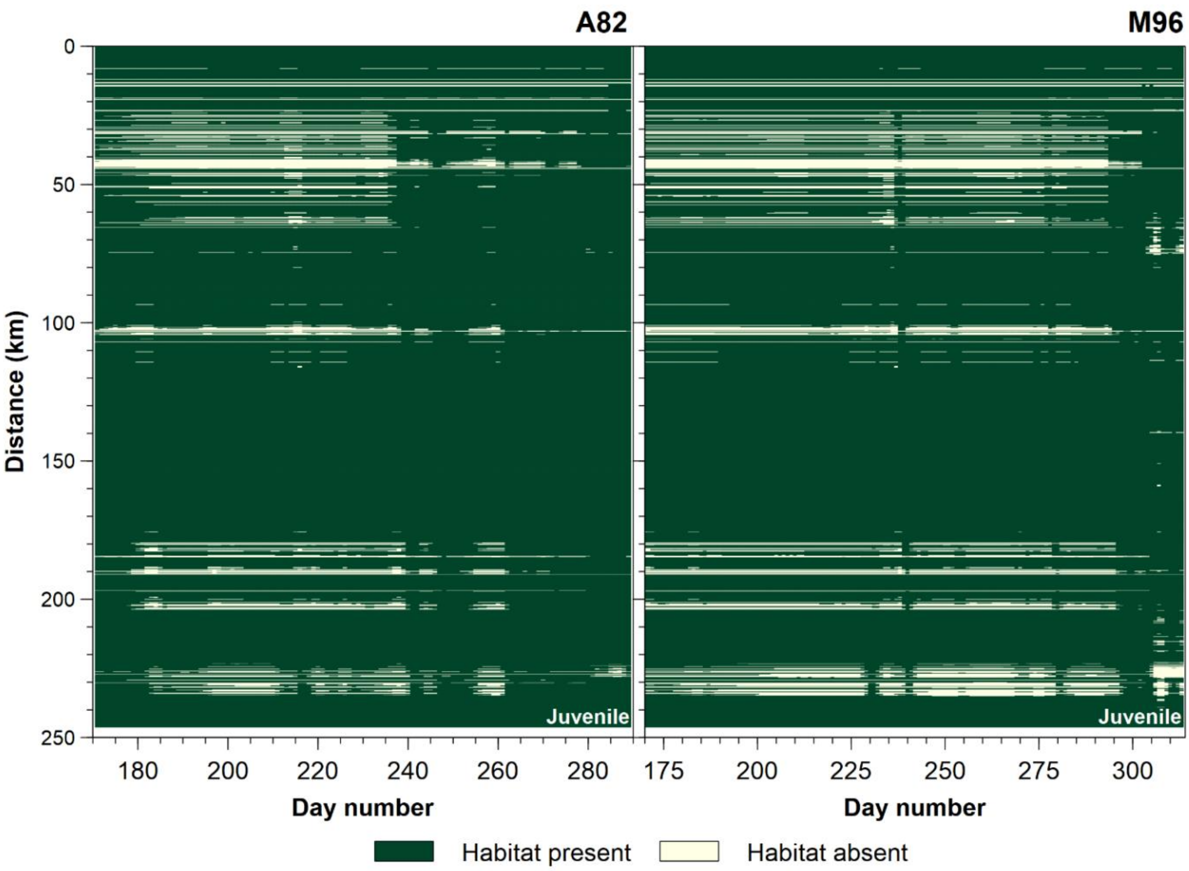
European eel

The down reach baseline European eel habitat for the reference conditions is presented in **A 48.**

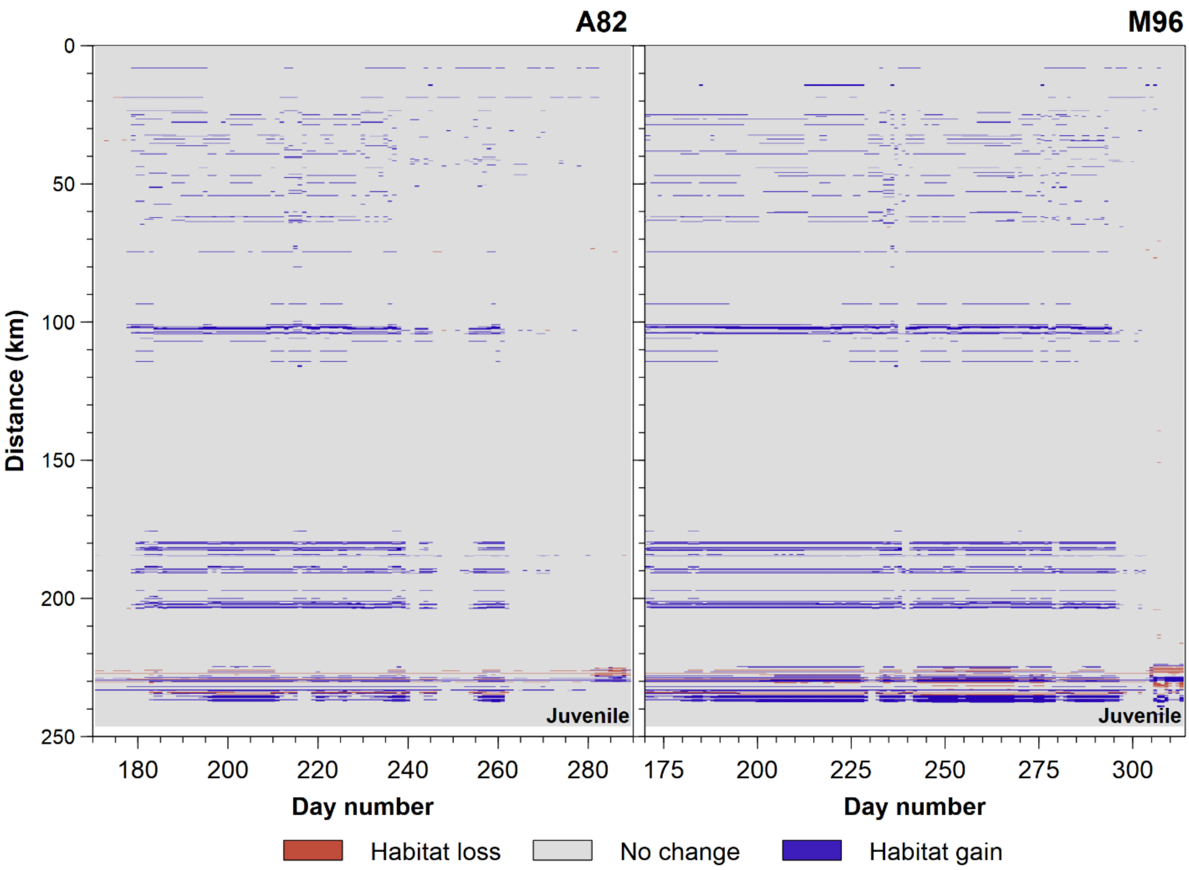
For the European eel juvenile habitat there abundant habitat in the study reach for the model runs, with 91% for the A82 run, dropping slightly to 86% for the M96 run.

The down reach change in European eel habitat between the modelled reference conditions and when the release is operating is presented in **Figure A 49**.

For the European eel juvenile habitat there are no major changes in habitat, although gains of ~3% for the A82 run and ~5% for the M96 run are seen, mostly 100km and downstream. There are some areas of habitat loss (<1% for both runs), though these are concentrated around 220-240km downstream, significantly around areas where habitat gain is noted.



A 48 Down reach baseline European eel habitats



A 49 Down reach changes in European eel habitats between reference conditions and release

A.7.2 MINWORTH RELEASE

To analyse any potential changes in habitat due to the Minworth release a study reach of ~124km in length has been used, beginning on the River Avon at the confluence with the River Sowe, continuing along the River Avon and then into the River Severn at its confluence with the River Avon at 108km downstream and ending at the tidal limit of the River Severn (**A 37**).

Atlantic salmon

The down reach baseline Atlantic salmon habitat for the reference conditions are presented in **A 50**.

For each the Atlantic salmon life stages, the data indicate the following baseline habitat presence and distribution:

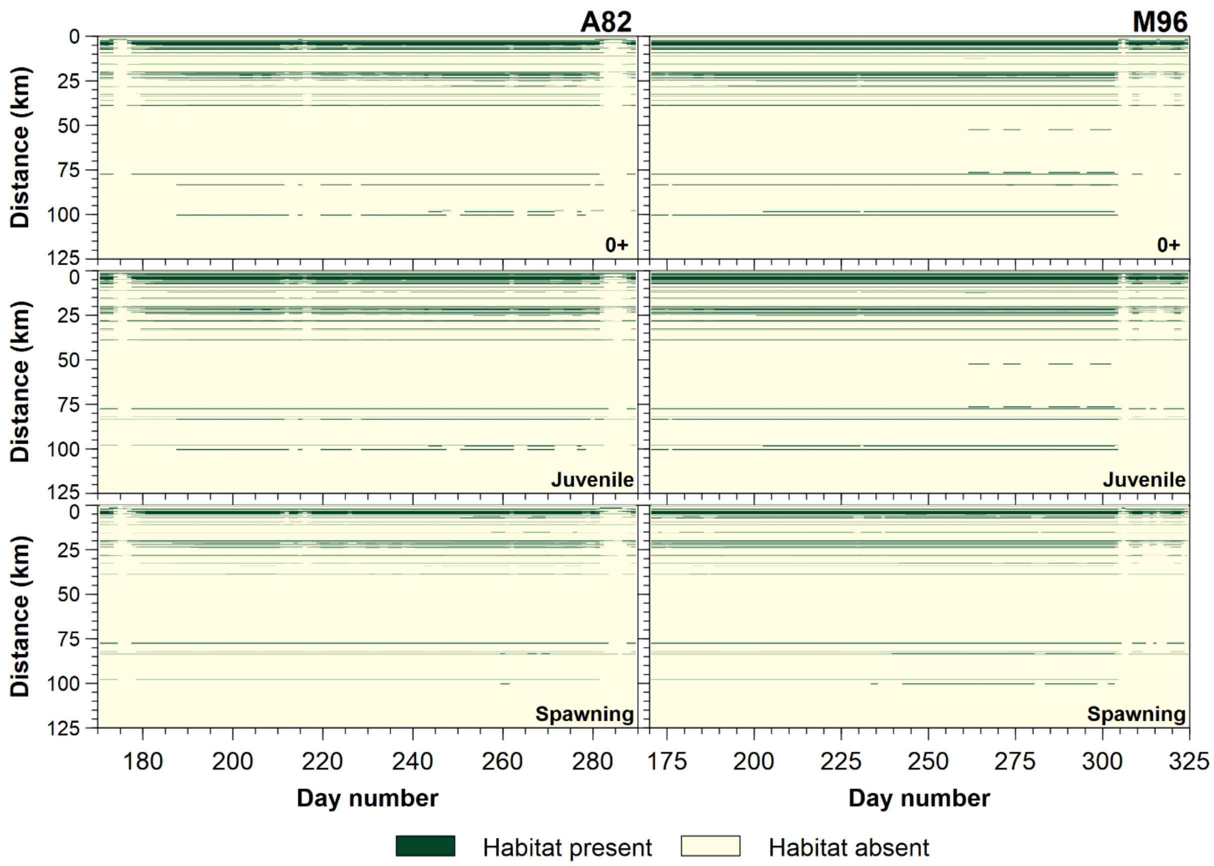
- **0+** – For the A82 model runs 8% of the study reach contains suitable flow habitat, while for the M96 run this increases slightly to 9% of the study reach. Most habitat is distributed over the first 25km of the River Avon, with some reduction in habitat around day 210 to day 220, likely due to reductions in flow as these reductions are not as clear in the M96 runs.
- **Juvenile** – For the A82 model runs 10% of the study reach contains suitable flow habitat, while for the M96 run this increases slightly to 11% of the study reach. Habitat distribution and temporal variability is relatively unchanged from 0+ habitat.
- **Spawning** – For the A82 model runs 7% of the study reach contains suitable flow habitat, while for the M96 run this increases slightly to 8% of the study reach. Habitat distribution and temporal variability is relatively unchanged from to 0+ and juvenile habitat.

For each of the Atlantic salmon life stages, when compared to the model habitat baseline, the habitat data indicate:

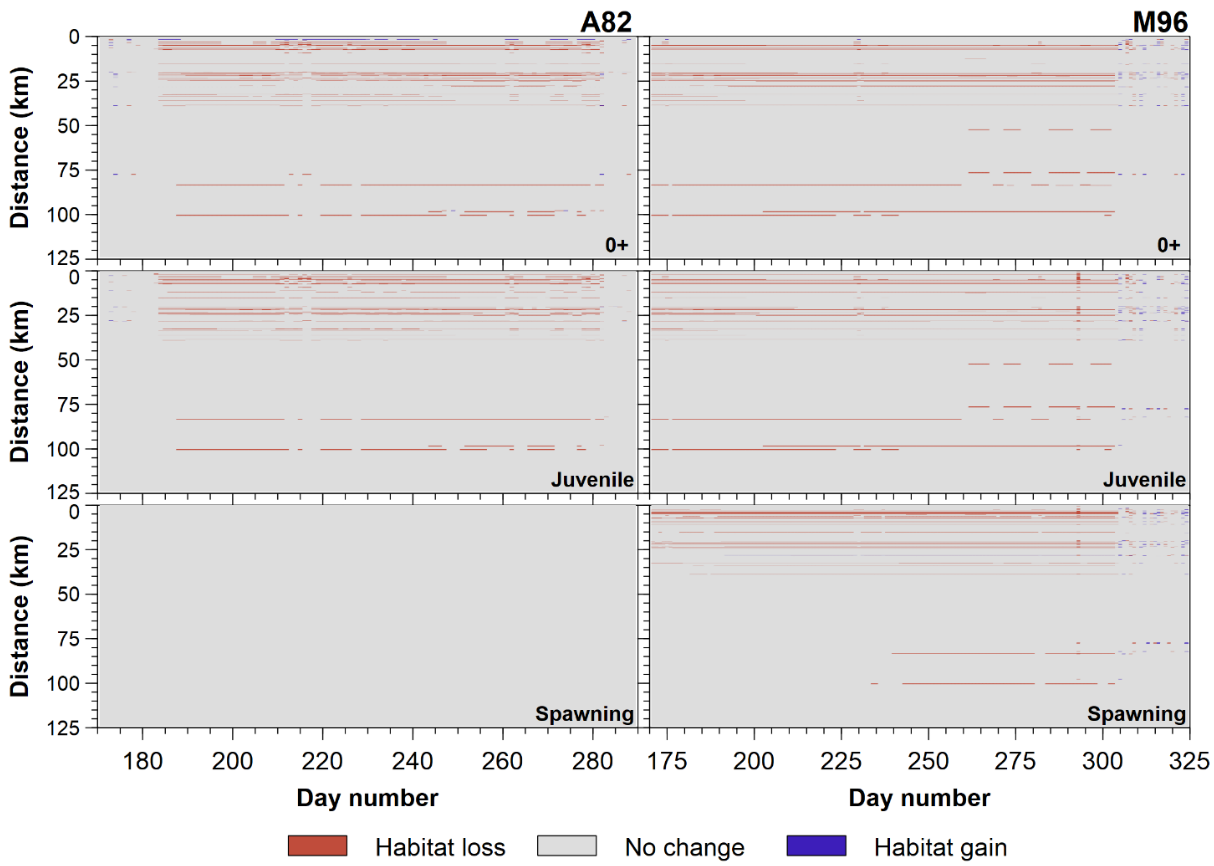
- **0+** – For the A82 and M96 model runs, ~97% of the habitat remains unchanged, with around a 3% loss in habitat (A82 having a slightly higher loss by 0.4%) and a gain of 0.1% for both A82 and M96 runs respectively. Most losses are concentrated in the first 30km of the reach in the River Avon, although there are some losses between 80-100km downstream.
- **Juvenile** – For both model runs, ~97% of the habitat remains unchanged, with around a 3% loss in habitat (A82 having a slightly higher loss by 0.3%) and a gain of 0.1% only for M96 and no gain for A82. Most losses are concentrated in the first 30km of the reach in the River Avon, although there are some losses between 80-100km downstream.
- **Spawning** – For spawning habitat no change in habitat is indicated for the A82 run. For the M96 run there is a 3.4% loss, 0.2% gain and 97% remains unchanged. Where present, habitat losses are focussed in the initial 30km

For the A82 and M96 runs, there is indicated to be relatively minor and local changes from the baseline habitat condition, with much of the changes concentrated in the upper 30km of the reach while the release is in operation.

The down reach change in Atlantic salmon habitat between the modelled reference conditions and when the release is operating is presented in **A 51.**



A 50 Down reach baseline Atlantic salmon habitats



A 51 Down reach changes in Atlantic salmon habitats between reference conditions and release

Brown / sea trout

The down reach baseline Brown / sea trout habitat for the reference conditions are presented in **A 52**.

For each of the Brown / sea trout life stages, the data indicate the following baseline habitat presence and distribution:

- **0+** – There is no habitat present for either the A82 or M96 runs.
- **Juvenile** – For both model runs, much of the study reach contains suitable juvenile habitat, with 56% for the A82 run, increasing slightly to 57% for the M96 run. Although habitat is distributed throughout the reach, the majority of this suitable habitat is focussed in the initial 60km of the reach, with a concentration around 100km.
- **Spawning** – For the A82 model runs 7% of the study reach contains suitable flow habitat, while for the M96 run this increases slightly to 8% of the study reach. The habitat is mostly present in the initial 30km of the reach, with a small amount around 75km downstream.

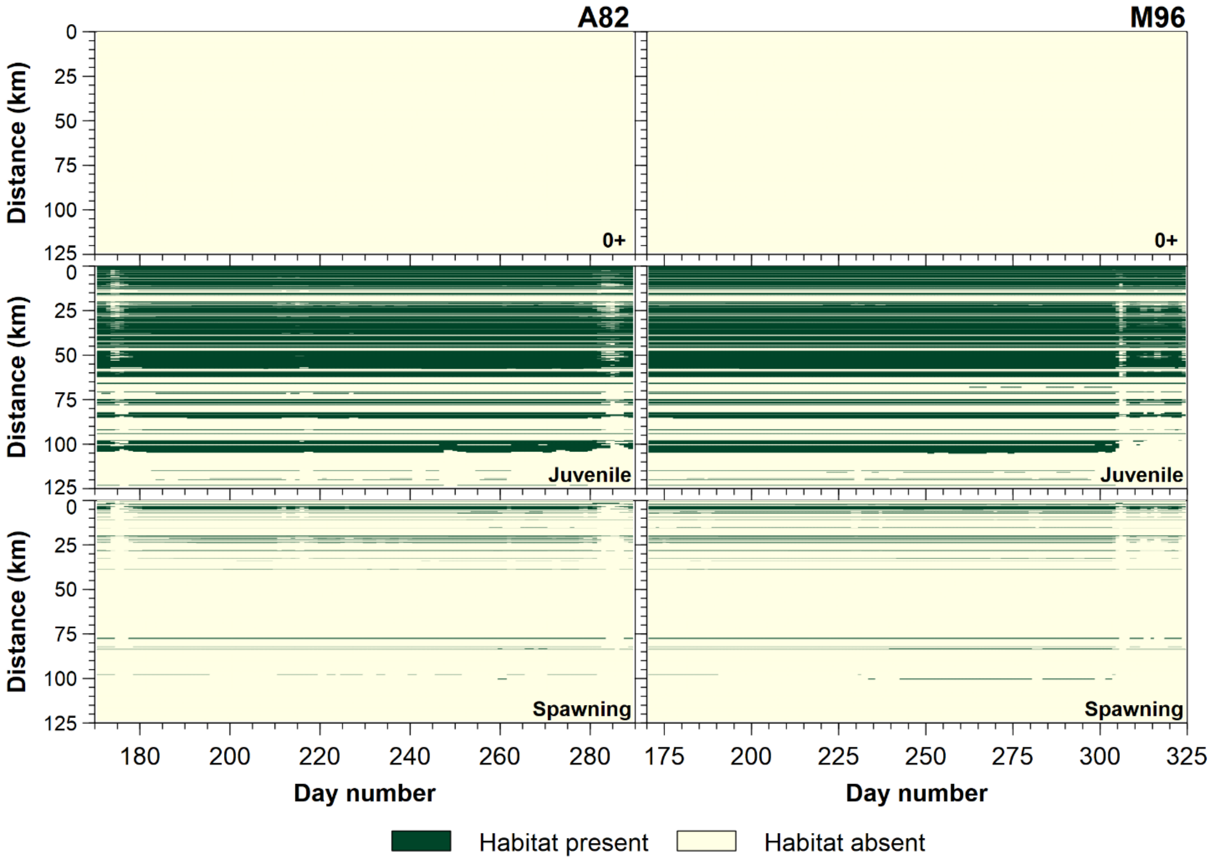
The down reach change in Brown / sea trout habitat between the modelled reference conditions and when the release is operating is presented in **A 53**.

For each of the Brown / sea trout life stages, when compared to the model habitat baseline, the habitat data indicate:

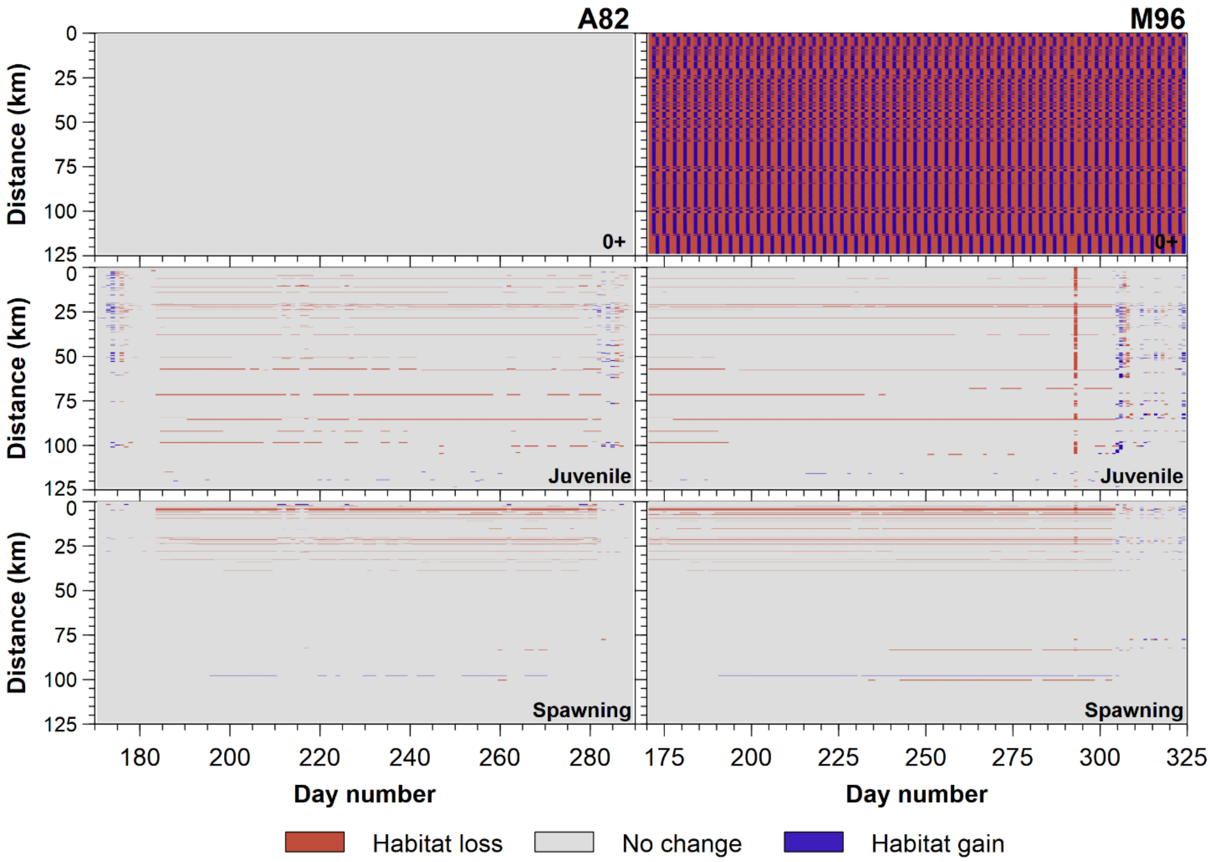
- **0+** – For the A82 model run no habitat change is noted.
- **Juvenile** – For the A82 and M96 model runs, ~98% of the habitat remains unchanged, with around a 2% loss in habitat and a gain of 0.2% and 0.3% for the A82 and M96 runs respectively. Most habitat loss is spread over ~100km. For the M96 run there is a short period of habitat gain over 100km towards the end of October 2022.
- **Spawning** – For spawning habitat 98% and 96% of the habitat remains unchanged for the A82 and M96 runs respectively. There is a 3% and 4% loss for the A82 and M96 runs respectively, while there is only 0.1% (A82) and 0.2% (M96) gain for both runs. Most habitat loss occurs in the first 25km. There are some temporally limited gains in habitat which are localised around 100km downstream.

For the M96 0+ habitat the model displays an unusual response of temporally varying changes in habitat, moving from habitat loss to habitat gain. It is not clear what is driving this, although it appears to be in significant contrast to the A82 0+ habitat runs.

The model data indicate that there could be a limited but focussed loss of habitat in the upper 25km of the River Avon.



A 52 Down reach baseline Brown / sea trout habitats



A 53 Down reach changes in Brown / sea trout habitats between reference conditions and release

Lamprey sp. Ammocoetes

The down reach baseline Lamprey habitat for the reference conditions are presented in **A 54**.

For each of the Lamprey life stages, when compared to the model habitat baseline, the data indicate the following baseline habitat presence and distribution:

- **Larvae** – For both model runs, there is limited suitable larvae flow habitat, with 6% for the A82 run, increasing slightly to 7% for the M96 run. There is limited temporal variability in habitat from around 245 to 280 days, and this is related to changes in river flow, although these changes are ameliorated somewhat for the M96 runs suggesting these are related to low flows. The suitable habitat is mostly concentrated in the initial 25km of the reach.
- **Spawning** – For both the A82 and M96 model runs there is very limited suitable habitat present, covering only ~0.3% of the reach. This is sparsely distributed through the reach and much of it lies in the initial 30km, occurring before and after the release periods.

The down reach change in Lamprey habitat between the modelled reference conditions and when the release is operating is presented in **Figure A 5**.

For each of the Lamprey life stages, when compared to the model habitat baseline, the habitat data indicate:

- **Larvae** – For the A82 and M96 model runs, ~97% of the habitat remains unchanged, with around a 3% loss in habitat (M96 having a slightly lower loss than A82 by 0.4%) and a gain of only 0.3% habitat gain for both runs. Most habitat loss is spread over the initial 40km downstream, although there are two areas of localised loss at around 80km and 100km downstream over the release period.
- **Spawning** – For spawning habitat nearly all of the habitat remains unchanged with only 0.1% habitat gains indicated for both runs. These sporadic gains occur in the first 30km of the reach.

The model data indicate that there could be a general loss of Lamprey larvae habitat, mostly in the upper reaches of the River Avon with essentially no change for spawning habitat.

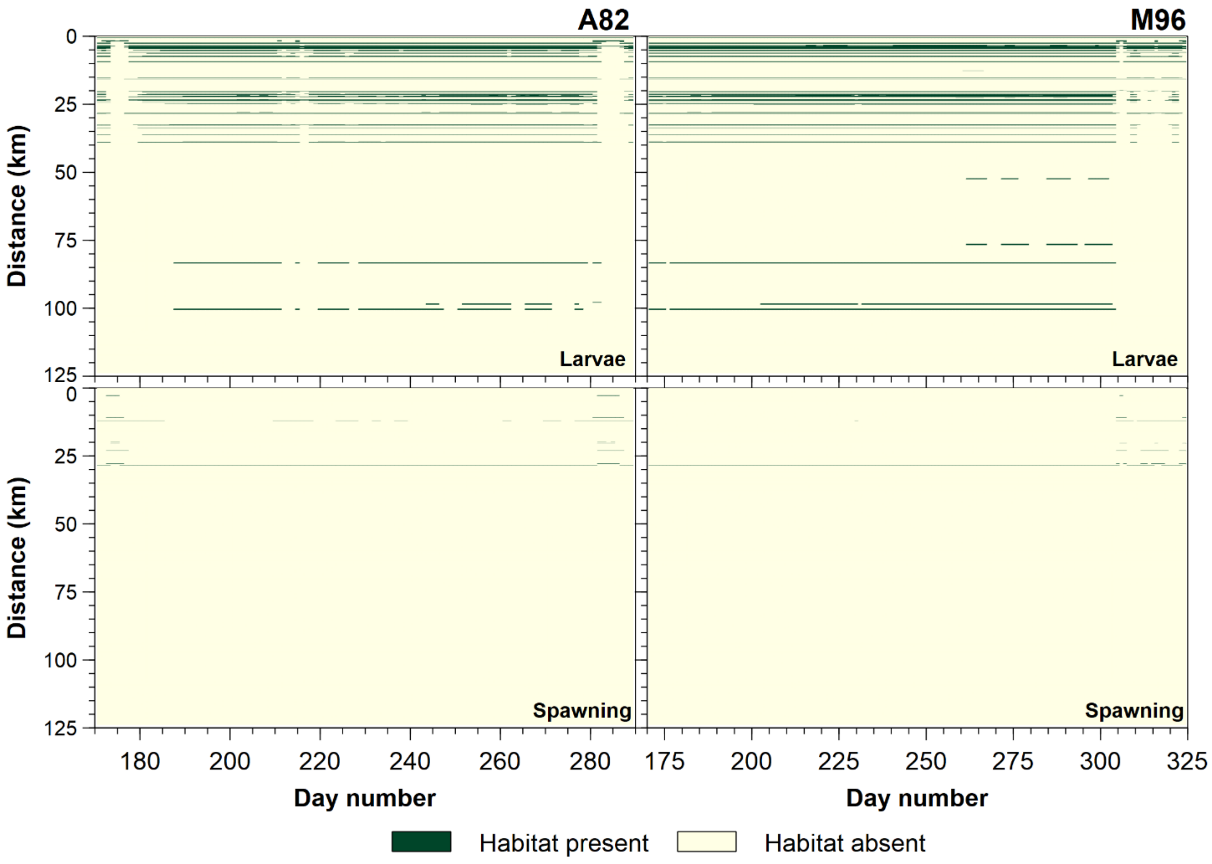


Figure A 54 Down reach baseline Lamprey habitats

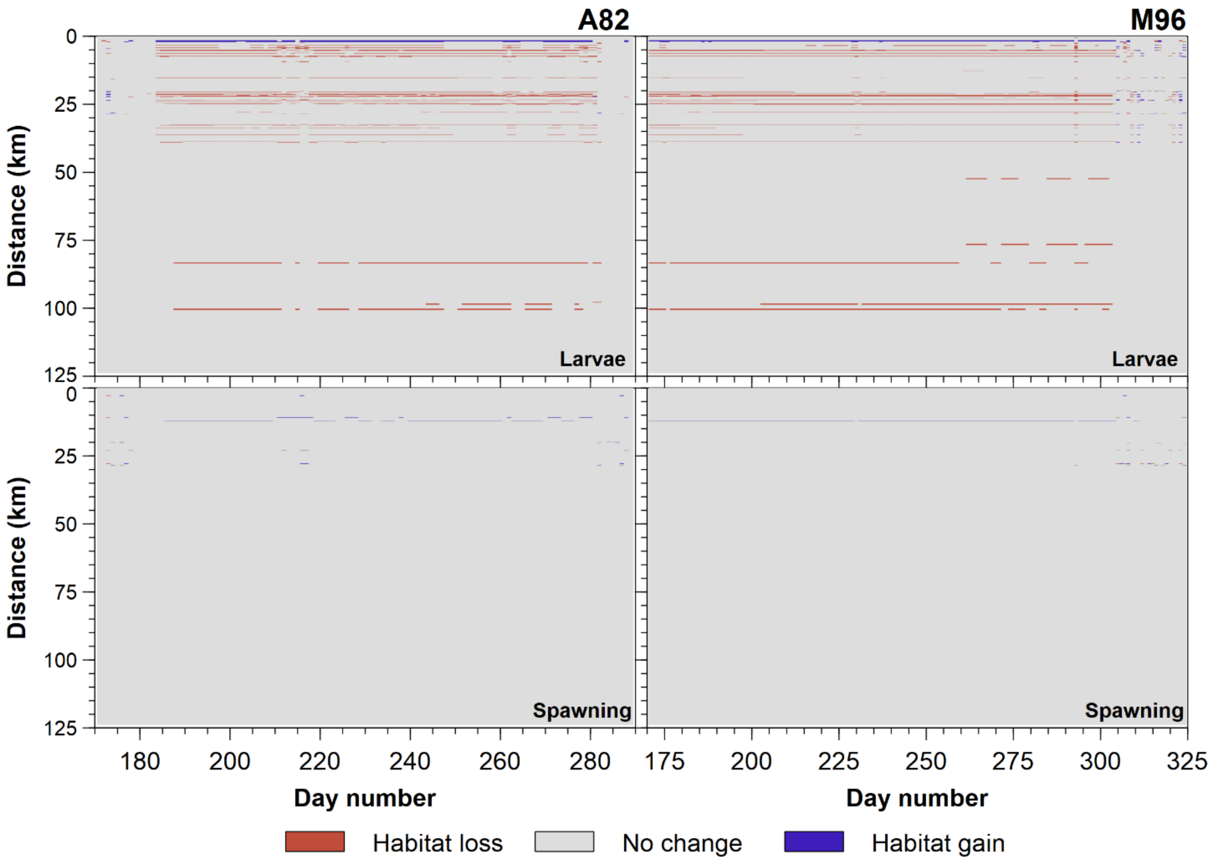


Figure A 55 Down reach changes in Lamprey habitats between reference conditions and release

Chub

The down reach baseline Chub habitat for the reference conditions are presented in **Figure A 55**.

For each of the Chub life stages, when compared to the model habitat baseline, the data indicate the following baseline habitat presence and distribution:

- **Juvenile** – For both model runs, juvenile habitat is very limited, covering only 0.5% (A82) and 0.6% (M96) of the reach. This is concentrated in the initial 5km of the reach.
- **Spawning** – For both the A82 and M96 model runs there is some suitable spawning habitat present. For the A82 run, 18% of the reach is covered by suitable habitat, increasing to 20% for the M96 run. Suitable habitat is spread from 0-60km, with much in the initial 25km. There are pockets of suitable habitat indicated at around 75km and 100km downstream.

The down reach change in Chub habitat between the modelled reference conditions and when the release is operating is presented in **Figure A 57.**

For each of the Chub life stages, when compared to the model habitat baseline, the habitat data indicate:

- **Juvenile** – There is essentially no change in habitat, with only 0.2% and 0.1% of habitat lost for the A82 and M96 model runs respectively. This loss is concentrated in the initial 5km of the reach.
- **Spawning** – For spawning habitat 96% and 95% remains unchanged for the A82 and M96 runs respectively. There is however a 4% and 5% loss for the A82 and M96 runs respectively, with only 0.2% (M96) habitat gain and no gain indicated for the A82 run. Losses are spread throughout the entire reach, but are focussed in the initial 50km of the reach, with concentrations of loss around 75km in the River Avon and 100km downstream in the River Severn.

For the A82 and M96 runs, juvenile habitat remains essentially unchanged, although there is increased spawning habitat loss.

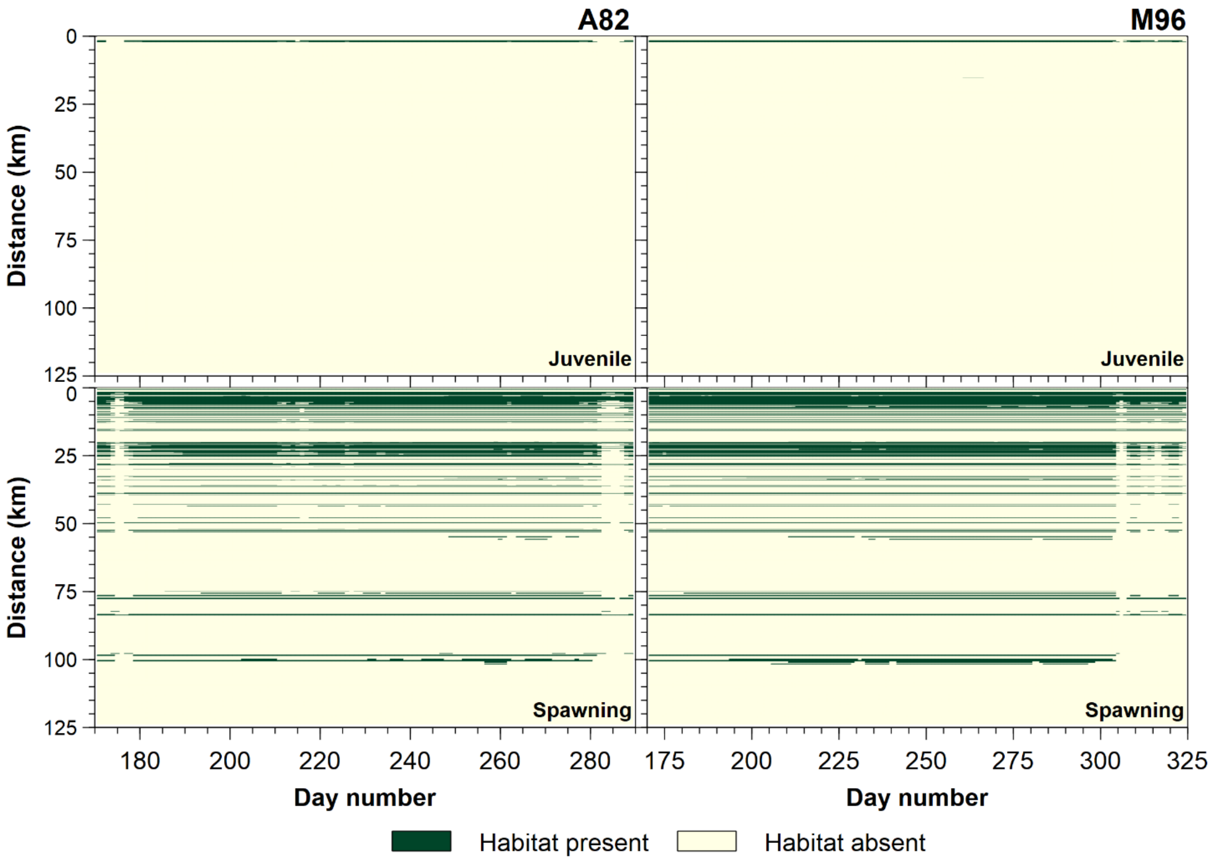


Figure A 56 Down reach baseline Chub habitats

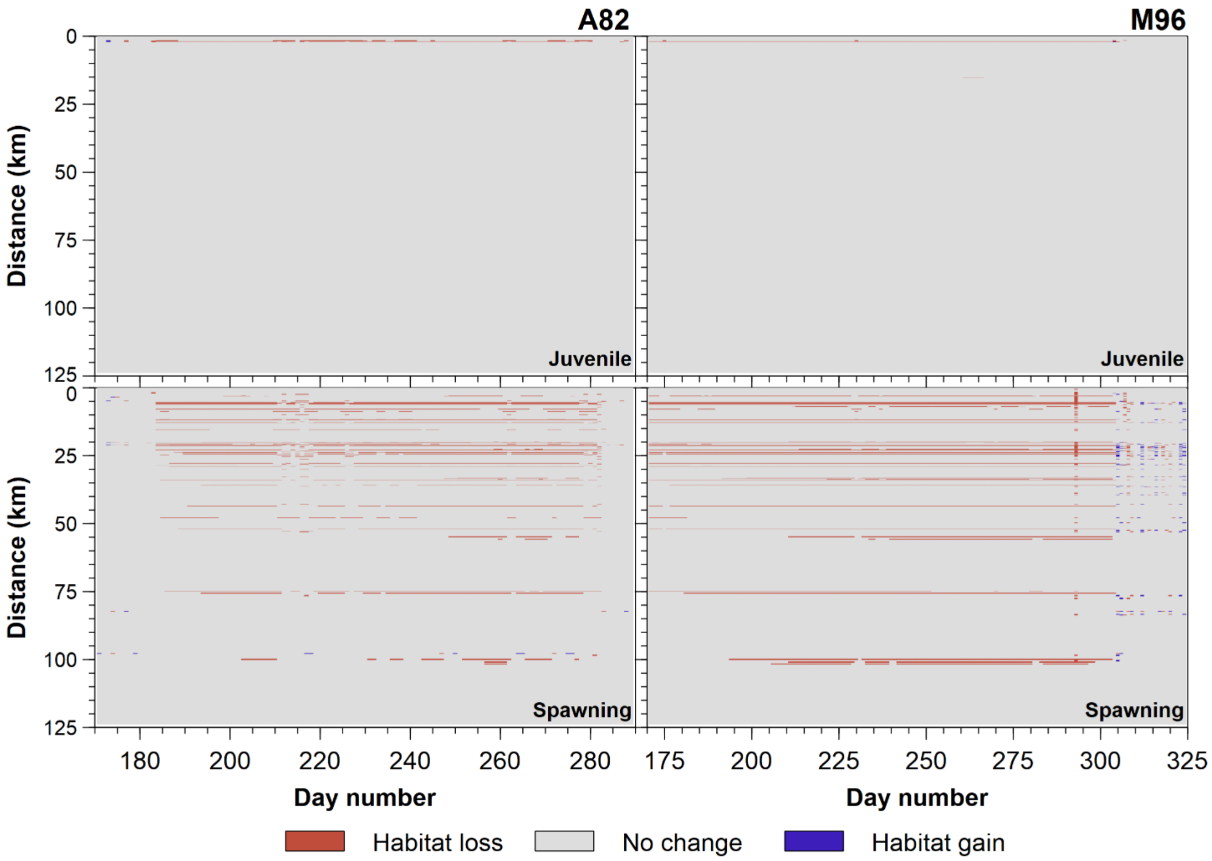


Figure A 57 Down reach changes in Chub habitats between reference conditions and release

Roach

The down reach baseline Roach habitat for the reference conditions are presented in **Figure A 58.**

For each of the Roach life stages, when compared to the model habitat baseline, the data indicate the following baseline habitat presence and distribution:

- **Juvenile** – For both the A82 and M96 model runs there is suitable spawning habitat present over 35% of the reach for the A82 run and 37% of the reach for the M96 run. There is limited temporal variability in habitat and suitable habitat is fairly evenly spread from the start of the reach to ~60km downstream, although there ae pockets of habitat at 75km and 100km downstream.
- **Spawning** – For both the A82 and M96 model runs there is very limited suitable spawning habitat present in the reach, at ~1% of suitable habitat covering the study reach for both the A82 and M96 runs. The majority of the limited suitable habitat is concentrated in the upper River Vyrnwy between 0-30km downstream.

The down reach change in Roach habitat between the modelled reference conditions and when the release is operating is presented in **Figure A 59.**

For each of the Roach life stages, when compared to the model habitat baseline, the habitat data indicate:

- **Juvenile** – For the A82 and M96 model runs there is a habitat loss of ~4% for both model runs, with a 0.2% and 0.4% gain for the A82 and M96 runs respectively. 96% of the habitat remains unchanged. The loss of habitat is distributed relatively evenly across the initial 60km of the reach, with an area of loss around 80km and 100km downstream in the River Avon. For the M96 run there is a short period of habitat loss over 100km towards the end of October 2022. Habitat gains seem to be focussed around specific periods outside of the release windows.
- **Spawning** – For spawning habitat, ~99% remains unchanged for both runs. There is however a 0.6% and 0.8% loss for the A82 and M96 runs respectively with no habitat gains. Losses are mostly concentrated in the first 30km downstream, with very limited losses around 80km downstream.

For the A82 and M96 runs losses in habitat are noted, with juvenile habitat losses being greatest and focussed mostly around the first 60km of the River Avon, while juvenile losses are focussed around the first 30km of the River Avon.

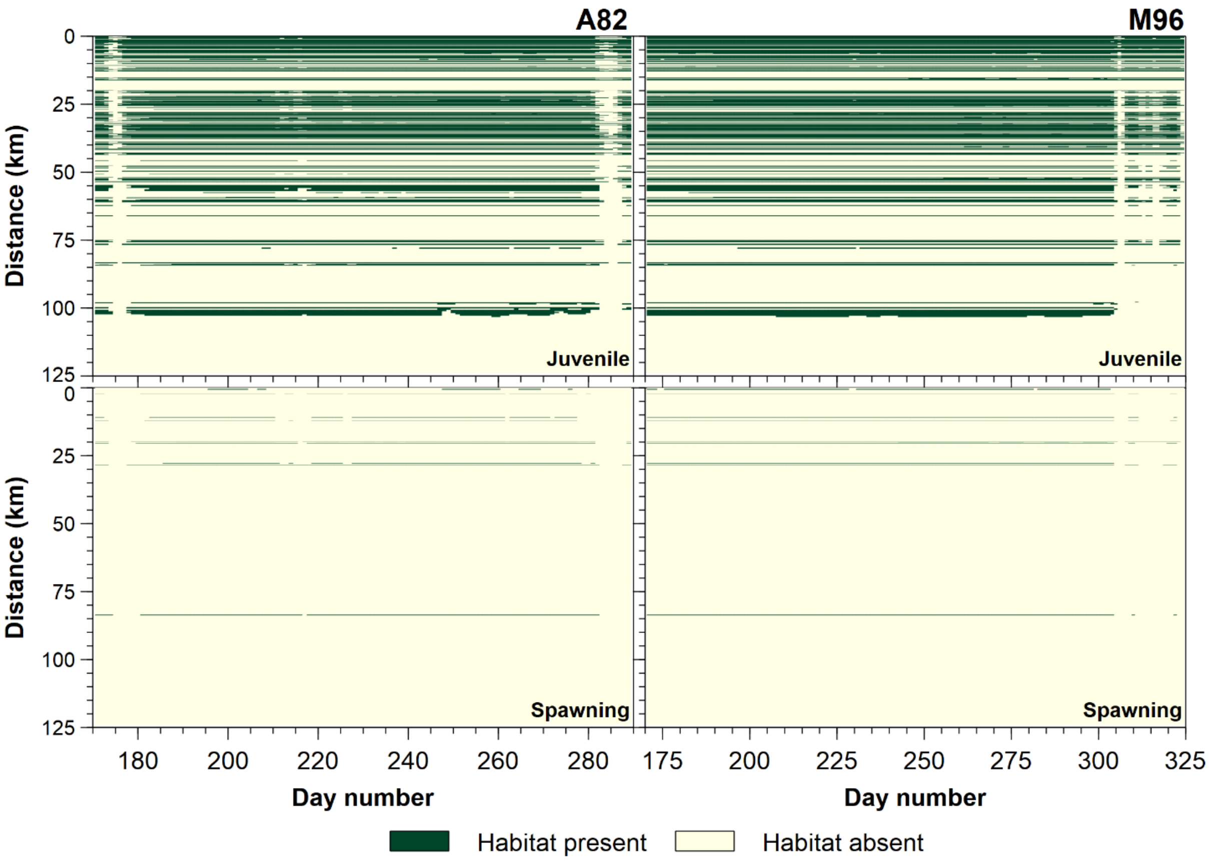


Figure A 58 Down reach baseline Roach habitats

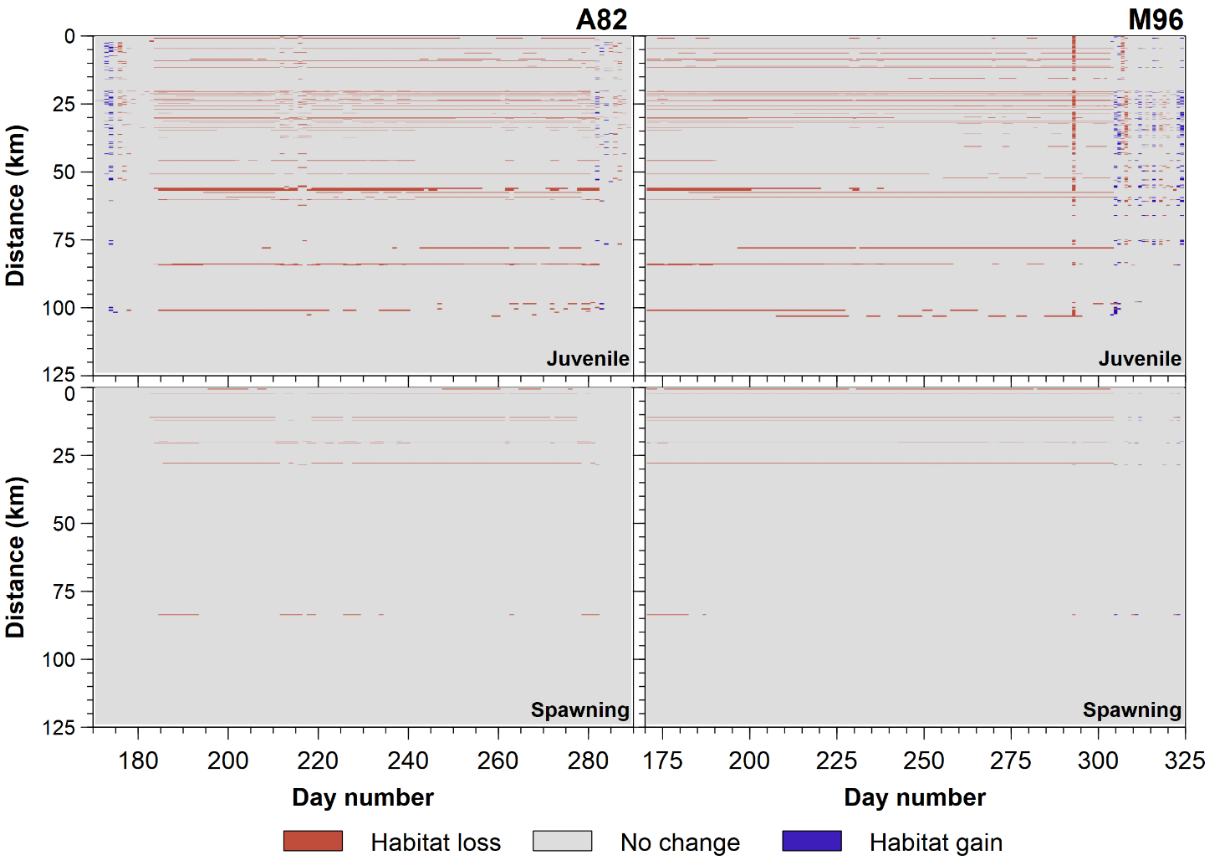


Figure A 59 Down reach changes in Roach habitats between reference conditions and release

European eel

The down reach baseline European eel habitat for the reference conditions are presented in **Figure A 60.**

For the European eel juvenile habitat there is available habitat in the study reach for the model runs, with 66% for the A82 run, dropping slightly to 59% for the M96 run.

The down reach change in European eel habitat between the modelled reference conditions and when the release is operating is presented in **Figure A 61.** For the European eel juvenile habitat there are no significant changes in habitat, although there are notable gains of ~9% for the A82 run and ~15% for the M96 run, these occurring throughout the reach. There are some limited areas of habitat loss (<1% for both runs) which are concentrated in the initial 10km of the reach and around 120km downstream.

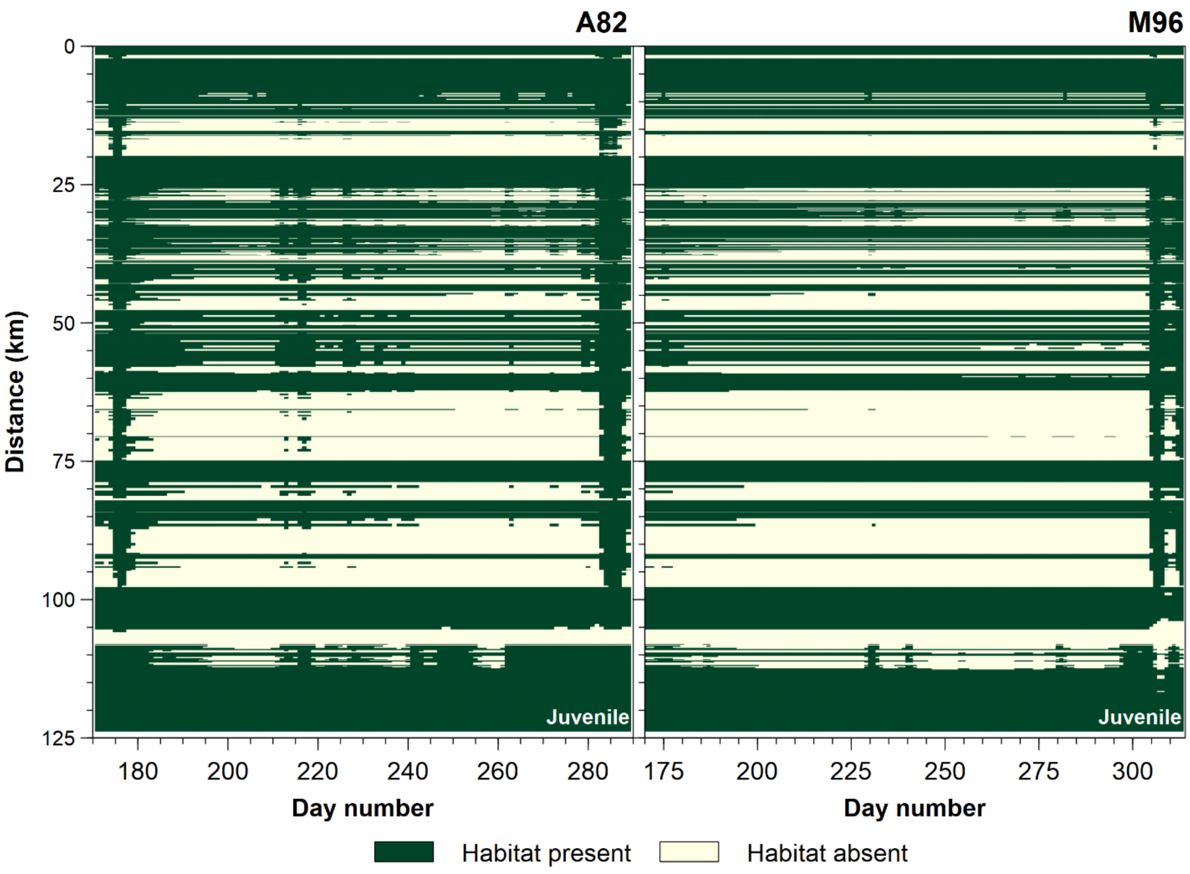


Figure A 60 Down reach baseline European eel habitats

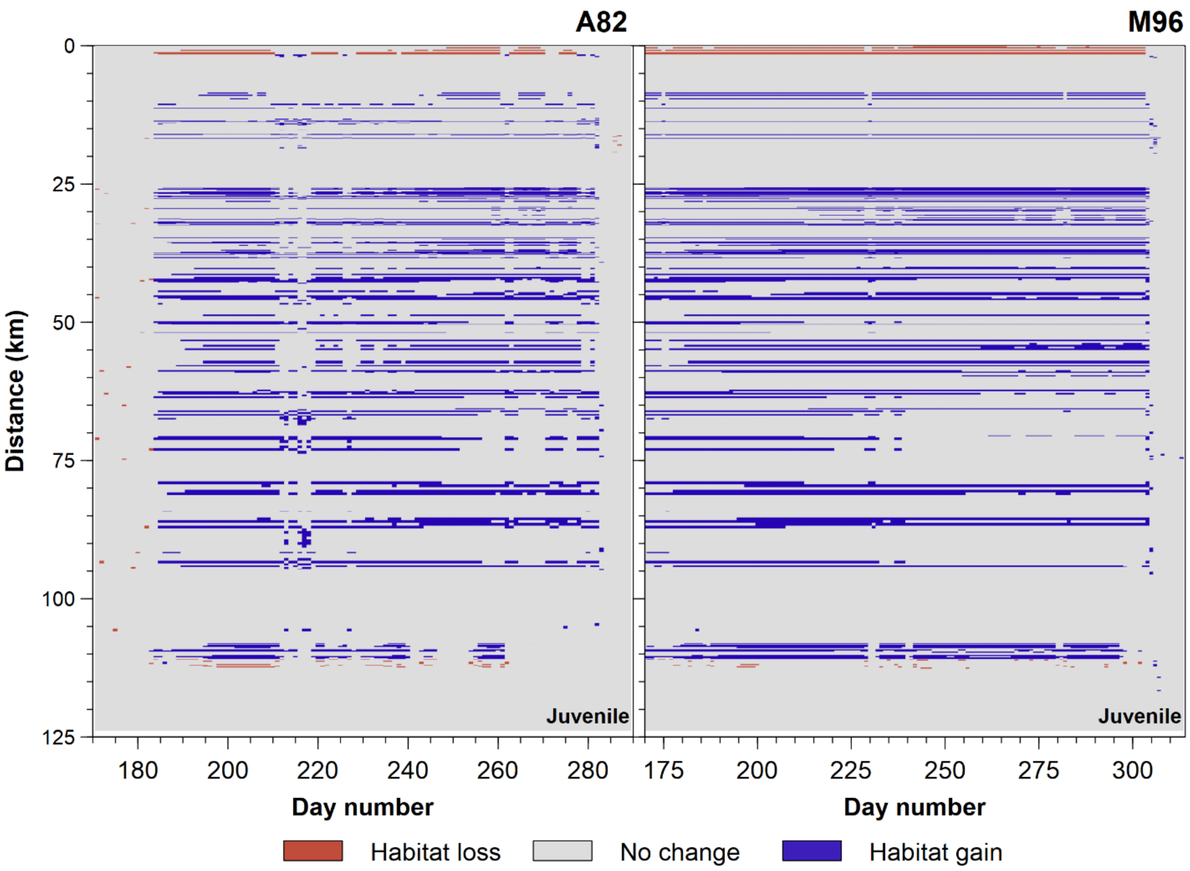


Figure A 61 Down reach changes in European eel habitats between reference conditions and release

A.8 CONCLUSIONS

The following conclusions can be provided based on the in-channel habitat assessment:

- A total of five ADCP survey sites with a range of flows were selected to understand the variability in fish hydraulic habitat preferences (velocity and depth) for six fish species (Atlantic salmon, brown / sea trout, lamprey, chub, roach and European eel) and their associated life cycles.
- Analysis of the ADCP data found that there was a range of suitable hydraulic flow habitat at each of the ADCP survey reaches, although this varied markedly between sites.
- Generally, the amount of suitable flow habitat was found to decrease slightly within increasing flow, although for some fish species at some ADCP survey sections, suitable habitat was found to increase due to increasing hydraulic radius and therefore more marginal inundation.
- Hydraulic predictions taken from the 1D STT hydraulic model were generated from two specific runs, A82 and M96. These represented moderate-low and very low flows respectively. The model outputs were compared with the ADCP data to understand the confidence in the use of the model outputs for understanding habitat variability over the two study reaches, River Avon to River Severn and River Vyrnwy to River Severn.
- The comparison found that although of a higher resolution than the 1D hydraulic model data, the ADCP data could not be used to understand changes in habitat throughout the study reaches due to only a limited range in flows being measured. However, the ADCP data highlighted the lack of granularity in the 1D model data for understanding spatial variability in habitat across a river cross-section and that this could lead to underprediction of habitat suitability and change when using the 1D model data.
- The comparison between the ADCP data and the 1D model indicated that the model data is applicable for understanding the gross changes in habitat across the different survey reaches for the releases.
- Predicted changes in fish habitat for the River Vyrnwy to River Severn due to the Vyrnwy releases (A82 run June to October, M96 run June to November, **Table A 7**) are:
    - **Atlantic salmon** – Generally baseline habitat for 0+, juvenile and spawning habitat is limited to around 10-14% of the reach and is concentrated in the initial 50km of the reach. The releases are forecast to lead to up to a 2% loss of habitat for all fish life cycles, with the loss spread throughout the reach and concentrated between 80-120km downstream.
    - **Brown / sea trout** – There is limited baseline habitat for 0+ life stages (<1%), but nearly 50% of the reach suitable for juvenile habitat and ~10% suitable for spawning habitat. Under releases, there is a loss of ~1-4% habitat, although juvenile habitat shows some very modest (<1%) gain in habitat.
    - **Lamprey** – There is very limited suitable baseline habitat for lamprey larvae and spawning throughout the reach. Most habitat is concentrated in the initial 60km of the reach. During releases there is estimated to be up to a 2% loss in suitable habitat for larvae life stage but a ~0.6% and 0.7% gain for the spawning life stage. Losses are spread over the initial 120km of the reach, with gains focussed in the upper 20km of the reach.
    - **Chub** – There is essentially no suitable juvenile baseline habitat in the survey reach, with around 20% suitable spawning baseline habitat in the reach, which is concentrated in the initial 50km. During releases juvenile habitat remains unchanged while there is up to a 3% loss in suitable spawning habitat, with highest concentrations of losses between 30-70km and 160-170km downstream.
    - **Roach** – Suitable juvenile baseline habitat is present in the reach (up to 26%), which is evenly spread through the reach, with up to 5.5% of this lost under release flows. Suitable spawning baseline habitat comprises only 6% of the reach, mostly in the upper 30km, and <1% of this is lost during releases, although there are also some very small and spatially limited habitat gains (<0.5%).
    - **European eel** – Eel habitat is abundant in the study reach, ranging from 91% for the A82 baseline run to 86% for the M96 baseline run. For both the A82 and M96 runs under a flow release there is minimal change in habitat, although there are gains of ~3% for the A82 run and ~5% for the M96 run, with <1% habitat loss over both runs.
- Predicted changes in fish habitat for the River Avon to River Severn due to the Minworth releases (A82 run June to October, M96 run June to November, **Table A 7**) are:

  - **Atlantic salmon** – Generally baseline habitat for 0+, juvenile and spawning habitat is limited to around 8-11% of the reach and is concentrated in the initial 25km of the reach. The releases are forecast to lead to up to a 3% loss of habitat for all fish life cycles.
  - **Brown / sea trout** – There is no baseline habitat for 0+ life stages in the reach, but 56-57% of the reach is suitable for juvenile habitat and ~8% suitable for spawning habitat in the initial 60-75km of the reach. Under releases, there is a loss of ~2-4% habitat, although juvenile habitat shows some very modest (<1%) gain in habitat.
  - **Lamprey** – There is very limited suitable baseline habitat for lamprey larvae (6%) and <0.5% suitable habitat for spawning throughout the reach. Most habitat is concentrated in the initial 30km of the reach. During releases there is estimated to be a 3% loss in suitable habitat for larvae life stage but a ~0.1% gain for the spawning life stage, both loss and gain focussed in the upper 40km of the reach.
  - **Chub** – These is essentially no suitable juvenile baseline habitat in the survey reach, with around 20% suitable spawning baseline habitat in the reach, which is concentrated in the initial 25km. During releases all juvenile habitat is lost while there is up to a 5% loss in suitable spawning habitat, with highest concentrations of losses between 50km and around 75km in the River Avon and 100km downstream in the River Severn.
  - **Roach** – Suitable juvenile baseline habitat is present in the reach (up to 37%), which is evenly spread through the reach, with up to 4% of this lost under release flows. Suitable spawning baseline habitat comprises only ~1% of the reach, mostly in the upper 30km, and ~1% of this is lost during releases.
  - **European eel** – Eel habitat is available in the study reach, ranging from 66% for the A82 baseline run to 59% for the M96 baseline run. For both the A82 and M96 runs under a flow release there is limited change in habitat, although there are notable gains of ~9% for the A82 run and ~15% for the M96 run, with <1% habitat loss over both runs.
- While there is suitable habitat available it is variable throughout the reaches, the upper reaches of the River Vyrnwy and River Avon are shown to hold the most suitable fish flow habitats.
- Within the limits of the current analysis two key conclusions can be drawn;
  1. When taken over the scale of an entire study reach (246km for the Vyrnwy release study reach and 124km for the Minworth release study reach), there are not likely to be significant wholescale changes of habitat throughout the study reaches caused by the flow releases.
  2. At the local scale in the upper Vyrnwy study reach (initial ~50km), the modelling indicates that there is likely to be only localised and very limited loss of flow habitats for a range of fish species under the different release conditions. This supports field observations and measurements taken in the River Vyrnwy during 2020 and 2021. Generally, losses in habitat are distributed throughout the entire study reach, particularly up to 200km downstream. Some localised gains in habitat are also noted, commonly in the initial 20km of the reach.
  3. At the local scale in the upper River Avon study reach (initial ~30km), the data clearly indicates that there is likely to be notable loss of flow habitat for a range of fish species in these reaches under the different release conditions.

REFERENCES

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

[V1] VyrnwyDsReservoir.xlsm - tab ‘Flow_Nat’
[V2] VyrnwyDsBanwy.xlsm - tab ‘Flow_Nat’
[V3] VyrnwyAtLlanymynech.xlsm – tab ’Flow_Nat’
[V4] VyrnwyDsReservoir.xlsm – tab ‘Flow’
[V5] VyrnwyDsReservoir.xlsm – tab ‘FlowChange’
[V6] VyrnwyDsBanwy.xlsm – tab ‘Flow’
[V7] VyrnwyDsBanwy.xlsm – tab ‘FlowChange’
[V8] VyrnwyAtLlanymynech.xlsm – tab ‘Flow’
[V9] VyrnwyAtLlanymynech.xlsm – tab ‘FlowChange’
[V10] VyrnwySaxons_LongSection_flows.xlsx – tab ‘Vyrnwy_Flow’
[V11] VyrnwySaxons_LongSection_flows.xlsx – tab ‘SeverntoWroxeter_Flow’
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[A3] AvonAtEvesham.xlsm – tab ’Flow_Nat’
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