Strategic Regional Water Resource Solutions: Annex B3.7: Protected Speciess Assessment

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

Date: November 2022

Severn to Thames Transfer

Protected Species Assessment

STT-G2-S3-124

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Disclaimer

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

SEVERN THAMES TRANSFER (STT) SOLUTION

Protected Species 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 25 Ml/d water licensed to UU from Lake Vyrnwy directly into the River Vyrnwy;
- **Vyrnwy Reservoir**: Utilisation of 155 Ml/d water licensed to UU from Lake Vyrnwy and transferred via a bypass pipeline ("Vyrnwy Bypass") to the River Severn;
- **Shrewsbury**: Diversion of 25 Ml/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**: 15 Ml/d of the Severn Trent Water licensed abstraction at Mythe remaining in the River Severn for abstraction at Deerhurst;
- **Minworth**: The transfer of 115 Ml/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 35 Ml/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.

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 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.

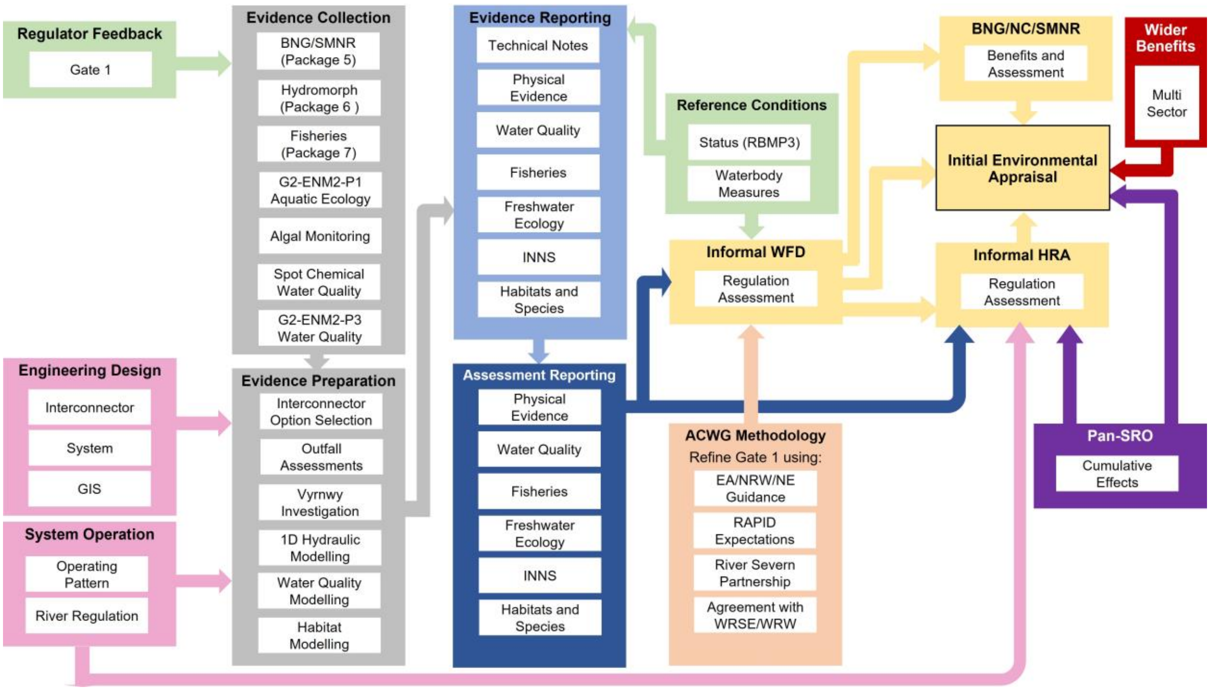

Figure 1.1 Flow chart showing the scope of investigations for STT Gate 2 and their interactions.

1.2 STUDY AREA

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

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

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

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 Wastewater Treatment Works (WwTW) to the River Avon, is included in Severn Trent Water's Minworth Strategic Resource Option (SRO) and therefore excluded from the STT solution assessment.

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

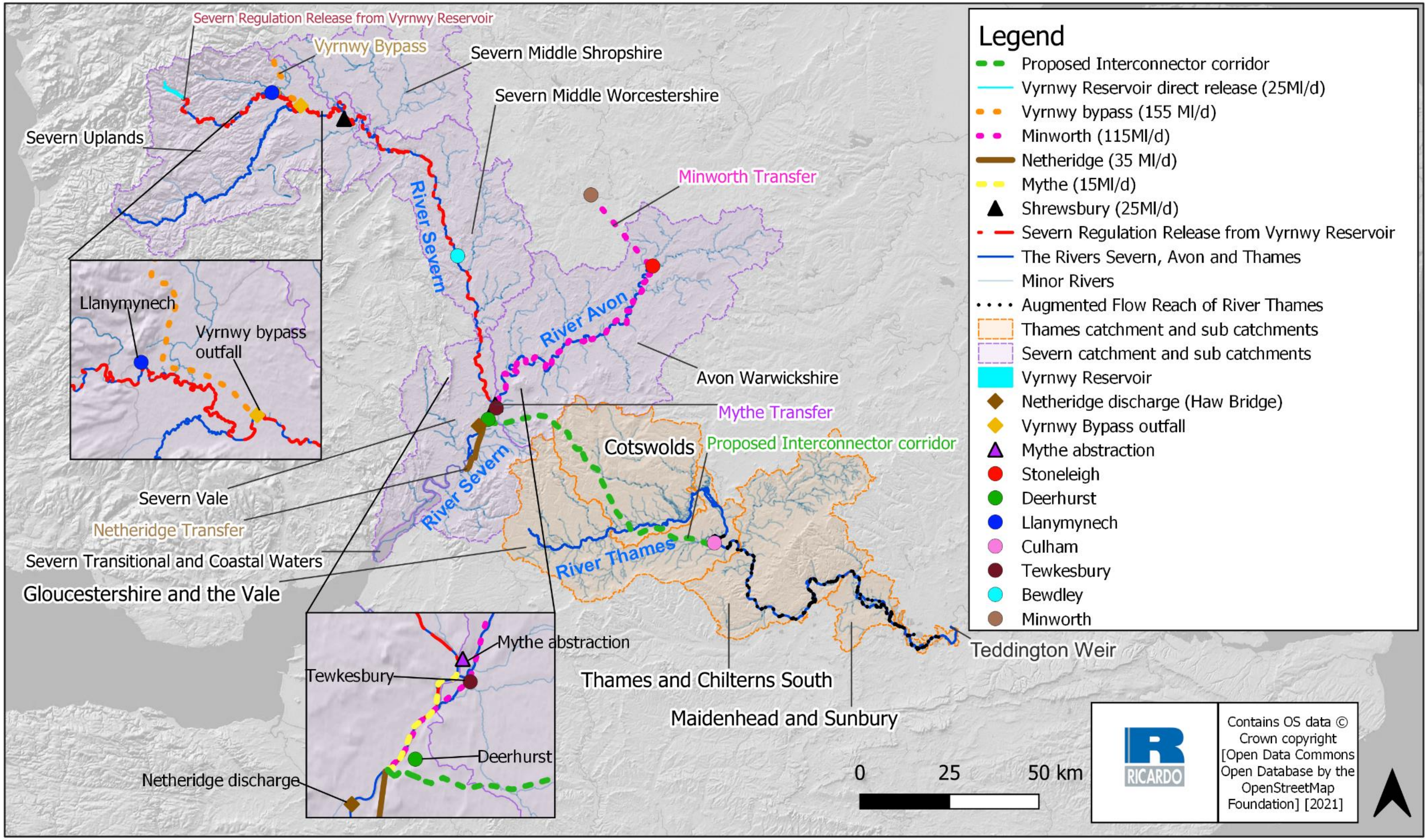

Figure 1.2 Map showing the study area and associated catchments.

1.3 SUMMARY OF THE SOLUTION COMPONENTS AND OPERATION

The STT solution developed for Gate 2 is described through its engineering components in the Conceptual Design Report. For environmental assessment purposes, as these relate to in-river physical environment effects, the solution has been split into two phases, with and without support, described as (i) an *early phase* of the STT solution, which is without the inclusion of most of the support options that augment flow in the River Severn (see Section 1.1.1), and (ii) a *full STT* solution, which includes all the support options. The river flow changes that comprise these two phases are set out in Table 1.1.

Supporting options would be operational at those times when the STT is transferring water from the River Severn to the River Thames, and when flows in the River Severn are lower than hands-off flow (HoF) thresholds in the River Severn. The EA has advised that a STT abstraction licence would be imposed so flows at Deerhurst flow gauging station do not drop below 2,568 Ml/d. Above this HoF, there is a maximum abstraction limit of 172 Ml/d, up to the next HoF condition of 3,333 Ml/d, where 335 Ml/d can be abstracted, in addition to the available 172 Ml/d unsupported[3]. This is summarised in Table 1.2.

The EA has advised the STT Group of appropriate values of "in-river losses" to include in the hydraulic modelling[4] and subsequent environmental assessments. The advised values include a 20 % loss in the River Vyrnwy and 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 370 Ml/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 353 Ml/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 (HoF) 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 HoF 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 HoF 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 HoF 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] Email from Caroline Howells (Environment Agency Environment Planning Officer) to Peter Blair (Thames Water, Water Resources Modelling Specialist) 27 February 2020.

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

Early Phase STT	Full STT
	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 HoF 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 HoF conditions; or • Supported abstraction by flow volume matching from Netheridge Transfer

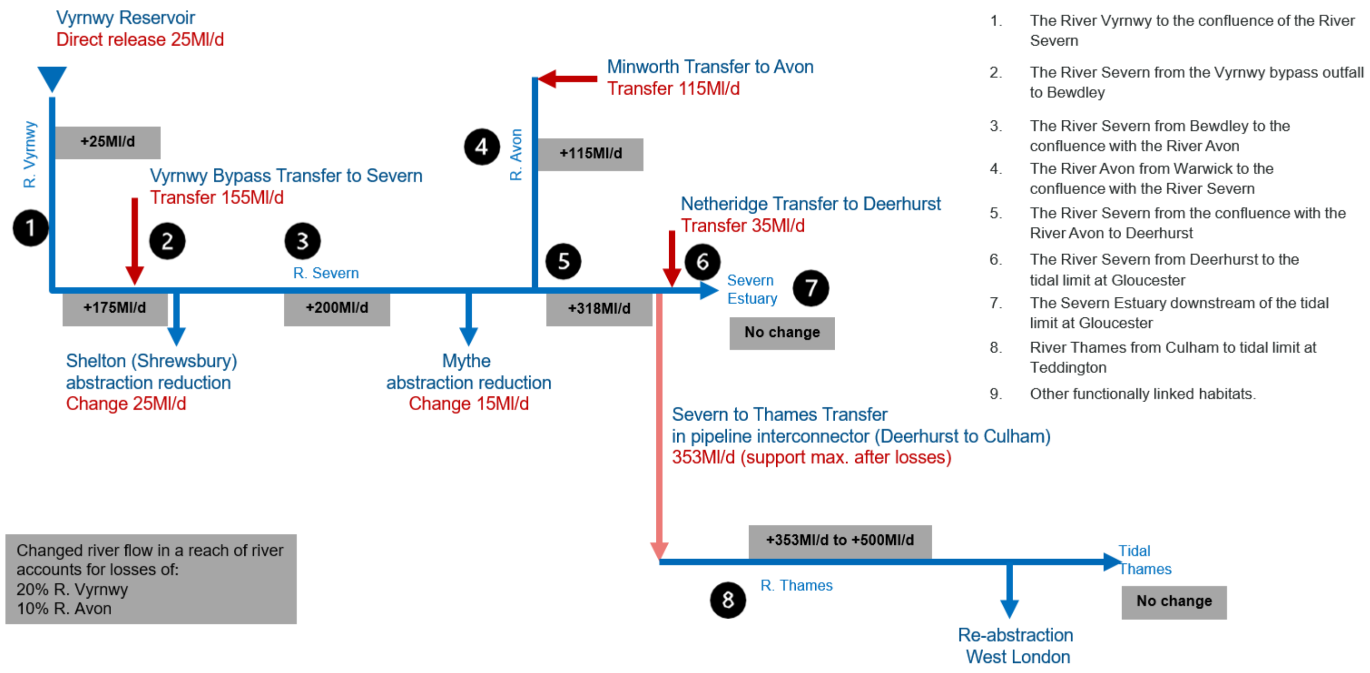

Figure 1.3 Schematic representing flow changes (accounting for losses) of STT Solution.

Table 1.2 River Severn at Deerhurst: hands-off flow 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[5] includes a suitable range of regular low and moderate low flow periods. It does not include extreme low flows that are considered to be less regular than once every fifty years. This is described further in the Physical Environment Assessment Report, with the derived representation of dates with the full STT in operation (for water resources purposes) as used in environmental assessment shown in Figure 1.4. It should be noted that this operating pattern is for the STT solution used on its own for Thames Water, without conjunctive use with other Thames Water SROs (such as the South East Strategic Resource Option (SESRO)). It also uses the controlling triggers developed by Thames Water for SESRO based on lower River Thames flows and Thames Water's total London reservoir storage.

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 the Physical Environment Assessment Report. 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.

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

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

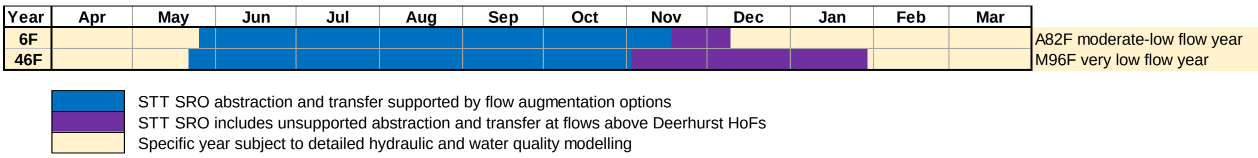

Figure 1.5 Representation of dates full STT solution would be on (for water resources purposes) for selected future scenarios as used in the environmental assessment.

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

1.4 SCOPE OF THIS REPORT

This report assesses the potential impacts of the STT solution on protected species. It analyses the information and data set out in the Protected Species Evidence Report. The findings of the analysis are presented on a reach by reach basis, addressing each metric of change. The information is presented in this way so there is clarity over where effects from the scheme are observed.

This report also identifies where 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 Protected Species 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 show the effect of the STT scheme on the protected species as a result of changes in flow, velocity, depth, level (flood regime) and water quality. 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. This includes the Protected Habitats Assessment Report, as impacts identified to supporting/ functionally linked habitat will have a direct impact on protected species populations. The assessment of protected species will also inform the informal Habitats Regulation Assessment (HRA) on the location of functionally linked habitat via the presence of qualifying species outside the boundaries of European sites that have been identified within the zone of influence.

1.4.2 Aspects covered by other SRO Gate 2 Reports

This report excludes the potential impact on any protected fish species or any protected aquatic macroinvertebrates. Impacts on these features have been considered in the Fisheries[6], and Macroinvertebrates[7] Assessment Reports.

[6] Ricardo Energy and Environment (2022). Severn Thames Transfer SRO, Fisheries Assessment Report. Report for United Utilities on behalf of the STT Group.

[7] Ricardo Energy and Environment (2022). Severn Thames Transfer SRO, Macroinvertebrates Assessment Report. Report for United Utilities on behalf of the STT Group.

2. ASSESSMENT

2.1 SUMMARY OF THE APPROACH

2.1.1 Overview

The scope of the assessment of effects on protected species 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 Protected Species Evidence Report.

Table 2.1 Evidence and approach to the Gate 2 assessment of protected species.

Task item	Scope of assessment	Approach to assessment	Evidence Base for Task
Protected species	• Update the Gate 1 assessment using additional baseline data collected during Gate 1 and Gate 2.	• Update the assessment to consider additional species/ community data collected during Gate 1 and Gate 2. • Use the updated schemed design and operation for Gate 2. • Consider the interpretation of the fluvial (flow) model, including the flow series at key locations for different scenarios to consider the risk of changes in velocities, depth and wetted margin that may result in changes in community structure, loss of preferred habitat, etc. • Include relevant SRO monitoring programme survey data such as Acoustic Doppler Current Profiler (ADCP), habitat walkovers and River MoRPh survey outputs and additional habitat modelling at key locations. • Update the assessment in consideration of the interpretation of the water quality assessment and model outputs to consider risk of water quality driven changes in community structure. • Suggest further mitigation and/or treatment measures (where required) for design/engineering interface.	• Physical Environment and Water quality assessments will provide scenario outputs to consider in the assessments. • Data obtained through data request to NRW. • Open-source data (e.g. NBN Atlas and NBN Atlas Wales INNS Portal) requests 100 m within the zone of influence. This included construction corridors for the Vyrnwy Bypass (option 27) and Deerhurst to Culham Interconnector, plus operational reaches from Vyrnwy reservoir to tidal limit of the River Severn at Gloucester and tidal limit of the River Thames at Teddington. • Targeted surveys completed in 2021, including surveys on higher plant species, lichens, bryophytes, Exposed Riverine Sediments (ERS) and water vole *Arvicola amphibius*.

2.1.2 Engagement with Stakeholders

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

2.1.3 Data collection and processing

Open source data, including the National Biodiversity Network (NBN) Atlas and Magic Maps were reviewed for any records of protected species. Species that are protected under UK legislation, considered as principle for conserving biodiversity or are considered as threatened or endangered were considered in the baseline review. This includes species listed as of principal importance for the purpose of conserving biodiversity under Section 41 of the Natural Environment and Rural Communities Act (NERC) (2006), species listed as priority in Section 7 of the Environment (Wales) Act (2016), species that are protected under Section 9 of the Wildlife and Countryside Act (1981), species listed on the IUCN Red List of threatened species, species previously listed as priorities for conservation action under the UK Biodiversity Action Plan (UK BAP) that are located within 100 m of the zone of influence.

Where possible, UK Technical Advisory Group on the Water Framework Directive Guidance on the Identification of Natura Protected Areas (final) March 2003 was used to identify whether protected species identified within the zone of influence are considered water dependent. Where features are identified upstream or downstream of a particular hydrological reach, but not in the reach, a precautionary approach was adopted, and it was assumed that the features are present.

Sites of international importance (Special Areas of Conservation, Special Protection Areas, Ramsar sites and Marine Conservation Zones) are excluded from this report as they are included in the informal HRA for the STT solution.

Targeted surveys were necessary to provide more certainty on the distribution of water vole *Arvicola amphibius* and European otter *Lutra lutra* if present along the River Avon from downstream of Warwick to Alvaston. Exposed Riverine Sediment (ERS) invertebrate surveys, higher plant, lichen and bryophyte targeted surveys were also conducted along the River Vyrnwy. The survey locations are presented in the supporting Excel workbook (*STT_Protected Species_Workbook*). The survey methodology was subject to consultation with the relevant regulators prior to implementation of the protected species monitoring programme[8].

2.1.4 Identifying relevant impact pathways

The assessment of impacts on protected species as a result of the operation of the STT was considered in the context of the ecological requirements and the extent to which abiotic parameters will be altered as a result of the operation of the STT. This included consideration of flow, depth, water level, velocity, flood regime and water quality changes within the River Vyrnwy, River Severn, River Avon and River Thames and potential impact pathways on protected species present.

The scoping exercise undertaken as part of the surveys completed in 2021 identified water vole and European otter as species potentially impacted during the operation of the STT. Waterbirds (including divers, grebes, cormorants, herons, swans, geese, ducks, rails, waders, gulls and terns) and macrophytes were not specifically surveyed at Gate 2 along the River Severn, Avon and Thames.

Table 2.2 The general ecology and potential impact pathways to protected species associated with the STT based on the likely operational pattern and potential changes in flow, velocity, depth and water quality.

Protected species	General ecology	Potential impact pathways
Water vole *Arvicola amphibius*	- Water voles are omnivores but largely feed on vegetation. - Habitat preference is within slow flowing watercourses with tall and steep river banks, with relatively soft sediment to create nest chambers above high water. They also reside in dense riparian vegetation or in the water[9]. - Piles of droppings (latrines) used as territory markers by females during the breeding season. - Also water voles leave accumulations of cut vegetation (reeds) in piles referred to as feeding stations.	- Increased flow could reduce the suitability of a watercourse for water vole if they are unable to commute between feeding stations and burrows. - Increased flow could cause deterioration in the health of macrophyte communities and spatial extent, impacting on food availability for water voles. - Increased water levels could flood burrows below surface water level, increasing vulnerability to predation and impacting on the spatial distribution of localised populations. - Changes in water quality could cause deterioration and potentially loss of macrophytes used for feeding and cover while commuting within riparian vegetation.
European otter *Lutra lutra*	- Otters are members of the Mustelidae family of carnivores. - They are solitary animals and are usually active at dusk and during the night, although they are known to be active during the daytime.	- Changes in water quality could have a direct impact on fish populations via a reduction in fitness and potentially mortality. This could impact on the availability of prey for European otter if present.

[8] Ricardo Energy & Environment (2021). Severn to Thames Transfer SRO. Gate 2- Monitoring Programme – Additional Protected Species Surveys for Higher plants, Lichens, Bryophytes, Water vole, and Exposed Riverine Sediment (ERS) Invertebrates. Report for Thames Water (on behalf of the STT Group). August 2021

[9] Tansley, D. (2014). A guide to water vole ecology and field signs. Water for Wildlife, Wildlife Trust.

Protected species	General ecology	Potential impact pathways
	- They are very territorial and can travel over large areas; male have been known to have a home range encompassing up to 50 km of river[10]. - Otters mainly eat fish, although crustaceans, frogs, voles and aquatic birds may also be a food resource. - In addition to rivers, otters are encountered on small streams, ditches, ponds, lakes, canals and marshes and can also be found in coastal areas and estuaries. - An otter's resting site is known as a holt, which may be in a tree root system, a hole in a bank or under a pile of rocks. - Breeding can occur at any time of year with one to four pups being born; the pups remain dependent on their mother for one year. - Females use a breeding site within their home range that is undisturbed, away from flooding (typically) and close to a good food supply[11].	- Loss of and redistribution of fine sediment, could impact on the suitability of spawning grounds for fish and therefore, availability of prey for European otter populations. - Increased velocity, flow and depth could impact on the spatial distribution and feeding success of European otter. - Changes in hydraulics (increased velocity and depth) could cause the direct loss or deterioration of habitats present, impacting on the habitat mosaic and ability to support European otter. - Increased water level could cause the direct loss of potential breeding and non-breeding sites. - Operation during extreme low flow conditions in summer periods may increase the risk of flooding outside of the natural flow regime of supporting/ functionally linked habitats.
Waterbirds	- Waterbirds use watercourses and wetted margins for feeding, breeding and roosting. - Access between feeding and roosting sites is important with birds typically roosting on waterbodies at night for protection from predators and feeding during the day either in waterbodies or other functionally linked land such as coastal floodplain grazing marsh, lowland meadows, fens and/ or arable and pastural land. - Food sources will vary from vegetation, invertebrates and fish. - Nesting location will vary from grassland, saltmarsh, gravel/ shingle, trees and in the watercourse itself.	- High flows may reduce the availability of exposed sediment along wetted margins used for feeding and suitability of watercourses for breeding waterbirds. - Increased velocity, flow and depth could impact on the spatial distribution and feeding success of waterbirds. - Increased water level could cause the inundation of suitable nest sites in marginal habitats and on low over-hanging branches. - Operation during extreme low flow conditions in summer periods may increase the risk of flooding outside of the natural flow regime of supporting/ functionally linked habitats. -
Macrophytes	- Macrophytes can vary from plants submerged, floating below the water surface or rooted on the river bed, plants with all or at least some leaves floating flat on the water surface, plants rooted on the river bed with leaves and stems emerging from the water and algae. - Zonation occurs from the river bank, riparian vegetation and open water vegetation. The vegetation composition will vary depending on abiotic parameters such as flow, nutrient concentrations, dissolved oxygen, water temperature, exposure (shaded vs unshaded) bedrock type and sedimentation.	- Changes in water quality (temperature and dissolved oxygen) could have a direct impact on the growth, health and distribution of macrophytes. - Loss of and redistribution of fine sediment could impact on the growth and distribution of macrophytes (some species require autumn flushing of fine sediment for regrowth in spring). - Changes in hydraulics (increased velocity and depth) could cause the direct loss or deterioration of habitats present, impacting on the habitat mosaic and ability to support a diverse range of protected species. - Operation during extreme low flow conditions in summer periods may increase the risk of flooding outside of the natural flow regime of supporting/ functionally linked habitats. This could alter the community assemblage of coastal floodplain grazing marsh and lowland meadows (in particular). - Increased nutrient loading could cause algal growth and potentially eutrophication within slow flowing waterbodies.

[10] Chanin P (2003). Ecology of the European Otter. Conserving Natura 2000 Rivers Ecology Series No. 10. English Nature, Peterborough.
[11] Liles G (2003). Otter Breeding Sites. Conservation and Management. Conserving Natura 2000 Rivers Conservation Techniques Series No. 5. English Nature, Peterborough.

3. REACH BY REACH ASSESSMENT

3.1 INTRODUCTION

This section addresses the effects of the STT Scheme on a reach by reach basis, addressing each metric of change in turn. The reaches, as shown 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 Stoneleigh 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 D/S 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 effects of the STT operation 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 Baseline

From the Vyrnwy Reservoir to Llanymynech

The community assemblages present in the River Vyrnwy are indicative of the geomorphology of the reach which consists of extensive bedrock with boulder, cobble, gravel and silt present and fast flowing water that creates rapids and riffles. This creates suitable spawning and nursery habitat for fish and macroinvertebrates, The river is largely lined with trees creating shade and shelter for water dependent birds and mammals to feed and rest. Exposed in-river bedrock and boulder outcrops also provide sites for colonisation of a range of bryophytes and lichens.

Water dependent protected species records in the River Vyrnwy include fish such as Atlantic salmon *Salmo salar,* bullhead *Cottus gobio* and brown/ sea trout *Salmo trutta*. Records have also been received for macroinvertebrates such as river limpets *Ancylus fluviatilis*, horny orb mussel *Sphaerium corneum* and river snail *Viviparus viviparus*. eDNA survey results in 2021 recorded freshwater pearl mussel *Margaritifera margaritifera* and depressed river mussel *Pseudanodonta complanata*. The freshwater pearl mussel is considered Critically Endangered by IUCN Red list and Nationally Rare, whilst the depressed river mussel is considered Vulnerable by IUCN Red list and Nationally Scarce. The potential impact pathways to these species will be discussed separately in the Fisheries[12] and Macroinvertebrate Assessment Reports[13].

Other water dependent protected species records in the River Vyrnwy that will be considered in this assessment include mammals (European hedgehog *Erinaceus europaeus* and European otter *Lutra lutra*) and macrophytes (floating water-plantain *Luronium natans*, marsh marigold *Caltha palustris* and reed canary-grass *Phalaris arundinacea* etc.). Water vole *Arvicola amphibius* surveys were completed in 2021 along the River Vyrnwy, however, no signs of water vole were recorded. The presence of European otter was confirmed at three sites within this reach via otter spraints.

In addition to species records, higher plant, bryophyte and lichen surveys were undertaken in 2021. The surveys showed that where conditions were particularly favourable in this reach, substantial populations of up to 400 plants were recorded. Target species such as the Marsh hawk's-beard *Crepis paludosa* appear to be ubiquitous in small populations and are found growing on thin soil and mossy crevices on banks and on skeletal

[12] Ricardo Energy & Environment (2021). Severn Thames Transfer SRO, Fisheries Assessment Report. Report for United Utilities on behalf of the STT Group.

[13] Ricardo Energy & Environment (2021). Severn Thames Transfer SRO, Macroinvertebrate Assessment Report. Report for United Utilities on behalf of the STT Group.

soils of vegetated shingle bars. Marsh hawk's-beard was recorded from downstream of the reservoir to Pontrobert.

Bryophyte records divide neatly into a suite of upland species of aquatic and marginal rocky habitats and lowland species of silt-washed trees. They were typically recorded where rapids were present. For example, greater water-moss *Fontinalis antiphyretica* and alpine water-moss *Fontinalis squamosa* were locally abundant in the upper half of the reach, with no records downstream of Dolanog. Much smaller populations of plants such as lesser meadow-rue *Thalictrum minus*, Welsh poppy *Papaver cambricum* and Wilson's filmy-fern *Hymenophyllum wilsonii* are also present upstream of the confluence with the River Banwy with some populations found roughly >3 m above the waterline in areas of high humidity.

The lichen communities associated with the River Vyrnwy are also highly diverse, with several nationally scarce and rare species recorded during the survey such as *Verrucaria pachyderma* and *Aquacidia antricola* . In the area near Dolanog, the assemblage is considered to be very close to the threshold for Site of Special Scientific Interest (SSSI) notification (10 species were recorded; the SSSI threshold is 11) and there is an additional scoring species recorded further upstream on the River Vyrnwy.

ERS invertebrate surveys were also undertaken in 2021 to inform the Gate 2 protected species assessment. Note that the survey was undertaken at one site only. Target surveys identified a total of 233 specimens comprising of 30 species. No species of interest listed by NRW were found, however, one Nationally Notable B ground beetle species was recorded, *Blemus discus*. Two non-native species were found: *Teropalpus unicolor* and *Phacophallus parumpunctatus*. Despite being non-native, both species are naturalised. Of the species recorded, five (the beetles *Bembidion atrocaeruleum*, *B*. *decorum*, *B*. *punctulatum*, *Clivina collaris* and *Paranchus albipes*) are known associates of ERS and three of these are new records for the River Vyrnwy. Of the other species recorded, *B. discus*, scarce 7-spot ladybird *Coccinella magnifica* and *Oedostethus quadripustulatus* are very scarce in Wales. *Pomatinus substriatus* is a vulnerable water beetle which is a SSSI qualifying feature on the River Usk (Lower Usk) SSSI and this is the first record for the River Vyrnwy.

Of note, Coed Copi'r Graig SSSI is located adjacent to the River Vyrnwy encompassing 850 m of the associated bank and channel. The site is 6.9 ha and consists of northern woodland (key example in Montgomeryshire) that supports marsh hawk's beard, globeflower *Trollius europaeus*, mountain melick *Melica nutans* and wood crane's-bill *Geranium sylvaticum* and a diverse lobarion lichen-dominated community[14].

From Llanymynech to the confluence with the River Severn

From Llanymynech to the confluence with the River Severn, the reach is slower flowing, dominated by silt bars and intermittently lined with trees such as willow *Salix* species (spp.), alder *Alnus* spp. and sycamore *Acer* spp.. The potential impact pathways to protected fish and aquatic macroinvertebrate species will be discussed separately in the Fisheries[15] and Macroinvertebrate Assessment Reports[16].

Other water dependent protected species records in this reach that are considered in the assessment include mammals (European hedgehog and European otter) and macrophytes (floating water-plantain, marsh marigold and reed canary-grass etc.). Water vole surveys were completed in 2021 along the River Vyrnwy, however, no signs of water vole were recorded. The presence of European otter was confirmed at four sites within this reach via otter spraints and a footprint.

In addition to species records, higher plant, bryophyte and lichen surveys were undertaken in 2021. 34 species of vascular plant were recorded in this reach including mugwort *Artemisia vulgaris*, spear-leaved orache *Atriplex prostrata* and marsh yellow-cress *Rorippa palustris*. The only bryophyte recorded in this reach was spruce's bristle-moss *Orthotrichum sprucei* and no species of lichen recorded. This demonstrates a reduction in diversity of higher plants, bryophytes and lichens in comparison to the previous reach. This is likely due to the slower flow of the watercourse and increased depth of the water column, limiting the number of bedrock and boulder outcrops for bryophytes and lichens to colonise.

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[14] Countryside Council for Wales (1993). Coed Copi'r Graig Site of Special Scientific Interest Citation. Natural Resources Wales, 1 – 2.

[15] Ricardo Energy & Environment (2021). Severn Thames Transfer SRO, Fisheries Assessment Report. Report for United Utilities on behalf of the STT Group.

[16] Ricardo Energy & Environment (2021). Severn Thames Transfer SRO, Macroinvertebrate Assessment Report. Report for United Utilities on behalf of the STT Group.

3.2.2 Relevant impact pathways

Considering the protected species records and the operational pattern, the support releases could, therefore, result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Increased water levels could cause inundation of higher plant, bryophyte and lichen communities present on bedrock and boulder outcrops, reducing the suitability of the River Vyrnwy to support species present, resulting in a reduction in extent and diversity of plant assemblages;
- Increased water levels could cause inundation of ERS, reducing the available habitat for multiple ground beetle species.
- Increased velocity and depth could cause the loss/ decrease in habitat quantity and quality due to changes in hydraulics, impacting on the habitat mosaic and ability to support a diverse range of protected species;
- Increased flows and velocities could result in direct damage to higher plants and washout of seeds;
- Increased water levels could cause the direct loss of potential non-breeding European otter holt sites nest sites for waterbirds in the riparian zone along the River Vyrnwy;
- Increased flows and velocities could cause the loss of and redistribution of fine sediment particularly from Llanymynech to the confluence with the River Severn where the substrate is dominated by silt bars. This could impact on the growth and distribution of macrophytes that require autumn flushing of fine sediment for regrowth in spring and suitability of spawning grounds for fish, impacting on the availability of prey for European otter populations and feeding habitat for waterbirds;
- Increased velocity, flow and depth could potentially impact on the spatial distribution and feeding success of European otter and protected waterbirds;
- Changes in water quality (temperature and dissolved oxygen) could have a direct impact on fish populations via a reduction in fitness and altering egg incubation periods. Water quality changes could also impact on the growth and extent of macrophytes. This could impact on the availability of prey for European otter if present and feeding habitat for waterbirds; and
- Operation during extreme low flow conditions in summer periods may increase the risk of flooding outside of the natural flow regime of supporting/ functionally linked habitats. This could alter the community assemblage of coastal floodplain grazing marsh and lowland meadows (in particular), therefore, reducing the suitability of the sites for breeding birds and water dependent mammals if present.

3.2.3 STT operation – current conditions

This section sets out the findings of the effect of the STT scheme operation during current or contemporary ('now') climate conditions.

3.2.3.1 Changes to flows, velocity and depths

In this reach, STT SRO would augment flows through a 25 Ml/d direct release from Vyrnwy Reservoir at selected times. 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. This is a percentage change in flow of between 25 - 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 SRO 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 SRO 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 difference between the reference and fully supported condition is slightly reduced compared to immediately downstream of the reservoir due to losses.

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 25th August. The reference flow increases from 45 Ml/d to 960 Ml/d on the 5th of December.

In the A82 scenario, the percentage change of flow in the River Vyrnwy is 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 the River Vyrnwy upstream Cownwy site, under the A82 scenario, there is an increase in depth between 27th June and 9th October. Over this period the depth increases by between 10.3 % and 34.0 % with the depth ranging between 0.29 m and 0.42 m (with a mean depth of 0.34 m compared to the reference, which ranged between 0.22 m and 0.38 m (with a mean depth of 0.29 m).

Similarly, the velocity in this period increases under this scenario. The range in percentage increase compared to the reference is between 4.4 % and 14.8 % with the scenario velocities ranging between 0.85 m/s and 1.00 m/s (with a mean velocity of 0.92 m/s) compared to the reference which ranged between 0.74 m/s and 0.96 m/s (with a mean velocity of 0.84 m/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 0.29 m and 0.46 m (with a mean depth of 0.39 m) compared to the reference which ranged between 0.21 m and 0.42 m (with a mean depth of 0.34 m Above Ordnance Datum (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 0.82 m/s and 1.04 m/s (with a mean velocity of 0.96 m/s) compared to the reference which ranged between 0.74 m/s and 1.00 m/s (with a mean velocity of 0.91 m/s).

3.2.3.2 Changes in water quality

Assessment of changes to temperature with changes in outflow volume show a weak relationship. Under the STT scheme operation, to release an additional 25 Ml/d, similar scale increase in outflow monitored have not resulted in clear temperature changes in the River Vyrnwy above the scale of background variability already present.

3.2.3.2.1 Impact assessment

Based on outputs from fish habitat modelling[17], a maximum loss of 5 % of suitable fish supporting habitat is anticipated for all life stages of Atlantic salmon, brown/ sea trout, lamprey, chub, roach and European eel. Therefore, a limited impact is anticipated on prey availability for European otter. In addition, due to the natural variability in flow rate of the River Vyrnwy (baseline conditions vary from 25 – 100 Ml/d) and limited impact on water depth due to the operation of STT SRO (mean depth change of 5 cm), no discernible impacts on the spatial distribution and feeding success of European otter and waterbirds are anticipated. European otter are also highly adaptable and found in a range of different habitat types, with differing flow rates such as ditches, streams, rivers and estuaries.

The resuspension and loss of fine sediment from Llanymynech to the confluence with the River Severn during STT SRO is unlikely to occur due to the low change in velocity anticipated (maximum mean change of 0.08 m/s). Therefore, no impacts have been identified on macrophyte communities or any spawning habitat present as a result of deposition of suspended sediment.

Water depth changes in the water course are anticipated to be minimal (mean depth change of 5 cm). Based on current management of releases from Vyrnwy Reservoir the higher plants, bryophytes and lichen communities are deemed to be adapted to fluctuations in water level and depth. Therefore, no discernible impacts are anticipated on higher plants, bryophytes and lichens present in-channel and adjacent to the River Vyrnwy.

Expected changes in water temperature as a result of STT SRO are not deemed to have a discernible impact on protected species, as they will remain within current water temperature fluctuations, as a result of volume releases from Vyrnwy Reservoir between 19 – 150 Ml/d.

[17] Ricardo Energy and Environment (2022). Physical Environment Assessment Annex A. Report for United Utilities on behalf of the STT Group.

3.2.4 STT operation – future climate

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

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 discernible change.

3.2.4.1 Change to flow

Downstream of the reservoir, the flow is increased by 25 Ml/d from the 23rd of May to the 20th of November in the A82 Future scenario. 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. The percentage of flow due to the supported release from Vyrnwy reservoir increases to approximately 5 % - 35 % of the flow downstream of the River Banwy, because the River Banwy increases the reference flow in the river. The long section shows that during low flows in the Future Scenario, on the 18th of October, the reference flow is 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 24th of May to the 20th of November from the reservoir release (less the losses between the reservoir and Llanymynech) at Llanymynech. The flow increase with the scheme is around 15 % of the total flow in the river under Future conditions on the 18th of October. Again, the flow increase is less than the release flow because of losses.

Comparison of the baseline habitat at (45 Ml/d) compensation flow only and habitat under the 25 Ml/d Vyrnwy Reservoir flow augmentation release for STT shows only limited reductions in suitable habitat under the A82 Future scenario run, but thus is likely to exacerbate the effects of prolonged, large Severn Regulation releases included in the reference scenario.

Due to the complexity and volume of data, this is a brief overview of the potential changes only.

3.2.4.1.1 Impact assessment

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.

3.2.4.2 Changes to water quality

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

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

3.3.1 Baseline

Species records included fish (Atlantic salmon *Salmo salar* and sea lamprey *Petromyzon marinus*) aquatic and terrestrial invertebrates (depressed river mussel *Pseudanodonta complanata,* large garden bumblebee *Bombus ruderatus* and streak *Chesias legatella*), mammals (harvest mouse *Micromys minutus*, European hedgehog *Erinaceus europaeus* and European otter *Lutra lutra*), macrophytes (floating water plantain *Luronium natans*, pennyroyal *Mentha pulegium*, slender hare's-ear *Bupleurum tenuissimum* and scarce yellow splinter *Lipsothrix nobilis*) and bird species (scaup *Aythya marila,* house sparrow *Passer domesticus* and tree sparrow *Passer montanus*). Water dependent protected species records returned from NBN Atlas were limited for the River Severn at Gate 2 and are not deemed representative of the species diversity associated with this reach.

No additional protected species surveys were completed for this reach of the River Severn. This reach also overlaps with Countryside Stewardship priority areas for corn bunting *Emberiza calandra*, and curlew *Numenius arquata.*

Protected habitats including Sites of Special Scientific Interest (SSSI)[18] and priority habitats[19] located in the River Severn or adjacent (within 100 m), give an indication of potential water dependent protected species present. Note that sites where impact pathways have been identified to protected species have been underlined. These include:

- River Severn at Montford SSSI (water dependent); no protected species listed in citation.
- Attingham Park SSSI (not water dependent); designated for diversity of saproxylic invertebrates associated with mature and over-mature trees.
- Buildwas River Severn SSSI (water dependent); no protected species listed in citation.
- Tick Wood and Benthall Edge SSSI (not water dependent); Sessile oak *Quercus petraea* and birch *Betula spp*..
- Eymore Railway Cutting SSSI (not water dependent); no protected species listed in citation.
- Wyre Forest SSSI (not water dependent); Site is ancient oak woodland.
- Coastal floodplain grazing marsh priority habitat (water dependent habitat); rich in plants and invertebrates and of particular importance for breeding waders and overwintering birds.
- Lowland meadows priority habitat (water dependent habitat); Provide suitable bird breeding habitat for species such as skylark *Alauda arvensis* and other farmland species such as yellowhammer *Emberiza citronella.*
- Lowland dry acid grassland priority habitat (not water dependent habitat but supports water dependent species); Provides breeding and overwintering bird habitat.
- Deciduous woodland priority habitat (water dependent); Broad habitat category that may include lowland mixed deciduous woodland, wet woodland and lowland beech and yew woodland.
- Woodpasture and parkland priority habitat (supports water dependent species); sites support a diversity of species including fungi, saproxylic invertebrates, lichens, bryophytes, bats and birds.

3.3.2 Relevant impact pathways

Considering the protected species records and the operational pattern, the support releases could therefore, result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Changes in water quality (temperature and dissolved oxygen) could have a direct impact on fish populations via a reduction in fitness and altering egg incubation periods. Water quality changes could also impact on the growth and extent of macrophytes. This could impact on the availability of prey for European otter if present and feeding habitat for waterbirds;
- Increased flows and velocities could cause the loss of and redistribution of fine sediment, impacting on the growth and distribution of macrophytes (some species require autumn flushing of fine sediment for regrowth in spring) and suitability of spawning grounds for fish, impacting on the availability of prey for European otter populations and feeding habitat for waterbirds;
- Increased velocity, flow and depth could potentially impact on the spatial distribution and feeding success of European otter and protected waterbirds;
- Increased velocity and depth could cause the loss/ decrease in habitat quantity and quality due to changes in hydraulics (i.e. increased velocity and depth), impacting on the habitat mosaic and ability to support a diverse range of protected species;
- Direct loss of potential non-breeding holt sites along the River Severn due to increased water level. Based on the size of the main channel natal holts are deemed unlikely to be present as typically located on small feeder streams; and
- Operation during extreme low flow conditions in summer periods may increase the risk of flooding outside of the natural flow regime of supporting/ functionally linked habitats. This could alter the community assemblage of coastal floodplain grazing marsh and lowland meadows (in particular), therefore, reducing the suitability of the sites for breeding birds and water dependent mammals if present.

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[18] Site information on habitat types and associated protected species provided by Natural England SSSI citations.
[19] Site information on associated protected species provided by JNCC UK Biodiversity Action Plan Priority Habitat Descriptions.

3.3.3 STT operation – current conditions

This section sets out the findings of the effects of the STT operation during current or contemporary ('now') climate conditions.

3.3.3.1 Change to flow, velocity, depth and flood regime

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 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.

On the River Severn, downstream of the confluence with the River Vyrnwy, 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.

At Bewdley on the River Severn 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 modelling results shows 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.

For the Shrewsbury right bank, under the A82 scenario, there is an increase in level between 27th June and 10th October. From the 27th of June to the 25th of August the level increases by between 1.0 cm and 3.9 cm with a mean level of 47.50 m AOD compared to the mean baseline level of 47.47 m AOD over this period. Between 26th August and 10th October the level increase is more variable, fluctuating between 1.1 cm and 3.6 cm with a mean level of 47.62 m AOD compared to a mean baseline level of 47.59 m 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 0.5 cm and 3.9 cm increase in level with the mean level over the period being 47.53 m AOD compared to 47.49 m AOD in the baseline.

The modelled changes in velocity at Montford SSSI are summarised as follows:

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

0.59 m/s (with a mean velocity of 0.56m/s) compared to the reference which ranged between 0.53 m/s and 0.59 m/s (with a mean velocity of 0.55 m/s).

3.3.3.1.1 Impact assessment

From the results above, it is evident that the change in flow is not discernible on the upstream and downstream mitigation of prey species as hydrological cues for migration will not be impacted and the increased flows will not impact on the passability of any in-channel barriers. Therefore, no impacts to the feeding success of European otter and protected waterbirds have been identified as a result of changes in prey availability. In addition, due to the plasticity of European otters and ability to commute in varying flow conditions, no discernible impacts on species distribution are anticipated.

The small increase in velocity will not cause the resuspension of fine sediment and therefore, no impacts on the growth and extent of macrophytes have been identified. In addition, limited impacts have been identified on holts or nesting birds in the riparian zone based on the minor increase in water depth.

In addition, due to the minor risk of increased frequency of flooding, there would be no discernible change in the seasonality, duration, or frequency of periodic inundation in adjacent coastal and floodplain grazing marsh, lowland fens, lowland meadows, deciduous woodland, pasture and parkland priority habitat and SSSIs within this reach. Overall, no impacts on the hydrologically connected protected habitats as a result of hydrological and hydraulic changes in this reach are expected under the current conditions[20]. Therefore, no impacts to water dependent species are anticipated.

3.3.3.2 Change to water quality

There is no pathway of general water quality change in this reach from the STT operation. This is because the water that would be discharged in this reach is from the same source (i.e., the Vyrnwy Reservoir) and will simply be discharged in the River Severn instead of entering the River Severn via the River Vyrnwy. As such no assessment is included at Gate 2 for this reach. Information on the general water quality parameters: pH, acid neutralising capacity, biochemical oxygen demand, ammoniacal nitrogen, nutrients (reactive phosphate) is available to be reviewed in the Gate 2 Environmental Water Quality Evidence Report[21] for the site: 25 River Severn (upper) downstream Option 4.

3.3.4 STT operation - future climate

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

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 discernible change.

3.3.4.1 Change to in flow, velocity and depth

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

Downstream of the Vyrnwy Bypass, 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 - 21st November and is a flow increase of around 22 %.

At Bewdley on the River Severn, 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 – 2nd November. The flow increase then reduces and drops off by the 23rd of November.

The long section 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.

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[20] Ricardo Energy and Environment (2022). Severn Thames Transfer SRO, Protected Habitats Assessment Report. Report for United Utilities on behalf of the STT Group.

[21] Ricardo Energy and Environment (2022). Severn Thames Transfer Solution, Environmental Water Quality Assessment Report. Report for United Utilities on behalf of the STT Group.

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

3.3.4.1.1 Impact assessment

From the results above, it is evident that the change in flow is not discernible on the upstream and downstream mitigation of prey species as hydrological cues for migration will not be impacted and the increased flows will not impact on the passability of any in-channel barriers. Therefore, no impacts to the feeding success of European otter and protected waterbirds have been identified as a result of changes in prey availability. In addition, due to the plasticity of European otters and ability to commute in varying flow conditions, no discernible impacts on species distribution are anticipated. The small increase in velocity will not cause the resuspension of fine sediment and therefore, no impacts on the growth and extent of macrophytes have been identified. In addition, limited impacts have been identified on holts or nesting birds in the riparian zone based on the 7 % increase in water depth.

It is noted that during the lowest flow periods, the operation of STT SRO will alter flow rates to a present day condition which may benefit protected species present.

In addition, based on the future scenario outputs, there would be no discernible change in the seasonality, duration, or frequency of periodic inundation in adjacent coastal and floodplain grazing marsh, lowland fens, lowland meadows, deciduous woodland, pasture and parkland priority habitat and SSSIs within this reach. Overall, no impacts on the hydrologically connected protected habitats as a result of hydrological and hydraulic changes in this reach are expected under the current conditions[22]. Therefore, no impacts to water dependent species are anticipated.

3.3.4.2 Changes in water quality

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

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

3.4.1 Baseline

Species records included fish (Atlantic salmon and sea lamprey) aquatic and terrestrial invertebrates (depressed river mussel, large garden bumblebee and streak), mammals (harvest mouse, European hedgehog and European otter), macrophytes (floating water plantain, pennyroyal, slender hare's-ear and scarce yellow splinter) and a bird species (scaup). Water dependent protected species records returned from NBN Atlas were limited for the River Severn at Gate 2 and are not deemed representative of the species diversity associated with this reach.

No additional protected species surveys were completed for this reach of the River Severn. This reach also overlaps with Countryside Stewardship priority areas for corn bunting, curlew, lapwing and snipe.

Protected habitats including SSSIs[23] and priority habitats[24] located in the River Severn or adjacent (within 100 m), give an indication of potential water dependent protected species present. Note that sites where impact pathways have been identified to protected species have been underlined. These include:

- Shrawley Wood SSSI (water dependent habitat); wet woodland present along the River Severn utilised by dipper *Cinclus cinclus* and kingfisher *Alcedo atthis*. The ancient woodland present supports other breeding birds such as garden warbler *Sylvia borin*.

[22] Ricardo Energy and Environment (2022). Severn Thames Transfer SRO, Protected Habitats Assessment Report. Report for United Utilities on behalf of the STT Group.

[23] Site information on habitat types and associated protected species provided by Natural England SSSI citations.

[24] Site information on associated protected species provided by JNCC UK Biodiversity Action Plan Priority Habitat Descriptions.

- Grimley Brick Pits SSSI (water dependent habitat); Wetland habitats present including willow, alder carr, sedge and reedmace swamp, and open water. Site provides supporting habitat for a variety of species including breeding and wintering birds and invertebrates such as red-eyed damselfly *Erythroma najus* and black tailed skimmer *Orthetrum cancellatum*.
- River Teme SSSI (water dependent habitat); The river supports several protected species including twaite shad *Alosa fallax*, sea lamprey *Petromyzon marimus*, brook lamprey *Lampetra planeri*, Atlantic salmon, bullhead *Cottus gobio*, grayling *Thymallus*, European otter, Atlantic stream crayfish *Austropotomobius pallipes* and freshwater pearl mussel *Margaritifera margaritifera*. Note that impacts to fish and macroinvertebrates will be assessed in the Fisheries, and the Macroinvertebrates Assessment Reports.
- Upton Ham SSSI (water dependent habitat); The site consists of an unimproved flood meadow supporting a nationally restricted plant (small-flowered winter-cress *Barbarea stricta*), plus breeding (curlew) and wintering birds (snipe).
- Traditional orchard priority habitat (not water dependent); ecologically similar to wood pasture and parkland priority habitat however, species composition is dominated by Rosaceae.
- Lowland fens priority habitat (water dependent); The site is described as minerotrophic as it primarily receives nutrients from the groundwater, through mineral rich soils, rock or surface waters. They support a diversity of water dependent species such as *Sphagnum* (bog moss).
- Coastal floodplain grazing marsh priority habitat (water dependent habitat), lowland meadows priority habitat (water dependent habitat), deciduous woodland priority habitat (water dependent) wood pasture and parkland priority habitat (supports water dependent species); see description in **Section 3.3**.

3.4.2 Relevant impact pathways

Considering the protected species records and the operational pattern, the support releases could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Changes in water quality (temperature and dissolved oxygen) could have a direct impact on fish populations via a reduction in fitness and altering egg incubation periods. Water quality changes could also impact on the growth and extent of macrophytes. This could impact on the availability of prey for European otter if present and feeding habitat for waterbirds;
- Increased flows and velocities could cause the loss of and redistribution of fine sediment, impacting on the growth and distribution of macrophytes (some species require autumn flushing of fine sediment for regrowth in spring) and suitability of spawning grounds for fish, impacting on the availability of prey for European otter populations and feeding habitat for waterbirds;
- Increased velocity, flow and depth could potentially impact on the spatial distribution and feeding success of European otter and protected waterbirds;
- Increased velocity and depth could cause the loss/ decrease in habitat quantity and quality due to changes in hydraulics (i.e. increased velocity and depth), impacting on the habitat mosaic and ability to support a diverse range of protected species;
- Direct loss of potential non-breeding holt sites along the River Severn due to increased water level. Based on the size of the main channel natal holts are deemed unlikely to be present as typically located on small feeder streams; and
- Operation during extreme low flow conditions in summer periods may increase the risk of flooding outside of the natural flow regime of supporting/ functionally linked habitats. This could alter the community assemblage of coastal floodplain grazing marsh and lowland meadows (in particular), therefore, reducing the suitability of the sites for breeding birds and water dependent mammals if present.

3.4.3 STT operation – current conditions

This section sets out the findings of the effects of the STT scheme operation during current or contemporary (‘now’) climate conditions.

3.4.3.1 Change to flow, velocity, depth, water level and flood regime

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 previously described, 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.

On the River Severn upstream of the confluence with the River Avon 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 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).

The modelled changes in flow, velocity and water depth are summarised as follows:

- The most discernible change **at Bewdley** as a result of the increased flows will be an average daily velocity increase of 0.1 – 15.5% from June to October in the A82 scenario and an average daily increase in velocity of 8.5 – 16.7% from June – November in the M96 scenario. The average daily increase in water depth will be 1.6 – 3.3% from June to October in the A82 scenario, and 8.5 – 16.7% increase in June – November in the M96 scenario. The resulting change in velocity and depth will not be discernible, with velocity in summer expected to increase by ~0.03m/s and depths by ~3cm. As a result, average velocity in summer will remain at ~0.18m/s and depths will remain at ~1.9m.
- The impact of the STT scheme near Upton Ham is taken from the change at the Saxon Lode gauge, with supported flow increase of 2.55 m^3/s. The flow is increased by 0.6 % in the 50 % Annual Exceedance Probability (AEP) (2 year return period) and by 0.3 % in the 2 % AEP (50 year return period). The impact on the frequency at which flooding occurs is therefore, minor. The flood levels are increased by around 15 mm in the frequent AEPs based on the change at the Bewdley gauge, as extreme water level results were unavailable at Saxon Lode[25].
- The modelled changes in water level are summarised as follows: For Lincomb, generally the change in level fluctuates between 2 cm and 4 cm increase in level with the mean level over the period being 15.97 m AOD compared to 15.94 m AOD in the baseline.
- For Holt, generally the change in level fluctuates between a 3 cm and 4 cm increase in level with the mean level over the period being 14.08 m AOD compared to 14.04 m AOD in the baseline.
- For Bevere, generally the change is an approximate increase in level of 4 cm with the mean level over the period being 10.77 m AOD compared to 10.73 m AOD in the baseline.
- For Digilis, generally the change in level fluctuates between a 2 cm and 3 cm increase in level with the mean level over the period being 10.69 m AOD compared to 10.66 m AOD in the baseline.

3.4.3.1.1 Impact assessment

From the results above, it is evident that the change in flow is not discernible on the upstream and downstream mitigation of prey species as hydrological cues for migration will not be impacted and the increased flows will not impact on the passability of any in-channel barriers. Therefore, no impacts to the feeding success of European otter and protected waterbirds have been identified as a result of changes in prey availability. In addition, due to the plasticity of European otters and ability to commute in varying flow conditions, no discernible impacts on species distribution are anticipated. The small increase in velocity will not cause the resuspension of fine sediment and therefore, no impacts on the growth and extent of macrophytes have been identified. In addition, limited impacts have been identified on holts or nesting birds in the riparian zone based on the 1.9 – 3 cm increase in water depth and 2 – 4 cm in water level.

In addition, due to the minor risk of increased frequency of flooding, there would be no discernible change in the seasonality, duration, or frequency of periodic inundation in potentially hydrologically connected priority habitats (coastal and floodplain grazing marsh, lowland fens, lowland meadows, deciduous woodland, wood pasture and parkland and SSSIs) within the impacted reach. Overall, no impacts on the hydrologically connected protected habitats as a result of hydrological and hydraulic changes in this reach are expected under the current conditions[26]. Therefore, no impacts to water dependent species are anticipated.

3.4.3.2 Change to water quality

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

3.4.4 STT operation - future climate

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

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 in flow, velocity, depth and water level

On the River Severn upstream of the confluence with the River Avon 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.

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 modelled changes in water level are summarised as follows:

- For Lincomb, generally the change in level fluctuates between 1 cm and 6 cm increase in level with the mean level over the period being 15.97 m AOD compared to 15.94 m AOD between 24th May and 23rd November.

- For Holt, the level increase is variable at the start of the scheme until 18th June, with a level increase between 1 cm and 6 cm and a mean level of 14.12 m AOD compared to the mean baseline level of 14.09 m AOD. There is subsequently low variability between 18th June and 8th September, with a mean level increase of 4 cm and a mean level of 14.04 m AOD compared to a mean baseline of 14.00 m AOD. From 9th September to 23rd November, the level change is much more variable with a level increase ranging between 1 cm and 5 cm, and a mean level of 14.12 m AOD compared to the mean baseline level of 14.09 m AOD.

- For Bevere, the level increase is variable at the start of the scheme until 17th June, with a level increase between 2 cm and 6 cm. The mean level during this period is 10.81 m AOD compared to the mean baseline level of 10.78 m AOD. There is subsequently low variability between 7th June and 8th September, with a mean level increase of 4 cm and a mean level of 10.71 m AOD compared to a mean baseline of 10.67 m AOD. From 9th September to 23rd November, the level change is much more

[26] Ricardo Energy and Environment (2022). Severn Thames Transfer SRO, Protected Habitats Assessment Report. Report for United Utilities on behalf of the STT Group.

variable with a level increase ranging between 2 cm and 6 cm, and a mean level of 10.82 m AOD compared to the mean baseline level of 10.79 m AOD.

- For Digilis, the level increase is variable at the start of the scheme until 17th June, with a level increase between 1 cm and 4 cm. The mean level during this period is 10.81 m AOD compared to the mean baseline level of 10.78 m 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 10.71 m AOD compared to a mean baseline of 10.67 m AOD. From 9th September to 23rd November, the level change is much more variable with a level increase ranging between 1 cm and 4 cm, and a mean level of 10.82 m AOD compared to the mean baseline level of 10.79 m AOD.

3.4.4.1.1 Impact assessment

From the results above, it is evident that the change in flow is not discernible on the upstream and downstream mitigation of prey species as hydrological cues for migration will not be impacted and the increased flows will not impact on the passability of any in-channel barriers. Therefore, no impacts to the feeding success of European otter and protected waterbirds have been identified as a result of changes in prey availability. In addition, due to the plasticity of European otters and ability to commute in varying flow conditions, no discernible impacts on species distribution are anticipated. The small increase in velocity will not cause the resuspension of fine sediment and therefore, no impacts on the growth and extent of macrophytes have been identified. In addition, limited impacts have been identified on holts or nesting birds in the riparian zone based on the 7 % increase in water depth and maximum increase of 6 cm in water level.

In addition, based on the future scenario outputs, there would be no discernible change in the seasonality, duration, or frequency of periodic inundation in adjacent coastal and floodplain grazing marsh, lowland fens, lowland meadows, deciduous woodland, pasture and parkland priority habitat and SSSIs within this reach. Overall, no impacts on the hydrologically connected protected habitats as a result of hydrological and hydraulic changes in this reach are expected under the current conditions[27]. Therefore, no impacts to water dependent species are anticipated.

3.4.4.2 Changes in water quality

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

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

3.5.1 Baseline

Species records included fish (Atlantic salmon), an aquatic invertebrate (depressed river mussel), mammals (European hedgehog) and birds (house sparrow and tree sparrow). Water dependent protected species records returned from NBN Atlas were limited for the River Avon at Gate 2 and are not deemed representative of the species diversity associated with this reach. In addition, water vole surveys were undertaken in 2021 with no signs of water vole recorded. The presence of European otter was confirmed at three sites via records of otter spraints and also the presence of American mink *Neovision vison* via skats (see **Figure 3.1**).

[27] Ricardo Energy and Environment (2022). Severn Thames Transfer SRO, Protected Habitats Assessment Report. Report for United Utilities on behalf of the STT Group.

AV10	AV13
	

Figure 3.1 AV10 showing European otter *Lutra lutra* spraint identified on a log and AV13 showing American mink *Neovision vison* skat.

This reach also overlaps with Countryside Stewardship priority areas for brown hairstreak *Thecla betulae*, corn bunting, curlew, lapwing and redshank.

Protected habitats including SSSIs[28] and priority habitats[29] located in the River Avon or adjacent (within 100 m) give an indication of potential water dependent protected species present. Note that sites where impact pathways have been identified to protected species have been underlined. These include:

- Coastal floodplain grazing marsh (water dependent habitat), lowland meadows (water dependent habitat), deciduous woodland (water dependent) and wood pasture and parkland priority habitat (not water dependent); see description in **Section 3.3**.
- Traditional orchard priority habitat (not water dependent); see description in **Section 3.4.1.**
- Guy's Cliffe SSSI; No protected species listed in citation.
- Racecourse meadows SSSI (water dependent habitat); The site is an unimproved field located on the floodplain of the River Avon. It supports a diversity of herbs and grasses including pepper saxifrage *Silaum silaus*, corn parsley *Petroselinum segetum*, meadow foxtail *Alopecurus pratensis*, great burnet *Sanguisorba officinalis,* common bent grass *Agrostic capillaris* and red fescue *Festuca rubra*.
- Welford Field SSSI (water dependent habitat); The site is an unimproved field located on the floodplain of the River Avon. It supports a diversity of herbs and grasses including salad burnet *Sanguisorba minor*, meadow foxtail, great burnet and red fescue*.*
- Tiddesley Wood SSSI (water dependent habitat); Largely broadleaved woodland which supports a diversity of butterflies and dragonflies. Along the western edge, tall fen and marsh habitat is present supporting breeding marsh warbler *Acrocephalus palustris*, which is nationally rare.
- Rectory Farm Meadows SSSI (water dependent habitat); The mesotrophic (neutral) grassland is characterised by meadow foxtail and great burnet. Frequent grasses include sweet vernal grass *Anthoxanthum odoratum*, red fescue and soft brome *Bromus hordeaceus*.
- Upham Meadow and Summer Leasow SSSI (water dependent habitat); Hay meadow with a high-water table that supports nationally important numbers of breeding waders including redshank, curlew and snipe. Ditches and wet areas provide suitable breeding habitat for reed warbler *Acrocepha scirpaceus*, sedge warbler *A. schoenobaenus* and reed bunting *Emberiza schoeniclus*. The site also important for wintering waders and wildfowl which use the site to feed and roost. It regularly supports large numbers of lapwing, dunlin *Calidris alphina* and up to 2000 golden plover *Pluvialis apricaria*. In some winters nationally important numbers of Bewick's swan *Cygnus columbianus* use the site.

[28] Site information on habitat types and associated protected species provided by Natural England SSSI citations.
[29] Site information on associated protected species provided by JNCC UK Biodiversity Action Plan Priority Habitat Descriptions.

3.5.2 Relevant impact pathways

Considering the protected species records and the operational pattern, the support releases could therefore, result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Changes in water quality (temperature and dissolved oxygen) could have a direct impact on fish populations via a reduction in fitness and growth of macrophytes. This could impact on the availability of prey for European otter if present and feeding habitat for waterbirds.
- Exposure of protected species to contaminants which could impact on the health of individuals and presence of population within the reach.
- Increased velocity and flow could cause the loss of and redistribution of fine sediment, impacting on the growth and distribution of macrophytes (some species require autumn flushing of fine sediment for regrowth in spring) and suitability of spawning grounds for fish, impacting on the availability of prey for European otter populations and feeding habitat for waterbirds.
- Increased velocity, flow and depth could potentially impact on the spatial distribution and feeding success of European otter and protected waterbirds.
- Increased velocity, flow and depth could cause the loss/ decrease in habitat quantity and quality due to changes in hydraulics (i.e. increased velocity and depth), impacting on the habitat mosaic and ability to support a diverse range of protected species.
- Direct loss of potential non-breeding holt sites and bird nesting sites in the riparian zone along the River Avon due to increased water level. Based on the size of the main channel natal holts are deemed unlikely to be present as typically located on small feeder streams.
- Operation during extreme low flow conditions in summer periods may increase the risk of flooding outside of the natural flow regime of supporting/ functionally linked habitats. This could alter the community assemblage of coastal floodplain grazing marsh and lowland meadows (in particular), therefore, reducing the suitability of the sites for breeding birds and water dependent mammals if present.

3.5.3 STT operation – current conditions

This section sets out the findings of the effects of the STT scheme operation during current or contemporary ('now') climate conditions.

3.5.3.1 Change to flow, velocity, depth and flood regime

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 of the STT solution involves discharges releases only in 24 of the 47 years, and on 15% of days overall. 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.

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, which is approximately 60% in A82 and 64% in M96 compared to the reference conditions summer flow.

Downstream of Warwick 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 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 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 model outputs show that the solution increases flow by 115 Ml/d initially downstream of the Minworth transfer outfall. 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.

The modelled changes are summarised as follows:

- The most discernible change **upstream of Alveston** as a result of the increased flows will be an average daily increase of 35.9 – 42 % in velocity in the months of July, August and September in an A82 scenario and an average daily increase in velocity of 19 – 50 % in the months of June – October in M96 scenario (as measured downstream of Warwick). The potential changes in depths have been assessed as a maximum increase of 1.7% (~4 cm) in both scenarios and is not considered discernible in consideration of the geomorphology. As a result, the proportionate change in the average velocities has been modelled as an increase of approximately 0.02 m/s in both scenarios
- The most discernible changes **downstream of Alveston** as a result of the increased flows will be an average daily increase of 20.9 – 25.7 % in velocity in the months of July, August and September in an A82 scenario and an average daily increase in velocity of 21.7 – 24.5 % in the months of July – October in M96 scenario. The potential changes in depths have been assessed as a maximum increase of 1 % (~2 cm) in both scenarios and is not considered discernible in consideration of the geomorphology. As a result, the proportionate change in the average velocities has been modelled as an increase of approximately 0.03 m/s in both scenarios.
- The most discernible change **upstream of the confluence with the River Severn** as a result of the increased flows will be an average daily increase of 18.6– 26.4 % in velocity in the months of July, August and September in an A82 scenario and an average daily increase in velocity of 21.9 – 25.9 % in the months of July – October in M96 scenario. No change in depth has been identified in either of the scenarios. As a result, the proportionate change in the average velocities has been modelled as an increase of approximately 0.01 m/s in both scenarios.
- The impact of the STT scheme on the lower River Avon is taken from the change at the Evesham gauge, including the additional flow from the Minworth component of the STT scheme, supported flow increase of 1.33 m^3/s. The flow is increased by 0.8 % in the 50 % AEP (2 year return period) and by 0.3 % in the 2 % AEP (50 year return period). The impact on the frequency at which flooding occurs is therefore, minor. The flood levels are increased by around 10 mm in the frequent AEPs[30].

Under the both the A82 and M96 scenarios, there is an increase in level between the end of June and mid-October with increased levels also observed into late October. The potential changes in depth are up to 4 cm upstream of Alveston or 0-2 cm in the sections of the reach downstream of Alverston. The most measurable increase in velocity would be observed upstream of Alveston where the maximum proportionate increase in velocity of 50 % would equate to a maximum increase of 0.02 m/s. The result will be that velocities in this reach will be ~ 0.07 m/s instead of 0.05 m/s. The assessment is further supported by data collected during hydraulic surveys in 2021. Two surveys were completed under two different flows, 229 Ml/d measured on 16th and 20th July 2021 and 381 Ml/d measured on 26th October 2021, a difference of 152 Ml/d. The surveys were completed in the reach downstream of Warwick and it is noted that the flows during the surveys were higher than the proposed release of 115 Ml/d.

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 – 5 cm in this reach. Note there are localised exceptions where water levels may increase outside of this estimated range.

3.5.3.1.1 Impact assessment

From the results above, it is evident that the change in flow is not discernible on the upstream and downstream mitigation of prey species as hydrological cues for migration will not be impacted and the increased flows will not impact on the passability of any in-channel barriers. Therefore, no impacts to the feeding success of European otter and protected waterbirds have been identified as a result of changes in prey availability. In addition, due to the plasticity of European otters and ability to commute in varying flow conditions, no discernible impacts on species distribution are anticipated. The small increase in velocity will not cause the resuspension of fine sediment and therefore, no impacts on the growth and extent of macrophytes have been

[30] HR Wallingford (2022). Severn Thames Transfer SRO – Hydraulic and Water Quality Modelling, Flooding Assessment. Report for Ricardo, 1 – 43.

identified. In addition, limited impacts have been identified on holts or nesting birds in the riparian zone based on the maximum increase of 1.7 % in depth 3 – 5 cm in water level.

Due to the minor risk of increased frequency of flooding, there would be no discernible change in the seasonality, duration, or frequency of periodic inundation on functionally linked habitat (coastal floodplain grazing marsh, lowland meadows, deciduous woodland, wood pasture and parkland priority habitat and SSSIs) for protected waterbirds, European otter and other water dependent habitats present in this reach. Overall, no impacts on the hydrologically connected designated sites or protected habitats as a result of hydrological and hydraulic changes in this reach are expected under the current conditions[31]..

Based on the operational timeframe of STT operation, no impact pathways have been identified for wintering waders and wildfowl associated with functionally linked habitat such as coastal floodplain grazing marsh, lowland meadows and Upham Meadow and Summer Leasow SSSI.

Therefore, no impacts to water dependent species are anticipated

3.5.3.2 Change to water quality

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

- During the scheme operation, the river water temperature would be higher. This increase is similar for both scenarios: up to 0.8 °C upstream of Warwick, and up to 0.5 °C at Evesham and at the confluence with River Severn. Modelled data indicates that in summer temperatures will remain below 17.5 ^{0}C
- The discharge will reduce dissolved oxygen immediately downstream of the outfall up to the confluence with the River Leme by ~1.5 mg/l. Dissolved oxygen (as % saturation) will remain above 75 % within the first 20 km and remain above 90 % for the remainder of the reach, up to the confluence with the River Severn.
- Ammoniacal nitrogen is expected to increase by 0.1-0.15 mg/ downstream of Warwick with the increase of 0.05 mg/l at Evesham and 0.02 mg/l at the confluence with the River Severn. Soluble reactive phosphate concentrations are reduced by the scheme throughout the River Avon by up to 0.1 mg/l.
- Increase in nonylphenols, cypermethrin, perfluorooctane sulfonic acid and its derivatives and permethrin concentrations resulting in further deterioration in current Environmental Quality Standard failures in the River Avon.

3.5.3.2.1 Impact assessment

The results of the water quality modelling indicate that water quality changes are expected to be minimal with a slight decrease in some nutrients expected. The temperature and dissolved oxygen (as % saturation) will remain within the range for achieving high ecological status. Therefore, no discernible impacts are anticipated on protected species. The impacts of exposure to contaminants will be reviewed in detail at Gate 3.

3.5.4 STT operation - future climate

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

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 discernible change.

3.5.4.1 Change to in flow, velocity and depth

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, which is approximately 64 % in A82 Future compared to the reference conditions summer flow. The scheme runs from the 25th of May to the 21st of November in the A82 Future climate.

[31] Ricardo Energy and Environment (2022). Severn Thames Transfer SRO, Protected Habitats Assessment Report. Report for United Utilities on behalf of the STT Group.

Downstream of Warwick, 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 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, 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 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.

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).

3.5.4.1.1 Impact assessment

From the results above, it is evident that the change in flow is not discernible on the upstream and downstream mitigation of prey species as hydrological cues for migration will not be impacted and the increased flows will not impact on the passability of any in-channel barriers. Therefore, no impacts to the feeding success of European otter and protected waterbirds have been identified as a result of changes in prey availability. In addition, due to the plasticity of European otters and ability to commute in varying flow conditions, no discernible impacts on species distribution are anticipated. The small increase in velocity will not cause the resuspension of fine sediment and therefore, no impacts on the growth and extent of macrophytes have been identified.

However, a 0.11 m mean change in water depth is predicted for immediately downstream of the Minworth Transfer outfall. If emergent macrophyte communities are present these may become inundated and deteriorate, causing a loss of supporting habitat for potential waterbirds and riparian mammals present. As the water depth change predicted is not representative of the river as a whole, further assessment is recommended to determine habitats present.

In addition, based on the future scenario outputs, there would be no discernible change in the seasonality, duration, or frequency of periodic inundation due to flooding on functionally linked habitat (coastal floodplain grazing marsh, lowland meadows, deciduous woodland, wood pasture and parkland priority habitat and SSSIs) for protected waterbirds, European otter and other water dependent habitats present in this reach. Overall, no impacts on the hydrologically connected designated sites or protected habitats as a result of hydrological and hydraulic changes in this reach are expected under the current conditions[32]..

3.5.4.2 Changes in water quality

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

3.5.4.2.1 Impact assessment

Therefore, the results of the water quality modelling indicate that water quality changes are expected to be minimal with a slight decrease in some nutrients expected. The temperature and dissolved oxygen (as %

[32] Ricardo Energy and Environment (2022). Severn Thames Transfer SRO, Protected Habitats Assessment Report. Report for United Utilities on behalf of the STT Group.

saturation) will remain within the range for achieving high ecological status. Therefore, no discernible impacts are anticipated on protected species.

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

3.6.1 Baseline

Species records included fish (Atlantic salmon and sea lamprey) aquatic and terrestrial invertebrates (depressed river mussel, large garden bumblebee and streak), mammals (harvest mouse, European hedgehog and European otter), macrophytes (floating water plantain, pennyroyal, slender hare's-ear and scarce yellow splinter) and a bird species (scaup). Water dependent protected species records returned from NBN Atlas were limited for the River Severn at Gate 2 and are not deemed representative of the species diversity associated with this reach.

No additional protected species surveys were completed for this reach of the River Severn. This reach also overlaps with Countryside Stewardship priority areas for corn bunting, curlew, lapwing and redshank.

Protected habitats including SSSIs[33] and priority habitats[34] located in the River Severn or adjacent (within 100 m) give an indication of potential water dependent protected species present. Note that sites where impact pathways have been identified to protected species have been underlined. These include:

- <u>Severn Ham Tewkesbury SSSI</u> (water dependent habitat); The Ham is particularly rich in grass species such as cocksfoot *Dactylis glomerata*, meadow foxtail, meadow barley *Hordeum secalinum* and smooth brome *Bromus racemosus*. Marsh foxtail *Alopecurus geniculatus* is also present and becomes dominant in the lower lying, wetter areas.
- <u>Old River Severn Upper Lode SSSI</u> (water dependent habitat); Site is an old meander of the River Severn supporting a diversity of macrophytes and birds. Macrophytes include pondweed *Potamogeton* sp. while the muddy margins support abundant flowering rush *Butomus umbellatus*, water forget-me-not *Myosotis scorpioides*, water-cress *Nasturtium officinale* and water dock *Rumex hydrolapathum*. Birds present at the site include mallard *Anas platyrhynchos* and coot *Fulica atra* on the open water. Reed warblers and sedge warblers breed in the willows. Kingfisher is regularly seen, as are waders such as redshank common sandpiper *T. hypoleucos* and lapwing. Several species of dragonflies have been recorded including the scarce hawker *Aeshna mixta* and white-legged damselfly *Platycnemis pennipes*.
- <u>Coastal floodplain grazing marsh</u> (water dependent habitat), <u>lowland meadow</u> (water dependent habitat) and <u>deciduous woodland</u> (water dependent) priority habitat; see descriptions in **Section 3.3.**

3.6.2 Relevant impact pathways

Considering the protected species records and the operational pattern, the support releases could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Changes in water quality (dissolved oxygen) could have a direct impact on fish populations via a reduction in fitness and potentially mortality and growth of macrophytes. This could impact on the availability of prey for European otter if present and feeding habitat for waterbirds.
- Increased velocity, flow and depth could potentially impact on the spatial distribution and feeding success of European otter and protected waterbirds.
- Loss/ decrease in habitat quantity and quality due to changes in hydraulics (i.e. increased velocity and depth), impacting on the habitat mosaic and ability to support a diverse range of protected species.
- Direct loss of potential non-breeding holt sites along the River Severn due to increased water level. Based on the size of the main channel natal holts are deemed unlikely to be present as typically located on small feeder streams.

[33] Site information on habitat types and associated protected species provided by Natural England SSSI citations.
[34] Site information on associated protected species provided by JNCC UK Biodiversity Action Plan Priority Habitat Descriptions.

- Operation during extreme low flow conditions in summer periods may increase the risk of flooding outside of the natural flow regime of supporting/ functionally linked habitats. This could alter the community assemblage of coastal floodplain grazing marsh and lowland meadows (in particular), therefore, reducing the suitability of the sites for breeding birds and water dependent mammals if present.
- Exposure of protected species to contaminants which could impact on the health of individuals and presence of population within the reach.

3.6.3 STT operation – current conditions

This section sets out the findings of the effects of the scheme operation during current or contemporary ('now') climate conditions.

3.6.3.1 Change to flow, velocity and depth

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, 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.

The increase in flow upstream of Deerhurst, 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. The flow increase during the summer period is around 309 Ml/d.

The modelled changes in flow, velocity and depth are summarised as follows:

- The most discernible change **at the Upper Lode weir/downstream of the confluence with the river Avon** as a result of the increased flows will be an average daily increase of 4.3- 12.6 % in velocity in the months of June - October in an A82 scenario and an average daily increase in velocity of 3.2 – 15.7 % in the months of June – November in M96 scenario. As a result, the proportionate change in the average velocities has been modelled as an increase of approximately 0.02 m/s in both scenarios. The modelled data shows that depth will not change during operation, although a slight decrease in depth is noted in October (~0.5 cm).
- The most discernible changes **downstream of Upper Lode weir/upstream of Deerhurst** as a result of the increased flows will be an average daily increase of 0.1- 15.1 % in velocity in the months of June - October in an A82 scenario and an average daily increase in velocity of 1.9 – 18.4 % in the months of June – November in M96 scenario. As a result, the proportionate change in the average velocities has been modelled as an increase of approximately 0.02 m/s in both scenarios. The modelled data shows that depth will not change during operation, although a slight decrease in depth is noted in October (~0.5 cm).

In relation to water level, under the full STT A82 scenario, between, roughly, the 1st of April and 20th June the level reduces by a range of 0.4 cm and 0.6 cm 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 0.9 cm and an increase of 3.0 cm 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 0.2 cm to a reduction of 12.8 cm, with the level ranging between 6.70 m AOD and 10.54 m AOD (with a mean level of 7.63 m AOD) compared to the reference levels which range between 6.71 m AOD and 10.60 m AOD (with a mean level of 7.69 m 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 0.4 cm and 0.6 cm 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 0.9 cm reduction to a 3.3 cm 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 0.5 cm and 11.3 cm with the level ranging between 6.78 m AOD and 11.41 m AOD (with a mean level of 9.09 m AOD) compared to the reference levels which range between 6.79 m AOD and 11.45 m 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.

3.6.3.1.1 Impact assessment

From the results above, it is evident that the change in flow is not discernible and will not impact on the feeding success of European otter and protected waterbirds, distribution and growth of macrophytes or migration of prey species upstream and downstream. The potential changes in velocity and depth are not considered to be of a magnitude to result in impacts on protected species present. For example, the potential changes in depth are limited to a 0.5 cm reduction in October. The Old River Severn Upper Lode SSSI would consequently be subject to an equivalent reduction in water level (-0.5 cm) in October. Due to the small scale and duration of water level changes in the River Severn and the existing fluctuations in water level within the site, no changes in habitat distribution or species composition are anticipated. In addition, due to the minor risk of increased frequency of flooding, there would be no discernible change in the seasonality, duration, or frequency of periodic inundation in Severn Ham, Tewkesbury SSSI, Old River Severn Upper Lode SSSI, and areas or the coastal and floodplain grazing marsh adjacent to the impacted reach. Therefore, no impacts to water dependent species are anticipated.

3.6.3.2 Change to water quality

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

- In the River Severn upstream of Deerhurst, water temperature is not predicted to change due to the STT operation;
- Dissolved oxygen concentrations, nor saturations, are not predicted to change due to the STT operation;
- Ammoniacal nitrogen concentrations are also not predicted to change due to the STT operation; and
- Soluble reactive phosphate concentrations are predicted to be reduced by up to 0.05 mg/l during the operation of STT.
- Increase in nonylphenols, cypermethrin, perfluorooctane sulfonic acid and its derivatives and permethrin concentrations resulting in further deterioration in current Environmental Quality Standard failures in the River Avon.

3.6.3.2.1 Impact Assessment

As there are no changes in the physico-chemical characteristics of the water, no impacts on protected species are expected. Decreased phosphate concentration would provide a potential benefit through a reduction in algal growth. Potential impacts from exposure to contaminants on protected species will be further assessed at Gate 3.

3.6.4 STT operation – future climate

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

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 discernible change.

3.6.4.1 Change to in flow, velocity and depth

The increase in flow upstream of Deerhurst, due to the fully supported STT scheme is around 17 % in the A82 Future climate scenario. The period of the scheme is 28th May – 20th November in the A82 Future scenario, which is longer than in the M96 baseline scenario. 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.

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.

3.6.4.1.1 Impact assessment

From the results above, it is evident that the change in flow is not discernible and will not impact on the feeding success of European otter and protected waterbirds, distribution and growth of macrophytes or migration of prey species upstream and downstream. Note that additional water in the River Severn, upstream of Deerhurst may have positive impacts on protected species as the flow rate has been predicted to be 30 % less than present low flow conditions. No impact pathways from changes in velocity and depth have been identified on protected species in this reach due to limited change.

3.6.4.2 Changes in water quality

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

3.6.4.2.1 Impact assessment

As there are no changes in the physico-chemical characteristics of the water, no impacts on protected species are expected. Decreased phosphate concentration would provide a potential benefit through a reduction in algal growth.

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

3.7.1 Baseline

Species records included fish (Atlantic salmon and sea lamprey) aquatic and terrestrial invertebrates (depressed river mussel, large garden bumblebee and streak), mammals (harvest mouse, European hedgehog and European otter), macrophytes (floating water plantain, pennyroyal, slender hare's-ear and scarce yellow splinter) and birds (scaup, house sparrow and tree sparrow). Water dependent protected species records returned from NBN Atlas were limited for the River Severn at Gate 2 and are not deemed representative of the species diversity associated with this reach.

No additional protected species surveys were completed for this reach of the River Severn. This reach also overlaps with Countryside Stewardship priority areas for curlew and lapwing.

Protected habitats including SSSIs[35] and priority habitats[36] located in the River Severn or adjacent (within 100 m) give an indication of potential water dependent protected species present. Note that sites where impact pathways have been identified to protected species have been underlined. These include:

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[35] Site information on habitat types and associated protected species provided by Natural England SSSI citations.

[36] Site information on associated protected species provided by JNCC UK Biodiversity Action Plan Priority Habitat Descriptions.

- Wainlode Cliff SSSI; No protected species mentioned in citation.
- Ashleworth Ham SSSI (water dependent habitat); Grassland overlying alluvial soils of the Severn floodplain. Parts of the site are of botanical interest while the whole area, which floods each year, is an important refuge for wintering waders and wildfowl.
- Coastal floodplain grazing marsh (water dependent habitat), lowland meadows (water dependent habitat) and deciduous woodland (water dependent); see description in **Section 3.3**.
- Traditional orchard priority habitat (not water dependent); see description in **Section 3.4.1.**

3.7.2 Relevant impact pathways

Considering the protected species records and the operational pattern, the support releases and/or unsupported could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Changes in water quality (dissolved oxygen) could have a direct impact on fish populations via a reduction in fitness and potentially mortality and growth of macrophytes. This could impact on the availability of prey for European otter if present and feeding habitat for waterbirds.
- Decreased velocities could potentially impact on the spatial distribution and feeding success of European otter and waterbirds.
- Increase in suspended sediment loading due to a decrease in velocity could result in smothering of benthic habitats and coastal saltmarsh, key feeding grounds for European otter and waterbirds.

3.7.3 STT operation – current conditions

This section sets out the findings of the effects of the STT operation during current or contemporary ('now') climate conditions.

3.7.3.1 Change to change to flow, velocity, depth and flood regime

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 HoF conditions identified by EA. The indicative system operation pattern shows the STT solution abstraction occurring in 24 of the 47 years, and on 11% of days overall.

Early phase (Unsupported)

Water 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. 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.

The modelled long profile of flow 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. 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 modelling results show 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.

Habitats in this reach is generally uniform with some change in habitat availability near the Maismore weir.

- The most discernible change in an unsupported abstraction will be an average daily decrease of 4.6 % in velocity in November in an A82 scenario and an average daily increase in velocity of 2.5 % in December in an M96 scenario. As a result, the proportionate change in the average velocities will not be discernible. The change in depth in both scenarios is not expected to exceed 2 % which equates to approximately 2 cm in autumn noting that depths will exceed 3.6 m.

- The most discernible change in a supported abstraction will be an average daily decrease of 2.1- 4.6 % in velocity in the months of September - November in an A82 scenario and an average daily increase in velocity of 0.1 – 4.6 % decrease in velocity in the months of October to January in M96 scenario. Depths are likely to decrease by 0.5 – 1.9 % between September and November in the A82 scenario and 0.1 – 1.9 % in the M96 scenario. As a result, the proportionate change in the average velocities will not be discernible. The change in depth in both scenarios is not expected to exceed 2 % which equates to approximately 2 cm in autumn noting that depths will exceed 3.6 m.
- The impact of the STT scheme near Gloucester is taken from the change at the Deerhurst gauge with an increased flow of 3.87 m^3/s. The flow is increased by 0.7 % in the 50 % AEP (2 year return period) and by 0.4 % in the 2 % AEP (50 year return period). The impact on the frequency at which flooding occurs is therefore minor. The flood levels are increased by around 6 mm in the less frequent AEPs based on the change at the Deerhurst gauge. As data was not available for the frequent floods an increase of around 10 mm was inferred from the Avon at Evesham and Severn at Bewdley[37].

3.7.3.1.1 Impact assessment

From the results above, it is evident that the change in flow is not discernible and will not impact on the feeding success of European otter and protected waterbirds, distribution and growth of macrophytes or migration of prey species upstream and downstream. The potential changes in velocity and depth (not expected over 2 cm) are not considered to be of a magnitude to result in impacts on protected species present. In addition, due to the minor risk of increased frequency of flooding, there would be no discernible change in the seasonality, duration, or frequency of periodic inundation in areas of functionally linked habitat such as coastal floodplain grazing marsh, lowland meadows and the SSSIs[38]. Overall, no impacts on the hydrologically connected protected habitats as a result of hydrological and hydraulic changes in this reach are expected under the current conditions. Therefore, no impacts to water dependent species are anticipated.

3.7.3.2 Change to water quality

Similar changes in water quality are generally predicted for both the A82 and M96 scenarios under the fully supported STT operation and are summarised below:

- In the River Severn downstream of Deerhurst (upstream of the Netheridge discharge) and at the tidal limit, the STT operation is predicted to reduce water temperature by 0.2°C (A82) and 0.3°C (M96);
- Dissolved oxygen concentrations are predicted to be reduced by about 0.1 mg/l at both sites (a reduction of less than 1 % saturation);
- Ammoniacal nitrogen concentrations are predicted to be increased by about 0.02 mg/l at both sites; and
- Soluble reactive phosphate concentrations are predicted to be reduced by up to 0.02 mg/l during the operation of the scheme at both sites.

3.7.3.2.1 Impact assessment

The results of the water quality modelling indicate that water quality changes are expected to be minimal with a slight decrease in some nutrients expected. The temperature and dissolved oxygen (as % saturation) will remain within the range for achieving high ecological status. No impact pathways have been identified for dissolved oxygen or temperature for hydrologically connected water dependent designated sites or protected habitats and associated species.

The reduction in soluble reactive phosphate within the River Severn associated with the STT scheme operation is not considered likely to alter community composition or vegetation structure within adjacent site or habitats due to the baseline conditions and period in which the scheme will be operational. The UKHab surveys undertaken in 2021 indicate that the habitats within the reach are typically modified through agriculture and indicative of high nutrient levels with low species diversity in a large proportion of the grasslands adjacent to the lower Severn. A reduction in Soluble Reactive Phosphorus (SRP) within the river has potential benefits for the adjacent habitats and associated protected species.

3.7.4 STT operation - future climate

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

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[37] HR Wallingford (2022). Severn Thames Transfer SRO – Hydraulic and Water Quality Modelling, Flooding Assessment. Report for Ricardo, 1 – 43.

[38] Ricardo Energy and Environment (2022). Severn Thames Transfer SRO, Protected Habitats Assessment Report. Report for United Utilities on behalf of the STT Group.

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 discernible change. In the A82 Future reference conditions River Severn flows are below HoF 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, velocity and depth

In the fully supported STT scheme, there is a flow reduction of approximately 1.5 % during the summer. 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 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.

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).

3.7.4.1.1 Impact assessment

No impact pathways from changes in depth and velocity have been identified due to the small magnitude of change predicted. From the results above, it is evident that the change in flow is not discernible and will not impact on the feeding success of European otter and protected waterbirds, distribution and growth of macrophytes or migration of prey species upstream and downstream.

3.7.4.2 Changes to water quality

Under Scenario A82F, the predicted water quality in the River Severn downstream of Deerhurst is very similar to that predicted under A82 and M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for A82F in this sub-reach occurs over a longer period, the peak changes in concentrations are very similar to A82/ M96 for all parameters.

3.7.4.2.1 Impact assessment

The results of the water quality modelling indicate that water quality changes are expected to be minimal with a slight decrease in some nutrients expected. The temperature and dissolved oxygen (as % saturation) will remain within the range for achieving high ecological status. No impact pathways have been identified for dissolved oxygen or temperature for hydrologically connected water dependent designated sites or protected habitats and associated species.

The reduction in soluble reactive phosphate within the River Severn associated with the STT scheme operation is not considered likely to alter community composition or vegetation structure within adjacent site or habitats due to the baseline conditions and period in which the scheme will be operational. The UKHab surveys undertaken in 2021 indicate that the habitats within the reach are typically modified through agriculture and indicative of high nutrient levels with low species diversity in a large proportion of the grasslands adjacent to the lower Severn. A reduction in Soluble Reactive Phosphorus (SRP) within the river has potential benefits for the adjacent habitats and associated protected species.

3.8 THE SEVERN ESTUARY DOWNSTREAM OF THE TIDAL LIMIT AT GLOUCESTER

3.8.1 Baseline

Species records included fish (Atlantic salmon and sea lamprey) aquatic and terrestrial invertebrates (depressed river mussel, large garden bumblebee and streak), mammals (harvest mouse, European hedgehog and European otter), macrophytes (floating water plantain, pennyroyal, slender hare's-ear and scarce yellow splinter) and birds (scaup). Water dependent protected species records from NBN Atlas were limited for the River Severn at Gate 2 and are not deemed representative of the species diversity associated with this reach.

No additional protected species surveys completed for this reach of the River Severn. This reach also overlaps with Countryside Stewardship priority areas for curlew, lapwing, redshank and snipe.

Protected habitats including SSSIs[39] and priority habitats[40] located in the River Severn or adjacent (within 100 m) give an indication of potential water dependent protected species present. Note that sites where impact pathways have been identified to protected species have been underlined. These include:

- Garden Cliff SSSI; No protected species mentioned in citation.
- Upper Severn Estuary SSSI (water dependent habitat); Seaward of high water the saltmarsh is dominated by species such as common cord-grass *Spartina anglica*, common saltmarsh-grass *Puccinellia maritima* and glasswort *Salicornia europaea.* It regularly supports more than 10,000 wintering wildfowl. Amongst these are internationally significant numbers of Bewick's swans (350; c. 3% of the European wintering population), European white-fronted geese *Anser albifrons* (3500; c. 2%) and wigeon *Anas penelope* (6600; over 1%). The Severn Estuary also provides feeding and roosting grounds for large numbers of gulls and waders, particularly in the winter.
- Severn Estuary SSSI (water dependent habitat); The estuarine fauna includes internationally important populations of waterfowl, invertebrates of considerable interest and large populations of migratory fish, including the nationally rare and endangered Allis shad *Alosa*.
- Purton Passage SSSI; No protected species mentioned in citation.
- Lydney Cliff SSSI; No protected species mentioned in citation.
- Aust Cliff SSSI; No protected species mentioned in citation.
- Lowland meadow (water dependent habitat), coastal floodplain grazing marsh (water dependent habitat) and deciduous woodland (water dependent); see description in **Section 3.3**
- Traditional orchard (not water dependent); see description in **Section 3.4.1**
- Intertidal mudflats priority habitat (water dependent habitat); Mudflats are characterised by high biological productivity and abundance of organisms, but low diversity with few rare species. Under nutrient-rich conditions, algal mats can form consisting of *Enteromorpha* spp. or *Ulva* spp. Mudflats support large numbers of predatory birds and fish.
- Coastal saltmarsh priority habitat (water dependent habitat); Saltmarshes are an important resource for waders and wildfowl. They act as high tide refuges for birds feeding on adjacent mudflats, as breeding sites for waders, gulls and terns and as a source of food for passerine birds, particularly in autumn and winter. Areas with high structural and plant diversity, particularly where freshwater seepages provide a transition from fresh to brackish conditions, are particularly important for invertebrates.

3.8.2 Relevant impact pathways

Considering the protected species records and the operational pattern, the support releases could therefore, result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Changes in water quality (dissolved oxygen and nutrient loading) could have a direct impact on fish populations via a reduction in fitness and growth of macrophytes. This could impact on the availability of prey for European otter if present and feeding habitat for waterbirds.

[39] Site information on habitat types and associated protected species provided by Natural England SSSI citations.
[40] Site information on associated protected species provided by JNCC UK Biodiversity Action Plan Priority Habitat Descriptions.

- Impacts on the natural flow regime (freshwater inflows) which could change the community assemblage of supporting habitats and suitability for waterbirds and European otter.

3.8.3 STT operation – current conditions

This section sets out the findings of the effects of the STT scheme operation during current or contemporary ('now') climate conditions.

3.8.3.1 Change to flow, velocity, depth and flood regime

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 HoF conditions.

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 HoF conditions and as such the full licence abstraction rate can be abstracted without constraint from the HoF conditions. In the modelling outputs 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.

3.8.3.1.1 Impact assessment

Overall, the effect on pass-forward flows to the Severn Estuary from the STT solution is indiscernible on the flow duration curve for the full 47 year representative period (see the Physical Environment Assessment Report[41], 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 indiscernible 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.

Overall, the changes in freshwater inflows into the Severn Estuary is not discernible.

3.8.3.2 Change to water quality

Similar changes in water quality are generally predicted for both the A82 and M96 scenarios under the fully supported STT operation and are summarised below:

- In the River Severn at the tidal limit, the scheme is predicted to reduce water temperature by 0.2°C (A82) and 0.3°C (M96).
- Dissolved oxygen concentrations are predicted to be reduced by about 0.1 mg/l for both scenarios.
- Ammoniacal nitrogen concentrations are predicted to be increased by about 0.02 mg/l for both scenarios.
- Oxidised nitrogen is increased by about 0.8 mg/l during the scheme (~10% increase on baseline). DIN concentrations are increased by a similar amount.

Specific additional analysis has been undertaken in relation to DIN using the EA long term water quality monitoring point at Haw Bridge[42] for the 10 year period 2013-2022. The 117 data points identify DIN concentration as 5.65 mg-N/l with a standard deviation of 1.14 mg-N/l. Allowing for the expected removal rates of the Minworth SRO's advanced treatment processes for the Minworth Transfer, discharged concentration to the Avon could be 16.9 mg-N/l. Allowing for the expected removal rates of the Severn Trent Sources SRO's

[41] Ricardo Energy & Environment (2022). Severn to Thames Transfer SRO. Physical Environment Assessment Report. Report for United Utilities on Behalf of the STT Group. May 2022.

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

advanced treatment processes for the Netheridge Transfer, discharged concentration to the Severn at Haw Bridge could be 15.8 mg-N/l. Modelled assessment identifies:

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

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

3.8.3.2.1 Impact assessment

The results of the water quality modelling indicate that water quality changes are expected to be minimal with a slight decrease in some nutrients expected. The temperature and dissolved oxygen (as % saturation) will remain within the range for achieving high ecological status. No impact pathways have been identified for dissolved oxygen or temperature for hydrologically connected water dependent designated sites or protected habitats and associated species.

The reduction in soluble reactive phosphate within the River Severn associated with the STT scheme operation is not considered likely to alter community composition or vegetation structure within adjacent habitats due to the baseline conditions and period in which the scheme will be operational. The UKHab surveys undertaken in 2021 indicate that the habitats within the reach are typically modified through agriculture and indicative of high nutrient levels with low species diversity in a large proportion of the grasslands adjacent to the lower Severn[43]. A reduction in SRP within the river has potential benefits for the adjacent habitats. Therefore, no impact pathways to protected species and associated supporting habitat have been identified.

3.8.4 STT operation - future climate

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

3.8.4.1 Changes to flow, velocity, depth and flood regime

The pass-forward flow to the Severn Estuary from the freshwater River Severn would be amended by unsupported STT abstraction. Overall, a pattern of unsupported STT solution abstraction only for 22 days in A82 Future in the mid-November to early December period is anticipated; 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 identified 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, which is longer than in the current climate and this later seasonal trend may be a feature of future operating patterns.

3.8.4.1.1 Impact assessment

Based on the modelling results, no impact pathways that could have discernible impacts on protected species from flow, velocity, depth and flood regime have been identified.

3.8.4.2 Changes to water quality

Under Scenario A82F, the predicted water quality in the River Severn at the tidal limit is very similar to that predicted under A82 and M96. The main difference is that the period of the operation of the scheme is longer,

[43] Ricardo Energy and Environment (2022). Severn Thames Transfer SRO, Protected Habitats Assessment Report. Report for United Utilities on behalf of the STT Group.

starting in late May and ending in late November. Although the change in concentrations described for A82F in this sub-reach occurs over a longer period, the peak changes in concentrations are very similar to A82/ M96 for all parameters.

3.8.4.2.1 Impact assessment

Based on the modelling results, no impact pathways that could have discernible impacts on protected species from water quality have been identified.

3.9 THE RIVER THAMES FROM CULHAM TO TIDAL LIMIT AT TEDDINGTON

3.9.1 Baseline

Species records included fish (Atlantic salmon) aquatic and terrestrial invertebrates (depressed river mussel, large garden bumblebee and mud pond snail *Omphiscola glabra*), mammals (harvest mouse and European hedgehog), plants (pennyroyal and white helleborine *Cephalanthera damasonium*) and bird species (house sparrow and tree sparrow). Water dependent protected species records returned from NBN Atlas were limited for the River Thames at Gate 2 and are not deemed representative of the species diversity associated with this reach.

No additional protected species surveys were completed for this reach of the River Thames. This reach also overlaps with Countryside Stewardship priority areas for brown hairstreak, corn bunting, lapwing, redshank and snipe.

Protected habitats including SSSIs[44] and priority habitats[45] located in the River Thames or adjacent (within 100 m) give an indication of potential water dependent protected species present. Note that sites where impact pathways have been identified to protected species have been underlined. These include:

- Little Wittenham SSSI (water dependent); area of woodland with ponds, grassland and scrub present. The site is notified due to a large breeding population of great crested newt *Triturus cristatus* and assemblage of amphibians and invertebrates it supports.
- Holies Down SSSI (not water dependent); area of unimproved chalk grassland dominated by glaucous sedge *Carex flacca* with a range of coarser grasses and chalk flowers.
- <u>Hartslock SSSI</u> (water dependent); site consists of semi-improved broadleaved woodland, chalk scrub and riverine fen. The insect fauna contains many species uncommon in Oxfordshire including chalkhill, adonis and small blue butterflies, the rufous grasshopper *Gomphocerrippus rufus* and several uncommon moths, beetles and true flies *Diptera*. The woodland supports a large population of European badger *Meles* and a Schedule 8 Wildlife and Countryside Act plant species has been recorded at the site.
- <u>Temple Island Meadows SSSI</u> (water dependent); the site consists of wet meadows including marshy neutral grassland, tall fen and wet woodland that seasonally flood and become waterlogged. It supports the nationally rare summer snowflake *Leucojum aestivum* and a range of invertebrates and birds.
- Rodbed Wood SSSI (water dependent); consists of wet woodland and water meadows that support the nationally rare summer snowflake plus breeding (kingfisher and warblers) and wintering birds (redpoll *Carduelis flamma* and siskin *C. spinus*).
- Bisham Woods SSSI (not water dependent); large area of beech dominated broadleaved woodland which supports a diversity of molluscs including *Helicigona lapicida, Pomatias elegans* and *Cochlodina laminata.*
- Cock Marsh SSSI (water dependent); site consists of wet alluvial grassland and calcareous grassland with four silted pools supporting a diversity of macrophytes such as water violet *Hottonia palustris*, marsh arrowgrass *Triglochin palustris* and marsh stitchwort *Stellaria palustris*. The SSSI is subject to periodic flooding and occasional drying out, which aids the floral richness of the site. Also supports both breeding and wintering bird populations.
- South Lodge Pit SSSI (not water dependent); citation does not mention protected species.

[44] Site information on habitat types and associated protected species provided by Natural England SSSI citations.
[45] Site information on associated protected species provided by JNCC UK Biodiversity Action Plan Priority Habitat Descriptions.

- Bray Meadow SSSI (water dependent); site consists of unimproved meadows with a high diversity of flora including both caliccoles and damp meadow species. Riverside vegetation includes the nationally scarce greater dodder *Cuscuta europaea*.
- Bray Pennyroyal Field SSSI (water dependent); Site supports the nationally rare pennyroyal, a species included in Schedule 8 under the Wildlife and Countryside Act 1981 and listed in the British Red Data Book of vascular plants.
- Wraysbury No. 1 Gravel Pit SSSI (water dependent); site of national importance for wintering gadwall *Anas strepera* and supports a diversity of locally important wintering bird species.
- Wraysbury and Hythe End Gravel Pits SSSI; Site consists of a mosaic of open water, islands, grassland, scrub and woodland within an area of former gravel extraction. The habitat supports nationally important numbers of tufted duck *Aythya fuligula*, gadwall and goosander *Mergus merganser*, breeding birds and two nationally scarce invertebrates (a riffle beetle *Oulimnius major* and caddisfly *Leptocerus lusitanius*).
- Langham Pond SSSI (water dependent); The site is a remnant of an old ox-bow lake and supports several nationally scarce invertebrates (Diptera (flies) and Odonata (dragonflies)) and plants including whorled water-milfoil *Myriophyllum verticillatum*, orange foxtail grass *Alopecurus aequalis* and greater water parsnip *Sium latifolium*.
- Wraysbury Reservoir SSSI (water dependent); Site supports nationally important numbers of wintering cormorant *Phalacrocorax carbo*, great crested grebe *Podiceps cristatus* and Northern shoveler *Anas clypeata.*
- Thorpe Hay Meadow SSSI (water dependent); Site lies on alluvial gravels surrounded by ditches and high hedges and consists of a range of lime-loving (calcicole) plants. Associated with the drainage ditch purple willow *Salix purpurea* Cyperus sedge *Carex pseudocyperus* and *Riccia fluitans* (an uncommon liverwort) are present.
- Thorpe Park No. 1 Gravel Pit SSSI (water dependent); Site of national importance for wintering gadwall.
- Dumsey Meadow SSSI (water dependent); unimproved pasture consisting of mainly crested dog's tail *Cynosurus cristatus* and common knapweed *Centaurea nigra* and marshy depressions present along the river bank.
- Knight and Bessborough Reservoirs SSSI (water dependent); Site of national importance for wintering Northern shoveler.
- Bushy Park and Home Park SSSI (not water dependent); Site consists of woodland and grassland that support nationally important saproxylic invertebrate assemblages associated with heartwood decay, bark and sapwood decay. Veteran trees are predominantly lime and Pedunculate oak.
- Coastal and floodplain grazing marsh (water dependent), deciduous woodland (water dependent), woodpasture and parkland (supports water dependent species) and lowland meadows priority habitat (water dependent); see description in **Section 3.3**.
- Traditional orchards (not water dependent) and lowland fens priority habitat (water dependent); see description in **Section 3.4.1.**
- Reedbeds priority habitat (water dependent); Identified via dominance of common reed *Phragmites australis* and the water table is at or above ground level. They provide important habitat for a range of breeding birds. Reedbeds also provide wintering roost sites for several raptor species and support a diversity of invertebrates.
- Lowland calcareous grassland priority habitat (not water dependent).
- Purple moor grass and rush pasture priority habitat (water dependent); Key species associated with purple moor grass and rush pastures include: wavy St. John's wort *Hypericum undulatum*, whorled caraway *Carum verticillatum*, meadow thistle *Cirsium dissectum*, marsh hawk's beard *Crepis paludosa*, marsh fritillary butterfly *Eurodryas aurinia*, brown hairstreak, curlew, snipe and barn owl *Tyto alba*

3.9.2 Relevant impact pathways

Considering the protected species records and the operational pattern, the support releases and/or unsupported could therefore result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Changes in water quality (dissolved oxygen) could have a direct impact on fish populations via a reduction in fitness and growth of macrophytes. This could impact on the availability of prey for European otter and feeding habitat for waterbirds, although deemed unlikely.
- Changes in water level could have a direct impact on water vole (known to be present on River Thames) as burrows could become flooded, increasing vulnerability to predation and impacting on the spatial distribution of localised populations.
- Increased velocity, flow and depth could potentially impact on the spatial distribution of fish and the feeding success of European otter and protected waterbirds.
- Loss/ decrease in habitat quantity and quality due to changes in hydraulics (i.e. increased velocity and depth), impacting on the habitat mosaic and ability to support a diverse range of protected species.
- Operation during extreme low flow conditions in summer periods may increase the risk of flooding outside of the natural flow regime of supporting/ functionally linked habitats. This could alter the community assemblage of coastal floodplain grazing marsh and lowland meadows (in particular), therefore, reducing the suitability of the sites for breeding birds and water dependent mammals if present.

3.9.3 STT operation – current conditions

3.9.3.1 Change to flow, velocity and depth

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.

3.9.3.1.1 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 - 30th November and in Scenario M96 from the 31st of October - 9th January. 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. Upstream of the confluence with the River Pang, 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. Upstream of the Datchet intake 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. 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 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 ~100 km downstream and then re-abstracted. The long profile of flow 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.

3.9.3.1.2 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 - 30th November and in Scenario M96 from the 15th of June - 9th January. The supported period of abstraction (in the modelled scenario is a 330 Ml/d flow increase) 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. 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, 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. Upstream of the Datchet intake, 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. 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 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.

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 1 m. For example, at Culham Lock 90 % of gauged river levels in the last year have varied within in a 0.26 m range; at Whitchurch Lock (local to the River Pang confluence) by 0.22 m; at Romney Lock (local to the Datchet intake) by 0.40 m. This is in contrast to the differences in water depth which have been greater than 1 m during the scenario periods reported for the River Thames at Culham; upstream of the River Pang; and upstream of the Datchet intake.

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; and upstream of the River Pang and upstream of the Datchet intake average velocity would not fall below 0.25 m/s at times of operation of the STT solution.

3.9.3.1.3 Impact assessment

Based on the modelling results above, during early phase STT it is evident that the change in flow is not discernible and will not impact on the feeding success of European otter and protected waterbirds, distribution and growth of macrophytes or migration of prey species upstream and downstream. In addition, as the River Thames channel is managed for navigation, limited impacts on water depth as a result of the STT SRO are anticipated.

However, during full STT downstream of Culham outfall flows are predicted to increase from 60 – 103 % depending on whether it is a moderate - low flow year or a very low flow year. This will reduce to 22 – 33 % at the Datchet intake. The increase in flow rate is likely to have localised impacts on the spatial distribution of prey species such as Atlantic salmon and brown/ sea trout due to the energy expenditure required to commute upstream. This change in prey availability may alter the spatial distribution of European otter and waterbirds (including kingfisher) to downstream of the Culham outfall where the flow rate has reduced. In addition, localised changes in the spatial distribution of water vole may occur. Increases in flow rate could also impact on the suitability of areas downstream of the Culham outfall to support macrophyte communities and nesting waterbirds as the scheme will be operational from June - August. However, as the changes in flow are within the interannual flow variation for the River Thames, localised impacts on protected species are not anticipated to have an discernible effect on overall populations and the suitability of the River Thames to support a diversity of species. No impacts from changes in depth or velocity have been identified and flood modelling has not been completed for the potential impacts of STT SRO on the River Thames.

3.9.3.2 Changes to water quality

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

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

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

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

Phosphorus is predicted to increase during the scheme operation by around 0.05 mg/l (from a baseline of 0.12 – 0.35 mg/l) at Culham downstream of the STT interconnector outfall with a lower rate of increase downstream. Downstream of Culham, the River Thame is modelled to increase pressure on phosphorus concentrations and the Rivers Pang and Kennet to reduce pressure. Increases are greatest at times of low flow in the River Thames, which, in the modelled scenarios, coincide with 353 Ml/d supported transfer from the River Severn (Full STT solution). At times of up to 500 Ml/d unsupported transfer (both early phase and full STT solution), baseline river flows in the River Thames are modelled as higher and as such, phosphorus concentrations are modelled to increase by around 0.03 mg/l.

The pH change was calculated from pan-SRO monitoring data. Those spot monitoring data identify a pH range in the lower Severn at Deerhurst of 7.5 – 8.7 (mean 8.1). Although there is greater variability in the range of pH in the lower Severn than the middle Thames, the difference in mean value is indiscernible.

3.9.3.2.1 Impact assessment

Based on modelled outputs, no discernible impacts from changes in water quality are anticipated on protected species as the increases in ammoniacal nitrogen, phosphorus and dissolved oxygen saturation are minor and will not impact on the WFD status of the watercourse.

3.9.4 STT operation - future climate

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

3.9.4.1 Change to flow, velocity and depth

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. Flow augmentation would be at peak rate of 500 Ml/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 50 0Ml/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.

Flow augmentation at Culham in the M96 Future scenario would occur from the 22nd of May to the 29th of January. 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. 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 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. Upstream of the Datchet intake 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. 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.

3.9.4.1.1 Impact assessment

Based on the modelling results above, during early phase STT it is evident that the change in flow is not discernible and will not impact on the feeding success of European otter and protected waterbirds, distribution and growth of macrophytes or migration of prey species upstream and downstream. In addition, as the River Thames channel is managed for navigation, limited impacts on water depth as a result of the STT SRO are anticipated.

However, during full STT downstream of Culham outfall flows are predicted to increase from 60 – 103 % depending on whether it is a moderate - low flow year or a very low flow year. This will reduce to 22 – 33 % at the Datchet intake. The increase in flow rate is likely to have localised impacts on the spatial distribution of prey species such as Atlantic salmon and brown/ sea trout due to the energy expenditure required to commute upstream. This change in prey availability may alter the spatial distribution of European otter and waterbirds (including kingfisher) to downstream of the Culham outfall where the flow rate has reduced. In addition, localised changes in the spatial distribution of water vole may occur. Increases in flow rate could also impact on the suitability of areas downstream of the Culham outfall to support macrophyte communities and nesting waterbirds as the scheme will be operational from May - August. However, as the changes in flow are within the inter annual flow variation for the River Thames, localised impacts on protected species are not anticipated to have an discernible effect on overall populations and the suitability of the River Thames to support a diversity of species.

No impacts from changes in depth or velocity have been identified and flood modelling has not been completed for the potential impacts of STT SRO on the River Thames.

3.9.4.2 Changes to water quality

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

Under the M96 Future scenario, the predicted water quality in the River Thames is only a minor change from predicted under M96. The main difference is that the period of the operation of the scheme is longer, starting in late May and ending in late November. Although the change in concentrations described for M96F in the middle Thames at Culham occurs over a longer period, the peak changes in concentrations are very similar to M96 for all parameters.

3.9.4.2.1 Impact assessment

Based on modelled outputs, no discernible impacts from changes in water quality are anticipated on protected species as the increases in ammoniacal nitrogen, phosphorus and dissolved oxygen saturation are minor and will not impact on the WFD status of the watercourse.

3.10 OTHER FUNCTIONALLY LINKED HABITATS

3.10.1 Baseline

Several tributaries are associated with the River Severn and the Severn Estuary. This includes the rivers Wye, Usk and Teme. Both the rivers Wye and Usk are considered Special Areas of Conservation (SACs) with European otter and rivers with floating vegetation often dominated by water-crowfoot qualifying features of both European sites. Key rivers hydrologically connected to the River Thames include the rivers Isis, Thame, Kennet and Loddon and smaller streams and brooks including St. Patricks stream and Law Brook.

3.10.2 Relevant impact pathways

Considering the baseline protected species and the operational pattern, the support releases could therefore, result in changes in water quality, hydrology and hydraulics (in-stream habitat) which could result in the following:

- Changes in water quality (dissolved oxygen and nutrient loading) could have a direct impact on fish populations via a reduction in fitness and growth of macrophytes. This could impact on the availability of prey for European otter and waterbirds.
- Increase in flow in the River Severn and River Thames could impact on the upstream and downstream migration of prey species, impacting on the abundance and diversity of fish using functionally linked habitat and the suitability of supporting habitat for European otter and waterbirds.
- Increase in water level in the River Severn and River Thames could impact on availability of burrows, holts and suitable nesting sites in the riparian zone and connectivity with functionally linked supporting habitats, impacting on the spatial distribution and population dynamics of protected species in the catchment.

3.10.3 STT operation – current conditions

This section sets out the findings of the effects of the STT scheme operation during current or contemporary (‘now’) climate conditions.

3.10.3.1 Change to flow, velocity and depth

3.10.3.1.1 Impact assessment

From the assessment above, it is evident that the operation of the STT (either supported or unsupported) will not result in any hydrological or hydraulic impacts that will impact on migration of prey species upstream, feeding success or habitat suitability in the River Vyrnwy and River Severn. Furthermore, it is evident that the changes in pass forward flow into the Severn Estuary will not be discernible and will not impacts on European otter present in the Severn Estuary and subsequently into the rivers Usk, Wye or Teme. As the rivers are also upstream of the Severn Estuary, no impact pathways to rivers with water-crowfoot have been identified.

However, discernible changes in flow in the River Thames may impact on protected species distribution in the River Isis and Thame which are both within 10 km of the Culham outfall. This is due to potential reductions in the abundance of prey species successfully migrating upstream under the high flow conditions and reaching functionally linked habitat. Limited information is available on changes in water level and therefore, the impacts remain uncertain.

3.10.3.2 Changes to water quality

3.10.3.2.1 Impact assessment

The EA and NE have raised concerns with regards to the chemical cues (olfaction) to fish migration as a result of the diversion of WwTW discharge from the Tame. Change to olfaction could impact on prey availability for European otters if the upstream migration of fish to spawning grounds is reduced. The risk of impacts on olfactory ques as a result of the Minworth discharge is discussed in the Fisheries Assessment Report.

3.10.4 STT operation - future climate

No specific modelling has been completed on changes in flow, velocity and depth for functionally linked habitats.

4. CONCLUSIONS

4.1 SUMMARY OF THE EFFECT UNDER CURRENT CONDITIONS

The potential impact of the STT operation on protected species was determined based on a desk based data search and additional field surveys. European otter, waterbirds and water vole were identified as water dependent species potentially vulnerable to the operational effects of STT. Water vole surveys were undertaken in 2021, however, no signs of water vole were found, which is considered likely due to the presence of American mink.

From the results, it is evident that the potential changes in flow (as associated with either a supported or unsupported STT) are not considered discernible in the River Vyrnwy, River Severn/ Severn Estuary, River Avon and River Thames and will likely be within the inter annual variations that would be observed under reference conditions.

As a result, the potential changes in flow (as associated with either a supported or unsupported STT) will not impact on the protected species associated with water dependent habitats (SSSIs and priority habitats) in the River Vyrnwy, River Severn, River Avon and River Thames, as there is not predicted to be a discernible change in depth and velocity and the relative height difference between the protected habitats and the baseline river levels. The hydrological modelling and flood assessment did not identify changes in the frequency, extent or duration of winter inundation that could have potential to alter the extent, quality or distribution of potential functionally linked habitat identified within 100 m of the impacted reaches in the River Vyrnwy, River Severn and River Avon. No flood assessment undertaken for the River Thames.

No discernible impacts from water quality change were identified on hydrologically connected and potentially functionally linked habitat for protected species associated with the River Vyrnwy, River Severn, River Avon and River Thames. The reduction in soluble reactive phosphate associated with the impacted reaches of the River Avon and the Severn (from the Avon confluence to the tidal limit at Gloucester) has the potential for beneficial impacts on supporting habitat for protected species where nutrient concentrations are exceeding natural thresholds and causing changes in vegetation composition. Potential impacts from exposure of protected species to increased concentrations of nonylphenols, cypermethrin, perfluorooctane sulfonic acid and its derivatives and permethrin will be further reviewed at Gate 3.

4.2 SUMMARY OF THE EFFECTS UNDER FUTURE CONDITIONS

Under Future scenarios, the STT SRO would have a longer period of flow augmentation. As future baseline conditions typically have longer periods where low flow years occur, it is anticipated that the operation of STT SRO will have beneficial impacts on protected species that rely on surface water to supply supporting habitat. Limited changes to water quality were identified under future conditions.

4.3 UNCERTAINTY AND CONFIDENCE DATA GAPS

Baseline datasets from NBN Atlas were not deemed sufficient in this instance with limited protected species returns within 100 m of potentially affected watercourses. MagicMap was used to identify designated habitats (SSSIs) and priority habitats within and adjacent to the River Severn, River Avon and River Thames that could support water dependent protected species and therefore, may be affected by the STT operation. However, it is noted that limited impact pathways were identified from flow, water quality, water level, depth and flood regime that could lead to discernible effects on protected species.

4.4 RECOMMENDATIONS FOR GATE 3

It is recommended that protected species records are sought from relevant Local Environmental Records Centres within the operational and construction footprint of STT scheme to ensure that baseline datasets are representative of the diversity associated with the River Vyrnwy, River Severn, River Avon and River Thames. Based on modelling outputs, preliminary ecological appraisals/ river habitat surveys are recommended downstream of the bypass outfall on the River Severn, Minworth outfall on the River Avon and Culham outfall on the River Thames. This is to determine the current supporting habitats present and potential presence/ absence of protected species.

Further assessment of the potential impacts of contaminants on protected species will also be reviewed in Gate 3., with particular focus on the River Avon.