Strategic Regional Water Resource Solutions: Annex B2.1 Physical Environment Evidence Report

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

Date: November 2022

Severn to Thames Transfer

Physical environment evidence report

STT-G2-S3-104

November 2022

Disclaimer

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

SEVERN THAMES TRANSFER SOLUTION

Physical Environment Evidence 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 1

The STT Solution was subject to a detailed assessment in Gate 1 with the objective of delivering regulatory assessments of potential environmental effects of the Solution in the context of the All Company Working Group (ACWG) guidance. This methodology is aligned to the Water Resources Planning Guideline: Working Version for Water Resource Management Plan 2024 (WRMP24) so that there is a consistent approach to evaluating potential effects on environmental aspects.

At Gate 1, using the information available, the environmental appraisals did not identify any 'material issues', i.e. any unsurmountable obstacles that mean the scheme is unfeasible due to environmental reasons, at this stage. Both beneficial and adverse effects have been identified, which is to be expected given the scale of the scheme.

These conclusions were reached in the context of identified gaps in understanding, and the stated need for further data and evidence collection to support the Gate 2 investigations, further information on the operation of the scheme, and ongoing dialogue with regulators and other stakeholders.

1.1.2.1 Regulator feedback at Gate 1

Feedback from the regulators was sought before the submission of the Gate 1 submission and incorporated where possible. The environmental regulators also gave feedback as part of their formal Gate 1 review of the scheme. This feedback has informed the approach taken for Gate 2.

1.1.3 Gate 2

The ACWG guidelines set out that Gate 2 builds on Gate 1 activities to improve the detail and breadth of studies for a key decision point for strategic solutions. This will include concept solution designs with reduced uncertainty in costs and benefits and re-testing in revised regional and company models (to support updated decision making and filtering on outputs including those that are mutually exclusive).

At the end of Gate 2, the solution should be developed to a standard suitable for submitting into final regional plans and/or final WRMPs. In this context, this stage (Gate 2) of the programme aims to further enhance the funding portfolio, based on refined and consistent costs and benefits, with suboptimal solutions eliminated and viable solutions carried forward to the pre-planning stage.

To support the programme, the potential environmental effects associated with the STT Solution identified in Gate 1 will be considered in view of updated scheme design, changes in potential operational patterns, feedback on Gate 1 assessments from various regulators and stakeholders and further data gathering, modelling and assessment work completed since the publication of the Gate 1 assessment report[1].

RAPID issued a guidance document[2] in April 2022 to describe the Gate 2 process and set out the expectations for solutions at standard 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[3] and the Environment Agency Invasive Non-native Species risk assessment tool.

1.1.3.1 Overview of the environment assessment approach for Gate 2

Figure 1.1 shows the investigations undertaken for Gate 2 and their interactions, in order to show the full scope of work across both environmental engineering disciplines. Reporting for the environmental investigations is undertaken in a phased way. The Evidence reports (pale blue box in the figure below, and this report) are produced first, that set out the data and evidence to be used in the assessment. The Assessment Reports which use the evidence to determine the potential effect of the STT scheme on the different topics, are produced later (dark blue box in the figure below). Together with other inputs, these reports feed into the production of the statuary reports and summary reports (yellow boxes).

1.1.3.2 Regulator engagement for Gate 2

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 EA, NRW and 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.

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.

[1] United Utilities - Water Transfers – RAPID Gate 1 Submission
[2] RAPID (2022) Strategic regional water resource solutions guidance for Gate 2
[3] All Companies Working Group (2020) WRMP environmental assessment guidance and applicability with SROs

In the sessions with technical specialists, each of the proposed approaches to the topics and statutory reports have been set out and explained. Drafts of documents have been issued, plus other technical notes, to the regulators to solicit feedback on the proposed approaches. Feedback on the drafts have been used to inform the wider environmental assessment for Gate 2 and finalise the approach and reporting.

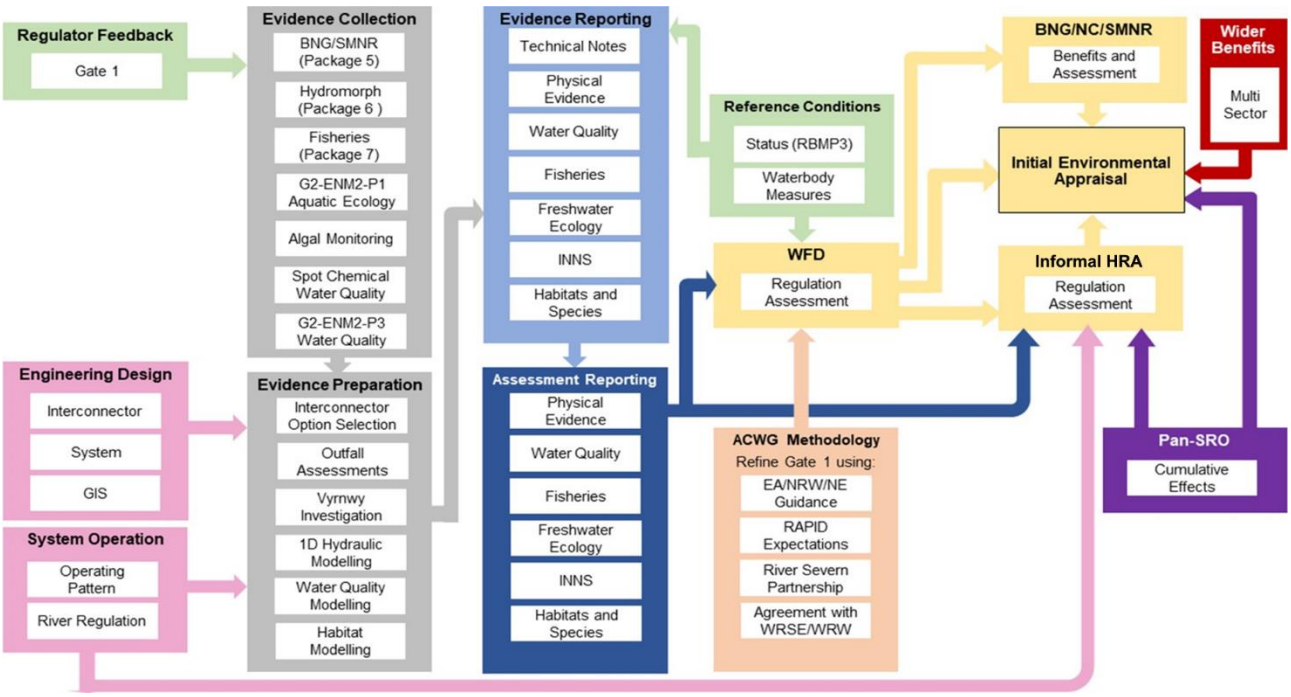

Figure 1.1 Flow chart showing the investigations undertaken for Gate 2 and their interactions

1.2 STUDY AREA

The study area for the 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).

It should be noted that the consideration of impacts in the River Tame and Trent, from the transfer of treated discharge from Minworth WwTW to the River Avon, is included in the ST Minworth Solution and therefore excluded from the STT scheme assessment.

1.3 AIM OF THIS REPORT

The assessment of potential impacts on the in-channel aquatic physical environment, as a result of the operation of the STT Solutions, provides evidence to the consequential assessments of water quality, aquatic ecological receptors, and the overarching assessment of environmental change undertaken in the Water Framework Directive (WFD) Regulations compliance assessment, the informal Habitats Regulation Assessment (HRA) and the Initial Environmental Assessment (IEA).

This report provides the evidence and data catalogue that will be used to inform the baseline in-channel aquatic physical environment associated with the proposed STT Solution. Furthermore, this report identifies the remaining data and evidence gaps, and provides a summary of a proposed programme of work to address them as part of RAPID's gated assessment process for the Solution.

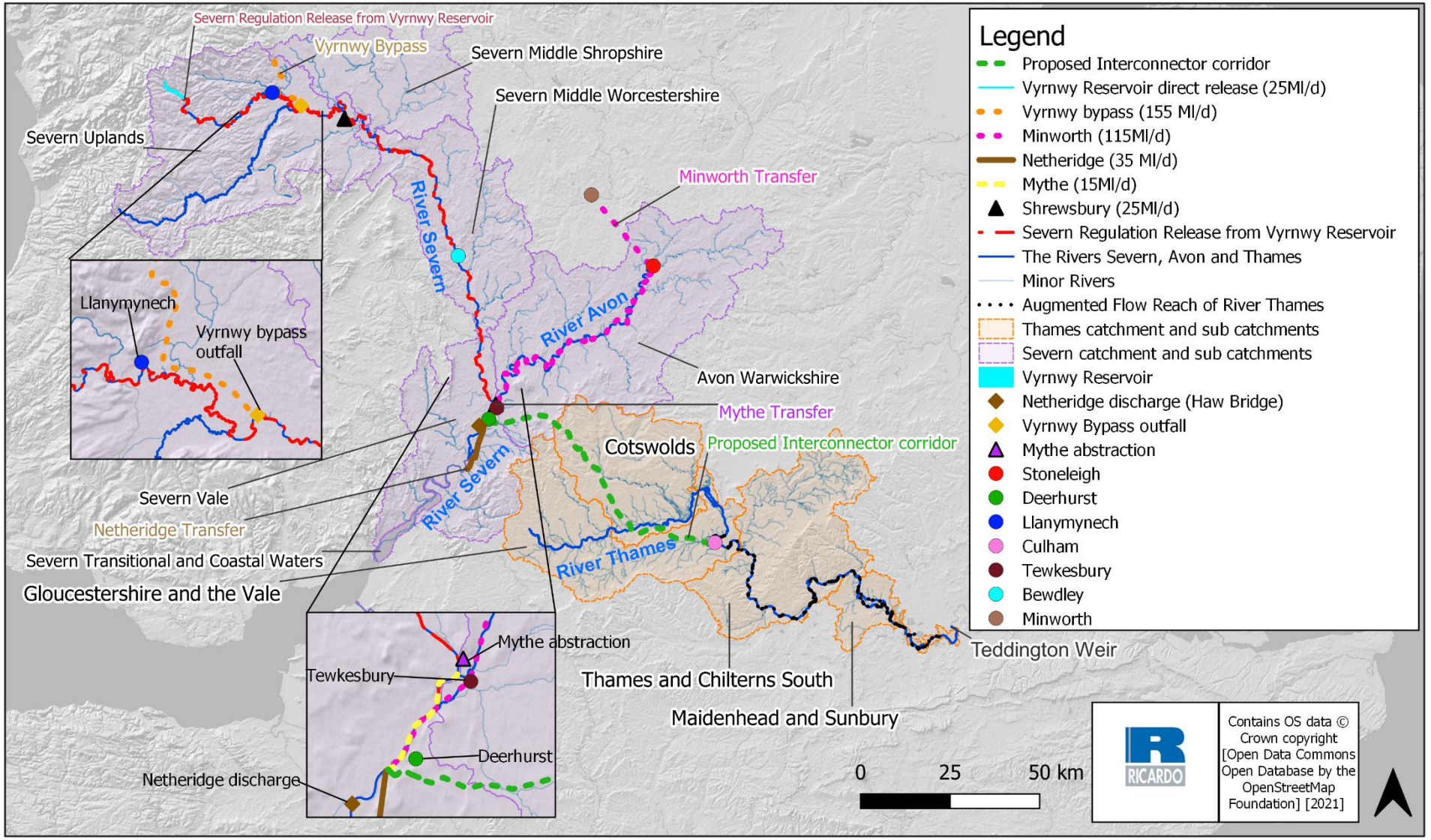

Figure 1.2 Map showing the proposed interconnector corridor

2. EVIDENCE BASE FOR, AND APPROACH TO, THE GATE 2 PHYSICAL ENVIRONMENT ASSESSMENT

Gate 1 of the STT Solution used several datasets and studies which formed the evidence base for the assessment of potential impacts on the in-channel aquatic physical environment. The Gate 1 process also identified where additional data would be necessary to undertake the required assessments for Gate 2.

Stakeholder consultation with the environmental regulators for England and Wales also identified additional datasets and studies that are required to improve the evidence base for the Gate 2 assessments.

This section:

1. Outlines the scope and approach to the physical environmental assessment tasks that will be undertaken;
2. Summarises the additional data and evidence collection tasks that were completed for Gates 1 and 2 in respect of the physical environment; and
3. Confirms the evidence base that will be used in the assessment of potential impacts on the physical environment in Gate 2.

2.1 ADDITIONAL DATA COLLECTED DURING GATE 1 AND GATE 2

2.1.1 STT Hydromorphological surveys in the River Vyrnwy, River Severn and River Avon

At Gate 1, a literature review and gap analysis identified that the ecological requirements and the potential impacts associated with a supported STT need to be considered using a holistic approach, based on a conceptual model. Furthermore, the Gate 1 assessment of the STT Solution also identified that the environmental/ecological assessments that underpin the Strategic Environmental Assessment (SEA), HRA and WFD should consider the predicted (modelled) changes in hydrology, geomorphology, habitat and water quality. Therefore, a hydromorphological survey programme was developed and completed to provide the necessary evidence for the Gate 2 assessment of changes in flow velocity and wetted area for key species. That survey programme in the River Vyrnwy, River Severn and River Avon included:

- The completion of hydraulic surveys/transects (velocity, depth, wetted width) under a range of different flow conditions;
- The installation and maintenance of water level loggers; and
- Extended and repeated hydromorphological and walkover surveys.

A more bespoke evidence collection programme for the River Vyrnwy was also undertaken, as reported in Section 2.2.3.

The hydromorphological survey evidence is presented in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

2.1.1.1 Hydraulic surveys

Table 2.2 details the surveys completed at each site to date. These surveys were completed in conjunction with the sub-reach site walkovers (see Section 2.2.1) to match the corresponding flows with any changes in habitats. It should be noted that some sites were only surveyed on two occasions as the required flow band levels were not recorded during the monitoring period to date. Flows within the River Vyrnwy did not reach the target lower flow bands during summer 2021. Therefore, surveys were completed during two of the lowest flows possible to capture available hydraulic data for these sites.

For each survey site (see **Figures 2.1**, **2.2** and **2.3**), an Acoustic Doppler Current Profiler (ADCP; a Sontek RS5) was used to acquire measurements of flow velocity, flow depth, and discharge under different flow conditions. Each ADCP survey was conducted at a series of cross-sections across the river. At all times, the onboard global navigation satellite system of the ADCP was active to capture georeferenced data. A water level logger was installed at each site on the first survey date. These data are a key component of the subsequent analysis, allowing the creation of velocity and depth maps across a reach, as well as depth profile.

2.2 SCOPE AND APPROACH TO GATE 2 ASSESSMENT AND EVIDENCE BASE

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 also includes a summary of the evidence base that will be used to inform the in-channel aquatic physical environment elements/receptors that require assessment, in terms of how they may be altered as a result of the operation of the STT Solution.

Table 2-1 Evidence and approach to the Gate 2 in-channel aquatic physical environment assessment

NB The name of a consultancy in brackets (e.g. (Ricardo) denotes the organisation that undertook the survey or work

Task item	Scope of assessment	Approach to assessment	Evidence Base for Task
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 a1D hydraulic model of the River Vyrnwy, River Severn and River Avon (Ricardo with HR Wallingford) • Use outputs from the 1D hydraulic model of the River Thames (Atkins)	• Hydraulic models development data • Hydraulic models scenario parameterisation data
b. River wetted habitat change (River Vyrnwy, 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	• STT Hydromorphology surveys in the River Vyrnwy, River Severn and River Avon (Ricardo) • Hydraulic model
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	• STT: information from surveys on barriers in the River Avon (APEM) • Hydraulic model
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	• SESRO: River Thames weir pool surveys (Atkins) as hydraulic model development data • Hydraulic model
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	• STT: Bespoke surveys in the River Vyrnwy (Ricardo) • Hydraulic model
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	• Hydraulic models scenario parameterisation data

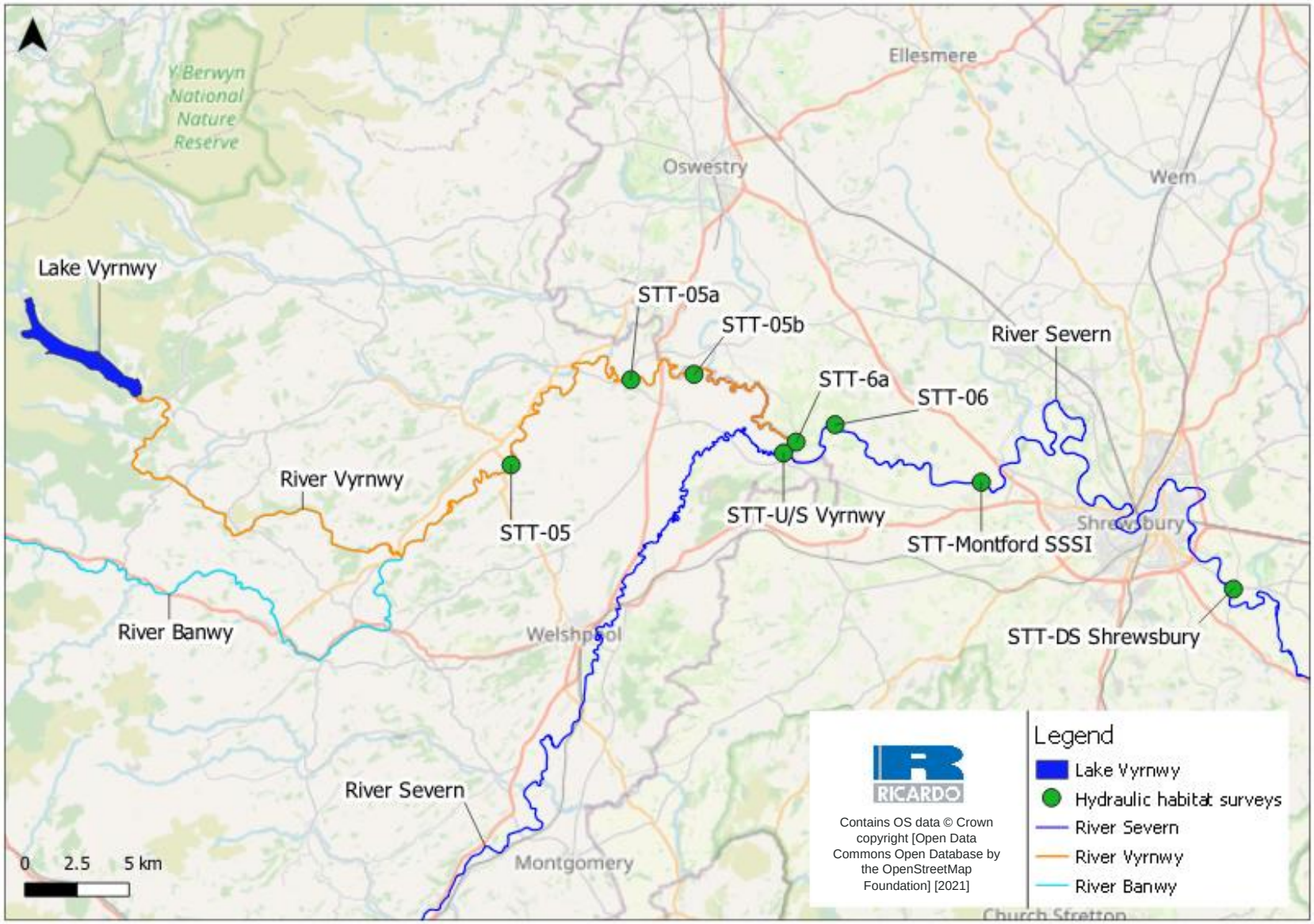

Figure 2.1: Site locations of hydraulic and in-channel habitat surveys conducted on the River Vyrnwy and River Severn from source to downstream of Shrewsbury

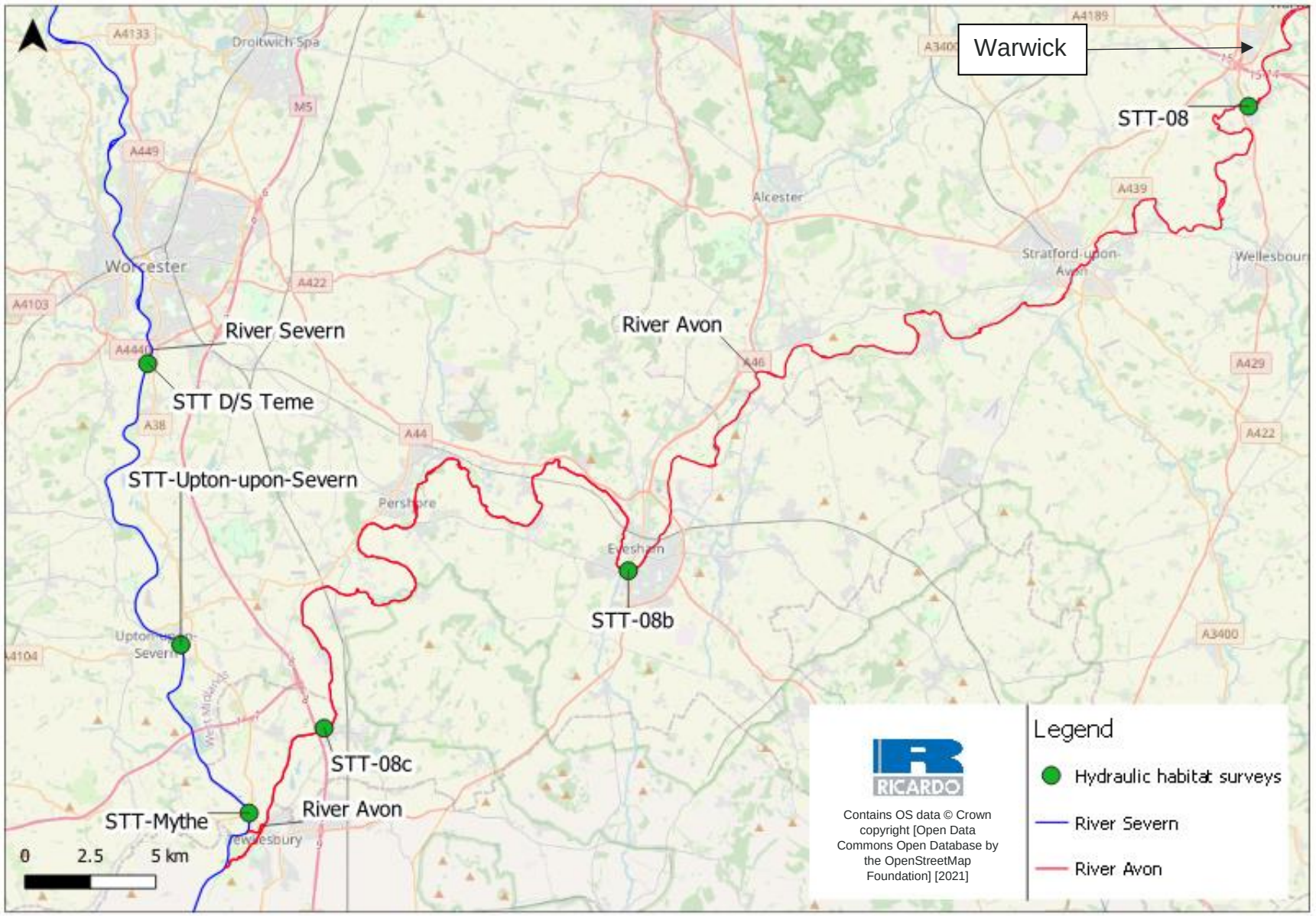

Figure 2.2: Site locations of hydraulic and in-channel habitat surveys conducted on the River Avon and River Severn upstream of the confluence with the River Avon

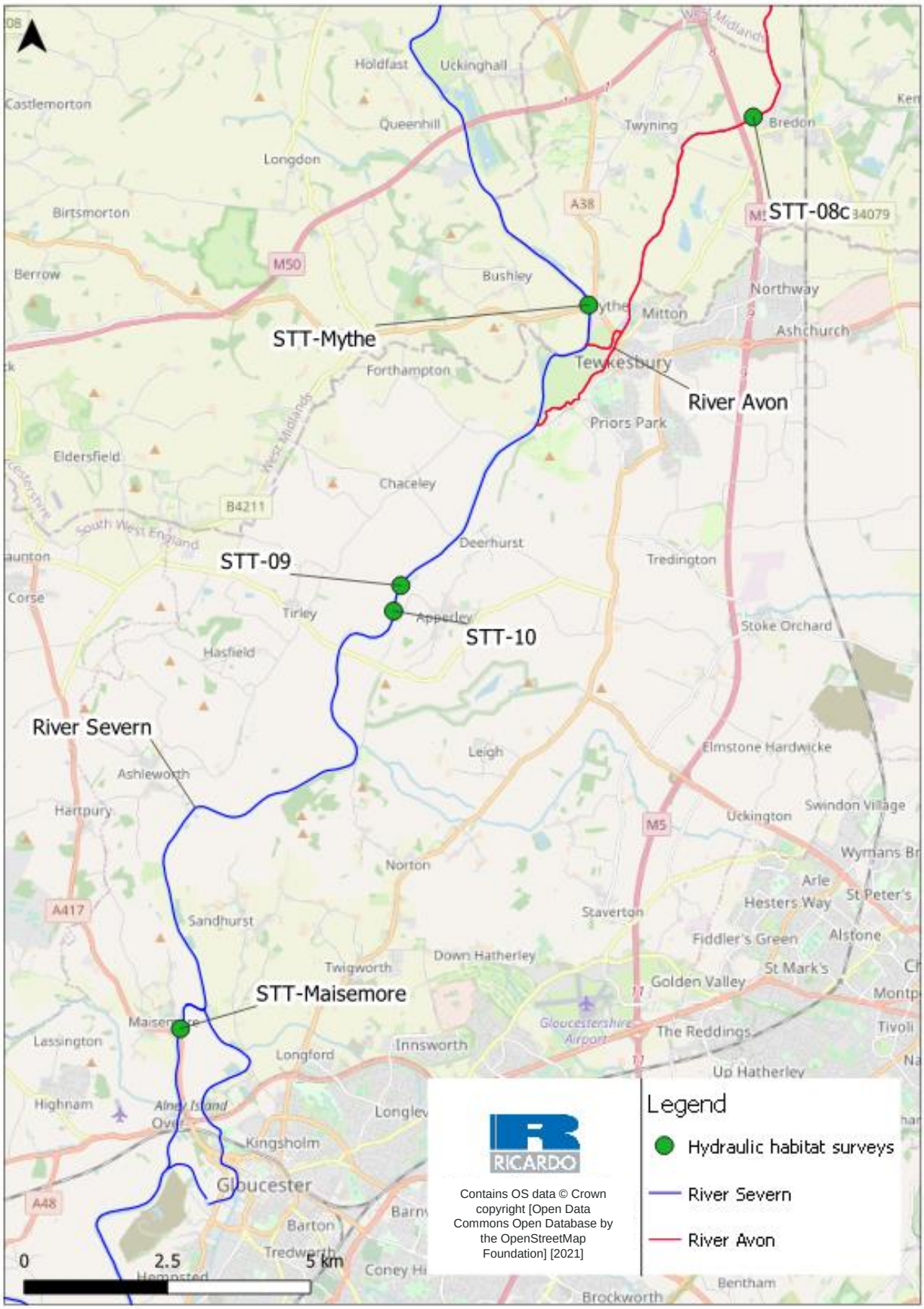

Figure 2.3: Site locations of hydraulic and in-channel habitat surveys conducted on the River Severn downstream of the confluence with the River Avon

Table 2-2 Hydraulic and in-channel habitat survey locations and dates

Site Name	River	NGR	Location	Dates visited
STT-05	Vyrnwy	SJ1959015638	River Vyrnwy D/S Meifod Valley	16/06/21* & 07/09/21****
STT-05a	Vyrnwy	SJ2537519608	River Vyrnwy U/S Llanymynech	16/06/21* & 07/09/21****
STT-05b	Vyrnwy	SJ2839319818	River Vyrnwy D/S Llanymynech	16/06/21* & 07/09/21****
STT-6a	Vyrnwy	SJ3321916522	River Vyrnwy U/S Confluence with River Severn	16/06/21* & 07/09/21****
STT-U/S Vyrnwy	Severn	SJ3261316005	River Severn U/S Confluence with River Vyrnwy	16/06/21**** & 14/10/2021*
STT-06	Severn	SJ3509917327	River Severn D/S Confluence with River Vyrnwy	15/06/21**** & 14/10/2021*
STT-Montford SSSI	Severn	SJ4204614493	River Severn at Montford SSSI	15/06/21**** & 14/10/2021*
STT-DS Shrewsbury	Severn	SJ5404709262	River Severn D/S Shrewsbury (U/S Tern)	15/06/21**** & 14/10/2021*
STT D/S Teme	Severn	SO8503551071	River Severn D/S confluence with River Teme	20/07/21**** & 15/10/21*
STT-Upton-upon-Severn	Severn	SO8626740279	River Severn D/S Upton-upon-Severn (near Upton Ham SSSI)	15/10/21*
STT-Mythe	Severn	SO8885433808	River Severn at Mythe U/S confluence with River Avon	20/07/21**** & 15/10/21*
STT-08	Avon	SP2687260974	River Avon D/S Warwick	14/06/21**; 20/07/21****; 26/10/21*
STT-08b	Avon	SP0332843105	River Avon D/S Evesham	20/07/21****; 05/08/21*; 19/08/21**
STT-08c	Avon	SO9172337063	River Avon at Twyning (U/S confluence with Severn)	20/07/21****; 05/08/21*; 18/08/21**
STT-09	Severn	SO8557228948	River Severn at Deerhurst	19/07/21****; 13/08/21***; 13/10/21**; 28/10/21*
STT-10	Severn	SO8544628505	River Severn at Deerhurst	21/07/21****; 13/08/21***; 13/10/21**; 28/10/21**
STT-Maisemore	Severn	SO8170621255	River Severn near Maisemore (U/S East Channel)	21/07/21**** & 28/10/21*

Where *= highest flow band **= 2nd highest flow band ***= 2nd lowest flow band ****= lowest flow band

2.2.1 Extended and repeated walkover hydromophology surveys

Extended walkovers were undertaken for each of the river reaches identified in **Table 2.2** which were considered representative to show the effect of the scheme on in-channel habitats. Information on flow types, sediment features, bed and bank substrate, bank morphology, in-channel and riparian vegetation and land cover throughout the study reach which were collected. As the reaches are nearly always wider than 30m, the established Modular River Physical Survey[4] and the Environment Agency (EA) River Habitat Survey[5] methodologies are deemed not suitable. As such, spatial mapping was undertaken which captured the aforementioned key features of interest for geomorphology, hydrology, ecology, and habitats over the total 58km of river surveyed. This approach provides a spatial overview of the features of interest which can be digitised within GIS.

In order to provide a robust baseline of habitats under appropriate flow conditions for STT Solution, the extended walkovers were undertaken during dry periods, when flows are close to Q95 flows. The extended surveys were completed between 15th June 2021 and 21st July 2021 across the respective reaches. **Table 2.3** details the approximate length of watercourse covered for each reach. This coverage was in line with the

[4] Gurnell, A., Shuker, L., Wharton, G. and England, J. (2018). The MoRPh Survey: A Modular River Physical Survey for Citizen Scientists. Technical Reference Manual 2018. 42pp.

[5] Environment Agency. (2003). River Habitat Survey in Britain and Ireland. Field Survey Guidance Manual: 2003 Version 1. 149pp.

proposed use of a 1 in 4 sampling methodology (e.g. one 500m sample site every 4km); such an approach has been shown to be statistically representative and would capture 90% of the variation within a river[6] and is the sampling frequency adopted for River Habitat Surveys.

Table 2-3 Distance surveyed per reach during extended walkover surveys

Reach	Reach Name	Approx. distance (km)
Reach 1	The River Vyrnwy from the Vyrnwy Reservoir to the confluence with the River Severn	11
Reach 2	The River Severn from the confluence with the River Vyrnwy to Bewdley	22
Reach 3	The River Severn from Bewdley to the confluence with the River Avon	10
Reach 4	The River Avon from Warwick to the confluence with the River Severn	2
Reach 5	The River Severn from the confluence with the River Avon to Deerhurst	7
Reach 6	The River Severn from Deerhurst to the tidal limit at Gloucester	3
Reach 7	The Severn Estuary downstream of the Tidal Limit	N/A
	Total	**58km**

The river reaches were further divided into sub-reaches. For each of the sub-reaches (250m in length), a repeat walkover survey was undertaken to map the key geomorphological features under different, targeted, flow conditions which are representative of the conditions that could be observed during STT operation. These walkovers are in addition to the extended walkover and provide additional information on habitat variability under varying flow conditions.

As for the extended walkovers, the repeat walkovers included information on flow types and bed substrate throughout the sub-reach, however the repeat walkovers focussed on the wetted channel itself to allow the impact of varying flow on habitats to be mapped. Any geomorphological features of interest, such as extensive eroding banks or sediment bars etc. were included in the repeat walkover mapping and fixed-point photography was used to record any evolution of these features under different flows.

Table 2.2 provides the location of the sub-reaches. The site walkovers were completed at the same time as the hydraulic surveys to allow a comparison of the habitat availability with changes in flows. The dates and flow conditions which these surveys were completed are provided in **Table 2.3**.

2.2.2 STT River Avon barrier surveys

The Gate 1 environmental assessments identified that the 2020 monitoring programme should be updated to include additional surveys and features. More details are required regarding the nature of barriers and passability during different flow conditions within the River Avon. As a result, a targeted monitoring programme was undertaken by APEM between March 2021 and November 2021 to address the data and evidence gaps.

[6] Wilkinson, J., Martin, J., Boon, P.J. and Holmes, N.T.H. (1998). Convergence of field survey protocols for SERCON (System for Evaluating Rivers for Conservation) and RHS (River Habitat Survey). In Boon, P.J. and Raven, P.J. (Eds), The Application of Classification and Assessment Methods to River Management in the UK. Special issue of Aquatic Conservation: Marine and Freshwater Ecosystems, 8, 579-596.

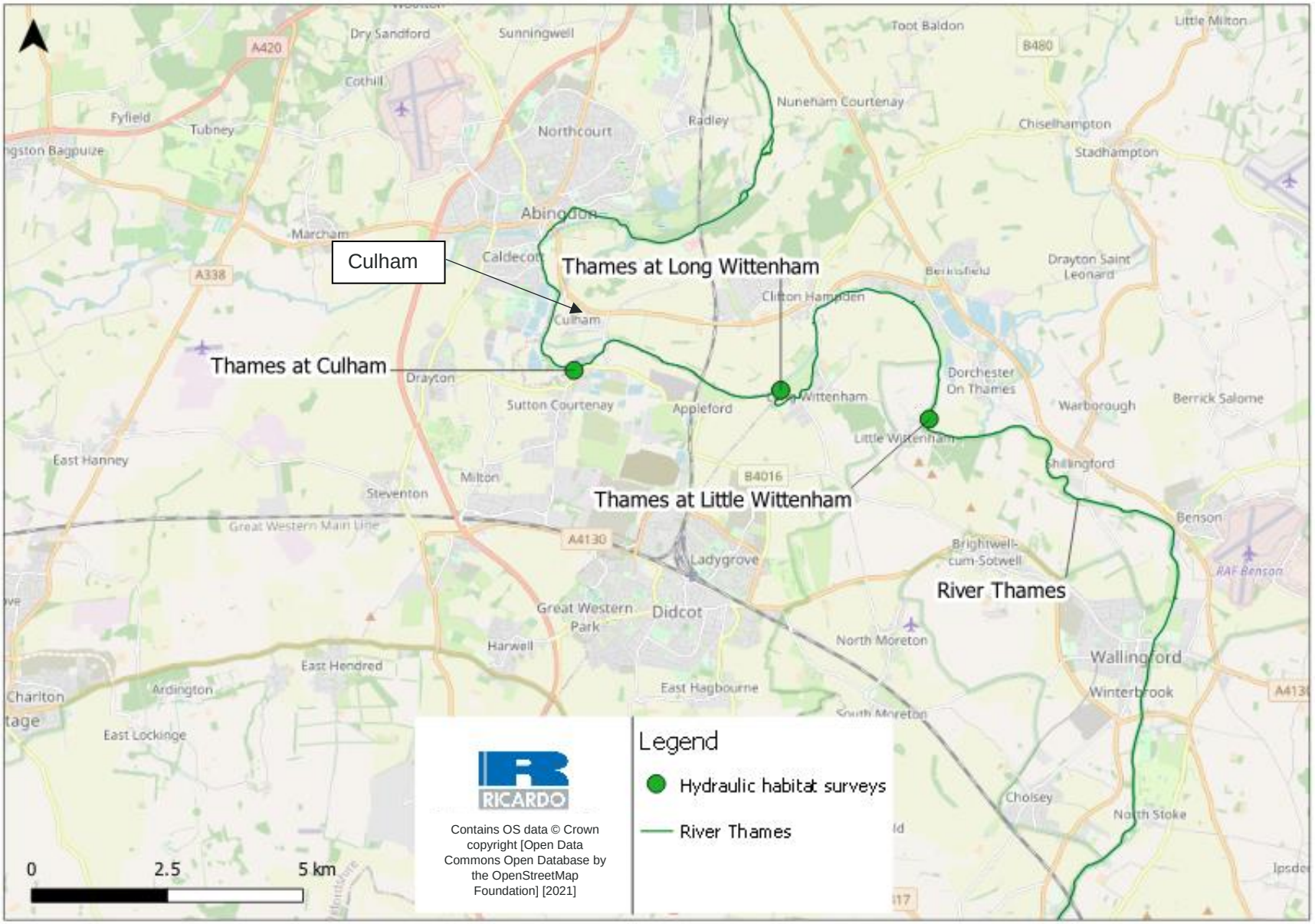

Figure 2.4: Site locations of hydraulic habitat surveys conducted on the River Thames

Table 2-4 Hydraulic habitat survey locations and date

Site Name	River	NGR (downstream from)	Location	Date visited
Culham Lock	Thames	SU501943	Sutton Pools, Culham	Nov-Dec 2021
Clifton Lock	Thames	SU540940	Weir pool at Clifton Lock, Long Wittenham	Nov-Dec 2021
Day's Lock	Thames	SU568936	Weir pool at Day's Lock, Little Wittenham	Nov-Dec 2021

2.2.3 STT Bespoke surveys in the River Vyrnwy

The potential releases from Vyrnwy Reservoir for STT have been subject to extensive consultation with Natural Resources Wales (NRW), the EA and other stakeholders. Through this consultation process, several issues or concerns have been raised by the regulators, in particular NRW. In response to the consultation, an evidence collection programme has been established through Gate 1 and Gate 2, including surveys at Vyrnwy Reservoir compensation flows and with trial releases to capture a range of suitable flow conditions.

A total of 4 survey reaches on the River Vyrnwy, of around 100m in length, were surveyed to collect evidence to understand how hydrological changes, associated with a potential release from Vyrnwy Reservoir, would impact on river hydraulics and habitats. Specifically:

- Habitats that support the notifiable plant communities of the Coed Copi'r Graig Site of Special Scientific Interest (SSSI); and
- Habitats required for juvenile salmonid life stages, as these would potentially be impacted the greatest during operation of the scheme at times of compensation flow only.

The surveys were completed during the trial releases aimed at understanding the losses associated with a Vyrnwy Reservoir release, in support of the STT Solution. Two trial releases were undertaken between 9th September 2020 and 19th September 2020, and between 26th September 2020 and 28th September 2020. The total volumes of the release during these trials were 295Ml/d (250Ml/d + 45Ml/d compensation flow) and 225Ml/d (180Ml/d + 45Ml/d compensation flow) respectively. Further surveys were under on 10th October 2021. These surveys were at times without regulation release albeit not just at compensation flow due to additional flow from the Afon Cownwy and represent a different set of flow conditions for the assessment.

The locations of these survey reaches were selected based on an understanding of the watercourse, importance for key fish species, and location with other features of habitat importance which could be affected by hydrological changes (e.g. the Coed Copi'r Graig SSSI). The locations, dates and survey types are provided in **Table 2.5**.

As part of the STT study, an understanding of the current particle size distribution of the bed of the River Vyrnwy is required. This will be used to understand what potential changes in sediment size distribution and sediment transport could occur due to releases made from Vyrnwy Reservoir. To improve this understanding, sediment surveys were undertaken at six locations, one on the River Banwy upstream of the River Vyrnwy confluence and five downstream of this confluence (see **Table 2.6**).

These sample locations were selected based on information on the survey sites in the River Vyrnwy, collected habitat walkover data, analysis of aerial imagery and reference to existing ADCP surveys. The sediment sampling site on the River Banwy was included both to act as a control and understand any the sediment contributions from the wider Banwy catchment and how these differ from the sediment size distribution of the River Vyrnwy.

Due to the need to collect as much data as possible in a short duration, and factoring in the increasing depth downstream in the channel (which renders more physical techniques such as Wolman pebble sampling unfeasible), a photosieving approach was used to capture relevant particle size data on sediment bars. This approach comprises taking a photograph of the surface which is then digitized for computer processing by tracing the outlines of the particles. The grain size distribution is then automatically determined using the PebbleCounts software. For each location, two photos of exposed fluvial sediment (in this case sediment bars) were taken, each at different points on the bar. As the key habitats under consideration are formed of coarser sediments, measurement was undertaken of particle sizes with b-axis >2mm.

Table 2-5 Locations of the River Vyrnwy trial release flow trial monitoring and SSSI specific monitoring

NB The use of Site 0 reflects an additional, more upstream site that was added after the July surveying

Site ID	Site description	Surveys undertaken	Approximate NGR of survey reach	Survey dates
Site 0	Immediately downstream of Lake Vyrnwy (~1.3km downstream from the reservoir).	ADCP, Hab Map, Wolman pebble sampling, Water level logger.	SJ 0307919061	8 Sept 2020 11 Sept 2020 23 Sept 2020 29 Sept 2020 10 Oct 2021
Site 1	A site within the Coed Copi'r Graig SSSI, Llwydiarth (~8.2km downstream from the reservoir)	ADCP, Hab Map, Wolman pebble sampling, Water level logger, time lapse photography	SJ 0321315428	23Jul 2020 8 Sept 2020 11 Sept 2020 23 Sept 2020 29 Sept 2020 10 Oct 2021
Site 2	Downstream of the Dolanog falls (~13.6km downstream from the reservoir)	ADCP, Hab Map, Wolman pebble sampling, Water level logger, time lapse photography	SJ 0706412816	21 Jul 2020 8 Sept 2020 11 Sept 2020 23 Sept 2020 29 Sept 2020 10 Oct 2021
Site 3	Downstream of the confluence with the Afon Banwy (~23.3km downstream from the reservoir)	ADCP, Hab Map, Wolman pebble sampling, Water level logger, time lapse photography	SJ 1438711493	21 Jul 2020 8 Sept 2020 11 Sept 2020 23 Sept 2020 29 Sept 2020 10 Oct 2021

Table 2-6 Sediment survey site locations

Site ID	Site name	Sample location	Watercourse
Site 1	Banwy - U/S Vyrnwy confluence	SJ1431911289	River Banwy
Site 2	Meifod	SJ1561012888	River Vyrnwy
Site 3	Waen-fach	SJ2016917316	River Vyrnwy
Site 4	U/S Llanymynech - River Vyrnwy U/S Llanymynech	SJ2426319831	River Vyrnwy
Site 5	Haughton	SJ3086519213	River Vyrnwy
Site 6	Melverley - River Vyrnwy U/S Confluence with Severn	SJ3315216447	River Vyrnwy

The hydromorphological survey evidence is presented in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

2.3 HYDRAULIC MODELS: DEVELOPMENT DATA

The physical environment assessment of the STT Solution for Gate 2 is reliant on hydraulic modelling throughout the study area. A 1D hydraulic model has been prepared by Ricardo and HR Wallingford covering the River Vyrnwy, River Severn, and River Avon reaches of the study area. A 1D hydraulic model has been prepared by Atkins for the River Thames reach of the study area. These models have been developed in Gate 2 in consultation with the regulators and have been subject to calibration and validation procedures, and will be documented in separate reports.

Extensive channel geometry cross-section data, river flow gauge data, licensed abstractions data and permitted discharge data have been sourced from the regulators and relevant water companies for the purposes of model build, calibration, and validation. These are documented in the model build, calibration and validation reports.

2.3.1 SESRO Weir pool surveys in the River Thames

The SESRO environmental assessment programme for Gate 2 includes evidencing the effects of Solution flow augmentation on selected weir pools in the River Thames downstream of the STT/SESRO outfall at Culham (see **Figure 2.4**). The three weir pools and their linked channels were surveyed using ADCP at cross sections at 50m spacing, at three selected river flow periods, to provide flow velocity and flow depth throughout the weir pools, downstream of the weirs, until the point of reconnection with the navigation channel downstream of the lock cut. The purpose of these surveys is for the SESRO assessment team to prepare a 2D hydraulic model of these weir pools. **Table 2.4** details the surveys completed at each site.

2.4 HYDRAULIC MODELS: SCENARIO PARAMETERISATION

The in-river environmental modelling assessment has explored 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 an understanding of the likely operational pattern. The scenarios, reference conditions and purpose of the modelling work are summarised in **Table 2.7**.

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 study area of the River Vyrnwy, River Severn, River Avon, River Thames and River Severn flows to the Severn Estuary. A list of the files containing model outputs and charts is presented in the supporting Excel workbook called "*STT_Physical Environment_Workbook".*

Table 2-7 The scenarios considered for the Gate 2 assessment

Note: all scenarios modelled as a pair: without STT operation (reference condition) and separately with the STT operation for 365 day period

Scenario		Flow (baseline without SRO)	Purpose
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 (to be determined using the agreed water resources modelling conditions)	Central to Gate 2 environmental assessments, WFD etc
2	Very low flow (1:20 return period)		Central to Gate 2 environmental assessments, WFD etc
3	Extremely low flow (1:50-1:100 return period)		Assists understanding of resilience
4	**Future** (2070s) version of "very low flow"	Represents a selected version of 2070s meteorological patterns, abstraction reductions in line with Environmental Destination; future forecast sewage returns and representative Severn Regulation pattern	Assists understanding of resilience
5	**Future** (2070s) version of "extremely low flow"		Assists understanding of resilience
6	**Natural** version of "Moderate-low flow"	Represents current meteorological patterns, without abstractions or discharges	Assists discussions of environmental significance with regulators

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 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.

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.

3. CONCLUSIONS

3.1 PHYSICAL ENVIRONMENT

3.1.1 Summary of baseline data, uncertainty and data gaps

The potential impacts of the STT Solution should be 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, will provide a robust evidence base for the Gate 2 assessment.

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 with other water resources options selected by both WRW and WRSE in their respective Regional Plans.

To date, there are no known data gaps in the physical environment evidence. However, it is recognised that the Gate 2 assessments of the potential effect of the STT Solution on ecological features may identify limitations in the field survey data collected in Gate 1 and Gate 2. For example, the 1D hydraulic modelling may identify that the extensive walkover surveys have not included the full range of representative river habitats, or that repeat hydromorphological surveys would provide more robust evidence if targeted at specific flow ranges that have not been surveyed. The assessment of the change in pass-forward flow to the Severn Estuary from the operation of the STT Solution may identify that there is sufficient uncertainty in the potential effects on tidal hydrodynamics within the estuary that a bespoke estuary model may be required, as the Gated process progresses, in order to assess STT Solution effects through scenarios and reduce the level of uncertainty.