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Thames Water Utilities Limited - Drought Permit Application 2022

Environmental Assessment of the Baunton (1) Drought Permit

Report for Thames Water Utilities Ltd

ED 13714 | Issue number 3 | Date 25/10/2022

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Thames Water Utilities Ltd

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Issue Log

Issue	Date	Author	Content/changes
Issue 1	23/09/2022	Ricardo	Original first draft issued to Thames Water, Environment Agency and Natural England
Issue 2	04/10/2022	Ricardo, Thames Water, Environment Agency and Natural England	Updated with comments from Thames Water, Environment Agency and Natural England
Issue 3	25/10/2022	Ricardo and Environment Agency	Updated with further information as requested by Environment Agency

Executive Summary

Introduction and Purpose of Report

Thames Water Utilities Ltd's (Thames Water) Drought Plan 2022 provides a comprehensive statement of the actions Thames Water will consider implementing during drought conditions to safeguard essential water supplies to customers and minimise environmental impact. It encompasses a number of drought options that will only be implemented if and when required and includes drought permit options.

A drought permit is a management action that, if granted, can allow more flexibility to manage water resources and the effects of drought on public water supply and the environment.

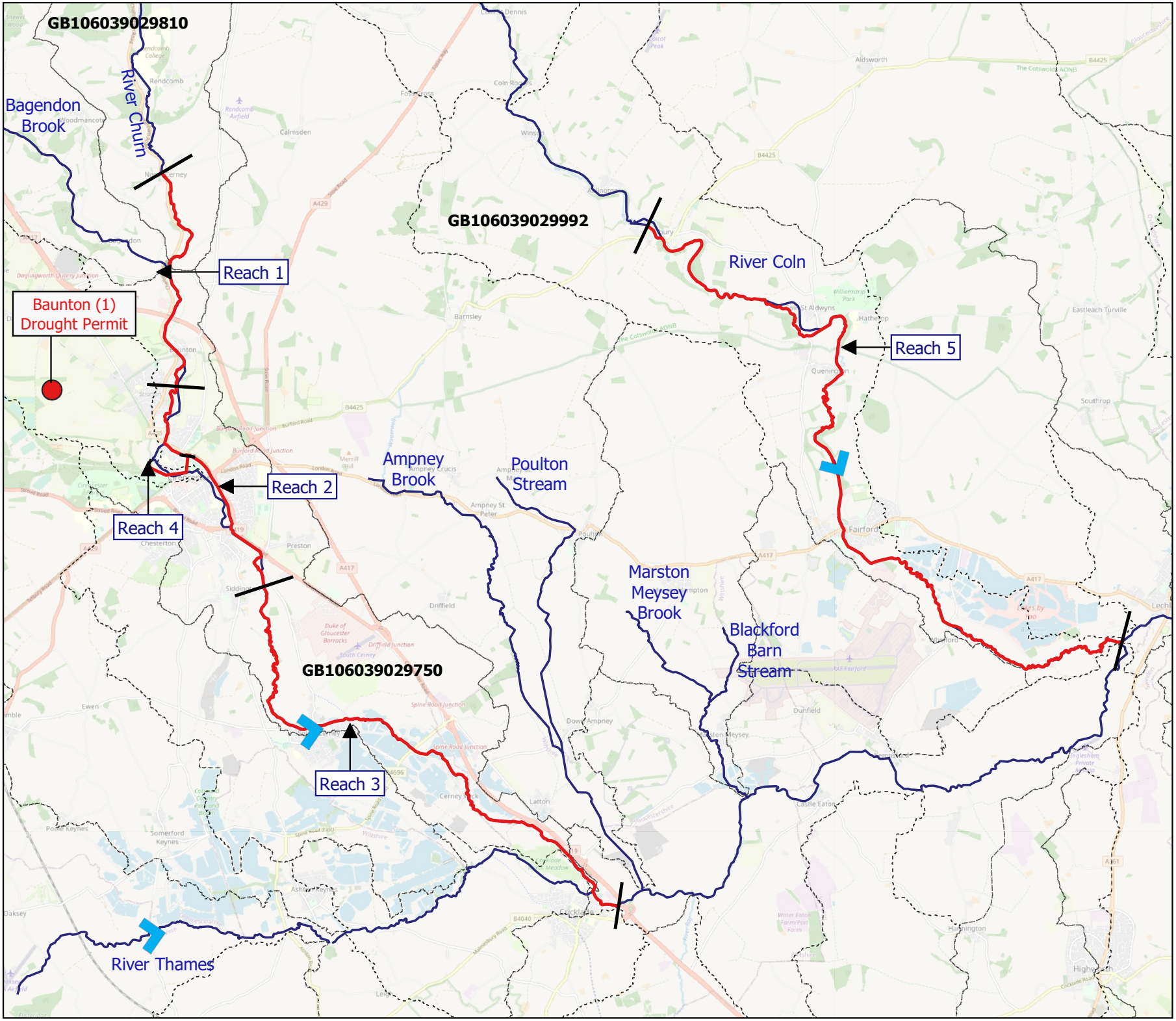
The objective of this environmental assessment report (EAR) is to provide an independent and robust assessment of the potential environmental effects of implementing a drought permit at Baunton, over and above those conditions that already exist under "normal", i.e. licensed, baseline conditions, with the onset of a natural drought. This document is being prepared to support an application for a drought permit at Baunton in October 2022. It has been undertaken in accordance with Government regulations and using the Environment Agency's 2020 Drought Plan Guidance (DPG)[1] and the July 2020 'Environmental Assessment for Water Company Drought Plans - supplementary guidance'.

Baunton (1) is located in Thames Water's Swindon and Oxfordshire (SWOX) Water Resource Zone (WRZ[2]). The study area and focus of this environmental assessment of the Baunton (1) drought permit, covers the following waterbodies, as set out in **Figure A**:

- River Churn (source to Perrott's Brook) (GB106039029810)
- River Churn (Baunton to Cricklade) (GB106039029750)
- River Coln (from Coln Rogers) and Thames (Coln to Leach) (GB106039029992)

The assessment also considers how implementation of the drought permit may affect the environment in combination with the effects of existing licences, consents and plans in line with the requirements of the Conservation of Habitats and Species Regulations 2017) and the Council Directive 92/43/EEC of 21 May 1992 (Habitats Directive).

[1] Environment Agency (2020) Water Company Drought Plan Guideline, December 2020 (Version 1.2)
[2] UKWIR/Environment Agency define a WRZ as: 'The largest possible zone in which all resources, including external transfers, can be shared, and hence, the zone in which all customers will experience the same risk of supply failure from a resource shortfall.'



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Legend

N

- Drought Permit
- River Reach
- Reach Divides
- Flow Direction
- WFD Waterbody Catchments

0 1 2 3 4 km

Project title:
Thames Water Drought Plan Environmental Assessment

Figure A:
Overview of Baunton (1) Drought Permit

Consultation

Consultation is identified as an essential exercise in the preparation of the EARs to allow a more considered process and to encompass consultees' concerns in a timely manner, avoiding the time constraints necessary for an actual drought permit / order application.

To ensure that the stakeholder and regulatory engagement requirements have been met, Thames Water have continuously consulted with both the Environment Agency and Natural England in preparation of the 2013 and 2017 Drought Plan (DP), and the Final DP 2022. This has included consideration and agreement on the approach to the "shelf-copy" Environmental Assessment Reports (EARs). Consultation with both the Environment Agency and Natural England on the Baunton (1) Drought Permit EAR has continued throughout the preparation of the application.

Drought Permit Details

If granted and implemented, the drought permit would involve a temporary suspension of the 32Ml/d flow constraint on the River Churn at Cirencester, and when flows in the River Churn are less than 32Ml/d, abstraction would be permitted to a maximum rate of 6.3Ml/d.

Need for the Drought Permit & Alternative Sources Considered

The Drought Permit is required because of an exceptional shortage of rainfall in the SWOX water resource zone. This has led to threat of a shortfall in supplies. This need is set out in detail in the Statement of Reasons including the case for an exceptional shortage of rainfall, which accompanies this application.

Potential Impacts of Drought Permit Implementation

The environmental assessment of the drought options in this report has been prepared in accordance with the DPG. The approach to environmental assessment and the bespoke assessment methodologies used have been developed and agreed in consultation with the Environment Agency and Natural England. These were documented separately in **the Methodology**[3]. The **Methodology** has been revised[4] to reflect the updates and changes made during the preparation of the application-ready EARs, in agreement with the Environment Agency and Natural England.

In completing the environmental assessment to demonstrate an understanding of the impact on the environment of the proposed drought action, the EARs include the following:

1. Set out the likely changes to the hydrology (or hydrogeology) due to a proposed action;
2. Identify the key features of the environment which are likely to be affected by these changes and assess their sensitivity;
3. Assess the likely impact on these features, allocate a level of confidence in the assessment and set out the actions to reduce uncertainty; and
4. Identify monitoring to be undertaken, split between pre-permit application (Onset), post-permit implementation (In-drought) and Post-drought (recovery) stages;
5. Mitigate against the potential impacts.

As described above, the scope of the assessment has been informed through consultation with the Environment Agency and Natural England prior to, and during, the preparation of the 'shelf-copy' EAR. This 'shelf-copy' assessment has been updated to reflect the revision of the timing of implementation

[3]Thames Water Utilities Ltd (2020). Thames Water Drought Plan 2022: Environmental Assessment Methodology Report – Prepared by Ricardo Energy & Environment (V3 02 October 2020).
[4]Thames Water Utilities Ltd (2022). Thames Water Drought Plan 2022: Environmental Assessment Methodology Report – Prepared by Ricardo Energy & Environment (V4 23 September 2022).

of the drought permit, i.e. it was previously anticipated that it would be in May). This assessment considers five potentially impacted river reaches (see **Figure A**):

- Reach 1 (River Churn from North Cerney to Stratton)
- Reach 2 (River Churn from Stratton to Siddlington)
- Reach 3 (River Churn from Siddlington to the confluence with the River Thames)
- Reach 4 (Gumstool Brook from the Daglingworth Stream to the River Churn)
- Reach 5 (River Coln from Ablington to confluence with the River Thames)

This report presents relevant existing information relating to the habitats and physical environment of watercourses within the Baunton (1) drought permit zone of influence, then identifies any potential changes to river level/flow regime and water quality. Ecological features (including fish, macroinvertebrates and aquatic plants) which are likely to be sensitive to these changes have been identified and the potential for any adverse impacts on these features have been considered. As a result of the sensitivity assessment, the ecological features for which further assessment was required comprised NERC Species, macrophytes, freshwater macroinvertebrates, fish, diatoms, invasive species (macroinvertebrates) and priority substances.

Potential impacts on designated sites which required further consideration as a result of the sensitivity assessment were considered in line with the requirements of the Conservation of Habitats and Species Regulations 2017) and the Council Directive 92/43/EEC of 21 May 1992 (Habitats Directive). In addition, consideration of any impacts to the status classification of the waterbody under the Water Framework Directive was assessed.

Summary of the Hydrological and Physical Environment Assessment

The evidence presented and reviewed is sufficient to list the likely impacts (negligible, low, moderate or high) to the flow/level regime due to implementation of the drought permit. The assessment of the drought permit has identified the following potential changes to the physical environment from implementation of the Baunton (1) drought permit:

- The effects on hydrology would be **moderate** in Reaches 1 – 3 and **negligible** in Reaches 4 and 5.
- There would be a **low** risk to water quality in Reach 3, and **negligible** risk in all other reaches.
- The drought permit is not considered to pose a significant risk to any other abstractors in any of the reaches.
- The drought permit is not considered to pose a risk to feasibility for groundwater abstractors in any of the reaches.
- There are no discharges within any of the reaches posing a risk to water quality.

These hydrological and physical environment impacts have been used to inform the assessment of potential impacts on ecological receptors. It should be noted, however, that the significance of hydrological impacts, e.g. negligible, major, etc. should not be interpreted as having the same potential impacts on ecological features, as the latter will depend on a number of different factors. This is summarised below.

Summary of the Environmental Features Assessment

The features assessment concluded the following significant impacts:

- Negligible to moderate impacts on designated sites;
- Minor/moderate impacts on WFD status/potential receptors;
- Negligible to moderate impacts on ecological community;
- Negligible to moderate impacts on NERC receptors;
- Negligible/minor impacts on ecologically significant species;
- Negligible impacts on invasive species; and
- Negligible impacts on other receptors.

Cumulative or In-combination Impacts

No cumulative or in-combination effects of implementing the drought permit with existing licences, consents and plans are anticipated.

No cumulative or in-combination effects of implementing the drought permit with other water company drought plans are anticipated.

An environmental drought could potentially extend for a long period, or recur after a short-term recovery in river flows. Should there be a requirement for an extension of the drought permit beyond the initial six months, Thames Water would submit an application for a second drought permit to the Environment Agency, which would also be supported by a specific Environmental Assessment Report prepared for that application.

Mitigation and Monitoring

The DPG states that mitigation and/or monitoring is not required for features where minor or negligible impacts are identified. The environmental assessment has concluded that there are a number of features sensitive to the potential impacts of the drought permit. As a consequence, baseline, on-set, in-drought and post-drought monitoring has been proposed. Pre-drought, in-drought and post-drought mitigation measures have also been proposed to minimise/reduce the likely environmental impact of implementing the Baunton (1) drought permit.

Conclusions

Overall, the impact of the Baunton (1) drought permit on hydrology has been assessed as moderate/negligible. Impacts on water quality have been assessed as low to negligible. Impacts on ecological features have been assessed as negligible to moderate.

Monitoring and mitigation has been proposed for features which have been assessed as potentially impacted by the Baunton (1) drought permit.

No cumulative or in-combination effects of implementing the drought permit with existing licences, consents and plans are anticipated.

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1 Introduction

1.1 Purpose of the document

Thames Water Utilities Ltd's (Thames Water) Drought Plan 2022 provides a comprehensive statement of the actions Thames Water will consider implementing during drought conditions to safeguard essential water supplies to customers and minimise environmental impact. It encompasses a number of drought options that will only be implemented if and when required and includes drought permit options.

A drought permit is a management action that, if granted, can allow more flexibility to manage water resources and the effects of drought on public water supply and the environment.

The objective of this environmental assessment report (EAR) is to provide an independent and robust assessment of the potential environmental effects of implementing a drought permit at Baunton (located in the Swindon and Oxfordshire (SWOX) Water Resource Zone (WRZ[5]), over and above those conditions that already exist under "normal", i.e. licensed, baseline conditions, with the onset of a natural drought. **This document is being prepared to support an application for a drought permit at Baunton in October 2022**. It has been undertaken in accordance with Government regulations and using the Environment Agency's 2020 Drought Plan Guidance (DPG)[6] and the July 2020 'Environmental Assessment for Water Company Drought Plans - supplementary guidance'.

In accordance with the DPG, the environmental assessment comprises the following components:

1. an assessment of the likely changes in hydrology (flow/level regime) due to implementing the proposed drought options.
2. identification of the key environmental features that are sensitive to these changes and an assessment of the likely impacts on these features.
3. identification of mitigation that may be required to prevent or reduce impacts on sensitive features.
4. recommendations for baseline, in-drought and post-drought order monitoring requirements.

The methodology for this environmental assessment has been developed in consultation with the Environment Agency and Natural England and is documented separately in 'Thames Water's Drought Plan 2022 Environmental Assessment Methodology'[7]. The methodology document ('**the Methodology**') has been updated as required during consultation on the EARs throughout the preparation of the DP 2022. A summary of the assessment approach is provided in **Chapter 3**.

The assessments undertaken in this EAR confirm the features requiring consideration of mitigation and appropriate monitoring triggering mitigation. Appropriate mitigation actions identified are both available and practicable and reflect previous agreement with the Environment Agency (see **Section 1.3**). The methodologies and details for monitoring and mitigation requirements are documented in **Chapter 6** of this EAR.

Consideration has been given to the potential impacts of drought permit implementation on statutory designated sites including Habitats Directive sites. This is discussed further in **Chapters 3** and **5**.

In accordance with the DPG, the assessment also considers how the proposed drought permits / orders may affect the environment in combination with the effects of existing licences, consents and plans, including the potential for cumulative impacts of drought permit / order options implemented by

[5] UKWIR/Environment Agency define a WRZ as: 'The largest possible zone in which all resources, including external transfers, can be shared, and hence, the zone in which all customers will experience the same risk of supply failure from a resource shortfall.'
[6] Environment Agency (2020) Water Company Drought Plan Guideline, December 2020 (Version 1.2)
[7] Thames Water Utilities Ltd (2022). Thames Water Drought Plan 2022: Environmental Assessment Methodology Report – Prepared by Ricardo Energy & Environment (V4 23 September 2022).

neighbouring water companies. The cumulative assessments associated with each drought option in the WRZ is provided in **Chapter 7** of this EAR.

The assessments only consider the effects of a single drought permit / order application by Thames Water and not the cumulative, or in-combination effects if a second drought permit / order application were needed directly afterwards. If this situation were to arise where the drought permit / order would be required for more than six months, cumulative impacts would need to be considered in further detail at the time of the actual applications. It should be noted, however, that Thames Water provided a methodology for assessing the environmental impacts of severe droughts and a high-level summary of the environmental impacts of their drought actions in droughts worse than record ('severe droughts') in its Final DP 2017. In the context of the assessments, severe droughts referred to droughts with a return period of 1:200 or greater. These droughts were considered to be multi-season droughts that could require a re-application for drought permits / orders beyond their original six months.

Further details of this severe drought methodology and the findings of the assessments are described in **the Methodology**. The assessments undertaken were not updated for DP 2022. The impacts associated with a re-application will require a consideration of the antecedent conditions after a six month implementation. As such, there remains uncertainty with regards to the baseline against which impacts are assessed and the high-level summary provided to date is considered sufficient for DP purposes (e.g. screening of features at risk and monitoring and mitigation requirements).

1.2 Background to the study

Water companies in England and Wales are required to prepare and maintain Statutory DPs under Sections 39B and 39C of the Water Industry Act 1991, as amended by the Water Act 2003 (and subsequently the Water Act 2014) and in accordance with the DP Regulations 2005 and the DP Direction 2020, which set out the short operational steps a company will take before, during and after a drought. The Water Industry Act 1991 defines a DP as 'a plan for how the water undertaker will continue, during a period of drought, to discharge its duties to supply adequate quantities of wholesome water, with as little recourse as reasonably possible to drought orders or drought permits'.

The DP Direction 2020 states that all water company draft DPs should be sent to the Secretary of State prior to consultation before 1 April 2021. Water companies must then publish their DP as directed by Defra. A revised (final) DP must be published at least every 5 years from the date the previous DP was published. Thames Water published their current statutory DP in August 2022 (the 'DP 2022').

The DP provides a comprehensive statement of the actions Thames Water will consider implementing during drought conditions to safeguard essential water supplies to customers and minimise environmental impact.

DPs encompass a number of drought options that will only be implemented if and when required. Each drought is different in terms of its severity, season, location and duration and each combination of these factors may require a bespoke reaction in terms of measures. In the context of drought planning, individual drought options are taken to constitute alternatives. Thames Water's Final DP 2022 comprises a total of 44 drought options (nine supply side options, five demand options and 30 supply side drought permit / order options).

This EAR has been prepared in support of a drought permit application in October 2022. It provides an update to the 'shelf copy' report which was produced in support of Thames Water's DP 2022.

As described in Section 1.3, consultation with both the Environment Agency and Natural England has been undertaken on the "shelf-copy" Baunton (1) Drought Permit EAR and has continued throughout the preparation of the application.

Following agreement with the Environment Agency and Natural England[8], regarding how the shelf-copy" EARs should be updated to be made "application-ready", the baseline review, hydrology/environmental pressures and assessment of physical environment impacts presented in the 'shelf copy' report have been updated for this application EAR to incorporate antecedent conditions and to reflect the timing of drought permit implementation period (where different to assessed in the 'shelf copy' EAR.

It was also agreed with the Environment Agency and Natural England that the baseline water quality and ecological data presented in the 'shelf copy' report are retained for this application EAR. The baseline data presented in the 'shelf copy' report are considered suitable to support the current application as the baseline covered ten years of data (2010-2020) therefore any updates to these datasets were viewed as unlikely to change the assessments presented in the report.

However, as the 'shelf copy' report considered a different period of permit implementation to the period being applied for, the environmental features susceptibility and sensitivity and environmental features assessments has been updated to reflect the timing of period of drought permit implementation set out in this application (November 2022 to May 2023).

Further details regarding the tasks undertaken by Thames Water in order for the EARs to be "permit application ready" are provided in 'Thames Water's Drought Plan 2022 Environmental Assessment Methodology'[9] ("the Methodology").

1.3 Consultation

To ensure that the stakeholder and regulatory engagement requirements have been met, Thames Water have continuously consulted with both the Environment Agency and Natural England in preparation of the 2013 and 2017 DPs, and the DP 2022. This has included consideration and agreement on the approach to the EARs. This has included consideration and agreement on the approach to the EARs. This is summarised in **the Methodology**.

The Draft DP 2022 and accompanying environmental reports were issued to Defra on 30 March 2021. Thames Water received approval to consult on the draft Drought Plan on 10 May 2021 and subsequently published the draft Drought Plan 2022 for public consultation on 7 June 2021 for a seven week period up to and including 30 July 2021. The statutory consultation bodies (Environment Agency, Natural England and Historic England), as well as the public and retailers, were invited to express their views on the Draft DP 2022.

A Statement of Response was prepared and issued on 20 September 2021 which explains the changes Thames Water made to the Final DP 2022 (and accompanying documents, including the EARs) as a result of the consultation. Comments that were received through this consultation process, together with feedback from the specific consultation meetings / periods held over the course of the DP 2022 development listed in **Table 1.1**, have been taken into consideration in preparing this EAR.

[8] Discussion with the Environment Agency and Natural England on 23 August 2022 to confirm updates required to 'shelf copy' EAR to produce an 'application ready' version.
[9] Thames Water Utilities Ltd (2022). Thames Water Drought Plan 2022: Environmental Assessment Methodology Report – Prepared by Ricardo Energy & Environment (V4 23 September 2022).

Table 1.1 Stakeholder/regulatory engagement for DP2022

Date	Regulator/ stakeholder	Type	Aim of meeting/correspond
23/07/2020	Environment Agency (Area)	Teleconference	Discussion of the Environmental Assessment Methodology Document; SEA and HRA approaches.
07/08/2020	Natural England	Teleconference	
13/07/2020 – 14/08/2020	Environment Agency, Natural England and Historic England	Formal 5-week consultation period	SEA Scoping Consultation comments to be provided to Thames Water.
25/11/2020	Environment Agency	Teleconference	Draft EAR assessment outcomes; and update on SEA and HRA.
07/06/2021 – 30/07/ 2021	Public and regulators	Formal 7-week consultation period	To obtain feedback on the draft DP 2022 and its accompanying documents including the HRA, SEA and EARs.
24/08/2021	Environment Agency and Natural England	Teleconference	Discussion of the general progress with the Draft DP 2022, and feedback on the HRA, SEA and EARs.
02/09/2021	Environment Agency	Teleconference	Discussion of the general progress with the Draft DP 2022, and revisions to the EARs.
23/08/2022 – on-going	Environment Agency and Natural England	Teleconference	Discussion of the 2022 drought permit application process and developments, including revisions to the EARs and the specification of monitoring and mitigation.

Consultation with both the Environment Agency and Natural England on the Baunton (1) Drought Permit EAR has continued throughout the preparation of the application.

1.4 Structure and Content of the Report

The environmental assessment has been conducted in accordance with Government regulations and using the DPG. The 2020 DPG specifies the approach to the assessment and reporting requirements, which have informed the contents of this EAR.

Chapter 1: Introduction
Chapter 2: Background to the Drought Management Options
Chapter 3: Approach to Environmental Assessment
Chapter 4: Baunton (1) Drought Permit Environmental Assessment
Chapter 5: Habitats Regulations Assessment
Chapter 6: Environmental Monitoring Plan and Mitigation
Chapter 7: Cumulative Impacts.

2 Background to the Drought Management Options

2.1 Thames Water's Water Supply System and Drought Planning Process

Thames Water supplies water to around 10 million people and 250,000 businesses. For water resource planning purposes, the Thames Water water supply area is divided into six independent WRZs reflecting the different characteristics of the supply areas and associated risks to meeting demand within the Thames Water area (see **Figure 2.1**). The London WRZ is the largest of the six zones and covers the Greater London area. The next largest is the SWOX WRZ. The other WRZs are Kennet Valley (including Reading and Newbury), Henley, Slough/Wycombe/Aylesbury (SWA) and Guildford.

Apart from the London area, some 69% of Thames Water's water supply is derived from groundwater abstraction and the remainder is derived from surface water abstraction. In contrast, approximately 88% of Thames Water's water supply to the London area is derived from surface water and the remainder from groundwater. As for most of South East England, during periods of prolonged low rainfall leading to a serious drought, water supply is largely sustained by groundwater abstraction, baseflow within rivers and available water stored in reservoirs.

Thames Water sets out how it will maintain planned levels of service in a Water Resources Management Plan (WRMP). The WRMP is based on a twin-track approach of demand management measures together with timely development of new sources of supply in order to ensure a positive supply/demand balance at Thames Water's chosen level of service. For the purposes of supply-demand planning, water companies must plan for a dry year demand. This is the demand that would be expected during dry, hot conditions.

The amount of water resources available to maintain water supply during drought periods, with a given frequency of demand restrictions or supply interruptions, is termed "water available for use". Within a given WRZ, the difference between water available for use and the dry year demand plus an allowance for planning uncertainties (Target Headroom) is referred to as the supply demand balance. Should the dry year demand plus Target Headroom exceed water available for use then there is a shortfall or deficit in the supply demand balance. The greater the deficit, the greater the risk that demand restrictions would need to be introduced more frequently than the company's stated Levels of Service and ultimately the greater the risk to security of supply.

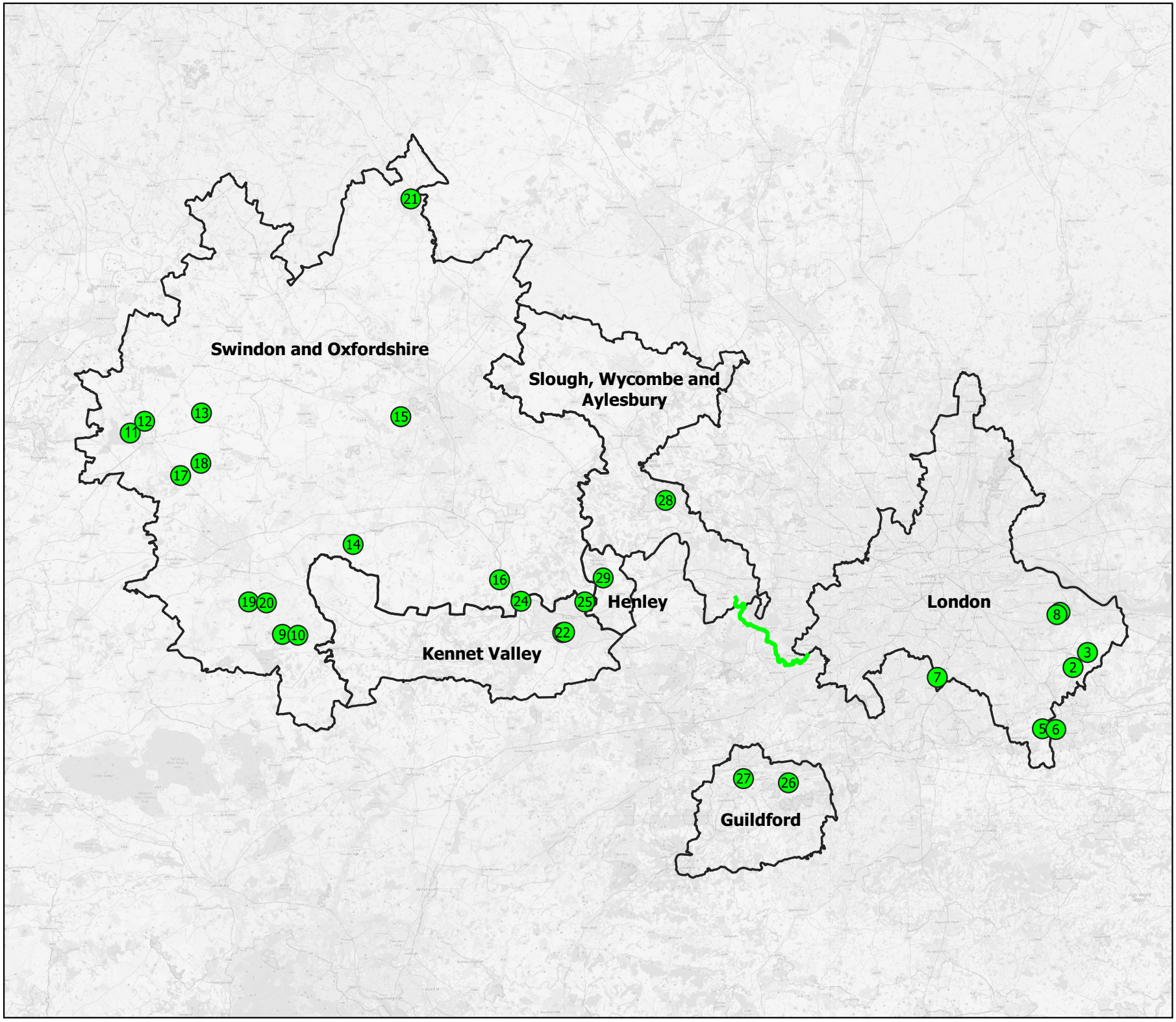
With the aim of maintaining security of supply, which ultimately means minimising the need for emergency drought measures, a DP sets out how a water company will manage supply and demand during the course of a drought.

The DP provides a comprehensive statement of the actions Thames Water will consider implementing during drought conditions to safeguard essential water supplies to customers and minimise environmental impact. It encompasses a number of drought options that will only be implemented if and when required.

Every drought is different in terms of its severity, season, location and duration and each combination of these factors requires a bespoke reaction. Thames Water's DP comprises a number of drought management options, which consist of demand-side options and supply-side options. The supply-side measures can be grouped into a number of categories including the optimisation of existing sources, strategic schemes and bulk supplies. Further information on all the drought management options is provided in the DP. The majority of the supply-side options are drought permits/order options.

The EAR of each drought permit/order option can assist in the prioritisation of which options are most appropriate for the ensuing drought. For example, it is noted that some drought options may have different environmental effects depending on the season of implementation. Through experience, there are a number of options that are considered by Thames Water to be required first, irrelevant of the characteristics of the drought. However, as guided by the DPG, Thames Water have produced a

comprehensive ‘shelf copy’ EAR for all drought options identified in DP 2022, as there is the potential that any of these drought options could be implemented.



Legend

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Water Resource Zone

Drought Options

London:

1 Crayford
2 Eynsford
3 Horton Kirby
5 Sundridge (1)
6 Sundridge (2)
7 Waddon
8 Wansunt

Increase in M2 annual licence

Lower Thames

Swindon and Oxfordshire:

9 Axford (1)
10 Axford (2)
11 Baunton (1)
12 Baunton (2)
13 Bibury
14 Childrey Warren
15 Farmoor
16 Gatehampton
17 Latton
18 Meysey Hampton
19 Ogbourne (1)
20 Ogbourne (2)
21 Oxford Canal

Kennet Valley:

22 Fobney Direct
23 Fobney Emergency Boreholes
24 Pangbourne
25 Playhatch

Guildford:

26 Albury
27 Shalford

Slough, Wycombe and Aylesbury:

28 Pann Mill

Henley:

29 Harpsden / Sheeplands

0 10 20 30 km

Project title:
Thames Water Drought Plan
Environmental Assessment

Figure 2.1:
Location of drought options in Thames Water's Water supply area

2.2 Associated drought permits

A summary of the drought permits considered in the SWOX WRZ is provided in **Table 2.1**.

Table 2.1 Details of Drought Permits to be considered in DP2022 for the SWOX WRZ

Water Source	Potential Drought Permits/Orders
Axford (1)	7.1Ml/d - removal of the flow constraint and increase abstraction to a daily average and peak from 6Ml/d to 13.1Ml/d.
Axford (2)	14Ml/d - removal of flow constraint and increase of average and peak abstraction from 6Ml/d to 20Ml/d.
Ogbourne (1)	3.5Ml/d - resume historical abstraction to previous licence limit following revocation of licence to abstract.
Ogbourne Emergency Boreholes	4Ml/d - no abstraction normally occurs, permit for abstraction to be pumped to Ogbourne WTW for treatment via existing pipeline.
Latton	5Ml/d - increase in the average license limit (to 20Ml/d) for the duration of the drought permit.
Meysey Hampton	11.37Ml/d - increase in abstraction from emergencies only to the conditions of the former “summer” licence.
Baunton (1)	6.3Ml/d - temporary suspension of the 32Ml/d flow constraint on the River Churn at Cirencester.
Baunton (2)	17Ml/d - temporary suspension of the 32Ml/d flow constraint on the River Churn at Cirencester.
Bibury	5Ml/d - increase peak daily abstraction at the current boreholes from 6.819Ml/d to 11.819Ml/d.
Farmoor	30Ml/d - proposed back-pumping of river flows from further downstream to help maintain a minimum flow in sensitive reaches.
Gatehampton	3.5Ml/d - increasing the normal operating licence of 101.5Ml/d to a total abstraction of 105Ml/d.
Childrey Warren	4.5Ml/d - resume historical abstraction to previous licence limit following revocation of licence to abstract.
Oxford Canal	5-10Ml/d - no abstraction normally occurs, permit for abstraction from the Bradley and Perry Hills boreholes via the Oxford Canal for transfer to Grimsbury Reservoir.

2.3 Statement of the Need for Drought Permit

The Drought Permit is required because of an exceptional shortage of rainfall in the SWOX water resource zone. This has led to threat of a shortfall in supplies. This need is set out in detail in the Statement of Reasons including the case for an exceptional shortage of rainfall, which accompanies this application.

2.4 Review of Alternative Options

Thames Water do not have any strategic drought sources as are available in the SWOX WRZ. Therefore, the alternative options are to use drought permit options as set out in our Drought Plan subject to availability of the options. This application will be followed by the following drought permit applications:

Meysey Hampton - Application submitted on 6th October, however additional information requested from Environment Agency. Therefore updated application ready EAR submitted on 25 October 2022.

Ogbourne - tbc (14th November subject to groundwater modelling requirement)

The further applications are subject to further work to confirm the assessment for the period the drought permits are required for, therefore the exact dates are not known yet. However, the further permits planned for at the moment are Baunton (2) and Axford (2) and Latton annual licence drought permit. Thames Water are not able to utilise the Oxford canal drought permit as the Grimsbury source is not available for use. Thames Water are not able to provide further supply from Bibury with the existing treatment capability. Thames Water are maximising the available supply from Gatehampton.

2.5 Drought Permit – Regulatory Arrangements

The Baunton (1) drought permit applied for is as per the DP 2022 and if granted and implemented, would involve a temporary suspension of the 32Ml/d flow constraint on the River Churn at Cirencester, and when flows in the River Churn are less than 32Ml/d, abstraction would be permitted to a maximum rate of 6.3Ml/d.

2.6 Drought Permit Programme

The application was made on the 6th October 2022 as part of a programme of drought permit applications required to address the risk to supply caused by the drought leading to reduction in storage at Farmoor reservoir. Following the Meysey Hampton drought permit application Thames Water received a letter from the Environment Agency (11 October 2022) notifying that the application was incomplete and requesting further information. Therefore, this application ready EAR has been updated to include additional information as requested by the Environment Agency. It is expected that the Environment Agency will determine the application as soon as possible following recipet of the additional information, assuming that a hearing is not required.

3 Approach to Environmental Assessment

3.1 Overview

The environmental assessment of the drought options in this report has been prepared in accordance with Environment Agency's 2020 DPG; specifically the Environment Agency's July 2020 'Environmental Assessment for Water Company Drought Plans - supplementary guidance'. The approach to environmental assessment and the bespoke assessment methodologies used have been developed and agreed in consultation with the Environment Agency and Natural England and are documented separately in **the Methodology**[10].

Depending on the particular ongoing water resources drought, different management options may be available and the full range of drought permit/orders may not be used by Thames Water at the same time. This EAR considers the impacts of implementation of all the Baunton (1) drought permit.

The Environment Agency's 2020 DPG requires the completion of environmental assessment and production of an environmental monitoring plan (EMP) for each of the supply side actions included in a drought plan. The environmental assessments should also include any mitigation measures that could be implemented. **The Methodology** provides detailed approaches to the specific requirements of the DPG which are:

1. Setting out the likely changes to the hydrology (or hydrogeology) due to a proposed action (see Section 3.4 of **the Methodology**).
2. Identifying the key features of the environment which are likely to be affected by these changes and assess their sensitivity (see Section 3.5 of **the Methodology**).
3. Assess the likely impact on these features, allocate a level of confidence in your assessment and set out the actions you will take to reduce uncertainty (see Section 3.6 of **the Methodology**).
4. Mitigating against the potential impacts and where datasets are considered insufficient to undertake an environmental assessment it is the responsibility of the water company to implement environmental monitoring to generate the information required (see Section 3.7 of **the Methodology**).

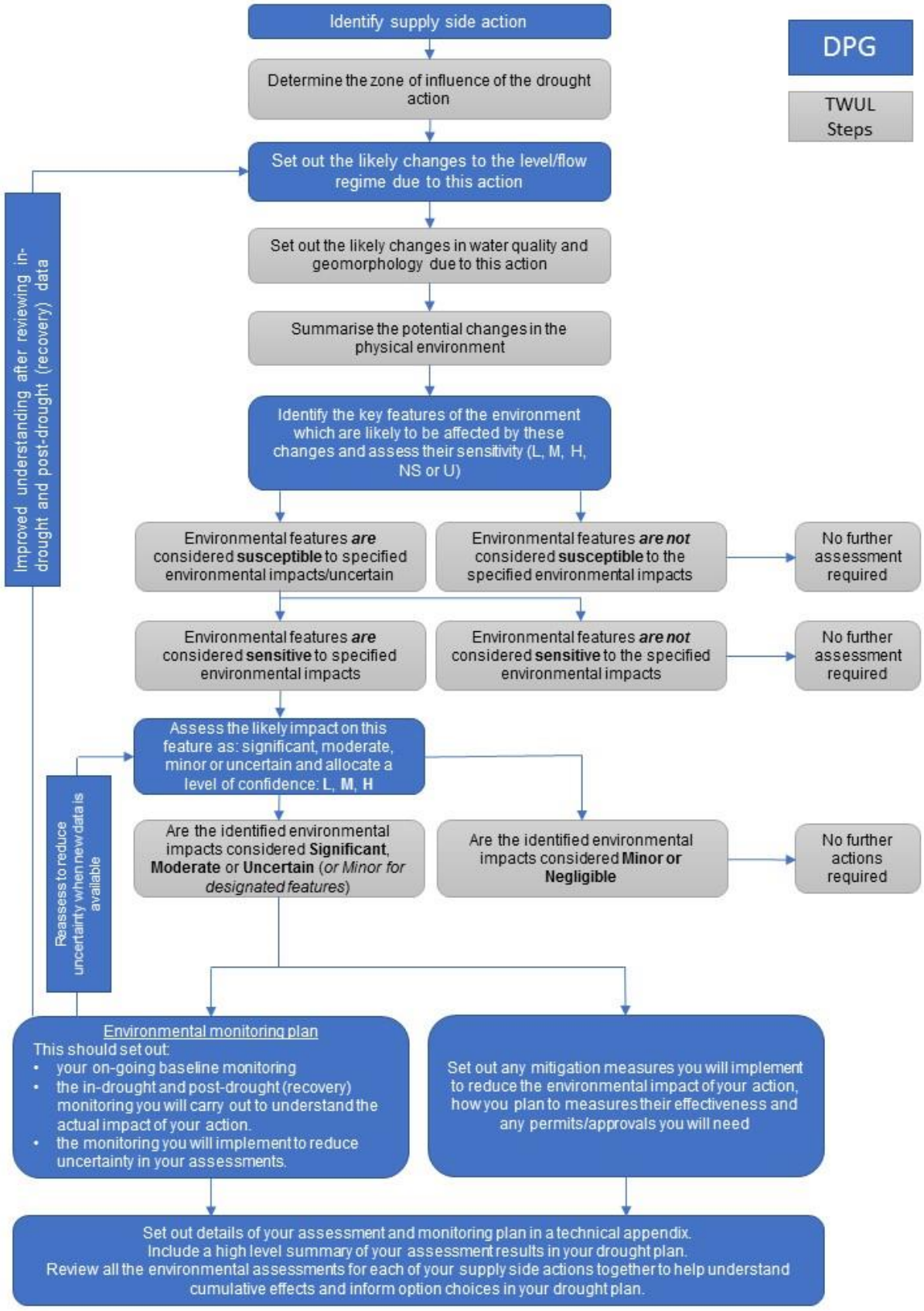
The overall approach taken in completing the environmental assessment to demonstrate an understanding of the impact on the environment of implementing the proposed drought options is illustrated in **Figure 3.1**.

Results of the assessment have also informed the Habitats Regulations Assessment (HRA)[11] and Strategic Environmental Assessment (SEA)[12] which support Thames Water's DP 2022, and are documented separately.

The Environment Agency's 2020 DPG also requires water companies to 'consider the combined environmental effects of your supply side drought options, and where relevant, the combination effects of your actions with those of neighbouring water companies and other abstractors'. The SEA and HRA for a drought plan as a whole has informed these combined assessments. HRA screening concluded no likely significant effects of the drought option on statutory designated sites, either alone, or in combination with other drought permits (see **Section 5**). The SEA did not identify any drought permit/order options in other water company drought plans that could result in cumulative effects with the Baunton (1) drought option (see **Section 7.3**).

[10]Thames Water Utilities Ltd (2022). Thames Water Drought Plan 2022: Environmental Assessment Methodology Report Prepared by Ricardo Energy & Environment (V4 23 September 2023).
[11] Thames Water Utilities Ltd (2022). Thames Water Final Drought Plan 2022: Habitats Regulations Assessment - Screening Report – Prepared by Ricardo Energy & Environment (17 August 2022).
[12] Thames Water Utilities Ltd (2022). Thames Water Final Drought Plan 2022: Strategic Environmental Report - Environmental Report – Prepared by Ricardo Energy & Environment (17 August 2022).

Figure 3.1 **Approach to undertaking environmental assessments as identified in the 2020 DPG.** The steps identified in blue are as per the DPG2022 and the steps indicated in grey are additional /interim steps included by Thames Water.



3.2 Limitations of assessments

Details on the quality of the data collected and used in the assessment, limitations and any assumptions made, are included in relevant sections of the EAR (**Chapter 4**).

For features where the assessment remains uncertain because of data limitation, the requirement for additional targeted monitoring has been considered and is documented in **Chapter 6** “Environmental Monitoring Plan and Mitigation”.

4 Baunton (1) Drought Permit Environmental Assessment

The key hydrological, geomorphological, water quality and ecological issues that would be associated with the implementation of the Baunton (1) drought permit have been identified as follows:

- The drought permit involves additional abstraction from existing boreholes.
- Five potentially impacted reaches over three rivers have been identified: Reach 1, Reach 2 and Rach 3 are located on the River Churn), Reach 4 on the Gumstool Brook and Reach 5 on the River Coln. As a result of drought permit implementation there are three **moderate** and two **negligible** hydrological impacted reaches.
- All impacts are associated with additional drawdown of the underlying Inferior Oolite aquifer and subsequent flow reductions as well as extended periods of no flow in the above rivers as a result of this. Impacts are anticipated to occur during implementation of the drought permit and in the months following cessation of the permit. The groundwater drawdown modelling indicates that groundwater levels recover to baseline (without drought permit) conditions within six months following cessation of the drought permit.
- Habitat availability would be negatively affected through reductions in wetted width and loss of marginal habitats in the upstream reach in particular
- In Reach 1 and Reach 2 there would be a negligible risk to water quality deterioration for all assessed determinants. In Reach 3 the drought permit would present a low risk to ammonia concentration and dissolved oxygen saturation while presenting a medium risk to SRP. Risk to water quality in Reach 4 and Reach 5 is considered negligible.
- No discharges, including STWs, are considered to pose a risk to water quality within the impacted reaches.
- Impacts on ecological features have been assessed as of **minor** to **moderate** significance in all reaches, including impacts on macroinvertebrates, macrophytes and fish communities.

4.1 Introduction

The objective of this EAR is to provide an independent and robust assessment of the potential environmental effects of the implementation of the Baunton (1) drought permit which is located in the SWOX WRZ (see **Section 1.2**).

A drought permit is a management action that, if granted, can allow more flexibility to manage water resources and the effects of drought on public water supply and the environment. This EAR has been prepared in support of an application to the Environment Agency for a drought permit at Baunton in October 2022.

The purpose of the assessment is to determine the environmental impacts of implementing a drought permit, over and above those conditions that already exist under "normal", i.e. licensed, baseline conditions, with the onset of a natural drought. The drought permit application would be submitted in October 2022 for an implementation period from November 2022 to May 2023. The assessment has included the period November to May as covering the range of likely dates.

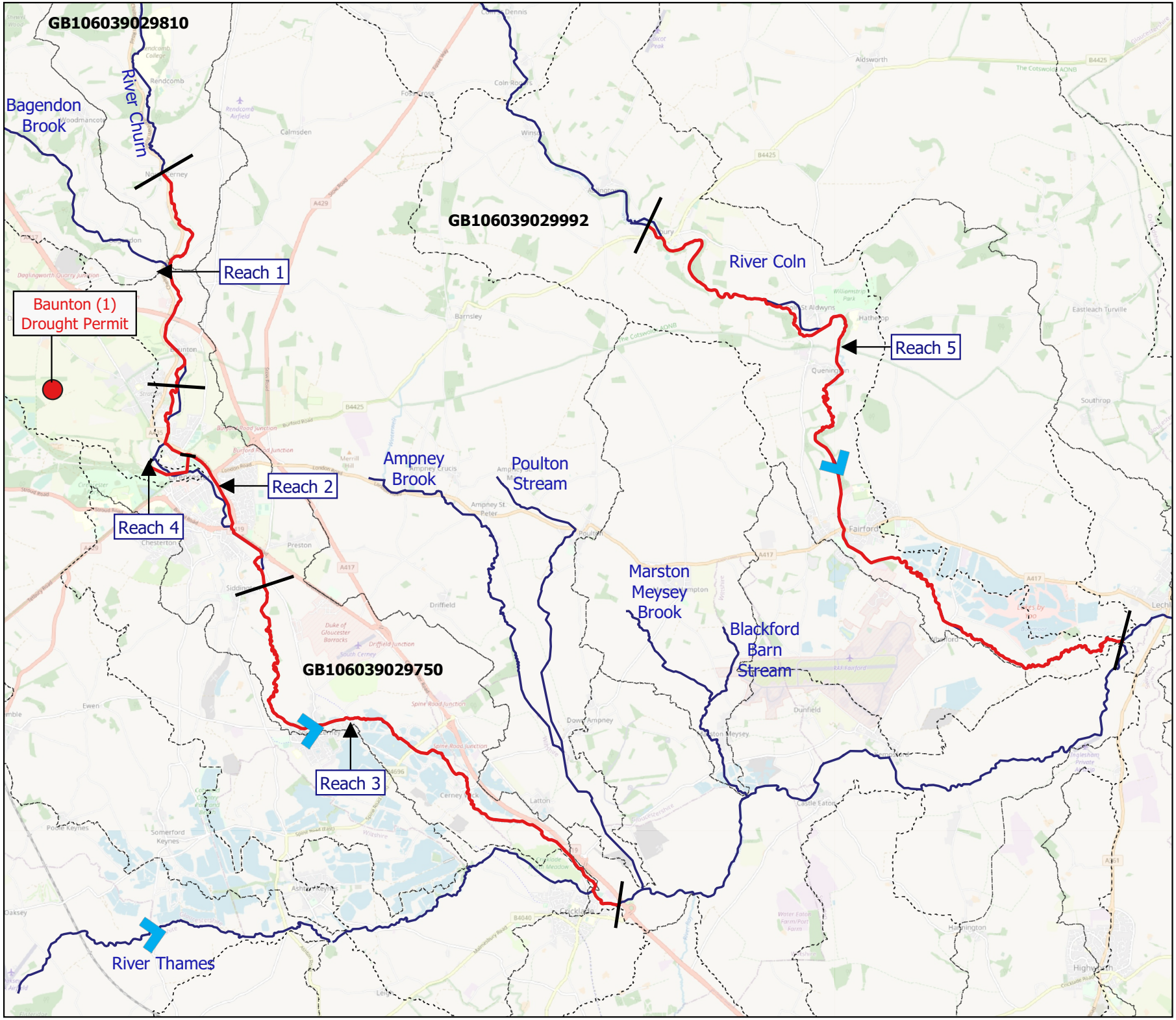
The study area and focus of this environmental assessment of the Baunton (1) drought permit, covers the following waterbodies, as set out in **Figure 4.1**:

- River Churn (source to Perrott's Brook) (GB106039029810)
- River Churn (Baunton to Cricklade) (GB106039029750)
- River Coln (from Coln Rogers) and Thames (Coln to Leach) (GB106039029992)

The assessment and findings are based on the current understanding of the baseline environmental conditions and also include an understanding of historical hydrological conditions. This “application ready” EAR has been updated from the “shelf copy” version to include the most recent available climatic,

hydrological and environmental conditions that will inform both the need for the application of the drought permit and provide an updated baseline for the assessment of any potential environmental impacts and the subsequent monitoring and impact mitigation requirements.

The outcomes of the assessment of the potential environmental impacts are summarised in **Section 4.7**.



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Legend

- Drought Permit
- River Reach
- Reach Divides
- Flow Direction
- WFD Waterbody Catchments

N

0 1 2 3 4 km

Project title:
Thames Water Drought Plan
Environmental Assessment

Figure 4.1:
Overview of Baunton (1) Drought Permit

4.2 Drought Permit overview

Licence details and proposed drought permit details are provided in **Table 4.1** below. The location of the abstraction is indicated on **Figure 4.1**.

Table 4.1 Baunton (1) Existing and Proposed Drought Permit Abstraction

Abstraction Water Source	NGR	Normal Abstraction	Proposed Drought Permit Abstraction	Benefit Ml/d
Inferior Oolite Aquifer	SP 0190 0485	The operation of the existing abstraction licence (28/39/2/63) is determined by the flow conditions in the River Churn at Cirencester Gauging Station. The River Churn flow constraint is at 32Ml/d. When flow is greater than 32Ml/d, abstraction is permitted at a rate of up to 21.6Ml/d with an annual average rate equivalent to 16.64Ml/d. No abstraction is permitted when flow in the River Churn is less than 32Ml/d.	The drought permit would involve a temporary suspension of the 32Ml/d flow constraint on the River Churn at Cirencester. When flows in the River Churn are less than 32Ml/d, abstraction would be permitted to a maximum rate of 6.3Ml/d.	Up to 6.3

Water is abstracted from the Inferior Oolite Aquifer at Baunton from four boreholes (each of which is cased to ensure that abstractions are from the Inferior Oolite Aquifer and not the overlying layers). The licence indicates that two of these boreholes may not exceed 41.15m in depth, while the remaining two may not exceed 52m in depth.

Thames Water reduced the amount that they abstract from Baunton in 2008 following discussions with the Environment Agency as part of an overall strategy to reduce the abstractions in the Cotswolds region. The "normal abstraction" therefore reflects the revised and current licence conditions. For a more detailed hydrogeological analysis of the Cotswolds please see **Appendix A**.

4.3 Key Environmental Issues

4.3.1 Study area overview

As set out in **Section 4.2**, the drought permit would involve a temporary suspension of the 32Ml/d flow constraint on the River Churn at Cirencester when abstraction from the Baunton boreholes would normally cease. Under the drought permit, when flows in the River Churn are less than 32Ml/d, abstraction would continue to be permitted but at a lower current licenced rate of 6.3Ml/d. Hence, the drought permit may lead to up to maximum of 1,153Ml of additional water being abstracted from the Inferior Oolite Aquifer during the implementation of the drought permit that would otherwise not be abstracted under the normal abstraction licence conditions.

An examination of physical habitat characteristics of the area surrounding the Baunton (1) abstraction has informed the study area for this hydrological impact assessment. The lakes and streams of the western Cotswold Water Park lie on clays and are thus not in connectivity with the Inferior Oolite. Ampney Brook (and its tributaries) and Marston Meysey Brook (and its tributaries) are beyond the extent of any groundwater impact, nor are they fed by the Inferior Oolite Aquifer. Hence each of these are not considered to be affected by the drought permit.

The effect of pumping from the Thames Water boreholes at Baunton on the groundwater heads has been shown to be small. A key point is that despite this abstraction, the groundwater heads in the Inferior Oolite Aquifer are generally above the bed of the River Churn for most of the year. Annually,

there is a large range in water levels in the Inferior Oolite Aquifer, with a fluctuation in the order of 6m. The groundwater flow direction is naturally to the south and southeast[13].

Following the approach set out in **the Methodology**, five potential reaches have been identified (see **Figure 4.1**):

- Reach 1 covers the 5.2km reach of the River Churn from North Cerney to Stratton
- Reach 2 covers the 5.3km reach of the River Churn, from Stratton to Siddington
- Reach 3 covers the 12.8km reach of the River Churn from Siddington to the confluence with the River Thames
- Reach 4 covers the 0.5km reach of the Gumstool Brook, a former mill leat in Cirencester, flowing between the Daglingworth Stream and the River Churn.
- Reach 5 covers the 20.0km reach of the River Coln from Ablington to the confluence with the River Thames

The following clarifications are made about the study area:

- Cotswold Water Park. In Reach 3 the River Churn flows alongside the Cotswold Water Park. The Water Park is a series of flooded former aggregate extraction pits. Although the river in Reach 3 is underlain with clay, there are superficial deposits of alluvium connecting the river with the adjacent pits. It is noted that during low flow periods the River Churn can lose some flow to the adjacent pits, confirming that they are in connectivity. However, noting that connectivity is water level dependent and that during an ongoing environmental drought the dominant factor on pit level locally will be evaporation, the drought permit would not influence the rate of water lost from the River Churn to the Water Park and would not influence pit level in the Water Park. Although impacts on Cotswold Water Park as a result of the Baunton (1) drought permit are unlikely, a precautionary approach has been taken. Therefore assessment of Cotswold Water Park has been included within this EAR.

4.3.2 Environmental features

The environmental sensitivity of the study area is informed by the key features present, their importance and designation status. These are described below. A more detailed description and screening of sensitive environmental features is provided in **Section 4.6**.

- Designated sites, including SACs, SSSIs, NNRs, LWS
- Mammals (including otter and water vole)
- Birds
- Macroinvertebrates
- Macrophytes
- Fish
- Diatoms
- Invasive species
- Landscape features
- Navigation features
- Recreation features
- Heritage features

Section 4.7 below presents the outcomes of the screening of the above features against the hydrological impacts within each reach. Where a potential impact on the features has been identified, an assessment of specific features has then been undertaken. The approach to environmental assessment and application of specific assessment methodologies have been developed and agreed

[13] Baunton Drought Permit Environmental Report Draft Final Report, Autumn Assessment Period (August 2006 to March 2007). Prepared by Scott Wilson on behalf of Thames Water, September 2006.

in consultation with the Environment Agency and Natural England and are documented separately in Thames Water's Drought Plan 2022 Environmental Assessment Methodology[14] (**the Methodology**).

It is important to note that any important or sensitive sites (SACs, SSSIs, NNRs, KWS and LWS) that could be affected by each drought options have been taken forward for screening (see **Section 4.6**).

Local Wildlife Sites (LWS)

For Thames Water's DP17, the assessment of impacts on LWS as a result of drought permit implementation was agreed to be undertaken at the time of application. The updated DPG2020 requires LWS to be assessed for each EAR, in accordance with Section 40 of the NERC Act 2006 which places duty on every public authority (including statutory undertakers) to conserve biodiversity, and this duty applies to LWS. For DP 2022, a revised approach to assessing LWS has been agreed with the Environment Agency and a screening assessment has been undertaken. The screening assessment considered the presence or absence of water dependent features and hydrological connectivity (via surface water or groundwater) to drought permits and options within Thames Water's Final DP 2022. The results of this exercise are included in this EAR.

NERC Priority Habitats

Screening of the NERC Act Section 41 Priority Habitats within each hydrological reach was updated for DP2017. Sites hydrologically connected or within 100m of the zone of influence were considered for screening, and the Section 41 habitats which may be water dependent have been considered in the EAR (e.g. floodplain and grazing marshes, lowland fen, reedbeds, etc.). In addition, information regarding the location of NERC Act Section 41 habitats (habitat of principle importance) was also considered and included in this EAR.

4.4 Physical Environment

4.4.1 Introduction

The approach to the hydrological impact of the drought permit is described in **the Methodology** and the findings of the assessment are described in **Section 4.6**. This has determined what the timing, magnitude, zone of influence, nature of change and duration of the Baunton (1) drought permit would be. Points of interest referred to throughout the text in **Section 4.4** are indicated in **Figure 4.2;** reference to these figures are included where appropriate.

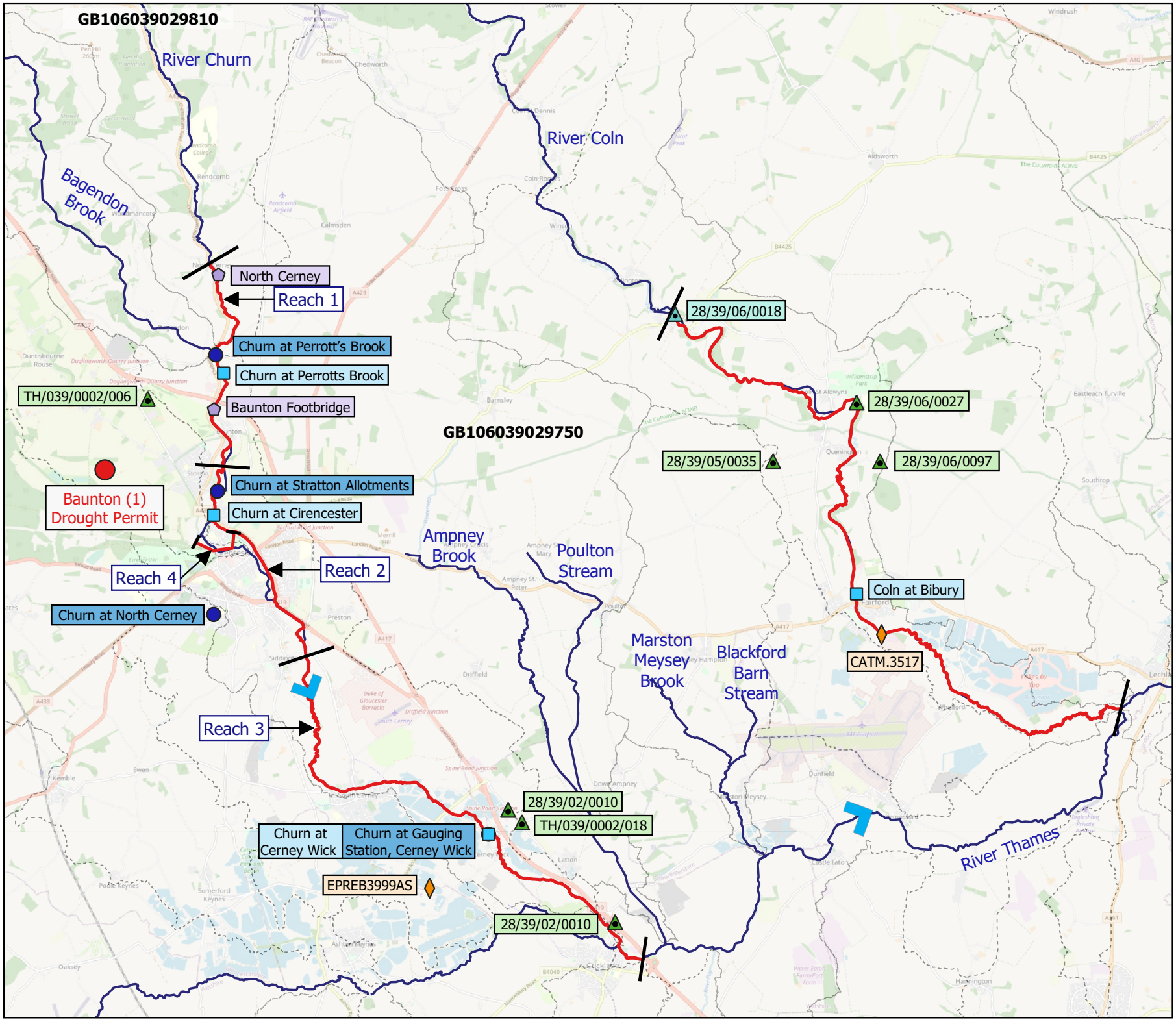
Section 4.4.2 provides a baseline description of the hydrology and physical environment focussing on conditions anticipated in natural drought and with all existing abstraction and discharge licences in operation. Potential changes to the physical environment (habitats and environmental pressures, including flow and water quality) as a result of implementing the drought permit are presented and this information is used to frame and support the assessments of features which have been scoped in further to the screening and scoping exercise (see **Section 4.7**).

The scheme would involve a temporary suspension of the 32Ml/d flow constraint on the River Churn at Cirencester when abstraction from the Baunton boreholes would normally cease. Under the drought permit, when flows in the River Churn are less than 32Ml/d, abstraction would continue to be permitted but at a lower than licenced maximum rate of 6.3Ml/d. Hence, the drought permit may lead to up to maximum of 1,153Ml of additional water being abstracted from the Inferior Oolite Aquifer during the implementation of the drought permit that would otherwise not be abstracted under the normal abstraction licence conditions.

Drought occurrence in the Thames supply area tends to be as a result of one or two dry winters and the onset of drought leading to concern over resource availability is generally driven by reservoir storage reduction leading to triggers for drought action being breached. In a severe drought leading to the need

[14] Ricardo Energy & Environment (2020) Thames Water Drought Plan 2022. Environmental Assessment Methodology. Report for Thames Water Utilities Ltd. September 2020

for Drought Permits this reduction would normally begin in the spring or early summer and would result in Thames Water implementing demand management measures which are a prerequisite for implementation of any drought permit options. The Baunton drought permit application is for an implementation period from November for a maximum of six months, spanning the autumn and winter period. Therefore, the focus for environmental reporting on drought permit impacts has focussed on the period November to May. However, where the implementation of a six month drought permit extends the recovery of impacts beyond the November to May period this has also been assessed within the EAR. It is noted that following the stochastic assessment of drought severity it is possible that more severe droughts could extend for longer than those seen in the historical record. It should be noted that Thames Water provided a methodology for assessing the environmental impacts of severe droughts, referred to as droughts with a return period of 1:200 or greater. These droughts were considered to be multi-season droughts that could require a re-application for drought permits / orders beyond their original six months. It should be noted that DP 2022 is for the period 2022 to 2027 and does not include the effects of likely future climate change or population growth.



Legend

- Drought Permit
- River Reach
- Reach Divides
- Flow Direction
- Level / Flow Gauging Station
- Water Quality Sites
- Spot Flow Monitoring Site
- Water Quality Pressures
- Groundwater Abstractions
- Surface Water Abstractions
- WFD Waterbody Catchment

N

0 1 2 3 km

Project title:
Thames Water Drought Plan Environmental Assessment

Figure 4.2:

Baunton (1) Drought Permit: Physical Environment Monitoring

4.4.2 Baseline review

4.4.2.1 Catchment overview

The River Churn rises from springs at Seven Springs, to the north of Cirencester at the faulted Inferior Oolite/Upper Lias boundary. Downstream, the River Churn initially gains additional flow from Inferior Oolite springs in the sides of the valley before potentially gaining or losing flow as the river flows over the Inferior Oolite. Just south of Perrott's Brook, the River Churn flows across an increasing thickness of Inferior Oolite. The river potentially loses flow over this stretch during summer and autumn, but groundwater becomes influent (contributes to flow) when groundwater levels are high. Around Baunton, the river flows over the Fuller's Earth formation wherein groundwater levels from the underlying Inferior Oolite are such that they generally contribute to flow in all but low groundwater level conditions[15]. For a more detailed understanding of the Fuller's Earth formation please see **Appendix A**.

Groundwater levels in the Inferior Oolite Aquifer at Baunton are artesian[16] relative to the valley floor in winter months, but decline to just below ground level towards the end of the summer months[17].

The Great Oolite outcrops just south of the Baunton groundwater source such that the base of the aquifer is always above the Churn valley floor (see accretion profile in **Appendix A** which shows the river flowing over the Fuller's Earth). Once the River Churn flows across the Great Oolite it usually loses flow to the aquifer. At Cirencester, the Churn flows onto the overlying Forest Marble. South of the town at Siddington, the river flows onto the Kellaways Beds. It then flows for a short section over the Cornbrash, before returning onto the Kellaways Beds to the northeast of South Cerney. It flows finally onto the Oxford Clay just north of Cerney Wick.

Downstream of where the River Churn starts to the cross the Kellaways Beds, the river is not thought to lose any more water to underlying limestone aquifers due to the impermeable nature of the overlying strata[18]. However, there is some interaction with groundwater in the gravels and the associated Cotswolds Water Park that can cause some flow loss during low flow periods (for a more detailed explanation of this, see **Appendix A**).

Appendix A provides a more detailed analysis and understanding of the Great Oolite, Inferior Oolite and Fullers Earth formations and their interactions with the River Churn.

The aquifer from which the Baunton source abstracts forms part of Burford Jurassic WFD groundwater body (GB40601G600400). The current (2015) overall status of the Burford Jurassic WFD groundwater body is poor, the quantitative status is good and the chemical status is poor. South of the abstraction boreholes, the River Churn also interacts with the Kemble Forest Marble WFD groundwater body (GB40602G600500). The current (2015) overall status of the Kemble Forest Marble WFD groundwater body is good, the quantitative status is good and the chemical status good.

At its confluence with the River Thames, the River Churn has a catchment area of 124km^2, dominated by grassland (38%), arable land (35%) and woodland (18%, concentrated in the upper catchment). Urban extent (2%) is focused around the town of Cirencester, the centre of an urban corridor extending from Baunton to Siddington.

Within the town of Cirencester, there are multiple managed watercourses of particular local interest with flow controlled through a series of sluices, primarily for flood risk management. Flow in these Cirencester watercourses is managed through a Memorandum of Understanding (MoU) between the

[15] Latton Drought Permit Environmental Report Draft Final Report, Autumn Assessment Period (August 2006 to March 2007). Prepared by Scott Wilson on behalf of Thames Water, August 2006.
[16] Artesian conditions arise when the energy per unit weight possessed by groundwater is great enough to force the water to the surface.
[17] Baunton Drought Permit Environmental Report Draft Final Report, Autumn Assessment Period (August 2006 to March 2007). Prepared by Scott Wilson on behalf of Thames Water, September 2006.
[18] Latton Drought Permit Environmental Report Draft Final Report, Autumn Assessment Period (August 2006 to March 2007). Prepared by Scott Wilson on behalf of Thames Water, August 2006.

Environment Agency and Cirencester Town Council[19]. The MoU includes operation and control of flow into the Barton Mill Pond, Gumstool Brook and the Daglingworth Stream downstream of the Gumstool Brook offtake sluice. Flow from the River Churn, controlled by the Gloucester Street sluices, enters the Barton Mill Pond and is then joined by Daglingworth Stream near Barton Lane. The Daglingworth Stream (with contribution from the Barton Mill Pond) continues to the Gumstool Brook offtake sluice, which controls flow into the Gumstool Brook, an artificial channel and former mill leat. The Gumstool Brook flows behind The Mead to Powell's School before flowing through the Thomas Street culvert to meet with the River Churn at Hereward Road. After the Gumstool Brook bifurcation, the Daglingworth Stream continues to flow through Cirencester until its outflow near the A429/A419 roundabout. These watercourses, including Barton Mill Pond, Gumstool Brook and Daglingworth Stream (d/s of the confluence with the Barton Mill Pond) are considered to comprise part of the study area for assessment due to their connectivity to the River Churn.

The River Coln rises in the Cotswolds, approximately 5km east of Cheltenham, fed from the Jurassic Inferior Oolite Group aquifer. From Bibury until Fairford, the River Coln flows over outcrops of the Inferior and Great Oolite Groups. The Inferior Oolite Group is an unconfined aquifer between the source of the River Coln and Fossebridge. After this point the Inferior Oolite becomes overlain by the Fullers Earth Formation. Due to the low permeability of this formation it acts as a barrier to flow and therefore the Inferior Oolite Group becomes confined. The Fullers Earth Formation is in turn overlain by the Great Oolite slightly further downstream. The River Coln continues to flow over the Great Oolite Group until it reaches Fairford, after which the Great Oolite Group is overlain by the younger Cornbrash Formation, Kellaways Formation and Oxford Clay Formation. Very little to no river flow is assumed to be lost to the deep limestone aquifers in this section, as the intervening lithologies are not identified as aquifers. However, locally there may be some interaction with the overlying gravel, especially in the vicinity of active or flooded gravel workings. In low flow periods there will generally be some small losses from the river to the gravels.

4.4.2.2 Hydrology

Long term flow monitoring is undertaken at three locations on the River Churn (from upstream to downstream): at Perrott's Brook in mid Reach 1, Cirencester in upper-mid Reach 2, and Cerney Wick in mid-lower Reach 3 (see **Figure 4.2**). Catchment areas at the gauges are as follows: Churn at Perrott's Brook (59km^2); Churn at Cirencester (84km^2); Churn at Cerney Wick (124km^2).

Long term measured flow data, up to August 2022, have been obtained for each of these gauges. Flow statistics were then derived from the data. These statistics, along with length of data records utilised, are displayed in **Table 4.2**. It should be noted that a previous larger abstraction regime was in operation (pre-2008), the statistics presented in **Table 4.2** are based on the updated abstraction regime after 2008. .

Table 4.2 Flow Statistics for Flow Gauges on the River Churn (2008-2022)

Flow Statistic[20,21]	Churn at Perrott's Brook (Ml/d) 2008-2022	Churn at Cirencester (Ml/d) 2008-2022	Churn at Cerney Wick (Ml/d) 2008-2022
Summer Q_{99}	0.9	0.8	0.2
Summer Q_{95}	5.8	5.3	3.1
Full year Q_{95}	6.9	6.6	3.8
Full Year Q_{70}	18.3	20.5	20.3
Full year Q_{50}	38.4	47.2	54.9
Full Year Q_{10}	155.1	160.7	201.0

[19] Memorandum of Understanding, Operation of Sluice Gates (River/water flow through Cirencester), September 2012.
[20] Flow statistics indicate the proportion of days a flow is equalled or exceeded. Therefore Q5 indicates flow equalled or exceeded for 5% of days in the measured record (equivalent to an average of 18 days per year)
[21] Summer Q flow statistics based on the hydrological summer, April to September inclusive. Full Year flow statistics based on the calendar year, January to December inclusive.

For context, the most recent gauged flow available for each of these gauging stations is as follows:

- Churn at Perrott's Brook: 6.4Ml/d on 31 August 2022[22]
- Churn at Cirencester: 6.1Ml/d on 18 October 2022[23].
- Churn at Cerney Wick: 3.0 Ml/d on 24 August 2022[24].

Previous studies have indicated that the River Churn can dry up between Cirencester and Baunton where there is varied interconnectivity with the Inferior Oolite contributing to flow in all but low groundwater level conditions and between Baunton and Siddington where the Great Ooloite outcrops and flow is lost to it when groundwater levels are low[25]. Environment Agency springs and sources surveys also confirm that the river can dry up within these reaches, with dry reaches often being observed as far downstream as Siddington and just upstream of South Cerney. Flow in the river is typical of a groundwater dependent watercourse in that baseflow can augment flows in spring and early summer until groundwater flows drop below river bed levels (i.e. the river can dry up and downstream flows can be lower than upstream). A review of the flow records as presented in **Table 4.2** and previous investigations[26], indicated that during the summer and autumn parts of the River Churn can be dry (see discussion below). This has even occurred following the reduction in the Thames Water Cotswold groundwater abstractions (including at Baunton) that has occurred since 2007 (for example, in September 2011).

In the downstream stretch of the River Churn, south of South Cerney, the River Churn flows through river gravels that are connected to the Cotswold Water Park gravels to the south. The Water Park has a high wetted surface area and during the summer, water levels in the flooded gravel workings drop due to evaporative losses and groundwater outflow. In the autumn and winter periods, however, evaporation is lower and this pathway is weaker and losses via transmission/evaporation are lower.

Additional flow monitoring has been undertaken by Thames Water as part of the 2013 DP EMP. This included additional monitoring at four different sites along the River Churn, two in Baunton Reach 1, North Cerney and Baunton Footbridge, and another two in Baunton Reach 2, Stratton Allotments and Circencester, under a range of flow conditions as set out in the Baseline Monitoring Report. Flows in the River Churn did not drop below Q_{95} at the Cirencester gauging station during any of the spot flow measurements taken from 2012 to 2014.

Flows recorded upstream of Baunton at North Cerney where higher than those recorded at the Baunton Footbridge. In July 2013 the flow at Baunton Footbridge was 8Ml/d less than at North Cerney. The wetted width of the river at Baunton Footbridge is not impacted by decreasing flows however the maximum and mean velocity is. At North Cerney, both the wetted width and mean/maximum velocity is affected by lower flows however not as significantly as Baunton Footbridge.

Downstream of Baunton, the spot flow measurement results at Stratton Allotments and Cirencester are not as different. The spot flow measurements show flow, wetted width and mean/maximum velocity respond relatively the same at both sites during lower flows. Hence, the results indicate that the River Churn is not as affected by lower flows downstream of Baunton as they are upstream. It is recommended that spot flow monitoring is continued to be undertaken including visual inspection of the River Churn during dry periods and low flows.

Cirencester Town Council manages the sluices in Cirencester together with the Environment Agency as specified in a Memorandum of Understanding. The operation of the sluices ensures that during low flow periods, flows are maintained in the River Churn preferentially over the Gumstool Brook as the

[22] Data received from Environment Agency on 16 September 2022.
[23] Data from Environment Agency Hydrology Data Explorer: https://environment.data.gov.uk/hydrology/station/60914c18-1838-43e3-92c3-62765dfc7a99
[24] Data received from Environment Agency on 16 September 2022.
[25] Latton Drought Permit Environmental Report Draft Final Report, Autumn Assessment Period (August 2006 to March 2007). Prepared by Scott Wilson on behalf of Thames Water, August 2006.
[26] Hunter, S.M. and Davis, R.J. (1997) Report on the Pumping Trials at Baunton, Latton and Meysey Hampton Summer 1996.

Environment Agency consider there to be greater ecological value in the River Churn. This is managed by closing the Gloucester Street sluice that controls flow to the Barton Mill Pond from the River Churn (this flow is transferred to the Gumstool Brook via the Daglingworth Stream, see Catchment Overview). Therefore, under low flow conditions the River Churn provides no flow to the Daglingworth Stream. Furthermore, at such times the Gumstool Brook offtake sluice is also closed, retaining flow in the Daglingworth Stream. At the outflow of Gumstool Brook near Hereward Road, the River Churn is known to back up into the Thomas Street culvert during periods of high flow. The Gumstool Brook dried for periods of 2012, 2013 and 2014, years without prolonged environmental drought. These years are considered as part of the baseline as they occur after the 2008 Baunton abstraction licence reductions, which stops abstraction when flows in the Churn are below 32Ml/d.

At the Bibury and Fairford flow gauges on the River Coln no drying was identified, although flow did drop below the summer Q_{99} values at Bibury and Fairford gauges numerous times over the period considered (1991-2022). Downstream of Fairford there may be some losses into the gravel aquifer during low flows. However, these are believed to be caused by interaction with old gravel workings. The proportional reduction of flow caused by the drought permit will be largest at the lowest point where the stream interacts with the limestone aquifers: downstream of this point the proportional flow reduction will be the same although additional flow losses may occur for other reasons.

4.4.2.3 Geomorphology

Geomorphological information for the River Churn has been obtained from a series of walkover surveys undertaken for Thames Water by Ricardo in 2012 as part of the 2013 DP EMP using Ricardo's in-house assessment methodology called CHEW and bolstered, where necessary, using extant aerial imagery. For the purposes of the assessment the watercourses have been broken up into three individual reaches.

CHEW data are available for Reach 1 only, comprising two sites. There are no CHEW sites in Reaches 2 to 5.

Reach 1 (River Churn from North Cerney to Stratton)

The River Churn drops from 130m AOD to 115m AOD over the 4.8km length of this reach, an average slope of 0.18°. The valley sides are steep, sharply incised into the limestone. Three dry valleys are evident: two located near North Cerney and one just upstream of Baunton. The river channel is continuously lined with mixed trees and shrubs for most of the reach, with a 500m open stretch between North Cerney and Perrott's Brook being a notable exception. One significant tributary flows into the River Churn in this reach (Bagendon Brook), which joins the river near the settlement of Perrott's Brook, 2km from the start of the reach (see **Figure 4.1**). In two locations around Baunton, the river pools to form small ponds. These are likely to be created by small weirs or dams.

CHEW data indicate that flow in the River Churn was predominantly smooth, with only one riffle identified along the entire reach. Bed substrate comprised gravel and pebble with some sand present, with bank substrate predominantly composed of earth. Bank gradient was generally steep on both river banks (51-70%) in the upper section of the reach, reducing with distance downstream around Baunton to 11-30%.

Few geomorphological features were identified during the CHEW survey, comprising a point bar and mature island. Bank face vegetation was mostly simple with semi-continuous to continuous (right bank) and isolated/scattered (left bank) riparian tree coverage. Surrounding land use throughout the reach was predominantly rough pasture and improved grassland along the left bank with a predominance of broad leaved woodland along the right bank. A historical RHS survey undertaken in 1994 supports these observations and indicates through the Habitat Modification Score (HMS) that the reach has been obviously modified.

Reach 2 (River Churn from Stratton to Siddington)

The River Churn drops from 115m AOD to 100m AOD over the 5.8km length of this reach, a slope of 0.15°. The valley sides are less steep than in Reach 1, and decrease in steepness downstream. One dry valley is evident, just upstream of Cirencester. The river channel is less consistently shaded, often being semi-open, although tall bankside trees still shade the channel in parts. The ephemeral tributary (the Dunt) flows into the River Churn in this reach at Cirencester. The river in this reach frequently splits into multiple channels, and there are many backwaters and side channels. In Cirencester, one arm of the river is dammed to form a small lake.

Past channel modification, including installation of weirs, side channels, over-widening and over-deepening is considered to be a major factor influencing fluvial geomorphology in this reach. A historical RHS survey undertaken in 1996 supports these observations, a HMS score of 1678 was recorded indicating that the reach has been severely modified. This is most likely due to re-sectioning and bank reinforcement. In addition to the structures recorded within the CHEW survey, the historical RHS survey suggests that there are two major bridges and one minor bridge that cross the river within the reach,

Reach 3 (River Churn from Siddington to the confluence with the River Thames)

The River Churn drops from 100m AOD to 82m AOD over the 14.8km reach between Siddington and the confluence with the River Thames around Cricklade, a slope of 0.07°. The river in this reach occasionally splits into multiple channels, and there are various backwaters and side channels, most of which appear to be due to human modification.

Aerial imagery identifies that between Siddington and South Cerney, the river flows through arable and pastoral fields and is lined by scatted, semi-continuous and continuous riparian trees. In places, the river channel appears to be largely unmodified with meander sections and areas of erosion and deposition, though historical modification is evident in other sections (e.g. intersection of the river by field drains and an old canal network).

Around South Cerney, the river is subject to moderate levels of modification (re-sectioning and bank reinforcement) and the river bifurcates through the village before flowing into the Cotswolds Water Park. Here, the river flows through, or adjacent to, various small natural and artificial lakes. Aerial imagery suggests that, due to the increased level of modification in this section of the reach, the potential for geomorphological features to be present is low. Immediately downstream of South Cerney within the Cotswolds Water Park, the area surrounding the River Churn is largely managed for recreation and conservation (e.g. fisheries, nature reserves, etc.) and land use comprises grassed/wooded areas, hardstanding and footpaths.

Downstream of the Cotswolds Water Park at Cerney Wick, the river flows through agricultural land for ~4km before joining the River Thames at Cricklade. Riparian tree coverage is largely scattered or semi-continuous along this section of the reach. A historical RHS survey undertaken in 2008 supports these observations, a HMS score of 790 was recorded indicating that the reach has been significantly modified. This is most likely to be due to re-sectioning however poaching and bank reinforcement were also observed. The historical RHS survey also noted the presence of a minor bridge structure within the reach.

Reach 4 (Gumstool Brook from the Daglingworth Stream to the River Churn)

As detailed in the MoU, the Environment Agency have determined that flow is preferentially maintained in the River Churn over the Cirencester watercourses due to its ecological value. The Gumstool Brook is an artificial channel which was constructed to provide flow for the mills along its course; approximately 300m is an open channel while the remaining 260m (between Powell's School and the outflow at Hereward Road) is culverted. As a primarily artificial channel, there are not considered to be any geomorphological features that may be affected by the implementation of the drought permit.

Reach 5 (River Coln from Ablington to confluence with the River Thames)

The River Coln falls in elevation by 35m, over 25km, a gradient of 0.08°. The reach is fairly sinuous and bifurcates twice before the confluence with the River Thames.

Surrounding land use is dominated by farmland and woodland. Within the reach the River Coln flows through Coln St Andrews and Fairford. Riparian tree cover is continuous to semi-continuous.

Flow within the reach was dominantly smooth. However, pool-riffle sequences were also observed. The RHS data recorded three riffles and four pools. Bed substrate at all RHS sites was recorded as consolidated.

The reach ranges from pre-dominantly unmodified to severely modified. In the more modified sections of the reach, the river is resectioned and reinforced, and areas of poaching were also observed. At RHS site 38416, the river has been over-deepened.

4.4.2.4 Anthropogenic features

Using observations from the CHEW surveys, extant aerial imagery and OS map data, in-channel structures and bridges were identified in each reach.

Reach 1 (River Churn from North Cerney to Stratton)

The CHEW walkover identified that land use adjacent to the River Churn is a mix of urban development and improved grassland used for pasture, with arable fields located further from the channel. The river passes through the settlements of North Cerney, Perrott's Brook and Baunton, but remains largely unaltered. The river passes under nine bridges in the reach, all of which are small with the exception of the A417 bridge. Ponding in Baunton provides evidence for the presence of small weirs.

Reach 2 (River Churn from Stratton to Siddington)

Aerial imagery identifies that the River Churn passes under 15 bridges in this reach and shows a highly modified and controlled character where it passes through the town of Cirencester. It is culverted in two locations within the town where it passes under major roads. The river is extensively straightened, and there are areas of bank reinforcement. The numerous backwaters and side channels appear to be of anthropogenic origin. One weir is present throughout the reach, southeast of Stratton. The land use adjacent to the river is predominantly urban development, with some areas of improved grassland outside of Cirencester.

Reach 3 (River Churn from Siddington to the confluence with the River Thames)

Aerial imagery identifies that the River Churn passes under ten road bridges in this reach, the majority of which are located in South Cerney. In the uppermost section of the reach, land use surrounding the river is predominantly agricultural with some limited historical modification. In the mid-section of the reach around South Cerney, land use is dominated by urban development and the river is subject to increased modification. One sluice is present in the uppermost section of the reach. Three mills are present throughout the reach, including Upper Mill and Lower Mill, South Cerney. Three weirs are also present in the reaches middle sections, at Cerney Wick.

Reach 4 (Gumstool Brook from the Daglingworth Stream to the River Churn)

Flow in the Gumstool Brook is controlled through a series of sluices. The channel is an anthropogenic feature originally built to supply water to nearby mills, including the exposed portions and culverted portions. The Daglingworth Stream is also culverted for a portion of its length and (after its confluence with the Barton Mill Pond) canalised for the rest of its length. Aerial imagery suggests multiple bridges cross these watercourses where they are not culverted.

Reach 5 (River Coln from Ablington to confluence with the River Thames)

Aerial imagery identifies the River Coln passes under five bridges. No other anthropogenic features were observed.

4.4.2.5 Overview of habitats

The three reaches within the zone of impact of the Baunton (1) drought permit exhibit varying geomorphological and habitat characteristics.

Reach 1, River Churn from North Cerney to Stratton

Reach 1 is a typical low energy, lowland stream, indicated by the relatively low slope to the watercourse and uniform nature indicated in the geomorphological assessment. There is habitat diversity present in meander sections, where flow diversity increases, however these are relatively limited in extent.

There is significant riparian tree cover providing significant habitat opportunities for a number of species, in particular cover for fish, as well as providing some allochthonous energy[27]. The substrate of the watercourse is a mixture of alluvial sands, clay, silt and gravel, however, it is likely to be dominated by finer substrates, owing to the predominantly low energy environment present, with some areas of coarse substrate where flows are of greater energy.

Although semi-natural habitats dominate the reach, suburban/urban developments are present in the adjacent habitat with associated modification to the watercourse. The river remains largely unaltered along this reach even when passing through the settlements of North Cerney, Perrott's Brook and Baunton. The road bridges identified are small and likely to have limited impact on habitat availability.

Reach 2, River Churn from Stratton to Siddington

Reach 2 is likely to predominantly support low energy environments, indicated by the relatively low slope to the watercourse. The geomorphological characteristics of the watercourse are significantly different to Reach 1 due to the reach running dry in certain years. However, when the river is flowing, the habitat availability is likely to be similar to that described above for Reach 1.

Although semi-natural habitats dominate the reach, suburban/urban developments are present in the adjacent habitat with associated modification to the watercourse. Extensive straightening along the watercourse is likely to have significantly reduced the diversity of habitats present. The road bridges identified are only likely to have limited impact on habitat availability as these have not been culverted.

Reach 3, River Churn from Siddington to the confluence with the River Thames

Reach 3 is likely to support low energy environments, indicated by the relatively low slope to the watercourse. The geomorphological characteristics of the watercourse are significantly different to Reach 1 due to the reach running dry in certain years. However, when the river is flowing, the habitat availability is likely to be similar to that described above for Reaches 1 and 2. Habitat diversity is likely to be present in meander sections, where flow diversity increases. Aerial imagery identifies that there is significant riparian tree cover which is likely to provide habitat opportunities for a number of species, in particular cover for fish, as well as providing some allochthonous energy[28].

The road bridges identified around the village of South Cerney are likely to have limited impact on habitat availability given the level of modification that the river is subject to more generally in that section of the reach.

Reach 4 (Gumstool Brook from the Daglingworth Stream to the River Churn)

During low flow periods, Cirencester Town Council and the Environment Agency provide flow preferentially to the River Churn because it is of greater ecological value. As artificial channels which are partially culverted, Gumstool Brook is unlikely to support any marginal habitat (except when the channel bed is exposed during low flows) the habitat diversity is therefore expected to be very low.

[27] This would be important in a low order stream such as this as there will be limited input of energy from upstream in the reach.
[28] This would be important in a low order stream such as this as there will be limited input of energy from upstream in the reach.

Reach 5 (River Coln from Ablington to confluence with the River Thames)

Reach 5 is likely to support low energy environments, indicated by the relatively low slope to the watercourse. Habitat diversity is likely to be present in the more sinuous sections, where flow diversity increases. Aerial imagery identifies that there is significant riparian tree cover which is likely to provide habitat opportunities for a number of species, in particular cover for fish, as well as providing some allochthonous energy. Habitat diversity is expected to increase in areas of decreased management, especially within the more semi-natural sections of the reach.

4.4.2.6 Water quality

To support the assessment of potentially sensitive environmental features in **Section 4.7**, an understanding has been developed of the water quality of the rivers within the study area, including trends over time and with respect to river flow. For WFD classification, the Environment Agency has set out[29], following UKTAG evidence[30], what pressures, including water quality pressures, each biological quality element is capable of responding to. For the purposes of assessment here, the supporting water quality parameters are set out: for fish and macroinvertebrates (where identified as sensitive features) as dissolved oxygen saturation and total ammonia concentration; and for macrophytes and algae (phytobenthos/diatoms) (where identified as sensitive features) as soluble phosphorus. Specifically, for macrophytes, if the hydrological impacts of drought permit implementation have been identified within the main macrophyte growing season (April to September), an assessment of phosphorous has been undertaken.

Ten years of Environment Agency routine monitoring data were reviewed to provide an overview of baseline water quality in the study area (January 2010 to December 2019). Environment Agency water quality data from three sites were available covering Reaches 1, 3 and 5 (see **Figure 4.2**). The following Environment Agency sites have been used to help characterise the baseline:

- Reach 1: Churn at North Cerney site. For the analysis, river flows on the date of water quality sampling were taken from the Churn at Perrott's Brook flow gauge.
- Reach 2: No water quality sites are available within this reach.
- Reach 3: Churn at Cerney Wick gauging station. For the analysis, river flows on the date of water quality sampling were taken from the Churn at Cerney Wick flow gauge.
- Reach 4: No water quality sites are available within this reach.
- Reach 5: River Coln at Roundhouse, Lechlade site. For the analysis, river flows on the date of water quality sampling were taken from the Coln at Fairford flow gauge.

Values at the limit of detection were halved in line with standard Environment Agency practice. Additionally, Thames Water monitoring data was included for the 2012 – 2014 period for Reaches 1 and 2 (River Churn) to help characterise the baseline. Sites are located on **Figure 4.2** and are:

- Reach 1: Churn at Perrott's Brook gauge site. For the analysis, river flows on the date of water quality sampling were taken from the Churn at Perrott's Brook flow gauge.
- Reach 2: Churn at Stratton Allotments. For the analysis, river flows on the date of water quality sampling were taken from the Churn at Cirencester flow gauge.

Reach 1, River Churn from North Cerney to Stratton

The average pH over the ten-year review period was 8.3 and the maximum water temperature was 18.6°C in upper Reach 1 (North Cerney site) and both slightly lower in mid Reach 1 (Perrott's Brook gauge site) average pH 8.2, maximum water temperature 19.9°C.

[29] Environment Agency (2011) Method statement for the classification of surface water bodies v2.0 (external release) Monitoring Strategy v2.0 July 2011 Table 2.
[30] UK Technical Advisory Group on the Water Framework Directive (2008) Recommendations on Surface Water Classification Schemes for the purposes of the Water Framework Directive December 2007 (alien species list updated – Oct 2008 and Nov 2008). Appendix 1.

Dissolved oxygen saturation

Dissolved oxygen saturation was reviewed and data are presented in **Figure 4.3** for upper Reach 1 and **Figure 4.4** for mid Reach 1 against the relevant WFD standards for a lowland high alkalinity river[31].

Dissolved oxygen saturation measurements at North Cerney were mostly consistent with the WFD standard to support Good status for fish and invertebrates (75%). Annual average values were similar to those from the previous ten years. No association between dissolved oxygen saturation measurements and river flows are apparent at Perrott's Brook gauging station flow gauge.

Figure 4.3 Dissolved Oxygen Saturation in River Churn (North Cerney), Incorporating Appropriate WFD Status Bands

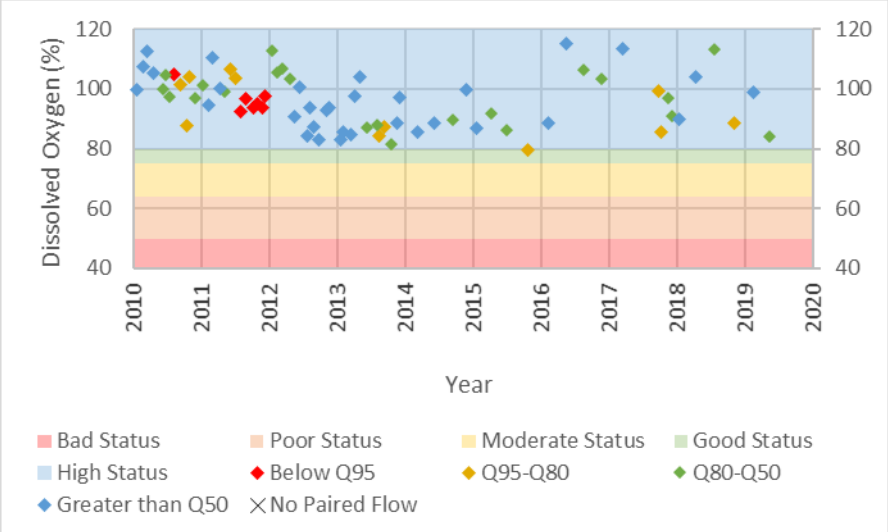
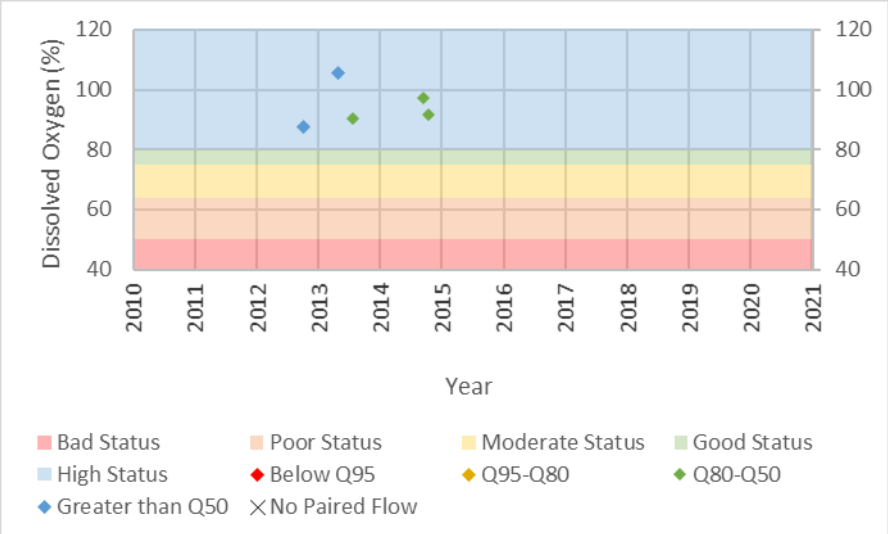


Figure 4.4 Dissolved Oxygen Saturation in River Churn (Perrott's Brook gauge), Incorporating Appropriate WFD Status Bands



Dissolved oxygen saturation measurements at Perrott's Brook gauge were also consistent with the WFD standard to support Good status for fish and invertebrates (75%). Annual average values were similar to those from the previous ten years at nearby sites. No association between dissolved oxygen saturation measurements and river flows are apparent at Perrott's Brook gauging station flow gauge.

[31] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.

Baseline monitoring at site Baunton Footbridge was undertaken on 20/10/2017 and DO saturation measured 81.1%. This was consistent with the WFD standard to support good status for fish and invertebrates (70%).

Total ammonia concentration

Total ammonia concentration was reviewed, and data are presented in **Figure 4.5** and **Figure 4.6** for upper Reach and mid Reach 1 against the relevant WFD standards for a lowland high alkalinity river[32].

Total ammonia concentrations at Cerney Wick gauge were all consistent with the WFD standard to support Good status for fish and invertebrates (0.3mg/l) and show no association with differing flows.

Figure 4.5 Total Ammonia in River Churn (North Cerney), Incorporating Appropriate WFD Status Bands

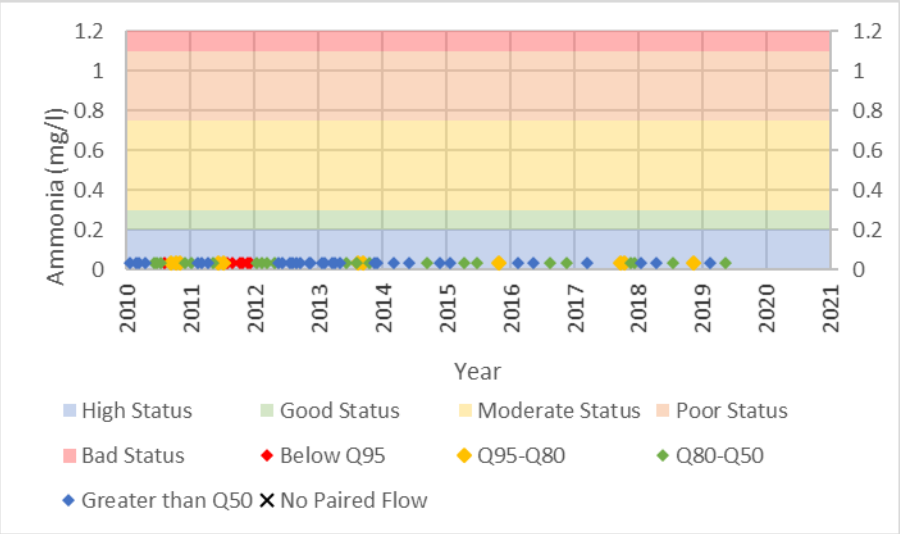
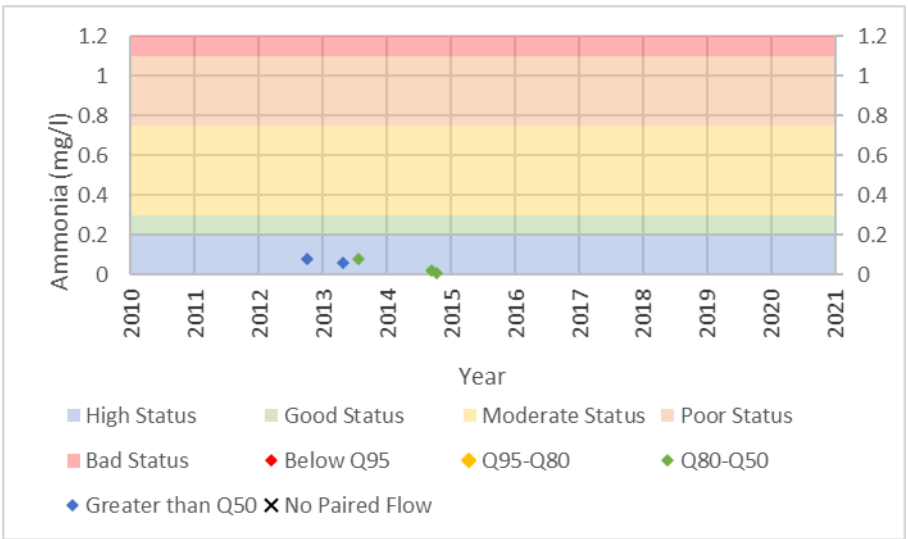


Figure 4.6 Total Ammonia in River Churn (Churn at Perrot's Brook), Incorporating Appropriate WFD Status Bands



Total ammonia concentrations at Perrott's Brook gauge were all consistent with the WFD standard to support Good status for fish and invertebrates (0.3mg/l) and show no association with differing flows.

[32] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.

Soluble Reactive Phosphorus (SRP) Concentration

SRP concentration was reviewed and data are presented in **Figure 4.7** for upper Reach 1 against the site specific relevant WFD standards provided by the Environment Agency[33] and **Figure 4.8** for mid Reach 1 against the relevant WFD standards for a lowland high alkalinity river[34].

SRP concentrations at North Cerney were mostly consistent with the WFD standard to support good status for diatoms and macrophytes (0.03mgP/l). One instance of moderate WFD status is noted on 12/10/2011 with 0.08mgP/l. No trend was identifiable between SRP concentration and river flow.

Figure 4.7 SRP concentration in River Churn (North Cerney), Incorporating Appropriate WFD Status Bands

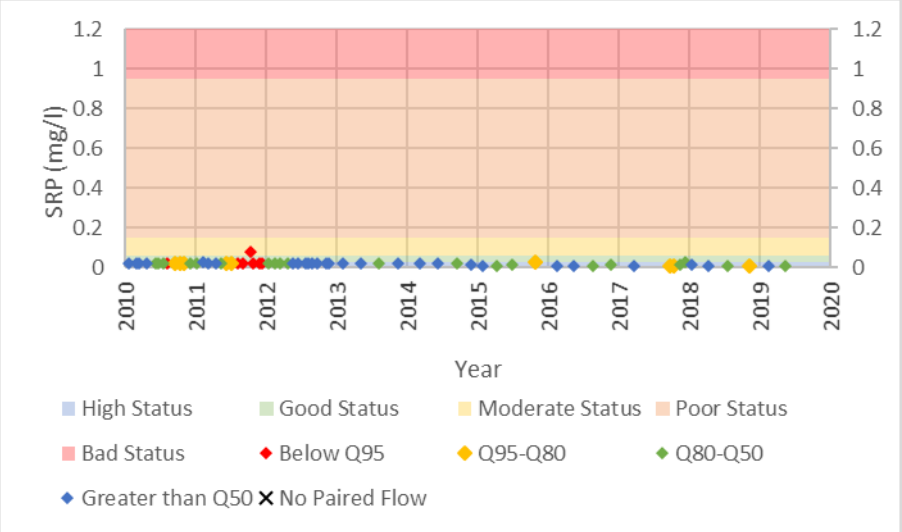
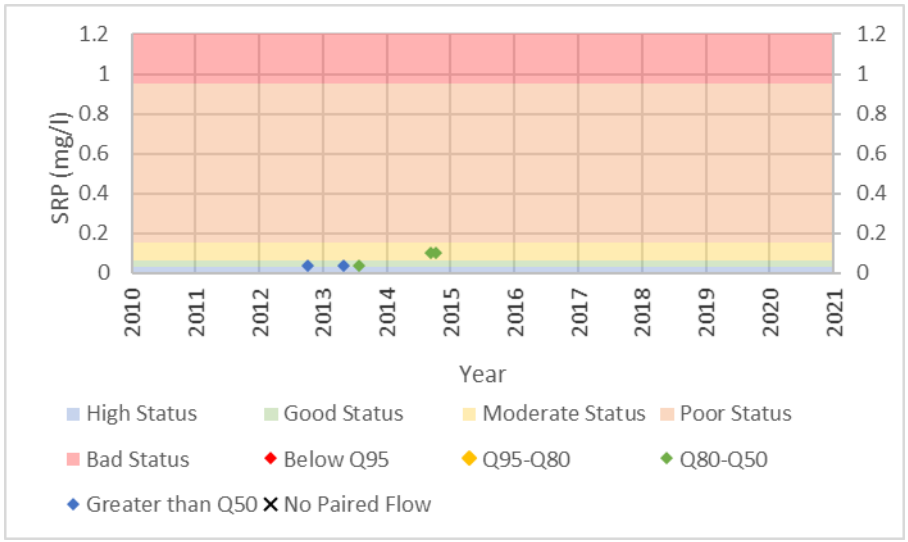


Figure 4.8 SRP concentration in River Churn (Perrott's Brook gauge), Incorporating Appropriate WFD Status Bands



SRP concentrations near Perrott's Brook gauge were mostly consistent with the WFD standard to support Good status for diatoms and macrophytes (0.03mgP/l). Two samples indicative of moderate status were collected on 15/09/2014 and 14/10/2014 (0.1mgP/l). No trend was identifiable between SRP concentration and river flow.

[33] Environment Agency (2015). WFD 2015 Cycle 2 – River & Canal Physico-chemical classifications – Site Specific Phosphate Standards
[34] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

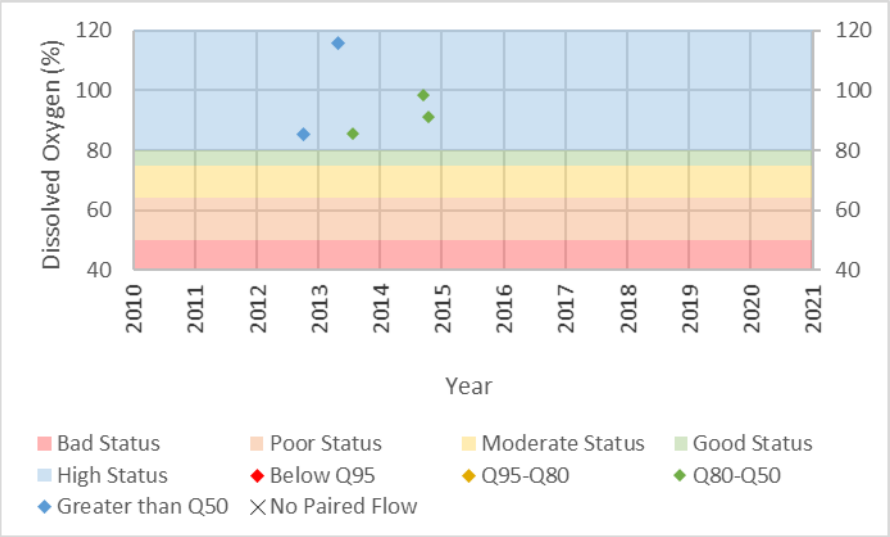
Reach 2, River Churn from Stratton to Siddington

The average pH over the two year data period was 8.2 and the maximum water temperature was 16.9°C.

Dissolved oxygen saturation

Dissolved oxygen saturation was reviewed and data are presented in **Figure 4.9** against the relevant WFD standards for a lowland high alkalinity river[35].

Figure 4.9 Dissolved Oxygen Saturation in River Churn (Stratton Allotments), Incorporating Appropriate WFD Status Bands



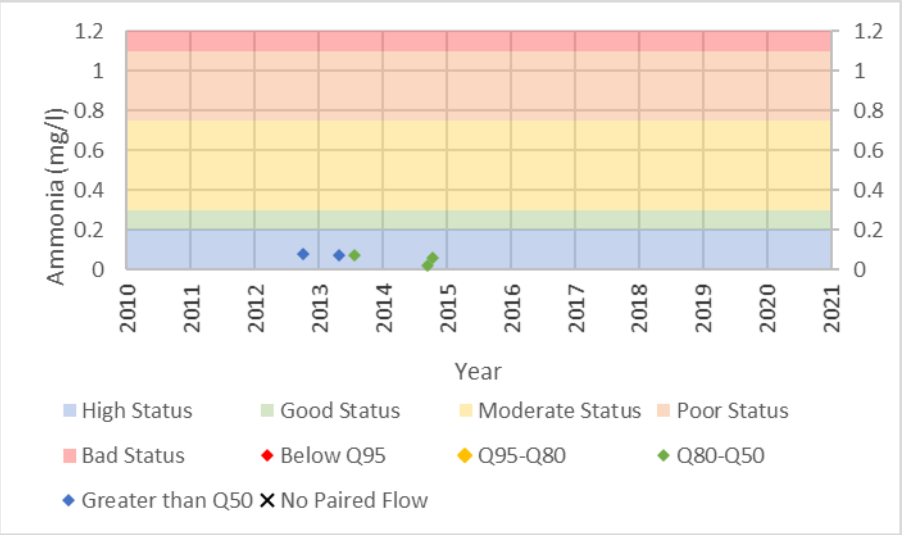
Dissolved oxygen saturation measurements at Stratton Allotments were consistent with the WFD standard to support Good status for fish and invertebrates (75%). No association is noted between total ammonia concentration and river flows. This reach is limited by data availability.

Total ammonia concentration

Total ammonia concentration was reviewed and data are presented in **Figure 4.10** against the relevant WFD standards for a lowland high alkalinity river[36].

[35] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.
[36] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

Figure 4.10 Total Ammonia in River Churn (Stratton Allotments), Incorporating Appropriate WFD Status Bands

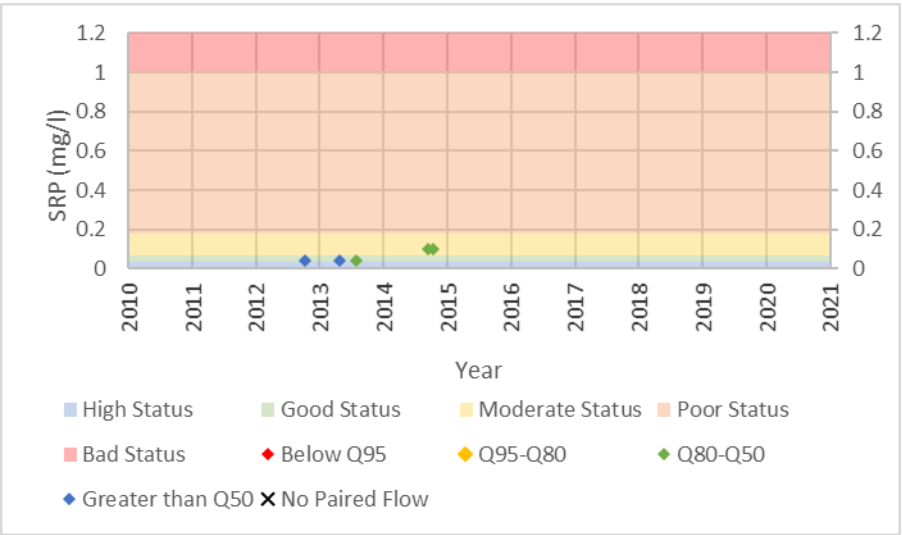


Total ammonia concentrations at Stratton Allotments were consistent with the WFD standard to support Good status for fish and invertebrates (0.3mg/l). No association is noted between total ammonia concentration and river flows. This reach is limited by data availability.

SRP Concentration

SRP concentration was reviewed and data are presented in **Figure 4.11** against the relevant WFD standards for a lowland high alkalinity river[37].

Figure 4.11 SRP concentration in River Churn (Stratton Allotments), Incorporating Appropriate WFD Status Bands



SRP concentrations at Stratton Allotments were variable, ranging between the WFD standard to support Moderate-Good status for diatoms and macrophytes (0.07mgP/l). Two instances of moderate status are noted on 15/09/2014 and 14/10/2014 both measuring 0.1mgP/l. Higher SRP concentrations may associate with lower river flows although the data are, as yet, inconclusive. This reach is limited by data availability.

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

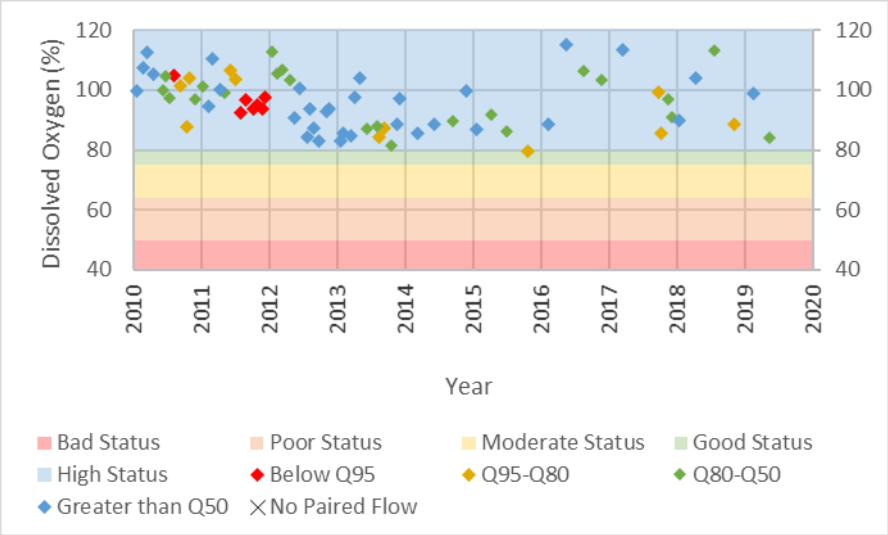
Reach 3, River Churn from Siddington to the confluence with the River Thames

The average pH over this time period was 8.2 and the maximum water temperature was 20.8°C.

Dissolved oxygen saturation

Dissolved oxygen saturation was reviewed and data are presented in **Figure 4.12** against the relevant WFD standards for a lowland high alkalinity river[38].

Figure 4.12 Dissolved Oxygen Saturation in River Churn (Cerney Wick), Incorporating Appropriate WFD Status Bands



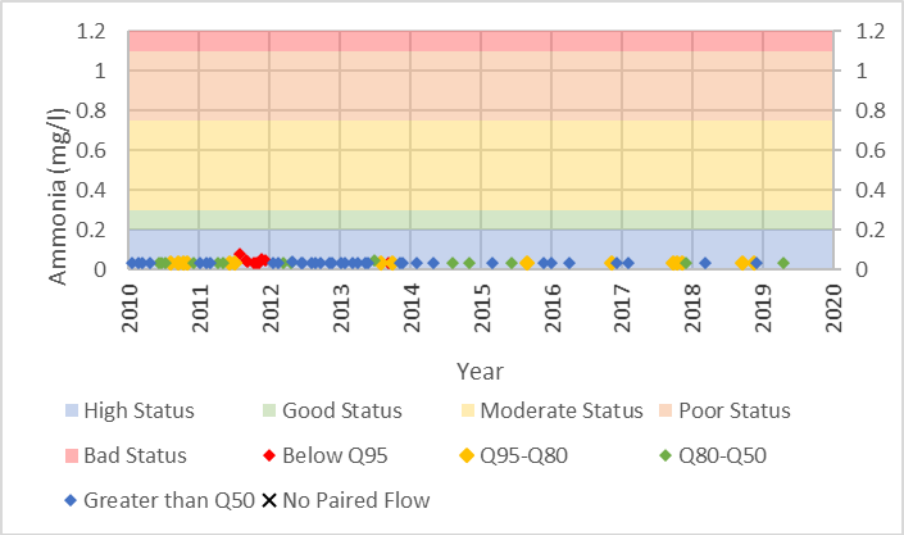
Dissolved oxygen saturation measurements near Cerney Wick gauging station were mostly consistent with the WFD standard to support Good status for fish and invertebrates (75%). Annual average values were similar to those from the previous ten years. A possible association is noted between dissolved oxygen saturation and river flows at Cerney Wick gauging station (especially after the winter drought in 2012).

Total ammonia concentration

Total ammonia concentration was reviewed and data are presented in **Figure 4.13** against the relevant WFD standards for a lowland high alkalinity river[39].

[38] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.
[39] The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.

Figure 4.13 Total Ammonia in River Churn (Cerney Wick), Incorporating Appropriate WFD Status Bands

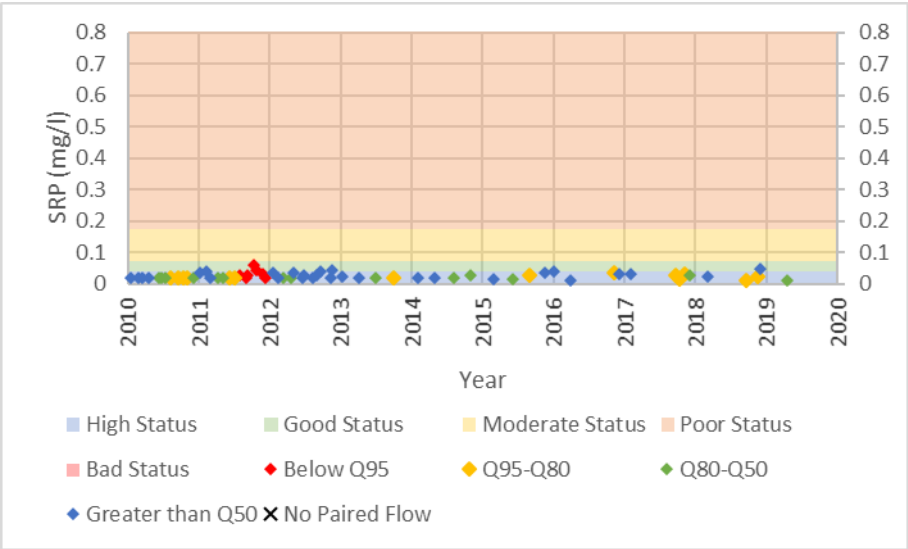


Total ammonia concentrations near Cerney Wick gauging station were all consistent with the WFD standard to support high status for fish and invertebrates (0.3mg/l). Annual average values were similar to those from the previous ten years. No association is noted between total ammonia concentration and river flows near Cerney Wick gauging station.

SRP Concentration

SRP concentration was reviewed and data are presented in **Figure 4.14** against the relevant site specific WFD standards provided by the Environment Agency[40].

Figure 4.14 SRP concentration in River Churn (Cerney Wick), Incorporating Appropriate WFD Status Bands



SRP concentrations near the Cerney Wick gauging station were mostly consistent with the site-specific WFD standard to support good status for diatoms and macrophytes (0.08mgP/l). No trend was identifiable between SRP concentration and river flow.

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

Reach 4 (Gumstool Brook from the Daglingworth Stream to the River Churn)

No water quality data is available for Reach 4. As this reach is connected to Reach 2, water quality is assumed to be similar to the assessment for this reach.

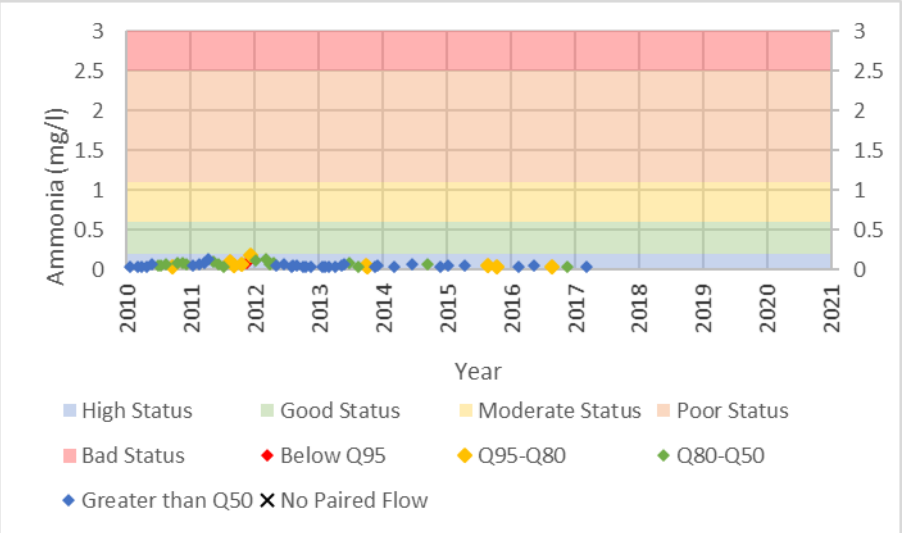
Reach 5 (River Coln from Ablington to confluence with the River Thames)

The average pH over this time period was 8.1 and the maximum water temperature was 20.4°C.

Total ammonia concentration

Total ammonia concentration was reviewed and data are presented in **Figure 4.15** against the relevant WFD standards for a designated salmonid river[41].

Figure 4.15 Total Ammonia in River Coln at Roundhouse, Lechlade, Incorporating Appropriate WFD Status Bands



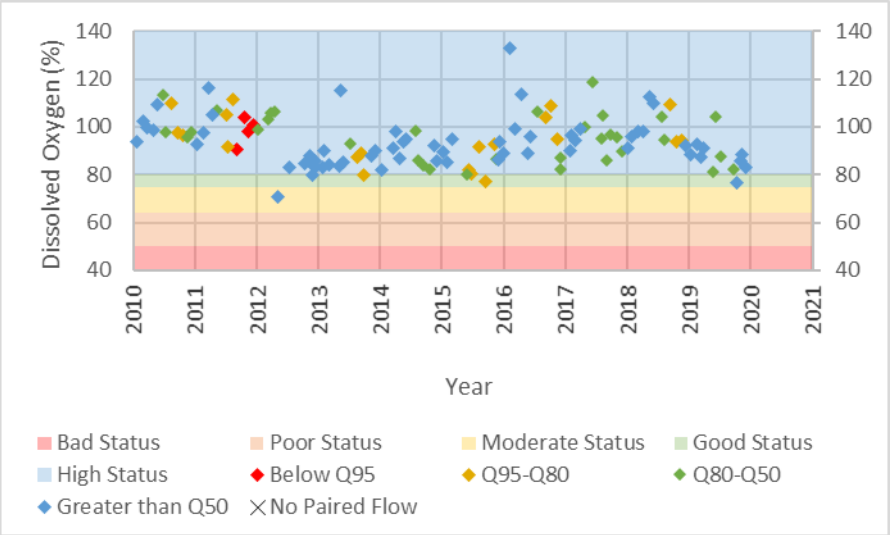
Total ammonia concentrations at River Coln at Roundhouse, Lechlade, were consistent with the WFD standard to support Good status for fish and invertebrates (0.6mg/l). No association is noted between total ammonia concentration and river flows.

Dissolved oxygen saturation

Dissolved oxygen saturation was reviewed and data are presented in **Figure 4.16** against the relevant WFD standards for a designated salmonid river[42].

[41] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.
[42] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.

Figure 4.16 Dissolved Oxygen Saturation in River Coln at Roundhouse, Lechlade, Incorporating Appropriate WFD Status Bands

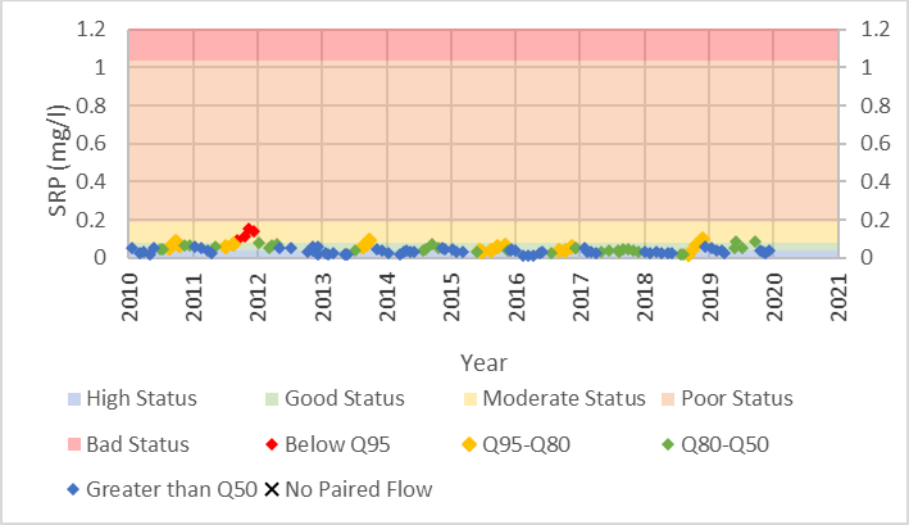


Dissolved oxygen saturation at River Coln at Roundhouse, Lechlade, were mostly consistent with the WFD standard to support Good status for fish and invertebrates (75%). Several occasions when this standard was not met are evident within the record. There is no particular association between low DO saturations and low river flows.

SRP Concentration

SRP concentration was reviewed and data are presented in **Figure 4.17** against the relevant site specific WFD standards provided by the Environment Agency[43].

Figure 4.17 SRP concentration in River Coln at Roundhouse, Lechlade, Incorporating Appropriate WFD Status Bands



SRP concentrations at River Coln at Roundhouse, Lechlade were indicative of conditions ranging from high status (0.041 mg/L) to moderate status (1.88 mg/L). Elevated SRP concentrations are linked to low flows and there is some element of seasonality within the recorded period.

[43] The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2015. ISBN 978-0-85521-192-9.

4.4.2.7 Environmental pressures

The overview of the physical environment includes identification of both flow and water quality pressures in the study area.

Flow Pressures (Other Abstractions)

During an environmental drought, abstractions put pressure on flow by removing water from rivers and groundwater aquifers and potentially exacerbating natural low flows. An overview of abstractions is given below based on information received from the Environment Agency (see **Table 4.3**). It was agreed during the consultation process in preparing the EARs (see **Section 1.3)** in 2012 that for DP completion, licensed abstractions less than 0.5Ml/d only need to be identified within the reports and do not require assessment. In addition, it was agreed that unlicensed abstractions are not required to be identified or assessed within the EARs. Any significant pressures (abstractions of over 0.5Ml/d) are shown on **Table 4.3** as shaded in grey.

Table 4.3 Groundwater and surface water abstractions in area of influence of the Baunton drought permit (Reaches 1, 2, 3 and 5) [elements of table should be redacted prior to public consultation]

Name	Licence Number	Abstraction source (GW only)	Holder	Use	Peak daily abstraction limit and licence conditions
Groundwater abstractions					
Latton Pumping Station	28/39/02/0010	Great Oolite Formation	Thames Water Utilities Ltd	Potable Water Supply - Direct	28Ml/d (returning to base licence conditions of 20 Ml/d 31/12/22)
Latton North Quarry Area	TH/039/0002/018	Great Oolite Formation	Hills Quarry Products Limited	Minerals	4.8Ml/d
Emin Way Farm, Stratton	TH/039/0002/009	Inferior Oolitic Limestone	William Gilder Limited	General Farming	0.54Ml/d
Eysey Manor Quarry	TH/039/0004/001		Tarmac Trading Limited	Minerals	4.67Ml/d
Warrens Gorse	TH/039/0002/006	Inferior Oolitic Limestone	John Randall	General Farming and Domestic	0.03Ml/d
Hatherop Estate, Hatherop, near Cirencester	28/39/06/0027	Inferior Oolite	The Ernest Cook Trust	General Farming and Domestic	0.08Ml/d
Leafield Farm, Quenington, Gloucestershire	28/39/06/0097	Great Oolite	Park Farm Syndicate Ltd	General Farming and Domestic	0.05Ml/d
Donkeywell Farm, Quenington	28/39/05/0035	Inferior Oolite	Mr C J E Peachey	General Farming and Domestic	0.03Ml/d
Abbey Estate Baunton	28/39/02/0033	n/a	William Chester Master	General Farming and Domestic	0.06Ml/d
Surface water abstractions (Reach 1)					
None	n/a	n/a	n/a	n/a	n/a
Surface water abstractions (Reach 2, 3 and 4)					
None	n/a	n/a	n/a	n/a	n/a
Surface water abstractions (Reach 5)					
Bibury Trout Farm	28/39/06/0018	n/a	Bradvine Ltd	Fisheries	11,501Ml/year (daily figure not available)

The potential impacts of the implementation of a drought permit on designated sites has been included in the EAR for each drought permit/option (see **Section 4.7**). During a drought any drought permit will take precedence, but it will still be important to determine the effect of the implementation of a drought permit/option on the abstraction of water for managed wetlands and the conservation of such wetlands.

At this stage any exemptions are still in place and no licences have been issued. As a result, a detailed assessment of the effect of a drought permit/option on the abstraction of water for managed wetlands will need to be determined at the time of implementation of a permit/option.

Water Quality Pressures

Discharges put pressure on water quality during a drought as lower than normal river flows mean that there is less water available to dilute discharges such as final effluent from STWs. Discharges impacting the oxygen balance and ammonia concentration in the river reaches have been reviewed. Discharges may be considered as beneficial as they contribute more flow to rivers however they may also pose risks to water quality (noting that only abstractions are considered as flow pressures in the section above). Significant discharge permits over 0.5Ml/d are displayed in **Table 4.4**.

Table 4.4 Summary of Significant Water Quality Pressures in Impacted River Reaches of the Baunton (1) Drought Permit (Reaches 1 – 5)

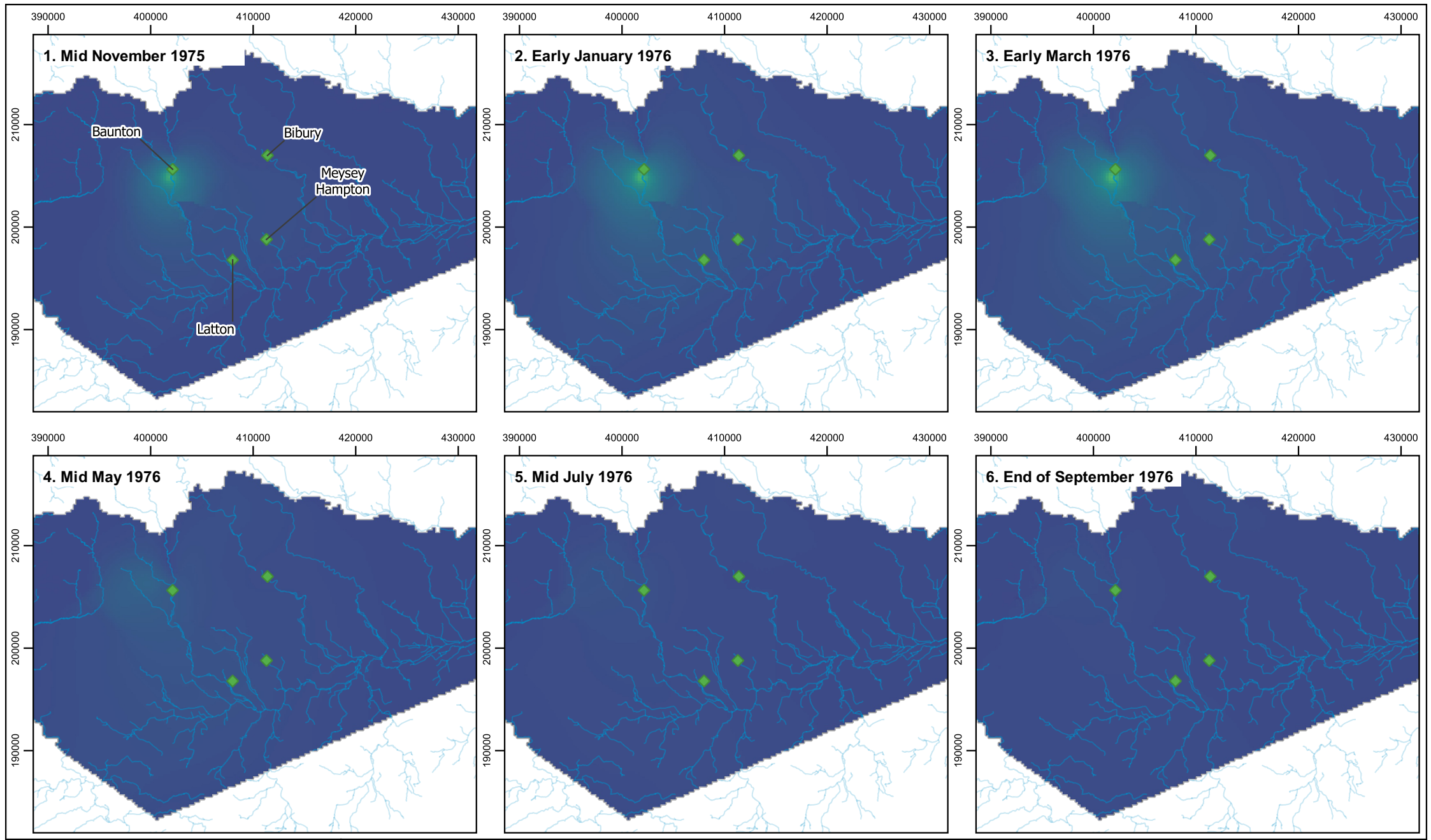
Reach	Water Quality Pressure (listed sequentially)	
	Permit number, holder, use	Permit conditions*
Reach 3	EPREB3999AS, Cerney Wick Quarry Complex, Extraction of Stone/Gravel	1.2Ml/d Maximum Daily Flow
Reach 5	CATM.3517, Fairford STW (Water Company), Sewage Disposal Works	1.4Ml/d Dry Weather Flow 5 mg/l Ammonia (N) 95%ile 15 BOD ATU 95%ile

4.5 Assessment of physical environment impacts

Potential impacts on the physical environment resulting from the Baunton (1) drought permit have been assessed using the Cotswolds Groundwater Model. The modelling outputs include groundwater drawdown and stream flows for a baseline (without drought permit) scenario and under drought permit conditions. For the purpose of this assessment the period 1975 to 1976 has been focussed on. Details of the groundwater modelling are outlined in **Appendix A**.

4.5.1 Potential Groundwater Drawdown from Implementation of the Drought Permit

The groundwater modelling has been used to understand the increased extent of groundwater drawdown associated with the Baunton (1) drought permit. The difference in groundwater drawdown in the Inferior Oolite under baseline (without drought permit) conditions and Baunton (1) drought permit conditions is illustrated on **Figure 4.18** below.



Project title:
Thames Water Drought Plan
Environmental Assessment

Figure 4.18:
Modelled groundwater drawdown in the Inferior Oolite under Baunton (1) Drought permit conditions compared to baseline (without drought permit) conditions

Legend

- Model boundary
- Watercourses
- Drought Permit groundwater abstractions

Drawdown (m)

<=-12	-5
-11	-4
-10	-3
-9	-2
-8	-1
-7	-0
-6	1
	2

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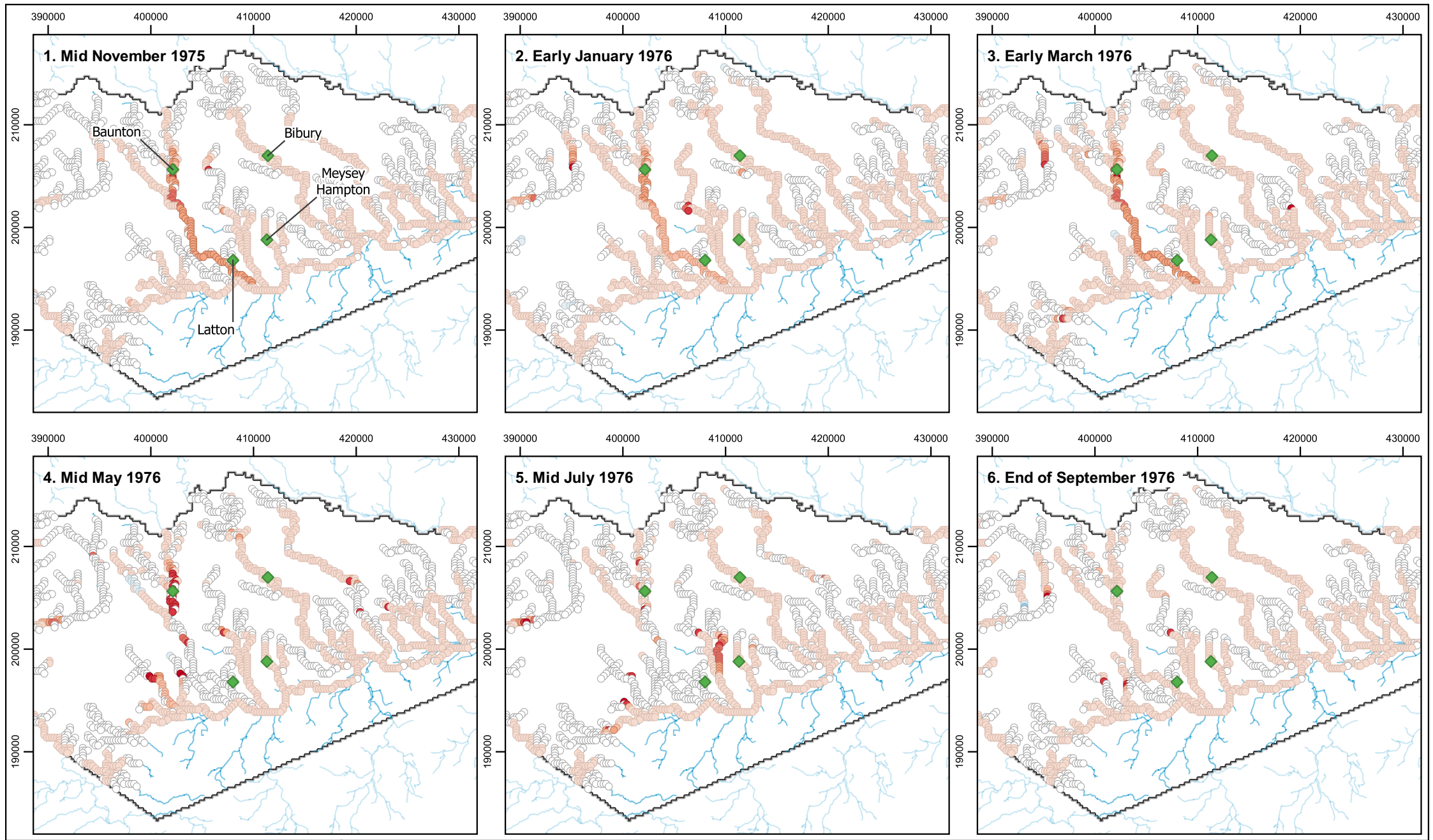
The modelling results show that the greatest drawdown within the Inferior Oolite associated with the Baunton (1) drought permit is in the vicinity and immediate surrounding area of the abstraction, with a maximum drawdown of 5.1m in March 1976 in the model run. Drawdown extends 4-6km in all directions from the abstraction point. By mid May 1976, modelled groundwater drawdown in the vicinity and immediate area of the abstraction is significantly reduced at 0.6m. Six months following cessation of the drought permit, groundwater levels have recovered to baseline (without drought permit) conditions.

4.5.2 Potential Changes to Hydrology from Implementation of the Drought Permit

The modelling results have also been used to understand the changes in stream flows associated with the Baunton (1) drought permit. The difference in stream flows under baseline (without drought permit) conditions and Baunton (1) drought permit conditions is illustrated on **Figure 4.19** below.



Project title:
Thames Water Drought Plan Environmental Assessment

Figure 4.19:
Baunton (1) Drought Permit: Modelled difference in stream flow under Drought permit conditions compared to baseline (without drought permit) conditions

Legend

- Model boundary
- Watercourses
- Drought Permit groundwater abstractions

Difference in streamflow under Drought Permit conditions compared to baseline (%)

- -100 - -50
- -50 - -20
- -20 - -15
- -15 - -10
- -10 - -5
- -5 - <0
- 0 - 0
- >0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 50
- 50 - 100

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Figure 4.19 shows flow reductions during the drought permit operation during November 1975 mainly affecting the River Churn (up to 31% reduction in streamflow). In March 1976 the largest reductions in streamflow were observed on the River Churn (up to 56% reduction in streamflow) and the River Frome (up to 34% reduction in streamflow). Simulated flows recover notably by the end of September 1976 to close to baseline levels.

The effect of the Drought Permit on the hydrology of each of the five study reaches is assessed below.

Reach 1 (River Churn, from North Cerney to Stratton)

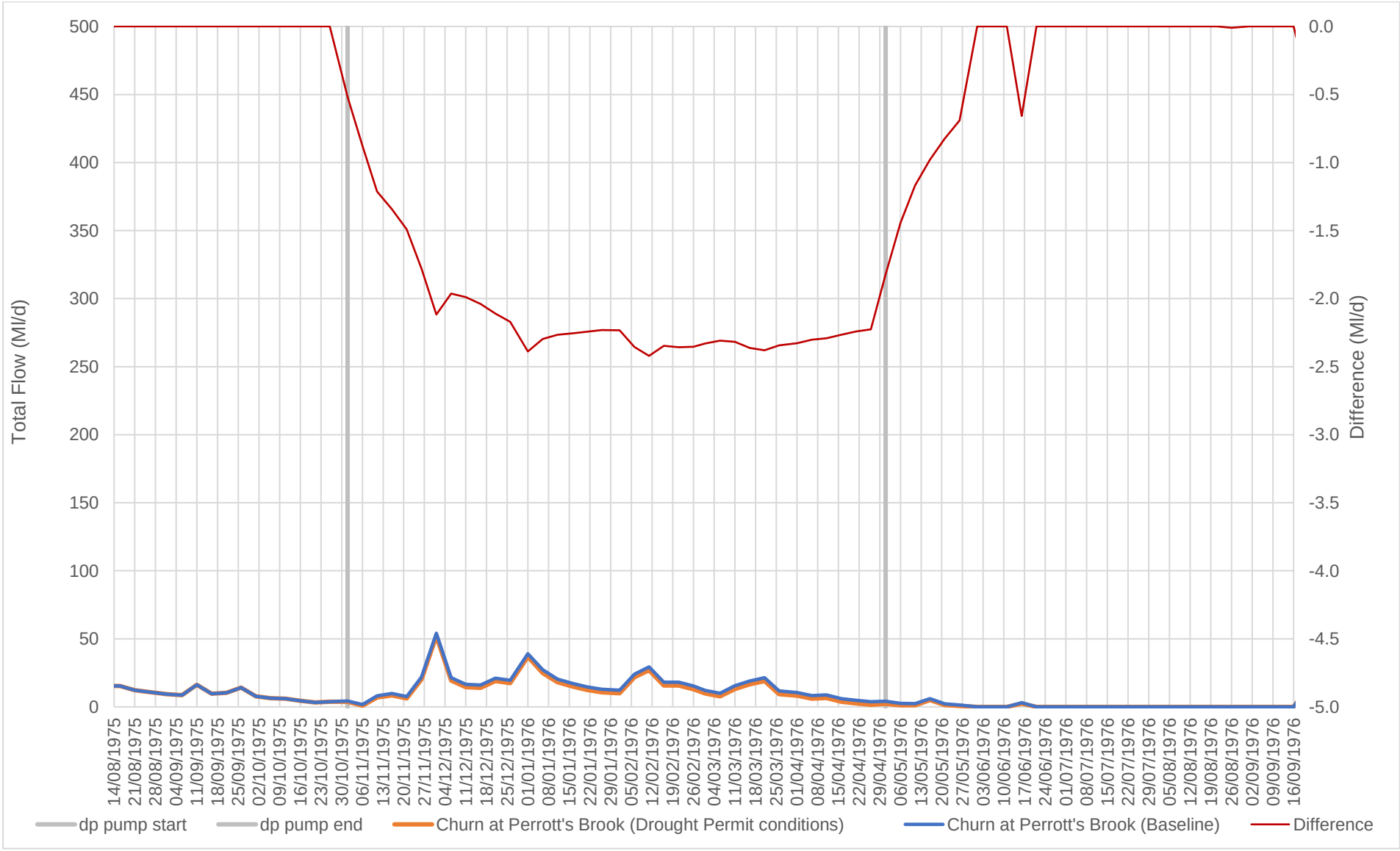
This area extends north to the upper extent of the zone of hydrogeological influence of the abstraction. At North Cerney, there was no apparent impact of the Baunton pumping trials and thus upstream there would be no impact on the River Churn[44].

Investigations in 1996 indicated that this reach of the River Churn, adjacent to the Baunton abstraction, did not dry up during the summer (acknowledging that 1996 was a dry year), although the hydrograph for the Churn at Perrott's Brook indicates that the River Churn can dry up within this section of the river adjacent to the abstraction. Groundwater levels were below bed level during the 1996 pumping trials for sections of the River Churn north of the abstraction (generally these low levels only occur in the worst droughts (i.e. 1976 and 1996). However, in the immediate vicinity of the pumping station, bed levels of between 117.86m to 117.75mAOD were lower than groundwater levels recorded during the 1996 pump test. This indicates that there is locally a hydraulic gradient between the Inferior Oolite aquifer partly confined by the leaky Fullers Earth formation, such that the Inferior Oolite no longer provides water to the river (see **Appendix A** for a more detailed explanation of this interaction).

Modelling results for the baseline and drought permit scenario for Reach 1 are based on modelled flow at the River Churn at Perrott's Brook gauge, located in mid Reach 1. Modelling results for flow in Reach 1 are presented for 1975/1976 on **Figure 4.20** below.

[44] Hunter, S.M. and Davis, R.J. (1997) Report on the Pumping Trials at Baunton, Latton and Meysey Hampton Summer 1996.

Figure 4.20 River Churn at Perrott's Brook: Modelled baseline flow vs Baunton (1) drought permit conditions



The baseline scenario modelling results show that the reach is ephemeral, with flow at 0Ml/d from the start of June 1976 for 112 days under baseline conditions. These results indicate that with the drought permit in place, the reach will not dry earlier than in the baseline scenario. The results also indicate that when surface water flow recovery commences (following the dry period) flows will be up to 0.4Ml/d lower until the following winter (once groundwater recovery has commenced).

As these watercourses can naturally dry up over summer, the intermittently flowing watercourse hydrological methodology (see **the Methodology**) has been applied. Given the potential impacts discussed above (no significant impact), the potential hydrological impact of the Baunton (1) drought permit on Reach 1 is considered to be **negligible** during the dry period in the spring following drought permit cessation.

Modelling indicates a reduction of up to 2.4Ml/d during the drought permit implementation period (November to May), which would be a reduction in annual Q95 and annual Q50 of 35% and 6% respectively (based on gauged flow statistics presented in **Table 4.2**).

Although these watercourses can dry up naturally over summer, there is a significant reduction in flow during the drought permit implementation period (November to May). Therefore, the upland perennially flowing watercourse hydrological impact assessment methodology (see **the Methodology**) has been applied to assess the impacts of the drought permit during implementation. Given the potential impacts discussed above (>25% reduction in annual Q95 and <10% reduction in annual Q50), the potential hydrological impact of the Baunton (1) drought permit is considered to be **moderate** during drought permit implementation.

Reach 2 (River Churn, from Stratton to Siddington)

This reach is underlain by the Great Oolite Group aquifer. Groundwater levels in the Great Oolite Group are several metres below the bed level of the River Churn throughout the whole year where there is good hydraulic connection with underlying Great Oolite Group lithologies. Hence, flow over this reach would be lost to the aquifer throughout the whole year.

In terms of magnitude, the proposed drought permit would have a small impact on flow within this reach (up to 0.76Ml/d reduction in flow). From 1km downstream of the transition to where the Great Oolite aquifer underlies the river, the influence of the abstraction on river flows would be much less pronounced than the impact of the flow losses to the Great Oolite (such reductions have been reported as up to 50% between Baunton and Cirencester[45]).

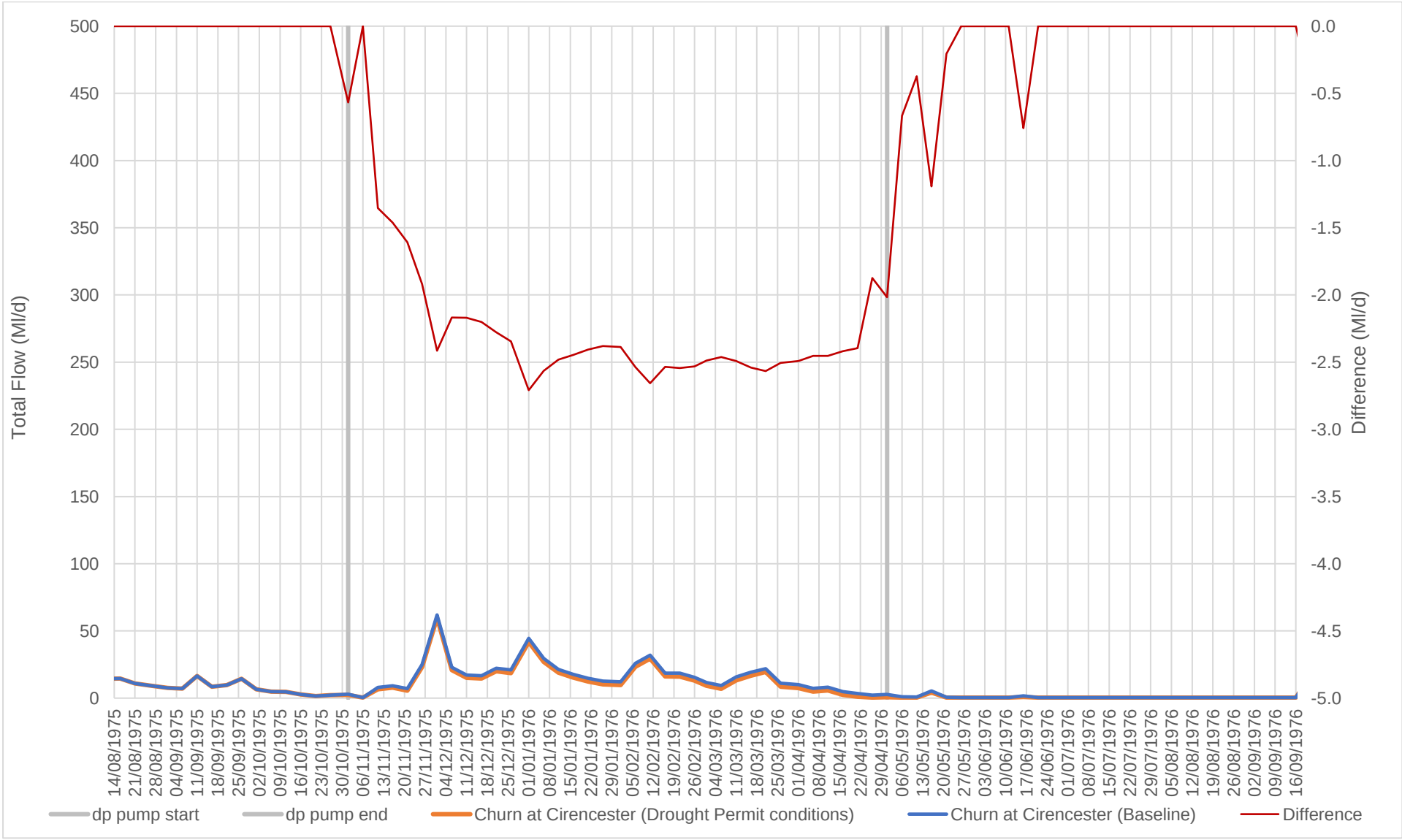
This river reach can naturally dry up over summer[46], as indicated by Environment Agency springs and sources surveys which shows that the source of the river migrates and has been observed as far downstream as Siddington and just upstream of South Cerney. If drying up were to occur, it is anticipated that the drought permit would result in segments of the channel drying up earlier than would occur without a drought permit. However, given that “natural” losses to the Great Oolite are considered to be the major groundwater control on flow within this part of the river, the increased rate of river drying occurring as a result of the drought permit is only considered to be a matter of a few days.

During the hydrological winter (i.e. the months of October to March inclusive), groundwater levels in the Great Oolite aquifer in this part of the river would be anticipated to recover and augment flows in the Churn.

Modelling results for the baseline and drought permit scenario for Reach 2 are based on modelled flow at the River Churn at Cirencester gauge, located in upper Reach 2. Modelling results for flow in Reach 2 are presented for 1975/1976 on **Figure 4.21** below.

[45] Hunter, S.M. and Davis, R.J. (1997) Report on the Pumping Trials at Baunton, Latton and Meysey Hampton Summer 1996.
[46] Hunter, S.M. and Davis, R.J. (1997) Report on the Pumping Trials at Baunton, Latton and Meysey Hampton Summer 1996.

Figure 4.21 River Churn at Cirencester: Modelled baseline flow vs Baunton (1) drought permit conditions



Gauged flow data for the Churn at Cirencester shows that the reach is ephemeral, with periods of drying in the autumn (c.f. Aug-Oct 1995, Oct-Nov 1997, Sept-Nov 2003) and extended periods where flows drop below the Q95 value of 0.053m^3/s (c.f. autumn periods of 1990, 1996, 1997, 1998, 2002, 2005 and 2011)[47]. Within the groundwater modelling, data indicates that modelled flows in the River Churn drop to a minimum value of 0.4Ml/d (0.0046m^3/s), which is ten times less than the measured Q95. At this flow rate there would likely be no discernible flow in the watercourse, as such it is taken that the modelled flow values indicates the reach has become dry. Considering this, the modelled data indicates that flow in the River Churn was at 0.4Ml/d from the start of June 1976 for 112 days under baseline conditions.

The modelling results show that with the drought permit in place, the reach dries up to ten days earlier than in the baseline scenario. The results indicate that when surface water flow recovery commences (following the dry period) flows will be up to 0.3Ml/d lower until the following winter (once groundwater recovery has commenced).

As these watercourses can naturally dry up over summer, the intermittently flowing watercourse hydrological methodology (see **the Methodology**) has been applied. Given the potential impacts discussed above (drought option resulted in sections drying up earlier by more than a handful of days), the potential hydrological impact of the Baunton (1) drought permit on Reach 2 is considered to be **moderate** during the dry period in the spring following drought permit cessation.

Modelling indicates a reduction of up to 2.7Ml/d during the drought permit implementation period (November to May), which would be a reduction in annual Q95 and annual Q50 of 41% and 6% respectively (based on gauged flow statistics presented in **Table 4.2**).

Although these watercourses can dry up naturally over summer, there is a significant reduction in flow during the drought permit implementation period (November to May). Therefore, the upland perennially flowing watercourse hydrological impact assessment methodology (see the Methodology) has been applied to assess the impacts of the drought permit during implementation. Given the potential impacts discussed above (>25% reduction in annual Q95 and <10% reduction in annual Q50), the potential hydrological impact of the Baunton (1) drought permit is considered to be **moderate** during drought permit implementation.

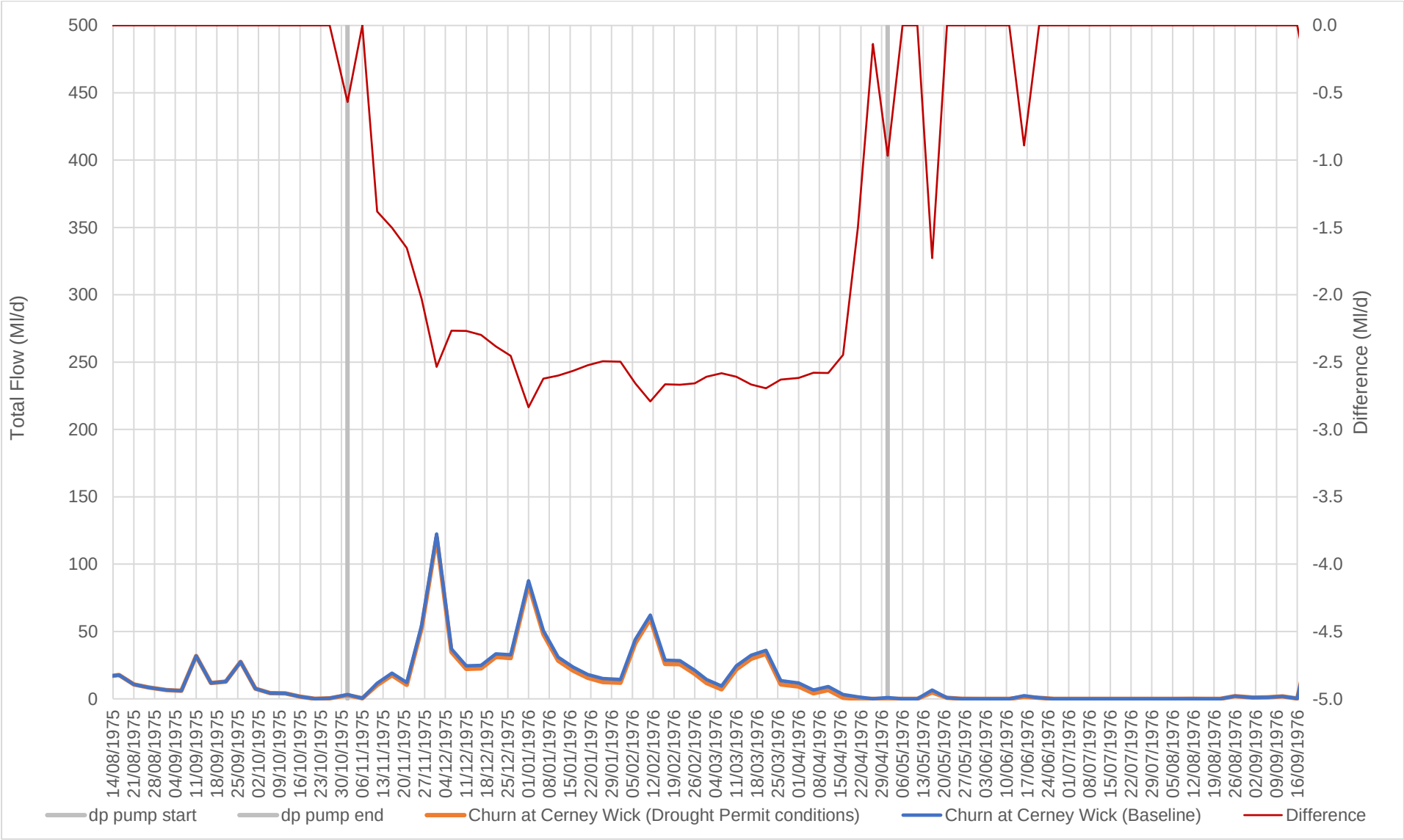
Reach 3 (River Churn, from Siddington to the confluence with the River Thames)

The impact of the drought permit is not expected to extend downstream of Siddington, however prolonged drying of the channel in Reaches 1 and 2 when the permit is in operation would decrease the amount of flow coming from upstream. Additionally, during low flows, the lower sections of the River Churn can dry up, as seen at Cerney Wick gauging station during the 2011 drought when zero flow was recorded in October and November. Although flow in this reach is not lost to the Great Oolite aquifer underlying the river bed, any reduction in flow as a result of the drought permit upstream could cause impact on the River Churn downstream until its confluence with the River Thames.

Modelling results for the baseline and drought permit scenario for Reach 3 are based on modelled flow at the River Churn at Cerney Wick gauge, located in upper Reach 3. Modelling results for flow in Reach 3 are presented for 1975/1976 on **Figure 4.22** below.

[47] https://nrfa.ceh.ac.uk/data/station/info/39073. Accessed 24 October 2022.

Figure 4.22 River Churn at Cerney Wick: Modelled baseline flow vs Baunton (1) drought permit conditions



The baseline scenario modelling results show that Reach 3 is ephemeral, with flow at 0 Ml/d from the start of May 1976 for 112 days under baseline conditions. The modelling results show that with the drought permit in place, the reach will dry up 20 days earlier than in the baseline scenario. The modelling results do not indicate a delay in recovery as a result of the drought permit.

As these watercourses can naturally dry up over summer, the intermittently flowing watercourse hydrological methodology (see **the Methodology**) has been applied. Given the potential impacts discussed above (drought option resulted in sections drying up earlier by more than a handful of days), the potential hydrological impact of the Baunton (1) drought permit on Reach 3 is considered to be **moderate** during the dry period in the spring following drought permit cessation.

Modelling indicates a reduction of up to 3.0Ml/d during the drought permit implementation period (November to May), which would be a reduction in annual Q95 and annual Q50 of 79% and 5% respectively (based on gauged flow statistics presented in **Table 4.2**).

The upland perennially flowing watercourse hydrological impact assessment methodology (see **the Methodology**) has been applied. Given the potential impacts discussed above (>25% reduction in annual Q95 and <10% reduction in annual Q50), the potential hydrological impact of the Baunton (1) drought permit is considered to be **moderate** during drought permit implementation.

Reach 4 (Gumstool Brook from the Daglingworth Stream to the River Churn)

The Gumstool Brook dried for periods of 2012, 2013 and 2014, years without environmental drought. The operation, by Cirencester Town Council, of the sluice controlling flow into the Gumstool Brook ensures that during low flow periods flows are maintained in the River Churn preferentially over the Gumstool Brook (this flow is transferred to the Gumstool Brook via the Barton Pond Mill and Daglingworth Stream). This operation would not be affected by a Baunton drought permit.

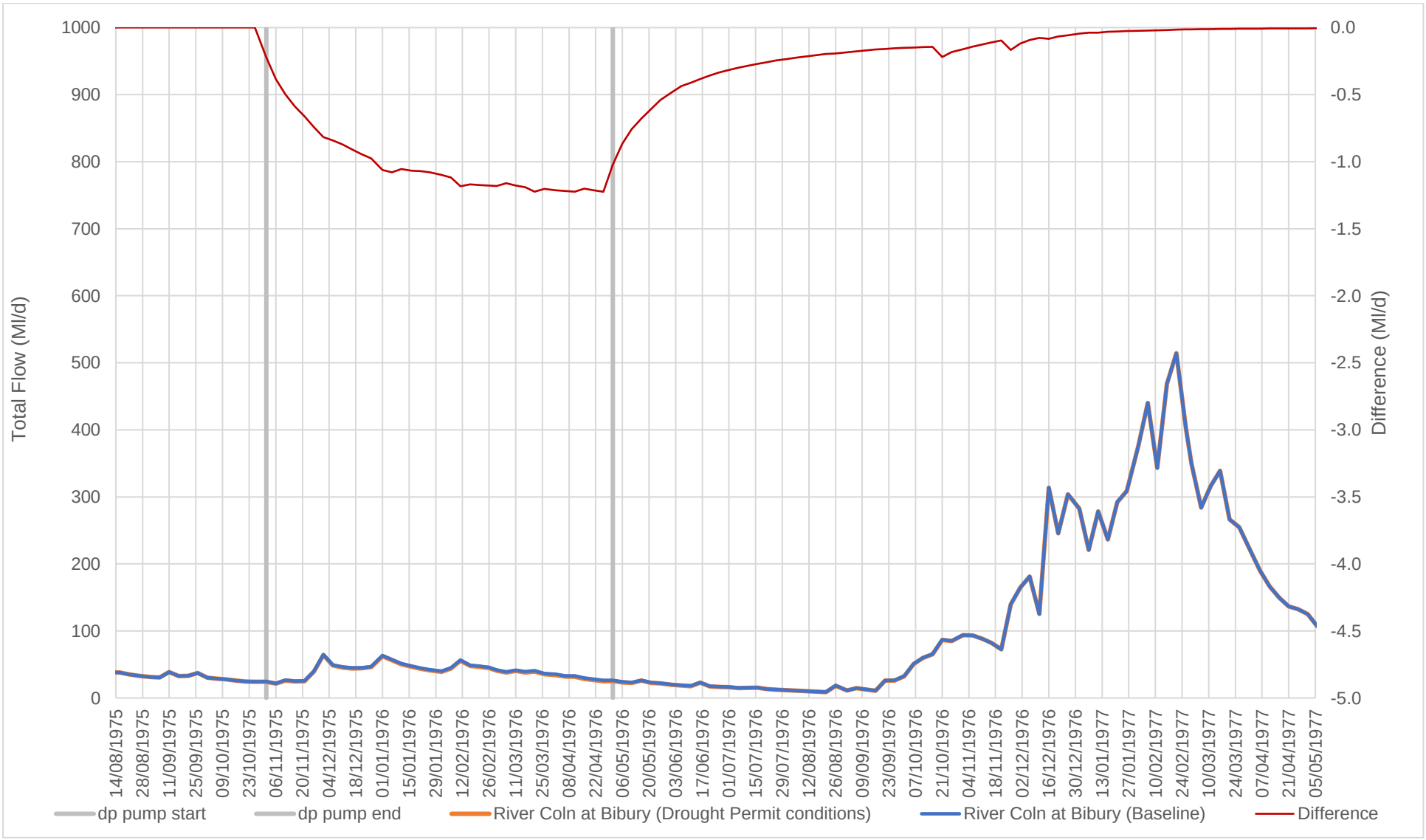
The closure of the Cirencester sluices is triggered by low flows in the River Churn which occur naturally without the drought permit in place, therefore it is likely that flow in Gumstool Brook will already be dry (with flow being retained in the River Churn). Therefore, the intermittent hydrological assessment (see **the Methodology**) has been applied. The drought permit will not result in further sections of Gumstool Brook drying. Furthermore, the Gumstool Brook is an artificial channel and is not in connectivity with the underlying Inferior Oolite, therefore will not be directly impacted by the groundwater recovery associated with the Baunton (1) drought permit.

It is therefore considered that the potential hydrological impact of the Baunton (1) drought permit on this watercourse will be **negligible**.

Reach 5 (River Coln from Ablington to confluence with the River Thames)

Modelling results for the baseline and drought permit scenario for Reach 5 are based on modelled flow at the Coln at Bibury gauge, located in upper Reach 5. Modelling results for flow in Reach 5 are presented for 1975/1976 on **Figure 4.23** below.

Figure 4.23 Coln at Bibury: Modelled baseline flow vs Baunton (1) drought permit conditions



The modelling results for the Coln at Bibury show that Reach 5 is a perennial reach. The baseline (without drought permit) reference conditions flow at Coln at Bibury would be as follows: summer Q95 of 10.23Ml/d, summer Q99 of 9.22Ml/d, annual Q50 of 34.3Ml/d and annual Q95 of 11.0Ml/d.

The modelling results show that with the drought permit in place there would be a reduction in the summer Q95 and Q99 flows of 2% at the Coln at Bibury assessment gauge. The modelling results also indicate that with the drought permit in place there would be a reduction in the annual Q50 and Q95 flows of 1%. The modelling results do not indicate a delay in recovery as a result of the drought permit, although flows following the drought permit will be slightly lower until winter.

With the exception of the last 4.6km of the reach whose elevation is slightly below 80mAOD, the majority of the reach lies above 80mAOD. This indicates the reach should be considered as an upland reach in the perennially flowing watercourses hydrological impact assessment methodology (see **the Methodology**). Given the potential impacts discussed above (<10% reduction in summer Q95 and summer Q95), the potential hydrological impact of the Baunton (1) drought permit at the Coln at Bibury assessment gauge is considered to be **negligible**.

Hydrological Impact Summary

The reaches are shown in **Table 4.5** and establish the full in-channel zone of influence of the drought permit for environmental sensitivity screening (see **Figure 4.1**).

Table 4.5 Hydrological Impact of the Drought Permit

Hydrological Reach	Reach Map Ref	Reach Boundary (start / end)		Reach Length (km)	Hydrological Impact
River Churn	Reach 1	North Cerney	Stratton	4.8	Moderate
River Churn	Reach 2	Stratton	Siddington	5.8	Moderate
River Churn	Reach 3	Siddington	Confluence with the River Thames	14.4	Moderate
Gumstool Brook	Reach 4	Daglingworth Stream	River Churn	1.2	Negligible
River Coln	Reach 5	Ablington	Confluence with the River Thames	25.0	Negligible

4.5.3 Potential Changes to the Physical Environment from Implementation of the Drought Permit

Section 4.4.2 provided an understanding of the baseline physical environment in the previously identified zone of impact. Using this knowledge, the potential changes to the impacted reaches from implementation of the drought option are summarised below:

- Changes in wetted width and water depth – Depending on the magnitude of the reduction in flows, in Reaches 1 to 3 there may be a reduction in wetted width and depth. This will lead to increasing exposure of channel margins and the margins of within-channel features. Such changes will be of particular importance in shallow sections of the channel in each reach (notably Reach 1), however given the channel modifications (e.g. bank re-profiling/reinforcement) recorded in most reaches such impacts may be limited, particularly in modified sections of Reach 2 and Reach 3.
- Changes in dry sections – The walkover survey referred to in **Appendix A** identified that sections of Reach 2 were dry. Given the groundwater fed nature of the reach it is possible that a reduction in baseflow discharge from the aquifer may lead to an increased distance of dry channel sections during the implementation of the drought permit. However, as the proportion of wet and dry channel in groundwater fed streams naturally change further quantification of these changes would be required before the impact of the scheme can be ascertained and this should be further investigated.

- Changes in sediment dynamics – Reductions in discharge will lead to reductions in flow depth and velocity. Given the already low energy environment of the watercourses and the low gradients of the surrounding landscape it is unlikely that significant volumes of sediment will be in transport during drought conditions.
- Impacts of in-channel structures – During the implementation of the drought option, in-channel structures, such as weirs, could influence sediment dynamics by creating ponded areas upstream of the structure. These areas will have very low flow velocities and increased depth in relation to other areas of the channel, this is likely to promote the deposition of fine sediment behind the structure. Only one weir was identified in the walkover survey and therefore the impacts of these structures are likely negligible, acknowledging that no CHEW data was obtained in Reaches 2/3.
- Bank stability – Reductions in wetted width and depth, leading to increased exposure of the channel banks, could potentially lead to increased drying and desiccation of earth banks, increasing the risk of bank collapse due to gravitational failure or erosion when higher flow discharges recommence. In sections of Reaches 1-3 where riparian vegetation dominates, or where the channel has been subject to sectioning/reinforcement, the risk of bank instability is reduced.
- Bed stability – Reductions in wetted width and depth could also impact upon the stability of vegetated sediment deposits or vegetated sections of the channel. The implementation of a drought option and a prolonged environmental drought may lead to loss of vegetation which could leave sediment exposed to erosion upon commencement of higher flows when drought conditions cease.
- Overall, geomorphology impacts are taken to be minor in reaches 1 to 3 and negligible in reaches 4 and 5.
- Water quality – Long term Environment Agency data were available for all three reaches, supplemented by additional monitoring undertaken by Thames Water. Dissolved oxygen saturation and total ammonia were generally consistent in supporting WFD good or high status for fish and invertebrates and without association with low flow. The exception was mid Reach 3, where the long term Environment Agency monitoring site Churn at Cerney Wick gauging station recorded reduced dissolved oxygen saturation at low river flows. There is a low risk in Reach 3 that oxygen quality will deteriorate associated with the minor hydrological effects on low flows in this reach. Reactive phosphorus quality was generally consistent in supporting WFD moderate-high status for diatoms and macrophytes, without association with river flow. There is negligible risk that nutrient quality will deteriorate associated with the drought option. In Reaches 4 and 5 hydrological impact has been assessed as negligible, therefore the risk to water quality is considered to be negligible.
- Additional abstraction pressures - There is one additional surface water abstraction pressure estimated to be greater than 0.5Ml/d. Although a daily quantity is unavailable, there is a maximum annual limit of 11,501Ml abstracted from the start of Reach 5 for the purpose of aquaculture. The hydrological impact in this reach as a result of the drought permit is negligible, therefore, it is unlikely that operation of the drought permit will have any effect on this abstraction.
- Additional abstraction pressures - There are four groundwater abstraction licences greater than 0.5Ml/d operational within the area of influence of the Baunton drought permit; Thames Water's Latton abstraction, an abstraction of industrial use just south of Latton, a further industrial abstraction near Cricklade and an agricultural abstraction approximately 1.3km west of the abstraction at Baunton. The abstraction at Latton is licensed for up to 28Ml/d (to return to 20Ml/d in 2023) and the abstraction at Latton North Quarry for 4.8Ml/d from the Great Oolite aquifer, located at the southernmost extent of the groundwater impact near Cerney Wick gauging station (see **Figure 4.2**). The additional industrial abstraction at Eysey Manor Quarry is located further south again, away from the groundwater impact. As the Baunton drought permit involves abstractions from the Inferior Oolite aquifer which is not hydrologically connected to the Great Oolite aquifer, the Latton abstraction licence and two industrial licenses are considered to present a negligible risk to groundwater levels in the Inferior Oolite and would not be limited by the drought permit. It would also not exert any additional flow pressure on flows in the River Churn because, during dry periods,

groundwater levels in the Great Oolite are always below the level of the bed of the river[48]. The agricultural abstraction to the west of Baunton does abstract from the same Inferior Oolite aquifer, and is located within the extent of groundwater drawdown impacts, however, the relatively small volume (0.54Ml/d) of the abstraction suggests that operation of the drought permit would present a low risk to this licence. There is one groundwater abstraction below 0.5Ml/d near Perrott's Brook that does abstract from the Inferior Oolite. This abstraction is small at 0.03Ml/d therefore the drought permit is unlikely to limit its feasibility.

- Specific water quality pressures – There are no identified discharges greater than 0.5Ml/d between Reach 1 and 2, and therefore no current known significant specific water quality pressures which could be exacerbated by the drought permit. In Reach 5 one discharge was identified, Fairford STW. Under dry weather flow conditions and consented limits, Fairford STW increases River Coln BOD concentrations by approximately 0.39mg/l. WFD high status for BOD in the River Coln is 3mg/l. The Baunton drought permit is not anticipated to reduce river flow in Reach 5, therefore risk to water quality during implementation of the Baunton (1) drought permit is considered negligible.

4.5.4 Summary of Potential Changes to the Physical Environment from Implementation of the Drought Permit

The potential changes to the physical environment due to implementation of the drought permit are summarised in **Table 4.6** below.

[48] Thames Water Utilities Ltd (2013), Drought Plan: Environmental Assessment of the Latton Drought Permit. Final. Prepared by Cascade Consulting.

Table 4.6 Summary of Potential Changes to the Physical Environment of the Impacted Reaches from Implementation of the Drought Permit

River Reach (Impact)	**Reach 1** River Churn from North Cerney to Stratton	**Reach 2** River Churn from Stratton to Siddington	**Reach 3** River Churn from Siddington to confluence with River Thames	**Reach 4** Gumstool Brook from the Daglingworth Stream to the River Churn	**Reach 5** River Coln from Ablington to confluence with the River Thames
Hydrology	Moderate. The drought permit would lead to a reduction in flows that would manifest as a reduction in levels, velocities and wetted widths (the latter are not considered significant as the channel banks are steep and modified). This would be limited to the period of drought permit implementation. Dry period in the spring/summer following cessation of the permit not extended and no delay in recovery.	Moderate. The drought permit would lead to a reduction in flows that would manifest as a reduction in levels, velocities and wetted widths. In the spring/summer following cessation of the permit the reach will dry earlier by a more than a handful of days and flows will remain slightly lower until the following winter (once groundwater recovery commences).	Moderate. The drought permit would lead to a reduction in flows that would manifest as a reduction in levels, velocities and wetted widths. In the spring/summer following cessation of the permit the reach will dry earlier by a more than a handful of days, no delay in recovery.	Negligible. Limited connectivity with the River Churn expected under low flow conditions. No interaction with Inferior Oolite aquifer.	Negligible. No significant flow reduction associated with groundwater drawdown.
Geomorphology	Minor and temporary. The drought permit may result in a reduction in wetted width and depth than might otherwise be expected under the current hydrological regime. This may result in a potential minor reduction in bank and bed stability.	Minor and temporary. The drought permit may result in an extended drying of the wetted perimeter than might otherwise be expected under the current hydrological regime. This may increase the likelihood of bank erosion.	Minor and temporary. The drought permit may result in a reduction in wetted width and depth than might otherwise be expected under the current hydrological regime. This may result in a potential minor reduction in bank and bed stability.	No risk as artificial channel	Negligible.
Water Quality	No risk	No risk	Low risk (specifically with regard to dissolved oxygen saturation)	Negligible risk (assumed from Reach 2 assessment)	Negligible
Additional abstraction pressures - surface water	No risk	No risk	No risk	No risk	No risk
Additional abstraction pressures - groundwater	Low risk – due to one relatively small groundwater abstraction 1.3km west of Baunton	No risk	No risk	No risk	No risk
Specific water quality pressures	No risk	No risk	No risk	No risk	Negligible

4.6 Environmental features susceptibility and sensitivity

4.6.1 Introduction

Environmental sensitivity screening of the drought permit was considered as part of the screening and scoping report[49] and has subsequently been reviewed and refined further to discussions and consultation with the Environment Agency and Natural England. The approach is described in **the Methodology**. The outcome of this process is described in **Section 0** which shows that a number of features were identified as either: 1) low; 2) medium; 3) high; 4) not sensitive; or 5) uncertain sensitivity in a designated site.

Section 4.7.5 summarises the findings of the features assessment, informed by the assessments presented in **Section 4.5** (including hydrology, geomorphology and water quality), and identifies the significance of any potential impacts.

A summary of the findings of the environmental sensitivity screening process is provided in **Sections 4.6.2, 4.6.3 and 4.6.4**. Environmental assessment (see **Section 4.7**) is neither required nor included for features where screening has identified a minor (undesignated) or negligible impact.

4.6.2 Designated Sites, NERC Species and Other Sensitive Fauna and Flora

In accordance with the DPG, **Table 4.7** identifies designated biodiversity sites (LNR, NNR, SSSI, SAC, SPA, Ramsar and LWS), NERC species/habitats and other fauna and flora that could be affected by the drought permit. Susceptibility to the flow/level impacts resulting from the drought permit (see **Section 4.4**) is identified according to whether interest features of the site or the species are water dependent. Sensitivity is then determined according to professional judgment based on susceptibility and the level of hydrological impact at the location. For the full assessment methodology, see **the Methodology.**

LWS were considered during the screening exercise (see **Section 4.3.2**) and are included in the environmental sensitivity screening.

[49] Thames Water Utilities Ltd (2012), Drought Plan: SWOX Resource Zone Drought Permit Environmental Assessments Scoping Report. Draft Final. Prepared by Cascade Consulting, 7 March 2012.

Table 4.7 Designated Sites, NERC Species and Other Sensitive Fauna and Flora within the Zone of Influence of the Baunton (1) Drought Permit

Site/Feature and designation	Hydro-logical Impact at Location (Major, Moderate, Minor or Limited to Groundwater)	Susceptibility to flow and level impacts	Sensitivity (Low, Medium, High, Not Sensitive, Uncertain)	Further Consideration Required (Yes/No)
North Meadow and Clattinger Farm SAC, SSSI and NNR	Moderate (Reach 3)	The lowland hay meadow is susceptible to changes in subsurface wetness, with subsequent changes in the floral community present if conditions become wetter or dryer. However, the Baunton abstraction is hydrogeologically isolated from this SAC, as described by previous studies which identify no likely significant effects from drought permit abstractions at Baunton[50].	Uncertain	Yes
Cotswold Water Park SSSI	Moderate (Reach 3)	The Cotswold Water Park is an extensive system of over a hundred lakes formed by mineral extraction from the Upper Thames floodplain in south-east Gloucestershire and north-west Wiltshire. A series of lakes has been selected to cover the range of variation of the aquatic plant communities associated with these nationally scarce marl waters. The species of interest are all submerged. These lakes also contribute to the importance of the Cotswold Water Park for wintering and breeding birds.	Uncertain	Yes
Wildmoorway Meadows SSSI	Moderate (Reach 3)	The site consists of a number of old, unimproved meadows lying between the River Churn and the disused Severn and Thames Canal, to the east of Fairford. They overlie the alluvium and gravels of the Thames floodplain, with ridge and furrow visible over much of the site. Traditionally the meadows have been managed by grazing and cutting for hay, and together form the largest remaining example of unimproved neutral grassland in south-east Gloucestershire.	Uncertain	Yes
River Churn KWS (Reach 1)[51]	Moderate	The site is identified for its mammal interest, which is likely to be water vole and otter. However, the impact of the drought permit upon these species is not considered likely to be significant against a baseline of reduced flows characteristic of a drought.	Low	No
Perrott's Brook Marsh KWS (Reach 1)[52]	Moderate	The marsh, bog and swamp habitats are likely to have some level of hydrological connectivity to the aquifer underlying the	Uncertain	Yes

[50] Thames Water Utilities Limited (2013) Habitats Regulations Assessment of Thames Water Utilities Limited Final Statutory Drought Plan Screening Report. 21 March 2013. Prepared by Cascade Consulting.
[51] Key Wildlife Site, data not updated since 2006.
[52] Key Wildlife Site, data not updated since 2006.

Site/Feature and designation	**Hydro-logical Impact at Location** (Major, Moderate, Minor or Limited to Groundwater)	**Susceptibility to flow and level impacts**	**Sensitivity** (Low, Medium, High, Not Sensitive, Uncertain)	**Further Consideration Required** (Yes/No)
		Baunton abstraction; however, the influence of this is uncertain at this stage.		
Stratton Football pitch Dew Pond KWS (Reach 2)[53]	Moderate	Although the pond is likely to be primarily fed from surface water, with puddle clay typically used in their construction, there may be some connectivity to the water table which could be impacted upon by the increased abstraction. However, the moderate hydrological impact is unlikely to be significant.	Uncertain	Yes
Whelford Meadow SSSI	Moderate (Reach 3)	The site is a meadow habitat supporting several uncommon and two nationally rare plant species. Some species may be water-dependant, including meadowsweet (*Filipendula ulmaria*) and snake's head fritillary (*Fritillaria meleagris*). The impact of drought permit implementation is uncertain.	Uncertain	Yes
Winson Meadows SSSI	Moderate (Reach 3)	The water meadows are composed of neutral grassland with marshy areas and the site is located upstream of the impacted Reach 5. Although the site is connected to a different aquifer, there is some connectivity between the Inferior Oolite from which the drought permit abstracts and the Great Oolite aquifer on which the site lies. It is, therefore, possible that groundwater levels in the site could be impacted by the drought permit.	Uncertain	Yes
Siddington Canal KWS (Reach 3)[54]	Moderate	The site is identified for its mammal interest, which is likely to be water vole. However, the impact of the drought permit upon these species is not considered likely to be significant against a baseline of reduced flows characteristic of a drought.	Low	No
Acre Farm Meadow SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Alvescot Meadows SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is Cornbrash underlain by Forest Marble Mudstone. There is an unlikely pathway between the Cornbrash bedrock and Great/ Inferior Oolite however depending on geological faults that may act as a pathway, a drawdown of less than 0.05m may be experienced.	Not Sensitive	No

[53] Key Wildlife Site, data not updated since 2006.
[54] Key Wildlife Site, data not updated since 2006.

Site/Feature and designation	**Hydro-logical Impact at Location** (Major, Moderate, Minor or Limited to Groundwater)	**Susceptibility to flow and level impacts**	**Sensitivity** (Low, Medium, High, Not Sensitive, Uncertain)	**Further Consideration Required** (Yes/No)
Chimney Meadows SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Clattinger Farm SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is Cornbrash underlain by Forest Marble Mudstone. There is an unlikely hydrogeological pathway between the Cornbrash bedrock and Great/ Inferior Oolite aquifer.	Not Sensitive	No
Cloatley Manor Farm Meadows SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is Cornbrash underlain by Forest Marble. There is an unlikely pathway between the Cornbrash bedrock and Great/ Inferior Oolite however depending on geological faults that may act as a pathway, a drawdown of less than 0.1m may be experienced.	Not Sensitive	No
Distillery Meadows SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Ducklington Mead SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Elmlea Meadows SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Cotswold Water Park Pits 86, 97, 300, 301 & 303 LWS	Moderate	Waterbodies may be groundwater dependent. As the site is located on rocks with essentially no groundwater and on mudstone bedrock, no impacts from reductions in groundwater availability are anticipated. However, it is uncertain if the water park relies on water supply from the River Coln (particularly for waterbodies witin 100m).	Uncertain	Yes
River Thames or Isis LWS	Moderate	Hydrologically connected to multiple rivers that will potentially be affected by a number of drought options.	Uncertain	Yes
Cerney Wick Meadow LWS	Moderate	Within drawdown and connectivity with River Churn. Also marsh, bog and swamp habitats are classified as groundwater dependent. As the site is located on rock with essentially no groundwater and mudstone bedrock, no impacts on reduced groundwater availability is anticipated. However, as the LWS boundary includes	Uncertain	Yes

Site/Feature and designation	**Hydro-logical Impact at Location** (Major, Moderate, Minor or Limited to Groundwater)	**Susceptibility to flow and level impacts**	**Sensitivity** (Low, Medium, High, Not Sensitive, Uncertain)	**Further Consideration Required** (Yes/No)
		the River Churn (potentially impacted reaches) and it is uncertain if the marsh habitat relies on water supply from the river, impacts cannot be ruled out.		
Cotswold Water Park LWS (west)	Moderate	Waterbodies may be groundwater dependent. As the site is located on rocks with essentially no groundwater and on mudstone bedrock, no impacts from reductions in groundwater availability are anticipated. However, it is uncertain if the water park relies on water supply from the River Coln (particularly for waterbodies witin 100m).	Uncertain	Yes
Crane Farm LWS	Moderate	Within drawdown and reaches of the River Churn potentially affected by drought option. Wetland habitats are groundwater dependent. As the site is located on mudstone bedrock and partially on rocks with essentially no groundwater it is anticipated that the site is not reliant on groundwater supply. However, due to the proximity to the River Churn, the wetlands may be reliant on water supply from the river.	Uncertain	Yes
Lake 6 Gateway (Cotswold Water Park) LWS	Moderate	Waterbody could be groundwater dependent. As the site is located on rock with essentially no groundwater and mudstone bedrock, no impacts from reduced groundwater availability are anticipated. However, due to the proximity to the River Churn breeding birds maybe impacted if reliant on functionally linked habitat and the lake itself may rely on water supply from the river.	Uncertain	Yes
Perrott's Brook Marsh LWS	Moderate	Site within 100m of reaches of the River Churn potentially impacted by the drought option. Water dependent features also identified. As the site is located on mudstone bedrock (low permeability), it is not anticipated that the site is reliant on groundwater supply. However, the site might be reliant on water supply from the river.	Uncertain	Yes
River Churn LWS	Moderate	The site is identified for its mammal interest, which is likely to be water vole and otter. However, the impact of the drought permit upon these species is not considered likely to be significant against a baseline of reduced flows characteristic of a drought.	Uncertain	Yes

Site/Feature and designation	**Hydro-logical Impact at Location** (Major, Moderate, Minor or Limited to Groundwater)	**Susceptibility to flow and level impacts**	**Sensitivity** (Low, Medium, High, Not Sensitive, Uncertain)	**Further Consideration Required** (Yes/No)
Emmet Hill Meadows	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Grafton Lock Meadow	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Haydon Meadow	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Juniper Hill, Edgeworth	Groundwater Zone of Influence	The underlying geology of the SSSI is the Great Oolite. The SSSI is unlikely to be dependent on the Great Oolite aquifer in its interfluve location. Any potential drawdown would be less than 0.05m. No pathway between the Inferior Oolite and SSSI.	Not Sensitive	No
Langley's Lane Meadow	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
North Meadow, Crickdale	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Pike Corner	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay and Kellaways Clay. There is no hydrogeological pathway between the Oxford Clay and Kellaways Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Restrop Farm & Brockhurst Wood SSSI	Groundwater Zone of Influence	0.16 water logged Oxford clays The underlying geology of the SSSI is Corallian underlain by Oxford Clay. There is no hydrogeological pathway between the Corallian bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Stoke Common Meadows	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Upper Waterhey Meadow	Groundwater Zone of Influence	Alluvial soils, GW fed during wet season The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Wildmoorway Meadows SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is the Kellaways Clay underlain by Cornbrash then Forest Marble Mudstone. There is no	Not Sensitive	No

Site/Feature and designation	**Hydro-logical Impact at Location** (Major, Moderate, Minor or Limited to Groundwater)	**Susceptibility to flow and level impacts**	**Sensitivity** (Low, Medium, High, Not Sensitive, Uncertain)	**Further Consideration Required** (Yes/No)
		hydrogeological pathway between the Kellaways Clay bedrock and Great/ Inferior Oolite aquifers.		
Winson Meadows SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is the Great Ooilte aquifer. There is a hydrogeological pathway between the meadows and the Great Ooilte with a potential drawdown of 0.05m.	Not Sensitive	No
Cotswolds Water Park SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is Oxford Clay. There is no hydrogeological pathway between the Oxford Clay bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
Whelford Meadow SSSI	Groundwater Zone of Influence	The underlying geology of the SSSI is Kellaways Sand, underlain by Kellaways Clay. There is no hydrogeological pathway between the Kellaways Sand bedrock and Great/ Inferior Oolite aquifers.	Not Sensitive	No
NERC Species-Freshwater Macroinvertebrates	Moderate	Likely to be susceptible to flow and level impacts as inhabit specialised niche habitat which are likely to be altered as a result of the drought permit. These alterations could occur as a result through siltation or decline in dissolved oxygen, for example.	Medium	Yes
Fine-Lined pea mussel *Pisidium tenuilineatum*	Moderate		Medium	Yes
	Negligible		Not Sensitive	No
NERC Species-Fish	Moderate	Potentially susceptible as the duration of impact could incorporate all seasons, thus could impact upon spawning, migration, provision of cover etc.	Medium	Yes
Brown trout *Salmo trutta*				
European eel *Anguilla anguilla*	Moderate		Medium	Yes
Brook lamprey *Lampetra planeri*	Negligible		Not Sensitive	No
NERC Species-Mammals	Moderate	The species are not expected to be significantly impacted on by the drought permit against a baseline of reduced flows characteristic of a drought.	Low	No
Otter *Lutra lutra*	Moderate		Low	No
Water vole *Arvicola amphibious*	Negligible		Not Sensitive	No
NERC Species-Birds	Moderate	Although some NERC bird species are reliant on water dependent habitats, they are not expected to be significantly impacted on by the implementation of the drought permit against a baseline of reduced flows characteristic of a drought.	Low	No
	Moderate		Low	No
	Negligible		Not Sensitive	No
NERC Act Section 41 Priority Habitats-	Moderate	NERC priority habitats are of principal importance for the conservation of biodiversity in England. Fifty-six habitats	Uncertain	Yes

Site/Feature and designation	**Hydro-logical Impact at Location** (Major, Moderate, Minor or Limited to Groundwater)	**Susceptibility to flow and level impacts**	**Sensitivity** (Low, Medium, High, Not Sensitive, Uncertain)	**Further Consideration Required** (Yes/No)
Coastal and floodplain grazing marsh Lowland Meadows		are included on the S41 list. They include terrestrial habitats such as upland hay meadows to lowland mixed deciduous woodland, and freshwater and marine habitats such as ponds and subtidal sands and gravels. Reduction in flow and water level could therefore impact on macroinvertebrates, macrophytes and fish communities associated with these habitats.		
Macrophytes *Ranunculus sp.*	Moderate Moderate Negligible	*Ranunculus* sp. often develop within specific hydraulic and nutrient conditions and thus alteration as a result of a drought permit would impact on the species, although the level of impact beyond that of a natural drought is uncertain.	Uncertain	Yes
Freshwater Macroinvertebrate [55] Riffle beetle *Riolus subviolaceus* *R. cupreus* Caseless caddisfly *Rhyacophila fasciata*	Moderate Moderate Negligible	All of these species live in niche habitats and their susceptibility to impacts are likely to increase if water levels fall, although the level of impact of this beyond that of a natural drought is uncertain.	Medium Medium Not Sensitive	Yes Yes No
Fish Barbel *Barbus barbus*[56]	Moderate Moderate Negligible	Barbel are typically a fast-flowing water species that require clean uncompacted gravels for spawning.	Medium Medium Not Sensitive	Yes Yes No
Invasive species-Invertebrates Signal crayfish *Pacifastacus leniusculus* Zebra mussel*Dreissena polymorpha*	Moderate Moderate Negligible	The Environment Agency report that signal crayfish are found throughout this catchment therefore the implementation of the drought permit will not extend this further. Zebra mussel records exist for the Cotswold Water Park and the Lower Churn. Further spread of the population will not occur through implementation of the drought permit. Low flows in Reach 2 will possibly act as a barrier to upstream migration.	Low Low Not Sensitive	No No No
Invasive species-Invertebrates	Moderate	There is uncertainty surrounding the likely effect of flow and level impacts on invasive	Uncertain	Yes

[55] These species have restricted distribution at the national scale thus is notable, however not identified as a NERC species
[56] Barbel is listed in Annex V of the Habitats Directive as a species of Community Interest

Site/Feature and designation	**Hydro-logical Impact at Location** (Major, Moderate, Minor or Limited to Groundwater)	**Susceptibility to flow and level impacts**	**Sensitivity** (Low, Medium, High, Not Sensitive, Uncertain)	**Further Consideration Required** (Yes/No)
Crangonyx pseudogracilis, *Potamopyrgus antipodarum*	Moderate	species ability to distribute further within the watercourse.	Uncertain	Yes
Dugesia tigrina, Pacifastacus leniusculus Physella acuta	Negligible		Uncertain	No
Invasive Species - Flora	Moderate	These invasive plant species can use the flow of the watercourse for dispersal but are not reliant on it. Implementation of the drought permit will do nothing to increase this dispersal.	Uncertain	Yes
Japanese knotweed *Fallopia japonica*	Moderate		Uncertain	Yes
Giant hogweed *Heracleum mantegazzianum*				
Himalayan balsam *Impatiens glandulifera*	Negligible		Uncertain	Yes

4.6.3 RBMP2 Water body Status

Table 4.8 identifies the WFD status of the WFD water bodies which contain the impacted reaches. Water bodies classified as overall high/good status/potential, or high/good status for fish or macroinvertebrates, are assessed as more likely to be sensitive to flow impacts (if more than minor). **Table 4.8** summarises the risk to WFD status compliance and indicates where further assessment has been carried out as reported in **Section 4.7.4** below.

Table 4.9 identifies the WFD status of the WFD groundwater bodies which contain the impacted reaches. The aquifer from which the Baunton source abstracts forms part of Burford Jurassic WFD groundwater body (GB40601G600400). The current (2019 RBMP2) overall status of the Burford Jurassic WFD groundwater body is poor, based on good quantitative status and poor chemical status. South of the abstraction boreholes, the River Churn also interacts with the Kemble Forest Marble WFD groundwater body (GB40602G600500). The current (2019 RBMP2) overall status of the Kemble Forest Marble WFD groundwater body is good, the quantitative status is good and the chemical status good.

However, as stated in **the Methodology**, WFD groundwater body status is a relatively 'coarse' feature to use for screening with respect to groundwater impacts. WFD groundwater bodies can be significant in size and the assessment for groundwater status involves the use of long term average data sets for the groundwater body as a whole. Hence, WFD groundwater body status has been identified for context, however, no further assessment of any impacts on the status has been made.

The DPG2020 indicates that environmental assessments should include details of the likely impacts of your actions on the *quantitative* status of groundwater as identified in river basin management plans (RBMPs). The groundwater associated options included in Thames Water's DP2022 may impact on groundwater quantity/level but will not impact on groundwater quality. As such, ground water quality has been screened out for assessment.

Table 4.8 RBMP2 WFD Status

Reach	Waterbody ID & Name	HMWB	Status				Sensitivity (Low, Medium, High, Not Sensitive, Uncertain)	Further Consideration Required (Y/N)
			Overall	Fish	Macroinverts	Macrophytes and Phytobenthos		
Reach 1	GB106039029810 River Churn (source to Perrott's Brook)	Not a HMWB	Moderate (Good, 2027)	Moderate (Good, 2015)	High (Good, 2015)	Moderate (Good, 2027)	Medium	Yes
Reach 1, Reach 2 and Reach 3	GB106039029750 River Churn (Baunton to Cricklade)	Not a HMWB	Moderate (Good, 2027)	Good (Good, 2027)	High (Good, 2015)	Moderate (Good, 2027)	Medium/ High	Yes
Reach 5	GB106039029991 Coln (Source to Coln Rogers)	Not a HMWB	Moderate (Good, 2027)	Good (Good, 2015)	High (Good, 2015)	Moderate (Good, 2015)	Minor	Yes

Table 4.9 WFD Groundwater Classifications based on RBMP2

Water body ID & Name	NGR	Status					
		Surface Area (km^2)	Overall Water Body Classification	Quantitative Dependent Surface Water Body Status	Quantitative GWDTEs test	Quantitative Saline Intrusion	Quantitative Water Balance
GB40601G600400 Burford Jurassic	SP0024216848	900.62	Poor (2019)	Good (2019)	Good (2019)	Good (2019)	Good (2019)
GB40602G600500 Kemble Forest Marble	SP4320811982	206.73	Poor (2019)	Good (2019)	Good (2019)	Good (2019)	Good (2019)

4.6.4 Landscape, Navigation, Recreation, Heritage and Industry

Table 4.10 identifies wider features taken into account in determining the potential impacts of drought permit implementation.

Table 4.10 Landscape, Navigation, Recreation and Heritage Features

Site/Feature	Hydrological Impact at Location (Major, Moderate, Minor, Negligible)	Susceptibility to flow and level impacts	Sensitivity (Low, Medium, High, Not Sensitive, Uncertain)	Further Consideration Required (Y/N)
Cotswolds AONB (*All reaches*)	Moderate	The AONB comprises certain water dependent habitats which depending on their location will have been taken into account through consideration of designated sites and NERC species.	n/a	n/a
Scrubditch Dike - Scheduled Ancient Monument (*Reach 1*)	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Perrott's Brook Dike – Scheduled Ancient Monument (*Reach 1*)	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Corinium Roman Town – Scheduled Ancient Monument *(Reach 2)*	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Tar Barrows – Scheduled Ancient Monument *(Reach 2)*	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Churchyard Cross – Scheduled Monument *(Reach 2)*	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
St John's Hospital chantry – Scheduled Monument *(Reach 2)*	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Tithe barn – Scheduled Monument (*Reach 2*)	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Potential impact on unknown water-dependent assets	Moderate	Unlikely to be impacted considering the annual fluctuations in groundwater levels.	Not Sensitive	No
Monarch's Way – National Trail	Moderate	The River Churn forms part of the landscape	Not Sensitive	No

Site/Feature	Hydrological Impact at Location (Major, Moderate, Minor, Negligible)	Susceptibility to flow and level impacts	Sensitivity (Low, Medium, High, Not Sensitive, Uncertain)	Further Consideration Required (Y/N)
		setting of the Monarch's Way National Trail. Hydrological impacts are not expected to impact the amenity value of the area for walkers.		
South Cerney Castle – Scheduled Monument *(Reach 3)*	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Cricklade town banks – Scheduled Monument *(Reach 3)*	Moderate	Site covers the Thames not the churn and therefore unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Area of Saxon 'burh' within the town walls – Scheduled Monument *(Reach 3)*	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Settlement W of Latton – Scheduled Monument *(Reach 3)*	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Settlement SE of Latton – Scheduled Monument *(Reach 3)*	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Upper Thames Clay Vales – National Character Area Level Landscape Feature *(Reach 3)*	Moderate	Unlikely to be impacted over the duration of the drought permit implementation.	Not Sensitive	No
Navigation	Moderate	The impact of the drought permit is unlikely to be significant against a baseline of drought conditions.	Not Sensitive	No
Angling	Moderate	Flows during a drought will be low such that further reduction in flows would not be likely to further reduce the angling quality of the reach.	Not Sensitive	No

4.7 Environmental Features Assessment

Desk-based assessments have been completed for each of the sensitive receptors, where applicable, in order to determine the magnitude of impact in the relevant river reaches for the Albury drought permit. All impacts are considered to be negative/adverse unless otherwise stated in the feature assessment. The approach is described in **the Methodology**. Environmental assessment is neither required nor included for features where screening has identified a minor (undesignated) or negligible impact. Only those features identified for further consideration in **Section 4.7** have been further assessed in this section. Points of interest referred to throughout the text in **Section 4.7** are indicated in **Figure 4.24**; direct reference to **Figure 4.24** is included where appropriate.

The assessment of impacts on environmental features should be considered in the context of the watercourse under baseline conditions, which are conditions under natural drought.

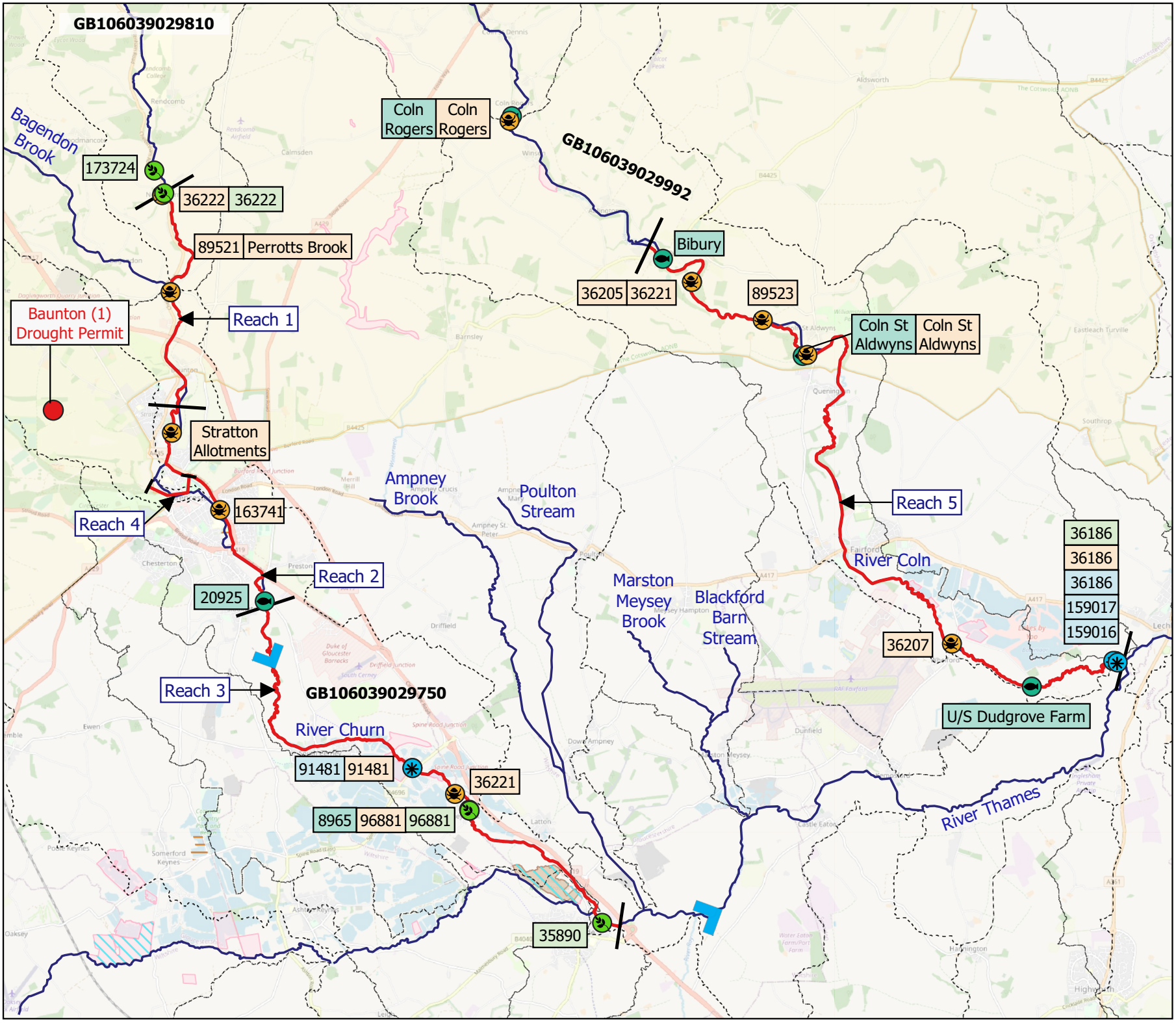
The potential hydrological impact of the Baunton (1) drought permit on Reach 1 is considered to be **negligible** during the dry period in the spring following drought permit cessation. However, modelling indicates a reduction of up to 2.4 Ml/d during the drought permit implementation period (November to May), which would be a reduction in annual Q95 and annual Q50 of 35% and 6% respectively. Therefore, the potential hydrological impact of the Baunton (1) drought permit is considered to be **moderate** during drought permit implementation.. For Reach 2, the potential hydrological impact of the Baunton (1) drought permit is considered to be **moderate** during the dry period in the spring following drought permit cessation. However, modelling indicates a reduction of up to 2.7 Ml/d during the drought permit implementation period (November to May), which would be a reduction in annual Q95 and annual Q50 of 41% and 6% respectively. Therefore, the potential hydrological impact of the Baunton (1) drought permit is considered to be **moderate** during drought permit implementation. For Reach 3, the potential hydrological impact of the Baunton (1) drought permit is considered to be **moderate** during the dry period in the spring following drought permit cessation. Modelling indicates a reduction of up to 3.0 Ml/d during the drought permit implementation period (November to May), which would be a reduction in annual Q95 and annual Q50 of 79% and 5% respectively. Therefore, the potential hydrological impact of the Baunton (1) drought permit is considered to be **moderate** during drought permit implementation.

The hydrological impact in Reach 4 is considered to be **negligible** with flows not expected to be impacted by the groundwater recovery associated with the Baunton (1) abstraction. This is due to the closure of the Cirencester sluices during low flow conditions, and absent channel connectivity with the underlying Inferior Oolite.

During drought permit implementation a reduction in summer Q99 and Q95 and annual Q95 and Q50 of 1% could be experienced in Reach 5, which corresponds to a **negligible** hydrological impact.

The impact of the drought permit is not anticipated to extend beyond Siddington, however, prolonged drying of the channel in Reaches 1 and 2 may reduce flow contribution downstream of Siddington. Consequently, on a precautionary basis, there may be a minor hydrological impact from Siddington to the River Thames (Reach 3) due to reduced flow contributions.

The hydrological effect of the drought permit is to delay the recovery of groundwater levels and hence river flow recovery in all the impacted reaches from November to May. This is within the within the hydrological winter period (October to March inclusive). Therefore, the assessment has considered the potential for impacts in the period from November to May on environmental features.



Legend

- Drought Permit
- River Reach
- Reach Divides
- Flow Direction
- Fish Site
- Diatom Site
- Macroinvertebrate Site
- Macrophyte Site
- WFD Waterbody Catchment

Designated Sites

- Special Areas of Conservation
- Local Nature Reserves
- National Nature Reserves
- Sites of Special Scientific Interest
- Areas of Outstanding Natural Beauty

Project title:
Thames Water Drought Plan Environmental Assessment

Figure title:
Baunton (1) Drought Permit: Ecology Monitoring

4.7.1 Designated Sites

The impact assessment for the site is identified following guidance provided by the Chartered Institute of Ecology and Environmental Management (CIEEM), providing a significance of impact which takes into consideration the magnitude of impact alongside the value of the feature (for the full assessment methodology, see **the Methodology**).

North Meadow and Clattinger Farm SAC (SSSI and NNR)

Baseline

North Meadow and Clattinger Farm SAC is located within reach three, close to the River Churn confluence with the River Thames (see **Figure 4.24**). The North Meadow and Clattinger Farm SAC site represents an exceptional survival of the traditional pattern of management for hay meadows with unique vegetation communities. Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*) are an Annex I habitat. The site also contains a very high proportion of snake's head fritillary (*Fritillaria meleagris*) (greater than 90% of the surviving UK population), a nationally rare species highly characteristic of unimproved damp lowland meadows.

Assessment

The hydro-ecology of North Meadow and Clattinger Farm SAC and the impact of licensed abstractions were the subject of detailed study as part of Stage 3 Review of Consents. The study considered the impact of abstractions on flows in the River Thames and River Churn and used an existing model to predict the likely changes in vegetation composition given a range of stream flows. The conclusion was that the cumulative effect of all the abstractions licensed by the Environment Agency on North Meadow and Clattinger Farm SAC were insignificant, as the site is isolated from the influence of aquifer water levels by clays. Therefore, while the Review of Consents assessed the existing abstraction licence at Baunton (rather than the Baunton drought permit), the hydrogeological situation remains the same: the Baunton abstraction is hydrologically isolated from the SAC site. The magnitude and significance of impact is therefore considered to be **negligible**.

Table 4.11 Summary of Impacts on North Meadow and Clattinger Farm SAC

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Within the geographical extent of groundwater impacts				
North Meadow and Clattinger Farm SAC	The Baunton abstraction is hydrologically isolated the SAC site and therefore no impacts are identified.	International	Negligible	**Negligible**

Cotswold Water Park SSSI

Baseline

The Cotswolds Water Park SSSI is located within Reach 3 and is formed of over a hundred lakes within the Upper Thames floodplain in south-east Gloucestershire and north-west Wiltshire. There are two predominant types of lakes, one type which is rich in stoneworts, a group of large freshwater algae, and the second type which is associated with more nutrient-rich water. This second type is richer in species and is typified by Canadian waterweed (*Elodea Canadensis*) and common duckweed (*Lemna minor*).

An outstanding feature is the presence of eight species of pondweed (*Potamogeton spp*.). These include shining pondweed (*Potamogeton lucens*), a species of clear, marl waters, and the nationally scarce, hairlike pondweed (*Potamogeton trichoides*). At least four species of stonewort, some of which are characteristic of marl lakes, also occur. These are indicators of high water quality and include the nationally scarce, bearded stonewort (*Chara aspera var aspera*). The lakes support a variety of common marginal species. One of the lake types is typically dominated by bulrush (*Typha latifolia*), and the other by soft rush (*Juncus effuses*). Other widespread species which form quite extensive stands in the

context of the Cotswold Water Park include reed canary-grass (*Phalaris arundinacea*), common reed (*Phragmites australis*) and common club-rush (*Scirpus lacustris*). Areas of mixed, marginal vegetation, with water-plantain (*Alisma plantago-aquatica*), common spike-rush (*Eleocharis palustris*), water mint (Mentha aquatic), and brookweed (*Samolus valerandi*), also occur.

Assessment

Lakes in the Cotswold Water Park SSSI are hydrologically connected to the River Churn through superficial river terrace deposits. It is noted that at low flow periods the River Churn can lose some flow to the adjacent pits, confirming that they are in connectivity. The drought permit would lead to a reduction in flows that would manifest as a reduction in levels, velocities and wetted widths within the River Churn. Uncertainty remains regarding impacts to the site. Conversations with both the Environment Agency and Natural England were undertaken on the 27th September 2022 regarding the monitoring procedure for the Cotswold Water Park SSSI. It was agreed that given the scale of the designated site it would not be feasible to undertake walkovers during the on-set, during drought or post drought implementation periods. In addition, it would be difficult to ascertain impacts as a result of the drought permit during a period of environmental drought. It was agreed that given river condition walkovers will be undertaken along the River Churn (impacts of which are the main driver to the Cotswold Water Park SSSI) then this would be sufficient and feasible to undertake and would provide information of the impacts of the drought permit.

Table 4.12 Summary of Impacts on Cotswold Water Park SSSI

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 3				
Cotswold Water Park SSSI	Cotswold Water Park lakes are in hydrological connectivity to the River Churn through superficial river terrace deposits. Connectivity is water level dependent and although the River Churn can lose flow to the pits during low flows	National	Minor (Hydrological)	**Uncertain**

Wildmoorway Meadows SSSI

Baseline

This site is located between the River Churn and the disused Severn and Thames Canal to the east of Fairford.

The rich grassland is characterised by crested dog's-tail (*Cynosurus cristatus*) and common knapweed (*Centaurea nigra*). More than twenty species of grass and sedge are present including abundant quaking-grass (*Briza media*), and sweet vernal-grass (*Anthoxanthum odoratum*). Many herbs typical of old meadows occur, including cowslip (*Primula veris*), betony (*Stachys officinalis*), pepper saxifrage (*Silaum silaus*), ox-eye daisy (*Leucanthemum vulgare*) and green-winged orchid (*Orchis morio*). Locally, in wetter areas, meadowsweet (Filipendula ulmaria), reed canary-grass (*Phalaris arundinacea*) and ragged-robin (*Lychnis floscuculi*) are frequent together with southern marsh-orchid (*Dactylorhiza praetermissa*). Scattered scrub has developed in part of the site and several old trees of the native form of black poplar (*Populus nigra var. betulifolia*), occur in the hedgerows. An assessment was undertaken of the one habitat unit present at the site (last assessed in 2011) which concluded that the whole site was of favourable condition. Overgrazing of the habitat have been attributed as a reason for averse conditions at the site.

Assessment

The Wildmoorway Meadows SSSI (**Table 4.13**) are unimproved species-rich neutral grassland which are underlain by alluvium and gravels of the Thames floodplain, with ridge and furrow visible over much of the site. Species associated with damp conditions are likely to depend on overland surface flow, which remain in the furrows, but not water levels from the River Churn. The magnitude and significance of impact is therefore, considered to be **negligible**.

Table 4.13 Summary of Impacts on Wildmoorway Meadows SSSI

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 3				
Wildmoorway Meadows SSSI	Ecological features of the site are not considered to be dependent on water levels from the River Churn.	National	Negligible	**Negligible**

North Meadow, Cricklade SSSI

Baseline

North Meadow SSSI forms part of the North Meadow and Clattinger Farm SAC and is therefore also designated for its lowland meadow habitat. Over 250 species of higher plant occur on the meadow, including abundant grasses such as red fescue, perennial rye-grass, meadow foxtail, crested dog's tail and yellow oat-grass. meadow brome, meadow barley, adder's tongue, common meadowrue and ragged robin are also present, alongside herbs such as pepper saxifrage, yellow rattle, great burnet, and black knapweed.

This SSSI contains a large population of snake's head fritillary, with approximately 500,000 plants flowering each year. It is estimated that this SSSI supports around 80% of the British population of wild fritillary plants.

In addition to the lowland meadow habitat (designated as SAC), the SSSI is also designated for its several ditches that border the meadow, adding to the biological diversity of the site. Plants found in these marginal watercourses include slender tufted-sedge (*Carex acuta*), marsh arrowgrass (*Triglochin palustris*) and great water-dock (*Rumex hydrolapathum*). The common frog also breeds in these areas. Old channels crossing the meadow hold tubular water-dropwort (*Oenanthe fistulosa*) (a NERC Act Section 41 species), marsh marigold (*Caltha palustris*), marsh foxtail (*Alopecurus geniculatus*), early marsh-orchid (*Dactylorhiza incarnate*) and brown sedge (*Carex disticha*).

Typical meadow butterflies such as meadow brown (*Maniola jurtina*), common blue (*Polyommatus Icarus*) and small heath (*Coenonympha pamphilus*) are common, whilst the more local marsh fritillary (*Eurodryas aurinia*) has been recorded. Bordering hedges support populations of gatekeeper (*Pyronia tithonus*), ringlet (*Aphantopus hyperantus*) and speckled wood (*Pararge aegeria*). Altogether 14 species of dragonfly have been recently recorded, mainly at the meadow edge, although several such as brown hawker (*Aeshna grandis*), black-tailer skimmer (*Orthetrum cancellatum*) and the ruddy darter (*Sympetrum sanguineum*) also feed over the meadow. An assessment was undertaken of the one habitat unit present at the site (last assessed in 2010) which concluded that the whole site was of favourable condition.

Assessment

No impacts are anticipated on the lowland meadow habitat, including the population of snakehead fritillary, see North Meadow and Clattinger Farm SAC assessment above. There appears to be some connectivity between the diches that are associated with the SSSI and the River Churn, hence potential impacts on this habitat have been assessed in more detail (**Table 4.14**).

Uncertainty surrounds the water level management practice at the site. Most aquatic plants highlighted as SSSI features are marginal and can withstand some degree of desiccation/periodic low water levels. There is, therefore, only a risk of an effect in case of a prolonged drought that could result in little to no water remaining in the ditches for a longer period of time. The aquatic macrophyte species highlighted are indicative of good water quality and suggest that the ditches are fed by wet flushes and/or surface water runoff but not groundwater or river water exclusively. It is also noted that most species are highly sensitive to increases in nutrient levels.

However, the impacts will overlap with the beginning of the aquatic macrophyte growing phase (April to May) with moderate hydrological impact anticipated. As it is likely that the site is fed by wet flushes and/ or surface water runoff and relatively small period of impact during the growing season, the magnitude and significance of impact is considered to be low magnitude and reversible. Therefore of **minor** significance (uncertain).

The magnitude and significance of impact is therefore considered to be a precautionary low magnitude and reversible, therefore of **minor** significance (uncertain).

Table 4.14 Summary of Impacts on North Meadow, Cricklade SSSI

Feature	Impact	Ecological Value of Feature	Impact Magnitude	**Significance of Impact**
Reach				
North Meadow, Cricklade SSSI	Two offtakes from the River Churn appear to provide most of the flow through the central ditch system supporting a macrophyte community, but uncertainty surrounds the water level management practice at the site.	National	Low (uncertain)	Minor (uncertain)

Winson Meadows SSSI

Baseline

Winson Meadows SSSI is a water meadow composed of neutral grassland and marshy areas. Marshy grassland occurs in two main areas, with vegetation dominated by jointed rush (*Juncus articulates)*, and meadowsweet (*Filipendula ulmaria)*. Yellow flag (*Iris pseudacorus)*, ragged robin (*Lychnis flos-cuculi)*, marsh marigold (*Caltha palustris*) and southern marsh orchid (*Orchis praetermissa*) are also present. An assessment was undertaken of the one habitat unit present at the site (last assessed in 2016) which concluded that the whole site was of unfavourable- declining condition. It was concluded that the site still receives cattle grazing, but despite this appropriate management the site had not shown any signs of recovery.

Assessment

The site is upstream of the hydrologically impacted reach of the River Coln and therefore, will not be impacted by changes to flows and levels in this reach. The site lies on the Great Oolite aquifer, while the drought permit abstraction is from the Inferior Oolite aquifer. It has been identified that there is some connectivity between the two aquifers through fissures and therefore, it is possible that groundwater levels in the site could be affected by the drought permit. Because the majority of the water levels are dependent on the Great Oolite aquifer which is not affected by the drought permit, any hydrological impact is considered to be of low or negligible magnitude, no significant impacts on the designated features of the site are anticipated (see **Table 4.15**).

Table 4.15 Impacts on Winson Meadows SSSI

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Upstream of Reach 5				
Winson Meadows SSSI	Habitat degradation as a result of reductions in groundwater levels	National	Negligible	**Negligible**

Whelford Meadows SSSI

Baseline

Whelford Meadows SSSI is a meadow habitat overlying gravels that contains several uncommon species, including several that may be water dependent such as meadowsweet, snakeshead fritillary (*Fritillaria meleagris*) and a variety of sedges *Carex spp*. The site also contains good undisturbed habitat

for breeding warblers and other passerines. An assessment was undertaken of the one habitat unit present at the site (last assessed in 2015) which concluded that the whole site was of unfavourable- no change condition. Inappropriate cutting/mowing of the habitat have been attributed for this adverse condition.

Assessment

This site is located adjacent to the Reach 5 and there is uncertainty regarding the influence of the River Coln on the habitat and species assemblage of the Whelford Meadow SSSI. As it is does contain a number of water-dependent species, it is possible that the Whelford Meadow SSSI may be periodically inundated and therefore any drop in flow in the River Coln associated with the implementation of the drought permit may have an impact on the designated site. However, the hydrological assessment has concluded negligible impacts to the watercourse and therefore, the impact on the Whelford Meadows SSSI is likely to be low, short-term and reversible and is considered to be **negligible** (see **Table 4.16**).

Table 4.16 Impacts on Whelford Meadows SSSI

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 5 - River Coln				
Whelford Meadows SSSI	Habitat degradation as a result of reductions in groundwater levels	National	Low	**Negligible**

Perrott's Brook Marsh & Copse LWS

Baseline

Due to the lack of information available for this non-statutory designated site, an assessment of aerial photography was undertaken, which identified the site supports a number of waterbodies immediately surrounded by woodland, with arable fields beyond. The site is likely to be hydrologically linked with local groundwater and surface water being a mixture of riparian and wetted habitats adjacent to the River Churn.

Assessment

No data is available for Perrott's Brook Marsh and Copse LWS. It is important to consider potential impacts in light of baseline conditions in which the movement of water from the aquifer to surface water bodies can stop in dry summers, as evident from the hydrograph data at Perrott's Brook (**Section 4.4.2.2**). Although there is uncertainty regarding the connectivity of the water dependent features of this site to either surface water or groundwater, the designated site is likely to be resilient to some degree to the impacts of desiccation as a result of reduced surface water and groundwater levels. Consequently, the impact magnitude is not considered to be greater than medium, which equates to a **minor** significance of impact on this site of local value (**Table 4.17**).

Table 4.17 Summary of Impacts on Perrott's Brook Marsh & Copse LWS

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 – River Churn				
Perrott's Brook Marsh and Copse LWS	Reduction in abundance or distribution of species supported by the designated site or deterioration in habitat quality, causing a decline in ecological status at the site.	Local	Medium	**Minor**

Stratton Football Pitch Dew Pond KWS

Baseline

Due to the lack of information available about this non-statutory designated site, an assessment of aerial photography was undertaken which identified that the site is surrounded by improved grassland with arable fields beyond. The site is not likely to be hydrologically linked with local groundwater (dew ponds have an impermeable base to hold water) although it may be linked to surface water flow (e.g. for replenishment) as the dew pond is located on the flood plain adjacent to the River Churn.

Assessment

The hydrological impact associated with the Baunton drought permit has been identified as a delay of up to one month for groundwater input to the River Churn to recover to levels typical (i.e. long term average) after a hydrological winter.

The impact on the Stratton Football Pitch Dew Pond needs to be considered in light of the baseline conditions, in which possible replenishment of the Dew Pond from surface water runoff is inconsistent, therefore, the likelihood the dew pond dries up intermittently is high. Although there is uncertainty regarding the connectivity of the water dependent features of this site to either surface water or groundwater, the designated site is likely to be resilient to some degree to the impacts of desiccation as a result of reduced surface water or groundwater input. Consequently, the impact magnitude is considered to be low, which equates to a **negligible** significance of impact on this site of local value (**Table 4.18**). Consequently, mitigation and monitoring of the site is not required.

Table 4.18 Summary of Impacts on Stratton Football Pitch Dew Pond KWS

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 2 – River Churn				
Stratton Football Pitch Dew Pond KWS	Dewponds are structures designed to capture and contain rainfall and surface runoff. Therefore, connectivity with the groundwater is unlikely although surface water runoff may be reduced with the dew pond located on a flood plain.	Local	Low	**Negligible**

River Thames or Isis LWS

Baseline

Due to the lack of information that has been available for this non-statutory designated site, an assessment of aerial photography was undertaken within the impacted reaches. Reach 3 is a tributary of the River Thames or Isis LWS which flows from WFD waterbodies Key (Source to Thames to Thames (Churn to Coln). Although the LWS will not be directly impacted by the impacts of the drought permit, the water course will receive reductions in flow from Reach 3 which may impact the LWS.

Assessment

Throughout its length, the River Thames lies on clay and is not in direct connectivity with the Great Oolite aquifer. Reach 3 is a tributary of the River Thames or Isis LWS, the water course will receive reductions in flow from Reach 3 as a result of the drought permit which may impact the LWS. The drought permit would lead to a reduction in winter flows that would manifest as a reduction in levels, velocities and wetted widths.

Flow in the River Ray (Ray at Eaton flow gauge) was examined and it was determined that flow in this river is normally at least 40 Ml/d at all times. This is because Swindon STW discharges an average (between February 2005 and December 2015) of 45.6 Ml/d into the River Ray upstream of its confluence with the River Thames. The River Ray enters the River Thames approximately 1.2 km downstream from the confluence with Ampney Brook. During dry periods, this would be the predominant flow in the downstream river and the river characteristics will reflect this level of relatively constant flow.

Thus, any of the upstream impacts of the drought permit on the River Thames are considered to be negated downstream of the confluence with the River Ray. In addition, the size of the River Thames or Isis LWS will dilute impacts Reach 3 given the number of tributaries across the length of the watercourse. The magnitude and significance of impact is therefore considered to be **minor** (see **Table 4.19**).

Table 4.19 Impacts on River Thames or Isis LWS

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 3				
River Thames or Isis LWS	The LWS is in direct connectivity to the impacted Reach 3, however as a result of the Swindon STW discharges During dry periods, this would be the predominant flow in the downstream river and the river characteristics will reflect this level of relatively constant flow. Thus, any of the upstream impacts of the drought permit on the River Thames are considered to be negated downstream of the confluence with the River Ray.	Local	Low	**Minor**

Cerney Wick Meadow LWS

Baseline

This LWS is located adjacent to River Churn and an unnamed watercourse which is a tributary of the River Churn. The section of the River Churn is an impacted reach of Baunton 1 drought option. The site consists of neutral grassland with marsh, bog, swamp and tall herb fen habitats. These habitats are water dependent. The site is located on rock with essentially no groundwater and mudstone bedrock.

Assessment

The Cerney Wick LWS is located on superficial alluvium, sands & gravels overlying Oxford clay, as a result, no impacts on reduced groundwater availability is anticipated. However, as the site boundary includes the River Churn (Impacted Reach 3) it is uncertain if the marsh habitat relies on water supply from the river. The drought permit would lead to a reduction in winter flows that would manifest as a reduction in levels, velocities and wetted widths. This may impact the periodic inundation of the marsh, bog, swamp and tall herb fen habitats dependent on their position within the site. As such information is not available, impacts cannot be ruled out. The magnitude and significance of impact is therefore, considered to be **minor** significance of impact on this site of local value (see **Table 4.20**).

Table 4.20 Summary of Impacts on Cerney Wick LWS

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 3 – River Churn				
Cerney Wick Meadows	The LWS is on the boundary of the impacted Reach 3; as limited data is available for the site, the marsh, bog, swamp and tall herb fen habitats may be as a result of the drought permit's effect on winter flows that would manifest as a reduction in levels, velocities and wetted widths.	Local	Low	**Minor**

Cotswold Water Park LWS (west)

Baseline

A multipart site consisting of new, developing and well-established gravel pits and lakes, situated in the upper Thames Valley, south of Somerford Keynes and South Cerney. The lake complex continues over

the border into Wiltshire and is adjacent to the River Churn. There are several areas of the LWS which are partially within the 100m buffer of the impacted reaches of River Churn. The LWS has bird and invertebrate interest. There is limited information on the species and habitats associated with the LWS, however, being lakes and gravel pits, these are likely to be water dependent.

Assessment

Several areas of the Cotswold Water Park LWS is within close proximity to the impacted Reach 3 of the Baunton (1) drought option. The drought permit would lead to a reduction in flows that would manifest as a reduction in levels, velocities and wetted widths within the River Churn. Uncertainty remains regarding impacts to the site. Conversations with both the Environment Agency and Natural England were undertaken on the 27th September 2022 regarding the monitoring procedure for the Cotswold Water Park SSSI (for which the Cotswold Water Park LWS is located within). It was agreed that given the scale of the designated site it would not be feasible to undertake walkovers during the on-set, during drought or post drought implementation periods. In addition, it would be difficult to ascertain impacts as a result of the drought permit during a period of environmental drought. It was agreed that given river condition walkovers will be undertaken along the River Churn (impacts of which are the main driver to the Cotswold Water Park SSSI and LWS) then this would be sufficient and feasible to undertake and would provide information of the impacts of the drought permit.

Table 4.21 Summary of Impacts on Cotswold Water Park LWS

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 3 – River Churn				
Cotswold Water Park LWS	Cotswold Water Park lakes are in hydrological connectivity to the River Churn through superficial river terrace deposits. Connectivity is water level dependent and although the River Churn can lose flow to the pits during low flows.	National	Minor	**Uncertain**

Lake 6 Gateway (Cotswold Water Park) LWS

Baseline

A multipart site consisting of new, developing and well-established gravel pits and lakes, situated in the upper Thames Valley, south of Somerford Keynes and South Cerney. The lake complex continues over the border into Wiltshire and is adjacent to the River Churn. There are several areas of the LWS which are partially within the 100m buffer of the impacted reaches of River Churn. The LWS has bird and invertebrate interest. There is limited information on the species and habitats associated with the LWS, however, being lakes and gravel pits, these are likely to be water dependent.

Assessment

Lakes in the Lake 6 Gateway (Cotswold Water Park) LWS are hydrologically connected to the River Churn through superficial river terrace deposits. It is noted that at low flow periods the River Churn can lose some flow to the adjacent pits, confirming that they are in connectivity. The drought permit would lead to a reduction in flows that would manifest as a reduction in levels, velocities and wetted widths within the River Churn. Uncertainty remains regarding impacts to the site. Conversations with both the Environment Agency and Natural England were undertaken on the 27th September 2022 regarding the monitoring procedure for the Cotswold Water Park SSSI (for which the Lake 6 Gateway LWS is located within). It was agreed that given the scale of the designated site it would not be feasible to undertake walkovers during the on-set, during drought or post drought implementation periods. In addition, it would be difficult to ascertain impacts as a result of the drought permit during a period of environmental drought. It was agreed that given river condition walkovers will be undertaken along the River Churn (impacts of which are the main driver to the Cotswold Water Park SSSI and the Lake 6 Gateway LWS) then this would be sufficient and feasible to undertake and would provide information of the impacts of the drought permit.

Table 4.22 Summary of Impacts on Lake 6 Gateway (Cotswold Water Park) LWS

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 3 – River Churn				
Cotswold Water Park LWS	Cotswold Water Park lakes are in hydrological connectivity to the River Churn through superficial river terrace deposits. Connectivity is water level dependent and although the River Churn can lose flow to the pits during low flows	National	Minor	**Uncertain**

Crane Farm LWS

Baseline

Crane Farm LWS is a mosaic of wetland vegetation and is of botanical interest. Habitats within the LWS are therefore, water dependent. The northern half of the LWS (furthest away from the River Churn) is located on a highly productive aquifer and the southern half is located on rocks with essentially no groundwater. The majority of the bedrock is mudstone with a small area limestone.

Assessment

Crane Farm LWS is located on Superficial alluvium, sands & gravels overlying Kellaways Clay. The connectivity between the LWS and the River Churn (Impacted Reach 3) is uncertain if the wetland habitat relies on water supply from the river or groundwater influences. The drought permit would lead to a reduction in winter flows that would manifest as a reduction in levels, velocities and wetted widths. As such information is not available, impacts cannot be ruled out. The magnitude and significance of impact is therefore considered to be **minor** significance of impact on this site of local value (see **Table 4.23**).

Table 4.23 Summary of Impacts on Cerney Wick LWS

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 3 – River Churn				
Crane Farm LWS	The LWS is on the boundary of the impacted Reach 3; as limited data is available for the site, the wetland habitats may be impacted as a result of the drought permit's effect on winter flows that would manifest as a reduction in levels, velocities and wetted widths.	Local	Low	**Minor**

River Churn LWS

Baseline

This is a section of the River Churn from north of Baunton to South Cerney (approximately 12 km length). The majority of the LWS is within the 100m buffer of impacted reaches of the River Churn. The LWS is also within the groundwater drawdown zone of Meysey Hampton and Baunton 2 drought options.

The LWS has riparian vegetation and qualifies as a LWS due to mammal interest (although no specific species is mentioned, it is assumed this is either water vole or otter). Therefore, habitats and species within the LWS are water dependent.

The northern two thirds of the LWS are located on a highly productive aquifer, whilst the southern third is located on rocks with essentially no groundwater. There is a mixture of mudstone and limestone bedrock.

Assessment

Impacts within the River Churn are discussed in detail within **Section 4.5.2**. The drought permit would lead to a reduction in autumn and winter flows that would manifest as a reduction in levels, velocities and wetted widths. This would be limited to the period of drought permit implementation. Features assessments for species within the River Churn are discussed below in **Section 4.7.2 to 4.7.4.** As a result the impacts associated with the implementation of the drought option to the features assessed below the significance of impact to the River Churn LWS concluded as **Moderate**.

Table 4.24 Summary of Impacts on River Churn LWS

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1, 2 and 3 – River Churn				
River Churn LWS	The drought permit would lead to a reduction in autumn and winter flows that would manifest as a reduction in levels, velocities and wetted widths which will impact several key and notable species which are discussed below.	Local	Medium	**Moderate**

Coastal and floodplain grazing marsh

Baseline

Floodplain grazing marsh is defined as periodically inundated pasture, or meadow with ditches which maintain the water levels, containing standing brackish or fresh water. As these habitats are periodically inundated, they are sensitive to drought and flood events. Coastal and floodplain grazing marsh is not a specific habitat but a landscape type which supports a variety of habitats. The ditches within these habitats are usually rich in plants and invertebrates. Sites may contain seasonal water-filled hollows and permanent ponds with emergent swamp communities, but not extensive areas of tall fen species like reeds. The principal environmental variables influencing vegetation include: salinity, water depth, substrate and successional stage.

Floodplain grazing marsh habitats is associated with Reach 1 and 2 of this drought permit.

Assessment

Low flows and water levels could therefore reduce aquatic habitat availability. This could impact on the fauna and flora assemblages associated with these ditches. Freshwater ditches often include various snail and mollusc species although the beetles *Graptodytes pictus, Gyrinus substriatus, Haliplus lineatocollis, Hydrophilus piceus, Laccobius colon, Laccobius minutus, Limnoxenus niger* and *Peltodytes caesus*, the bugs *Ilyocoris cimicoides, Plea minutissima and Sigara dorsalis, the mayflies Caenis robusta* and *Cloeon dipterum*, the swimming caddis *Triaenodes bicolor* are also known to occur in these habitats[57]. These species are generally adapted to slow flowing water and are not sensitive to water quality changes.

The hydrological impacts associated with the drought permit are related to changes in velocity and water levels and as such, hydrological impacts where habitats are connected may be prevalent during the hydrological winter. Impacts on the habitat are assessed as minor however monitoring is advised.

[57] Drake, C.M, Stewart, N.F., Palmer, M.A. & Kindemba, V. L. (2010) The ecological status of ditch systems: an investigation into the current status of the aquatic invertebrate and plant communities of grazing marsh ditch systems in England and Wales. Technical Report. Buglife – The Invertebrate Conservation Trust, Peterborough.

Table 4.25 Summary of Impacts on Costal and floodplain grazing marsh

Feature	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 and 2				
Coastal and floodplain grazing marsh	The drought permit would lead to a reduction in autumn and winter flows that would manifest as a reduction in levels, velocities and wetted widths which may impact the habitat.	Regional	Low	**Minor**

4.7.2 NERC species

Macroinvertebrates

Baseline

A summary of the baseline macroinvertebrate data received is provided in **Section 4.7.4**. Nine records of the fine-lined pea mussel (*Pisidium tenuilineatum*) exist from four survey locations within the impacted reaches: North Cerney (36222), Perrot's Brook (89521), South Cerney Outdoor Education Centre (91481), and Rivercourt, Cirencester (163741). The 2018 data, recorded at Perrot's Brook, had the highest fine-lined pea mussel abundance (12).

Consequently, based on the precautionary principle, the assessment has considered that a population of the species is present in impacted Reaches 1, 2, and 3 of the River Churn, albeit in low abundances. Baseline information did not identify the presence of the species in any of the invertebrate monitoring samples within impacted Reach 4. No data have been received for impacted Reach 5 on the River Coln. Therefore, on a precautionary principle, it has been assumed that fine-lined pea mussel is present in these reaches albeit in a low abundance.

Assessment

The main impact on the species will be associated with a loss of habitat rather than flow reduction in the watercourse and the ingress of fine sediments, notably as a result of urban and agricultural run-off. In many lowland rivers and canals where flow velocity is naturally reduced, the fine-lined pea mussel is a characteristic species. The Baunton (1) drought permit will have little additional impact on the species against a baseline of drought conditions. If refuge habitat is present, the standing water habitat remaining may be considered a potential short-term habitat for the species.

The water quality assessment has identified no risk of deterioration to the dissolved oxygen saturation in both Reaches 1 and 2 with a low risk to deterioration in Reach 3. The fine-lined pea mussel has some tolerance to water quality deterioration (i.e. organic pollution and dissolved oxygen) as identified by its low BMWP score (3 out of 10, where 1 is very pollution tolerant and 10 is pollution sensitive) and also evidenced by its colonisation of canal habitats and fine, muddy sediments.

Overall, the impact of drought permit implementation on the fine-lined pea mussel in Reaches 1, 2 and 3 is considered to be have **moderate** impacts which will be of low magnitude, short-term, temporary and reversible. Within Reach 4 and 5, the effects of drought permit implementation will cause **negligible** impacts which will be of low magnitude, short-term, temporary and reversible.

A summary of the impacts is provided in **Table 4.26**.

Table 4.26 Summary of Impacts on NERC Macroinvertebrate Species

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 - River Churn				
Fine-lined pea mussel	Reduction in species abundance as a result of increased stress in vulnerable habitats	National	Low	**Moderate**
Reach 2 - River Churn				
Fine-lined pea mussel	Reduction in species abundance as a result of increased stress in vulnerable habitats	National	Low	**Moderate**
Reach 3 – River Churn				
Fine-lined pea mussel	Reduction in species abundance as a result of increased stress in vulnerable habitats Reduction in species abundance or distribution as a result of changes in water quality	National	Low	**Moderate**
Reach 4 – River Frome				
Fine-lined pea mussel	Reduction in species abundance as a result of increased stress in vulnerable habitats Reduction in species abundance or distribution as a result of changes in water quality	National	Negligible	**Negligible**
Reach 5				
Fine-lined pea mussel	Reduction in species abundance as a result of increased stress in vulnerable habitats	National	Negligible	**Negligible**

Fish

Baseline

The baseline data sets for Environment Agency data within the River Churn was only available from 2005 to 2015.

Brown trout (*Salmo trutta)* have been recorded as present throughout Reach 3 (River Churn) and Reach 4 (River Frome). No Environment Agency or Thames Water survey data was available for Reaches 1 and 2. Trout populations within the Churn have been reported to be sparse and impoverished, primarily due to the intermittent flow nature of the river.

Reach 3 recorded a peak count of 67 brown at Siddington in 2015 and 6 brown trout at Cerney Wick; also, in 2015. The differences in abundance may indicate a natural barrier or pathway which brown struggle to migrate past or unsuitable spawning substrates.

In 2017, at Marley Lane (River Frome, Reach 4) brown trout were recorded in low abundances; 18 individuals. The longest trout recorded in this sample was 245mm. No Environment Agency sites found directly within Reach 4. However, an associated tributary, Nailsworth stream had one monitoring location; Kimmins Mill, Stroud 6290. This site has been included to aid in professional judgement in the absence of baseline data. In 2011, at this site, 50 individual brown trout were recorded.

The 2016 fish monitoring surveys of the River Coln (reach 5) undertaken by Thames Water, recorded brown trout at all sites. A count of 5 brown trout was recorded in 2018 at Ampney Brook. (Thames Water site) Brown trout had the highest abundance in three of the four survey sites with grayling (Thymallus thymallus) having the greatest abundance at Coln St Aldwyns. Brown trout abundance in Reach 5 on the River Coln ranged from 15 individuals at furthest downstream U/S Dudgrove Farm sample site to 66 individuals at the Coln St Aldwyns sample site.

Intermittent flow potentially creates a variable habitat unsuitable for many fish species. No data sets for sea trout have been made available, however based on the flow regime of the River Churn, it has been assumed that the watercourse is not accessible to sea trout.

One 2011 data set recorded nine European eel, within the tributary of the Frome (Nailsworth stream) associated with Reach 4. It can therefore be presumed that the Frome can support populations and foraging opportunities for eel. Given the poor spatial distribution of the data for Reaches 1 – 5 and eel migration strategies, presence of these species has been assumed within the River Churn on a precautionary basis.

Assessment

The impacts of reductions in water level and flows in watercourses may be significant during the spawning period if they limit habitat availability for spawning. Delay to watercourse recovery during egg incubation periods may adversely influence recruitment as a result of reduced flushing of gravel and lamprey habitats. However, it is likely that natural drought (i.e. without drought permit implementation) would limit spawning habitat availability in advance of any drought permit impacts. The spawning period of brown trout falls within the hydrological winter period. Spawning for European eels has not been considered as eels do not spawn in freshwater.

Any delay in the recovery of flows and water level could also extend the period in which fish species are contained within refuges. Despite potential delay, it is noted that any loss of habitat and increased density of fish species in refuges is an impact attributable to a natural drought. An extension of this period could impact on the community and as a result of density dependent mortality, with increased competition and increased predator efficiency. Impacts on spawning in Reach 3, as a result of reduced flow contributions from Reaches 1 and 2, are anticipated not to be significant.

Any delay to watercourse recovery may impact the ability of migratory European eel (elver) to access impacted reaches. Elvers migrate upstream from April to October. Based on drought permit implementation from November to May, there is potential for a delay in watercourse recovery to extend into June.

The risk of water quality deterioration has been identified as low in Reach 3 only due to changes in dissolved oxygen saturation. The impact has the potential to result in fish mortality or emigration from the impacted reaches, however, as this is likely to occur naturally in low flow/drought conditions the species are likely to return to baseline levels quickly.

Overall, considering the baseline conditions and the short-term, temporary and reversible hydrological impacts of the drought permit, impacts on NERC Act Section 41 fish species in the River Churn are considered to be of medium impact magnitude during November to May.

Hydrological impacts within Reach 4 and 5 have been assessed as negligible and therefore, the features will not be impacted within these reaches.

A summary of the impact magnitude and the significance of impact on NERC Act Section 41 fish species is provided in **Table 4.27.**

Table 4.27 Summary of Impacts on NERC Fish Species

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 - River Churn				
Brown trout	Reduction or loss of spawning habitat due to desiccation of habitat Increased stress and predation on species in refuges as a result of delay in recovery of flows	National	Medium	**Moderate**
European eel	Increased stress and predation on species in refuges as a result of delay in recovery of flows Habitat fragmentation due to increased significance of obstacles	National	Medium	**Moderate**
Reach 2 - River Churn				
Brown trout	Reduction or loss of spawning habitat due to desiccation of habitat Increased stress and predation on species in refuges as a result of delay in recovery of flows	National	Medium	**Moderate**
European eel	Increased stress and predation on species in refuges as a result of delay in recovery of flows Habitat fragmentation due to increased significance of obstacles	National	Medium	**Moderate**
Reach 3 – River Churn				
Brown trout	Reduction in species abundance or distribution as a result of changes in water quality	National	Medium	**Moderate**
European eel	Reduction in species abundance or distribution as a result of changes in water quality	National	Medium	**Moderate**
Reach 4 – River Frome				
Brown trout	Reduction in species abundance or distribution as a result of changes in water quality	National	Low	**Negligible**
European eel	Reduction in species abundance or distribution as a result of changes in water quality	National	Low	**Negligible**
Reach 5 – River Coln				
Brown trout	Increased stress and predation on species in refuges as a result of delay in recovery of flows Habitat fragmentation due to increased significance of obstacles Reduction in species abundance or distribution as a result of changes in water quality	National	Low	**Negligible**
European eel	Increased stress and predation on species in refuges as a result of delay in recovery of flows and drying of reach Habitat fragmentation due to increased significance of obstacles	Regional	Low	**Negligible**

4.7.3 Notable species

Macrophytes

Baseline

The baseline information obtained from the Environment Agency included four survey locations within the River Churn; Reaches 1 to 3 (see **Section 4.6.2**). One species of water crowfoot river water crowfoot (*Ranunculus fluitans*) was identified from two records at Cerney Wick Gauging Station and Cricklade. North Cerney, Cerney Wick Gauging Station, and 600m u/s North Cerney, also recorded three records

of one species of crowfoot; *Ranunculus subgenus batrachium*. Reach 4 is within the Frome - Ebley Mill to Severn confluence (GB109054032470) waterbody where one monitoring site was found; Hope Mill Lane 52042. One record of creeping buttercup (*Ranunculus repens*) was recorded in 2015 here, with a percentage cover band of one. Lesser celandine *(Ranunculus ficaria)* and creeping buttercup (*Ranunculus repens)* were recorded in Reach 5 on the River Coln at the Roundhouse,

The limited baseline data received is considered insufficient to characterise the whole watercourse. However, the information is sufficient to provide context and the assessment has been undertaken using professional judgement.

Assessment

The main hydrological impact is reduction in water levels and flows during implementation between November to May. This overlaps with the growing period of macrophytes from April to May. Hydrological impacts in Reach 3 are a small reduction in flow due to reduced contributions from Reach 1 and 2. No water quality impacts are anticipated. Impacts on the *Ranunculus* species of Reaches 1 and 2 are, therefore, considered to be low in April and May and negligible throughout the rest of the year. Impacts on *Ranunculus* species of Reach 3 are considered to be negligible throughout the year.

The impacts likely to arise from the hydrological changes as a result of a the Baunton drought permit are summarised in **Table 4.28.**

Table 4.28 Summary of Impacts on *Ranunculus* species

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 - River Churn				
Ranunculus sp.	Reduction in growth as a result of impacts on water levels and flows	District	Low (April and May only)	**Minor**
		District	Negligible (June to March)	**Negligible**
Reach 2 - River Churn				
Ranunculus sp.	Reduction in growth as a result of impacts on water levels and flows	District	Low (April and May only)	**Minor**
		District	Negligible (June to March)	**Negligible**
Reach 3 – River Churn				
Ranunculus sp.	Reduction in growth as a result of impacts on water levels and flows	District	Low (April and May only)	**Minor**
		District	Negligible (June to March)	**Negligible**
Reach 4 – River Frome				
Ranunculus sp.	Reduction in growth as a result of impacts on water levels and flows	District	Negligible	**Negligible**
		District	Negligible	**Negligible**
Reach 5 – River Coln				
Ranunculus sp.	Reduction in growth as a result of impacts on water levels and flows Reduction in growth as a result of impacts on water quality	District	Negligible	**Negligible**

Freshwater Macroinvertebrates

Baseline

The screening exercise, see **Section 4.6.2**, identified the requirement to consider the presence of a number of ecologically significant freshwater macroinvertebrate species identified as nationally rare or notable. Species found at six sites are listed below in **Table 4.29**. Species included: *Riolus subviolaceus,* a riffle beetle with "Nationally Scarce" status; *Riolus cupreus,* a riffle beetle with "Nationally Scarce" status and *Rhyacophila fasciata*, a caseless caddisfly also with "Nationally Scarce" status, *Rhyacophila fasciata*, a caseless caddisfly with "Nationally Scarce" status, *Tinodes dives*, a caseless caddis fly with "Nationally Notable" status and *Tinodes unicolor*, a caseless caddis fly with

"Nationally Notable" status. Baseline macroinvertebrate monitoring information for the River Churn included survey locations within all three reaches. The Nationally Scarce riffle beetle *Riolus subviolaceus* was recorded in all three reaches with the greatest abundance recorded in 2013 at South Cerney Outdoor Education Centre (individual count = 100).

The riffle beetle (*R. cupreus)* was recorded in Reach 1 at North Cerney (36222) and Reach 3 at Cerney Wick (96881), with *Riolus* spp. also recorded in Reach 1 at 36222. The cased caddisfly *(Rhyacophila fasciata)* was recorded in Reach 3 at South Cerney Outdoor Educational Centre (91481).

Reach 5 had four sites recorded with notable species such as *Atherix ibis, Sphaerium rivicola, R. fasciata, R. subviolaceus, R. fasciata, Hydroporus marginatus* and *Hydraena rufipes.*

The Thames Water site Edgeworth (Reach 1) was surveyed in 2018 and 2017, however, no notable species were recorded. No Environment Agency sites or Thames Water sites within the River Frome (Reach 4) similarly to Reach 1, did not return records of notable species.

Based on the precautionary principle, the assessment has considered that a medium population of these species is present in the impacted reaches of the River Churn. The River Frome has different flow pressures and is characteristically a different river. On a precautionary basis, it has been assumed that some flow sensitive species may be present.

Table 4.29 Summary of Abundance, Collection Date and Location of Notable Species Recorded from the River Churn During Environment Agency monitoring (2009 – 2019)

Site	Date	*Riolus subviolaceus*	*Rhyacophila fasciata*	*Riolus cupreus*	*Tinodes unicolor*	*Tinodes dives*
Cerney Wick (96881)	02/11/2010	1				
	19/04/2011	1				
	16/11/2018	2				
Gauging Station, Cerney Wick (36221)	10/05/2014		2			
North Cerney (36222)	15/04/2009	4				
	25/11/2009	9				
	25/05/2010	17				
	20/10/2010	3				
	28/03/2011	4				
	26/09/2011	5				
	28/09/2012	7				
	08/05/2013	2				
	05/05/2015	4		1		
	02/09/2015	1		1		
	20/04/2016	20				
	07/10/2016			1		
	24/05/2018				1	
Perrots Brook (89521)	25/11/2009	3				
	21/07/2010	2		3		
	13/10/2011			1		
	22/11/2012	1				
	21/05/2015	1				
	13/05/2016	9			2	
	11/02/2019	1				1
Rivercourt, Cirencester (163741)	29/10/2009	1				
	21/05/2015	1				
	01/04/2016	4				
	20/04/2016	1				

Site	Date	*Riolus subviolaceus*	*Rhyacophila fasciata*	*Riolus cupreus*	*Tinodes unicolor*	*Tinodes dives*
South Cerney Outdoor Education Centre (91481)	07/10/2016	2				
	10/03/2017			1		
	24/05/2018				1	
	18/03/2010			1		
	12/09/2012	3				
	14/05/2013	100				
	07/05/2015	2				
	07/10/2016	10				
	08/11/2017	12		6		
	24/05/2018		2			

Table 4.30 Summary of Abundance, Collection Date and Location of Notable Species Recorded from Reach 5 (2009 to 2019)

Site & Site ID	Date	*Riolus subviolaceus*	*Atherix ibis*	*Sphaerium rivicola*	*Hydroporus marginatus*	*Hydraena rufipes*	*Rhyacophila fasciata*
Conyegar farm (89523)	12/11/2010			20			
	26/09/2011	1		15			
	17/09/2012			13			
Coln St Aldwyns (Thames Water)	19/10/2016		6				
Guaging station, Bibury (36205)	16/05/2014	1			1		
Roundhouse, Lechlade (36186)	22/05/2009		1				
	17/11/2009		1				
	18/03/2010		1				
	24/08/2010		1				
	12/11/2010	1	1				
	17/05/2011	1	1				1
	16/11/2011	1					
	13/04/2012		2				
	26/04/2013	6					
	21/08/2013	8					
	24/04/2014	1					
	27/08/2014						
	15/05/2015	1				1	1
	17/08/2016	19					
	07/10/2016	8					
	12/05/2017	23					
	17/11/2017	64					
	24/05/2018	23					
	29/08/2018	35	1				
	08/10/2019	1					

Assessment

The assessment of impacts on the ecologically sensitive macroinvertebrate species present should be considered in the context of the watercourse under baseline drought conditions. The River Churn in Reach 1 is perennial, although it has been known to dry up infrequently. Therefore, the main hydrological impact associated with the drought permit is the delay to the recovery of flows in the

watercourse during the hydrological winter. Conversely, Reach 2 is classified as an intermittent watercourse, losing surface water to the groundwater and naturally drying up during the summer. Hydrological impacts in Reach 3 are a small reduction in flow due to reduced contributions from Reach 1 and 2.

Additionally, the water quality assessment has identified only a low risk of a reduction in dissolved oxygen saturation in Reach 3 as a result of drought permit implementation.

The notable species present in the River Churn occupy different flow group classifications associated with the LIFE methodology. The caddisflies *Rycaophilia fasciata* and *Tinodes dives* fall within flow class I; with T. unicolor classified as flow class II: *Riolus cupreus and R. subviolaceus* fall within taxon flow class II. Flow class I-II are associated with rapid and moderate/fast flows, respectively (i.e. 20cm/s and >100cm/s). Consequently, the potential impacts of low flows will be greatest on these species.

Low species LIFE scores are associated with fauna inhabiting fast flowing, oxygen rich water with a coarse substrate, whereas high species LIFE scores are associated with fauna inhabiting slow flowing water with reduced oxygen levels and silty substrates. Therefore, the identified caddisflies and riffle beetles (either flow class I or class II), may be impacted from the reduction in flow.

In conclusion, impacts on these species have been summarised as of medium magnitude, from November to May. The impacts likely to arise from the Baunton drought permit are summarised in **Table 4.31.**

Table 4.31 Summary of Impacts on Sensitive Macroinvertebrates

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 - River Churn				
Rhyacophila fasciata *Riolus cupreus* *Riolus subviolaceus*	Reduction in species diversity and abundance as a result of reduced recruitment	County	Medium	**Moderate**
Reach 2 - River Churn				
Rhyacophila fasciata *Riolus cupreus* *Riolus subviolaceus* *Tinodes* spp	Reduction in species diversity and abundance as a result of reduced recruitment	County	Medium	**Moderate**
Reach 3 – River Churn				
Rhyacophila fasciata *Riolus cupreus* *Riolus subviolaceus*	Reduction in species diversity and abundance as a result of reduced recruitment Alteration to community composition as a result of changes in water quality	County	Medium	**Moderate**
Reach 4 – River Frome				
Flow sensitive macroinvertebrates	Reduction in species diversity and abundance as a result of reduced recruitment Alteration to community composition as a result of changes in water quality	County	Low	**Negligible**
Reach 5 – River Coln				
Macro invertebrates	Reduction in species diversity as a result of the loss of flow-sensitive taxa Reduction in species diversity as a result of sedimentation	Regional	Low	**Negligible**

Fish

Baseline

The 2011 scoping report identified the requirement to consider the presence of Barbel *(Barbus barbus*) within the impacted reach, as the species is listed in Annex V of the Habitats Directive as a species of Community Interest.

Despite this the species has not been identified as present within the watercourse in the fish survey data (**Section 4.7.4**), and therefore no further assessment is required.

Identified in fish survey data, the bullhead (*Cottus gobio*) (an Annex II species) have been considered due to their sensitivity towards changes in habitat, notably low dissolved oxygen levels and sediment deposition[58].

Bullhead typically spawn around March and April with egg incubation taking place until the end of June. The potential for hydrological impacts to extend into this spawning period is possible, depending on rainfall during the hydrological winter, therefore any impacts are likely to be of greater magnitude as the spawning period of this species is not often affected by reduced flows.

Brook lamprey (*Lampetra planeri*), an Annex II species, was recorded to be present at Cerney Wick in low abundances in 2010. As a precaution, it is assessed that brook lamprey are present in low abundances within all the impacted reaches.

Brook lamprey ammocoetes are sedentary filter feeders living in marginal silts. As such they will be particularly susceptible to the reduction in flows and wetted width. Therefore, the reduction in flow due to the drought permit will reduce habitat availability and suitability for brook lamprey. The reduction in marginal habitats in watercourses that are not level controlled could have a significant impact on the species present, with each species showing a preference to marginal habitats at some point in their lifecycle. The impact will be particularly significant for lamprey species, with ammocoetes present in marginal silts potentially becoming stranded as the water levels decrease, resulting in mortality of individuals present.

A summary of the impact magnitude and the significance of impact on fish species is provided in **Table 4.32**.

Table 4.32 Summary of Impacts on bullhead, an ecologically sensitive fish species

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 - River Churn				
Bullhead	Reduction or loss of spawning habitat due to desiccation of habitat Increased stress and predation on species in refuges as a result of delay in recovery of flows	District	Medium	**Moderate**
Brook lamprey	Exposure/ reduction in extent of important habitats (marginal silt) Decreased growth, morphological change and/or alteration to feeding and migration Increased predation rates	Regional	Medium	**Moderate**
Reach 2 - River Churn				
Bullhead	Reduction or loss of spawning habitat due to desiccation of habitat Increased stress and predation on species in refuges as a result of delay in recovery of flows	District	Medium	**Moderate**
Brook lamprey	Exposure/ reduction in extent of important habitats (marginal silt)	Regional	Medium	**Moderate**

[58] Conserving Natura 2000 Rivers Ecology Series No.: 4 Ecology of the Bullhead

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
	Decreased growth, morphological change and/or alteration to feeding and migration Increased predation rates			
Reach 3 – River Churn				
Bullhead	Reduction or loss of spawning habitat due to desiccation of habitat Increased stress and predation on species in refuges as a result of delay in recovery of flows	District	Medium	**Moderate**
Brook lamprey	Exposure/ reduction in extent of important habitats (marginal silt) Decreased growth, morphological change and/or alteration to feeding and migration. Increased predation rates	Regional	Medium	**Moderate**
Reach 5 – River Coln				
Bullhead	No hydrological impacts are anticipated as a result of the drought permit implementation	District	Low	**Negligible**
Brook lamprey		Regional	**Negligible**	**Negligible**

Invasive Species – Macroinvertebrates and macrophytes

Baseline

Five invasive and alien species were identified in data obtained from the Environment Agency. These were: the shrimp *Crangonyx pseudogracilis*, New Zealand Mud snail (*Potamopyrgus antipodarum),* the flatworm *Dugesia tigrina*, signal crayfish (*Pacifastacus leniusculus*) and the acute bladder snail (*Physella acuta).*

The baseline information obtained from the Environment Agency contained anecdotal information that indicates the presence of zebra mussel (*Dreissena polymorpha)*, downstream of the impacted reaches. Zebra mussel have been identified on the River Churn, at the South Cerney Outdoor Education. Japanese knotweed *Fallopia japonica,* giant hogweed *Heracleum mantegazzianum and* Himalayan balsam *Impatiens glandulifera* have all been recorded within the impacted reaches.

Assessment

The impact associated with the drought permit may influence the migration of invasive invertebrate species to previously uncolonized habitats of the Churn catchment. There is no significant reduction in water quality in and reaches and therefore this is not considered to influence the distribution of invasive macroinvertebrates. The drought permit would lead to a reduction in winter flows that would manifest as a reduction in levels, velocities and wetted widths. This may provide greater opportunities for plants to establish in the riparian area. Establishing on river-banks can cause destabilisation and erosion of the riparian area, which is made worse by drought conditions.

The Baunton drought permit is considered likely to have an impact as a result of changes in the distribution of invasive invertebrates and macrophytes in the impacted reaches.

4.7.4 RBMP2 Water body Status

Surface Water Body Status

This section considers the potential impact on the feature community within each reach as well as identifying the risk of deterioration in status under the WFD.

The following definitions are provided for the determination of status under the WFD.

- **High ecological status** - the values of the biological quality elements for the surface waterbody reflect those normally associated with that type under undisturbed conditions and show no, or only very minor, evidence of distortion.
- **Good ecological status** - the values of the biological quality elements for the surface waterbody type show low levels of distortion resulting from human activity but deviate only slightly from those normally associated with the surface waterbody type under undisturbed conditions.
- **Moderate ecological status** - the values of the biological quality elements for the surface waterbody type deviate moderately from those normally associated with the surface waterbody type under undisturbed conditions. The values show moderate signs of distortion resulting from human activity and are significantly more disturbed than under conditions of good status.
- **Poor ecological status** - waters showing evidence of major alterations to the values of the biological quality elements for the surface waterbody type and in which the relevant biological communities deviate substantially from those normally associated with the surface waterbody type under undisturbed conditions, shall be classified as poor.
- **Bad ecological status** - waters showing evidence of severe alterations to the values of the biological quality elements for the surface waterbody type and in which large portions of the relevant biological communities normally associated with the surface waterbody type are absent, shall be classified as bad.

Macroinvertebrates

Baseline

The impacted reach of the River Churn includes two WFD water bodies: River Churn between its source and Perrott's Brook (GB106039029810) and the River Churn between Baunton and Cricklade (GB106039029750). The former covers a small part of upper Reach 1, the River Churn between Baunton and Cricklade covers the remainder of Reach 1 and all of Reach 2 and Reach 3.

The 2019 RBMP 2 WFD macroinvertebrate classifications for both these water bodies was classified as high biological quality. In the 2009 RBMP 1 assessment, waterbody GB106039029750 had a poor macroinvertebrate classification whilst waterbody GB106039029810 remained high. In the River Churn (between Baunton and Cricklade), recent data indicates that the biological quality of the waterbody for macroinvertebrates has improved to more favourable conditions.

Assessment of the sensitivity of the macroinvertebrate community was undertaken by analysis of recorded Lotic-invertebrate Index for Flow Evaluation (LIFE) scores. LIFE Ecological Quality Ratios (EQRs) for the sites are utilised to ascertain the sensitivity of the macroinvertebrate community to low flows. The macroinvertebrate assemblages of the River Churn represent communities that are varied and closely associated with moderate to fast flow conditions. The RAW LIFE scores range between 6.09 and 8.31 with an average across all sites of 7.4. The lowest LIFE score (6.09) is associated with 36222, Autumn 2013. In contrast, the highest LIFE score was recorded at North Cerney (Thames Water) with a peak of 8.31 Autumn 2019; which is indicative of a fast flow community.

The 2009-2019 monitoring surveys on the River Churn, conducted by the Environment Agency, identified 70 unique species. The macroinvertebrate samples for the River Churn contain records of several species primarily associated with rapid flows (LIFE score of I, indicative flow >100cm/s): the mayflies *Rhithrogena semicolorata* and *Heptagenia sulphurea*, the stonefly *Isoperla grammatica* and caddisflies *Rhyacophila dorsalis, R. fasciata, Tinodes dives, Goera pilosa, Silo pallipes*, and *S. nigricornis*. The moderate flow association band is relatively broad and covers species primarily associated with flows between 20 and 100cm/s. However, the majority of the families were from the band indicative of slow or standing flows.

Walley Hawkes Paisley Trigg (WHPT) Average Score Per Taxon (ASPT) and WHPT Number of Taxa (NTAXA) scores are available for the Environment Agency monitoring sites. WHPT and Empirical Proportion of Sediment-sensitive Invertebrates (EPSI) EQR scores are calculated based on available environmental parameters provided by the Environment Agency's online Ecology & Fish Data Explorer. Data which comprises of spring and autumn sampling occasions for a given year generate WFD

classifications, these EQR's are displayed for WHPTNTAXA and WHPTASPT, see **Figure 4.25, Figure 4.26** and **Figure 4.27**.

Although a low risk to deterioration of dissolved oxygen concentrations and potential pollution was noted in Reach 3, no significant water quality pressures were identified that could contribute to alteration in macroinvertebrate communities found in Reach 1 or Reach 2.

Reach 1

Thames Water have collected baseline data at two locations in Reach 1: North Cerney and Perrotts Brook; see **the Methodology.**

LIFE EQRs for North Cerney (36222), Perrotts Brook (89521) were above the flow pressure threshold of 1 during the entire survey period (2010 – 2019). Scores remained fairly consistent throughout indicating communities that are resilience to flow pressures. Raw LIFE scores indicate a community within the site which is composed of a high proportion of taxa which has low sensitivity to reduced flows. Raw LIFE scores ranged from 7.58 to 8.31.

Data showed slight variation in WHPTASPT scores across the survey period with each sample able to achieve high or moderate WFD status. Raw WHPTASPT scores ranged from 5.97 to 7.03 indicative of moderate water quality at the monitoring site. Recent (2019) WHPTASPT scores for 36222 were 6.31 and 6.33 for spring and autumn respectively. Similarly, WHPTASPT scores for 89521 in spring and autumn were 6.86 and 7.03. Both sites are indicative of fair water quality.

The data shows variable macroinvertebrate diversity, with WHPTNTAXA ranging between 14 and 38 This suggests that the baseline community is composed of species that are sensitive to habitat, water quality and flow pressures.

EPSI data was available at the Environmental Agency monitoring site which provides an indication of riverbed siltation conditions. EPSI scores ranged from 76.81 to 94.52 indicative of minimally sedimented conditions. EPSI 2019 data recorded at both sites ranged from 76.31 to 94.52 with an average of 84.12.

Reach 2

Rivercourt, Cirencester (163741) was the only site recorded from Environment Agency monitoring data. Data was found from 2013 to 2019. Additional data was collected at the Stratton Allotments site from 2012 to 2017.

LIFE EQRs occasionally fell below 1, notably in autumn 2015, autumn 2016, autumn 2018 and autumn 2019. LIFE EQRs of autumn 2017 at this site was recorded to be 1.009 (rounded to 1.01) This pattern indicates that during autumn, there are predictable and significant flow related pressures on the macroinvertebrates assemblages within this reach. LIFE EQRs at Stratton Allotments were all above 1 and ranged from 1.02 to 1.16 across the 5-year time period.

Data showed slight variation in WHPTASPT scores across the survey period. Higher ASPT scores identify a community that is representative of good water quality and lower WHPTASPT scores are representative of poor water quality. The communities identified in Reach 2 indicate the current community is representative of moderate water quality with a number of more pollution tolerant species present. Rivercourt, Cirencester maintained the lowest RAW ASPT values (average = 5.1) when compared to sites found in Reach 1 and 3. WHPTASPT scores at Stratton Allotments all achieved good WFD status. The RAW ASPT values ranged from 4.7 to 5.85 (average = 5.45) indicative of poor to fair water quality.

NTAXA EQR for 163741 between years and seasons showed variation with spring samples showing averages of 0.84 compared to autumn averages of 0.69; indicating that the macroinvertebrate assemblages are subject to taxa changes in composition and diversity seasonally. NTAXA EQRs for the Stratton Allotments showed variation ranging from 0.54 to 0.92 with spring averages of 0.81 and autumn averages of 0.72. Raw values ranged from 15 to 26 with only 2 scores not achieving good WFD status.

EPSI scores for the site also showed some seasonal variation. EPSI EQR scores fell from good to moderate during autumnal months; indicating some natural degradation of habitat suitability based on season. This is supported by the RAW EPSI data where scores varied from 26.77 (heavily sedimented, autumn 2018) to 80.95 (very slightly sedimented, spring 2013).

Reach 3

Within Reach 3, three sites had macroinvertebrate data recorded by the Environment Agency

Data for WHPTASPT EQRs from Gauging station, Cerney Wick (36221) was only recorded twice, however, both data scored good status. The WHPTASPT EQR value increase at South Cerney Outdoor Education Centre (91481) indicates a regime shift to a community where species are sensitive to flows and diverse in assemblages. This increase follows dry conditions in 2011 indicating a fair recovery to the community though robust recolonization strategies. Spring 2011, autumn 2011, spring 2012 and autumn 2012 ASPT EQRs for Cerney Wick (96881) showed a marked decrease following the summer 2011 drought. Scores were 1.03, 0.92, 0.96 and 1.05 respectively.

As seen in **Figure 4.27**, NTAXA EQR's sharply declined following the dry conditions of 2011 with a low of 0.35. 91481 and 96881 sites show large variations in taxa which may indicate flow and habitat pressures which impair macroinvertebrate diversity. Good to moderate NTAXA EQR values were recorded for 36221.

As with other EQR values, sediment pressures through decreases in EPSI EQR we noted during 2011 for 91481 and 96881.

Reach 5

Within this reach, 6 monitoring sites were recorded; four environment Agency sites (Gauging Station Bibury, 36205, Conyegar Farm 89523, Roundhouse, Lechlade 36186 and Whelford 36207) and two Thames Water sites (Coln Rodgers and Coln St Andrews).

The LIFE EQRs for sites found within Reach 5 are indicated **Figure 4.28**. In Reach 5, River Coln, the RAW LIFE scores were highly variable ranging from 5.17 to 8.2 with an average of 7.23 across all monitoring sites. LIFE EQR scores were on average highest (1.2) at the Roundhouse Lechlade site, immediately upstream of the Thames confluence, and show a general trend of increased scores from 2009 to 2012. LIFE EQR scores for all sites generally show good WFD status LIFE scores in Reach 5 indicate the presence of communities associated with medium to fast flow velocities, recorded in the upper and lower sections of Reach 5 respectively.

Macroinvertebrate communities at 89523 showed some flow pressures through a decrease in LIFE EQR and WHPTNTAXA scores during a dry 2011. LIFE EQRs dropped below 1 with scores recorded as 0.64, 0.60 and 0.83 during autumn 2011, spring 2012 and autumn 2012 respectively. The monitoring site at Roundhouse, Lechlade showed some signs of drought stress also, however LIFE EQRs did not drop below one indicating a shift from good to moderate communities.

RAW ASPT scores from Reach 5 data indicates the presence of macroinvertebrate communities that are representative of consistently good water quality. WHPTASPT scores in Reach 5 ranged from 4.90 to 6.53 with an average of 5.88 across all sites (**Figure 4.28**). WHPTASPT EQRs for all sites support a community associated with good water quality. Despite the drought conditions in 2011, sites that were affected such as Conyegar farm remained to support pollution intolerant communities of invertebrates.

WHPTNTAXA scores at 36186 varied from 13 to 30 with an average of 22, whilst WHPTNTAXA scores at 36207 ranged from 9 to 23 with an average of 18. Both sites show large variations in taxa which may indicate pressures which impair macroinvertebrate diversity. The data shows variable macroinvertebrate diversity, with WHPTNTAXA from all sites ranging between 24 and 41. This suggests that pressures which impair macroinvertebrate diversity such as habitat loss or changes to flow may influence the baseline community within the River Coln.

An indication of riverbed siltation conditions was calculated from EPSI data for the Environment Agency monitoring sites 36186 and 36207. All samples from both sites were able to achieve good WFD status. EPSI scores ranged from 48.68 to 85.36 indicating moderately to slightly sedimented riverbed conditions. The two most recent samples (spring 2019 and autumn 2019; recorded at Roundhouse, Lechlade) were 73.89 and 64.44 respectively; slightly sedimented riverbed conditions.

Figure 4.25 LIFE score sensitivities, EQR values for WHPTNTAXA, WHPTASPT and EPSI score for Baunton (1), Reach 1.

Figure 4.26 LIFE score sensitivities, EQR values for WHPTNTAXA, WHPTASPT and EPSI score for Baunton (1), Reach 2.

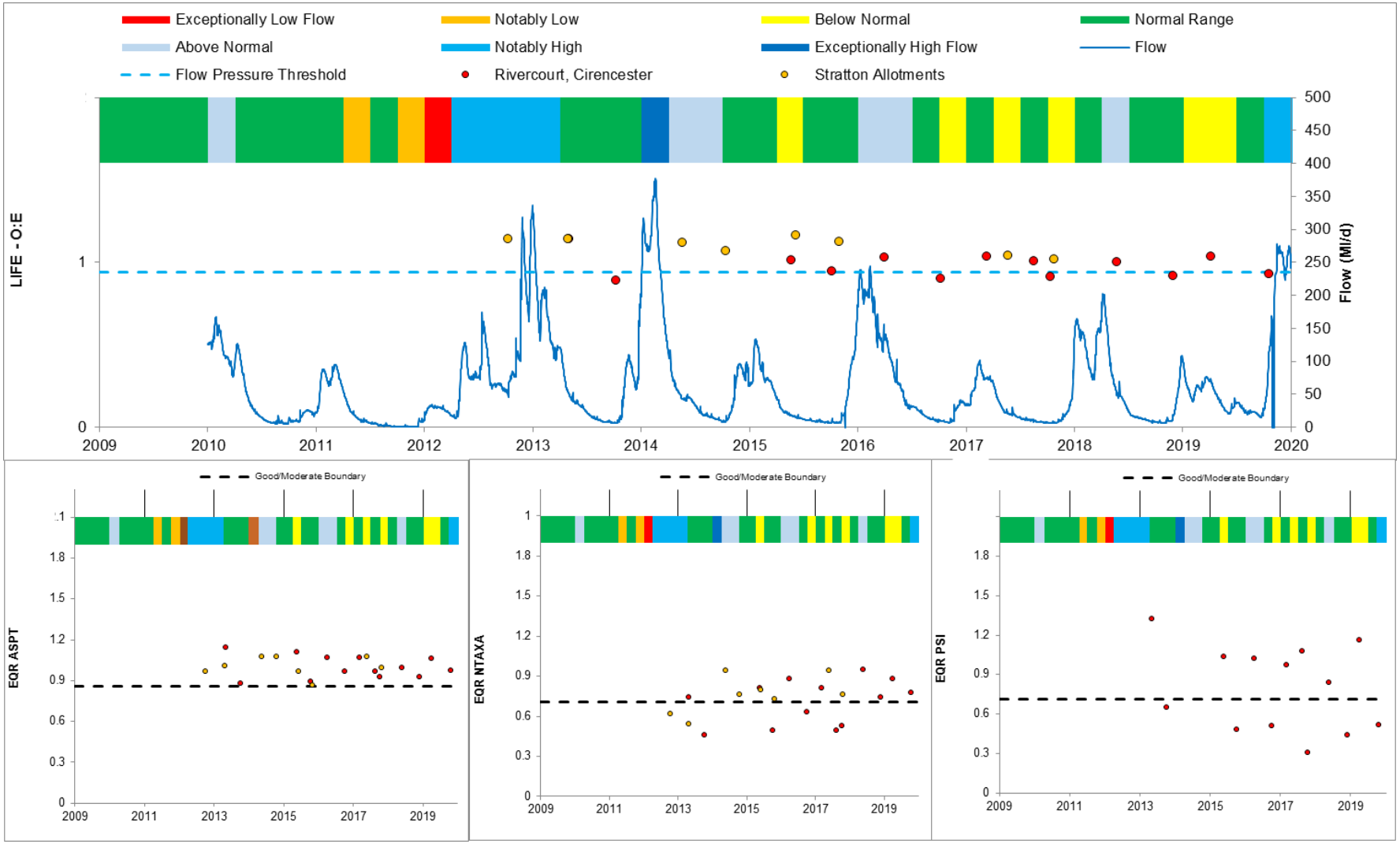
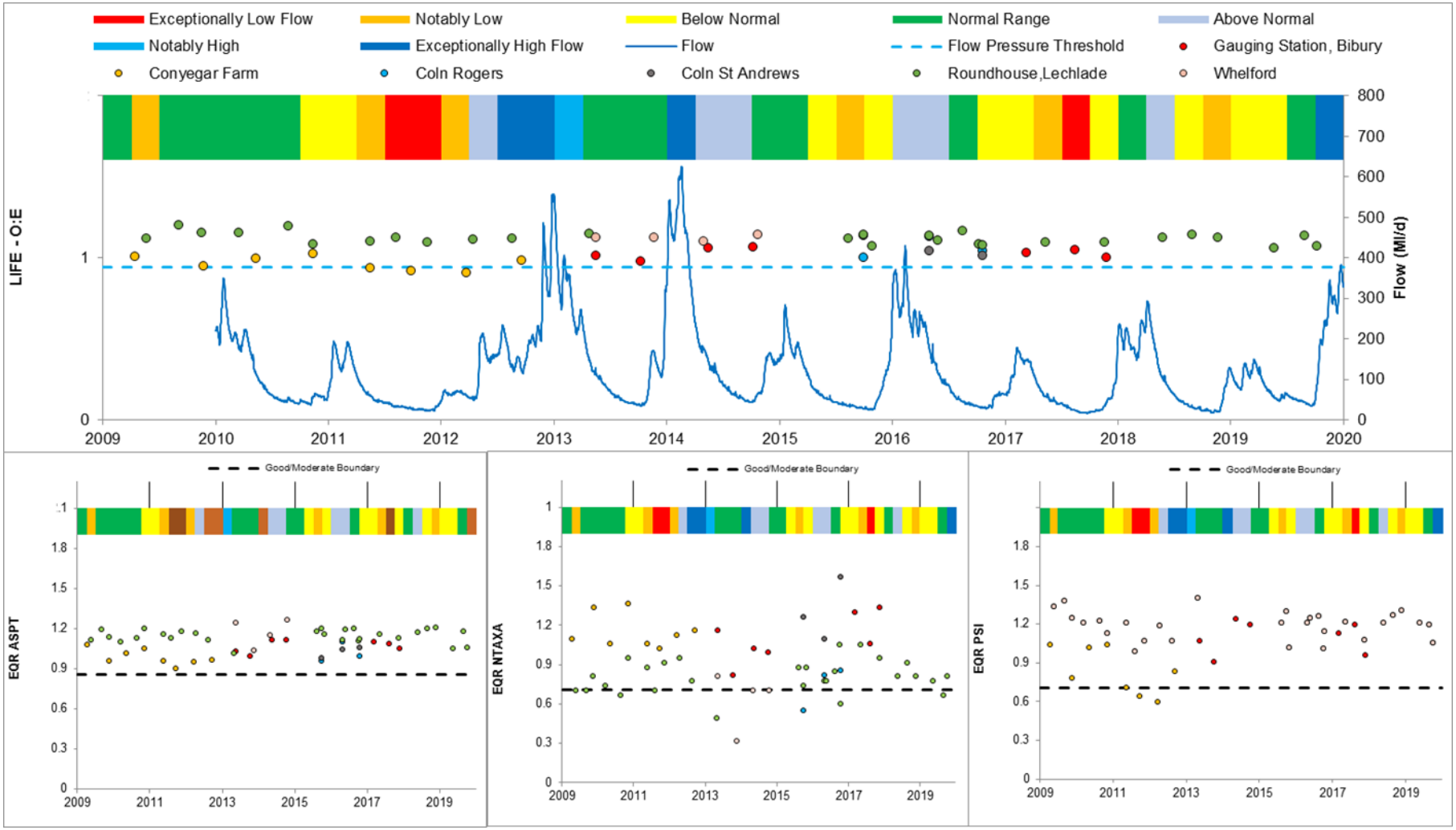


Figure 4.27 LIFE score sensitivities, EQR values for WHPTNTAXA, WHPTASPT and EPSI score for Baunton (1), Reach 3.

Figure 4.28 LIFE score sensitivities, EQR values for WHPTNTAXA, WHPTASPT and EPSI score for Baunton (1), Reach 5



Assessment

The assessment of impacts on the macroinvertebrate community should be considered in the context of the watercourses under baseline conditions. The River Churn in Reach 1 has been reported to dry up infrequently in drought conditions. Many streams can absorb infrequent drying up periods with subsequent recolonisation from refugia (e.g. perennial pools, subsurface (hyporheic zone) and up/downstream perennial reaches) or adaptation through lifecycles. Conversely, Reach 2 is an intermittently flowing stream that loses surface water to groundwater and naturally drying up during the summer. Reach 3 has a reduction in flow contributions from Reaches 1 and 2 may be experienced during drought permit implementation. The reduction of flows in Reach 1, extension of dry period in Reach 2 and reduced flow contributions in Reach 3 over the hydrological winter as a result of drought permit implementation is considered to occur at some point between November and May (**Section 4.4.2).**

Reductions in flow regime can impact macroinvertebrate communities either through physical habitat loss (e.g. changes to wetted width) or changes to habitat parameters (e.g. flow, sediment dynamics, water quality). These changes can result in reductions in populations or regime shifts in community structure (e.g. from a predominance of species adapted to fast flowing environments, to a predominance of those species adapted to slower flowing environments). In lotic environments macroinvertebrates can quickly recolonise once suitable flow conditions are restored by immigration from upstream habitats and local refugia (e.g. pools, subsurface habitats).

The delay in flow recovery due to the drought permit could have an impact on recruitment of the macroinvertebrate community present in the watercourse, however this needs to be considered against the baseline conditions likely to be present during the autumn period.

In the autumn period, flow and water level reductions may have an impact on macroinvertebrate species with a spring emergence, as the majority of these species lay their eggs in autumn with the eggs overwintering in the watercourse and emerging the following spring. The impacts could limit the recruitment of the species in the watercourses. Given the river conditions within study area, the macroinvertebrate communities present are likely to be adapted to the desiccation of habitats. The drought permit has no hydrological impact on the perennial (permanently flowing) head of the watercourses, and the recovery of the macroinvertebrate community is likely to be rapid following the cessation of drought permit hydrological impacts.

Water temperature and thermal regime are major regulators of macroinvertebrate communities. Groundwater dominated streams are thermally buffered, therefore, reduced flows and increases in temperature may not adversely influence insect emergence and life history in this reach. However, if groundwater input is reduced significantly this may have a negative impact on macroinvertebrates.

Macroinvertebrate adults can emerge as early as March (e.g. Large Dark Olive Mayflies *Baetis rhodani* and March Brown Mayfly *Rhithrogena germanica*) and as late as September (e.g. *Trichoptera Hydropsyche* sp. and Autumn Dun *Ecdyonurus dispar*), although the majority of macroinvertebrates will emerge between May and July. The implementation period is between November to April and therefore could potentially impact on those macroinvertebrate species with characteristic early emergence stages found in the River Churn (e.g. *Baetis rhodani*), thus potentially limiting recruitment of these species in the watercourse the following year. Therefore, impacts resulting from the drought permit on spring emerging species is likely to be of medium magnitude and low magnitude in Reach 1, 2 and 3 respectively.

The baseline information demonstrates the impact of dry periods on the macroinvertebrate assemblages in the River Churn with troughs evident in the LIFE scores following the dry years of 2010/2011. Although macroinvertebrate species typically have effective recolonisation strategies[59,60],

[59] Williams, D. D. (1977) Movements of benthos during the re-colonisation of temporary streams. Oikos 29, pp 306 – 312.
[60] Mackay, R. J. (1992) Colonisation by lotic macroinvertebrates: a review of process and patterns. Canadian Journal of Fisheries and Aquatic Science 49, pp 617 – 628.

the likely impacts on emergence of species and loss of suitable habitat for laying eggs is likely to limit the recolonisation strategies and have a significant impact on recruitment into the community.

ASPT scores exhibited less variability, although a reduction in ASPT scores was also observed post 2010/2011. Importantly, ASPT scores in 2011 were the lowest in 20 years, suggesting the River Churn has suffered a degradation of habitat since 2010; this coincides with the hydrological drought conditions prevalent across parts of the UK during 2011[61] and follows a similar pattern of reduced water quality in the River Churn since 2010. Although macroinvertebrate species typically have effective recolonisation strategies[62,63], the likely impacts on emergence of species and loss of suitable habitat for laying eggs is likely to limit the effectiveness of recolonisation strategies and may have a significant impact on recruitment into the community. This is particularly apparent when flows are reduced, with species characteristic of fast flows lower in abundance and species characteristic of low flows proportionally higher with a subsequent reduction in community LIFE scores.

The macroinvertebrate communities present may be affected by water quality deterioration. The water quality assessment has identified no risk of deterioration of dissolved oxygen saturation in both Reach 1 and Reach 2, however, there is a low risk in Reach 3. Macroinvertebrate families found in Reach 3 with a low tolerance to water quality deterioration include *Perlodidae*, *Nemouridae*, *Leuctridae*, *Goeridae* and *Elmidae*. As a result, these families may be impacted. Impact is assessed to be of low magnitude.

Hydrological impacts within Reach 4 and 5 have been assessed as negligible and therefore the features will not be impacted within these reaches.

Considering the length of the impact, the medium magnitude, and the temporary nature and reversibility in Reaches 1 2 and 3, the overall significance of impacts has been assessed as **minor**. An impact summary is provided in **Table 4.33**.

Table 4.33 Summary of Impacts on Macroinvertebrate Community

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 - River Churn				
Macro-invertebrates	• Loss of spring/autumn emerging species • Loss of suitable egg laying habitat for spring emergence species • Reduction in species diversity and abundance as a result of reduced recruitment • No effects on water quality in this reach	District	Medium (November to May)	**Minor**
Reach 2 - River Churn				
Macro-invertebrates	• Loss of spring/autumn emerging species • Loss of suitable egg laying habitat for spring emergence species • Reduction in species diversity and abundance as a result of reduced recruitment • No effects on water quality in this reach	District	Medium (November to May)	**Minor**
Reach 3 – River Churn				
Macro-invertebrates	• Alteration to community composition as a result of changes in water quality (notably dissolved oxygen)	District	Low (November to May)	**Minor**
Reach 4 – River Frome				

[61] http://www.ceh.ac.uk/data/nrfa/nhmp/hs/pdf/HS_201104.pdf
[62] Williams, D. D. (1977) Movements of benthos during the re-colonisation of temporary streams. Oikos 29, pp 306 – 312.
[63] Mackay, R. J. (1992) Colonisation by lotic macroinvertebrates: a review of process and patterns. Canadian Journal of Fisheries and Aquatic Science 49, pp 617 – 628.

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Macro-invertebrates	• Alteration to community composition as a result of changes in water quality (notably dissolved oxygen)	District	Low	**Negligible**
Reach 5 – River Coln				
Macro invertebrates	• Reduction in species diversity as a result of the loss of flow-sensitive taxa • Reduction in species diversity as a result of sedimentation	Regional	Low	**Negligible**

During drought permit implementation on the River Churn, there is a risk of short-term deterioration in WFD status of the macroinvertebrate component of the River Churn waterbody between its source and Perrott's Brook (GB106039029810) and the Baunton to Cricklade (GB106039029750) WFD waterbody, which are of high and good status respectively. Impacts of drought permit implementation on the macroinvertebrate communities in Reaches 1, 2 and 3(River Churn), have been summarised as **minor** adverse, short-term, temporary and reversible. Consequently, the macroinvertebrate component of both waterbodies is considered to be at **minor** risk of short-term deterioration.

Macrophytes

Baseline

The impacted reaches of the River Churn include two WFD water bodies: River Churn between its source and Perrott's Brook (GB106039029810) and the River Churn between Baunton and Cricklade (GB106039029750). In the RBMP2 (2019) assessment, the waterbody GB106039029810 was classified as moderate ecological status for macrophytes and phytobenthos combined. Under the same cycle, the River Churn between Baunton and Cricklade (GB106039029750) was also classified as moderate.

Baseline macrophyte monitoring information are limited to a small number of sampling sites and sampling occasions. **Table 4.34, Table 4.35** and **Table 4.36** identify the interpretation of Mean Flow Rank (MFR) and Mean Trophic Rank (MTR) scores. Reach 1 contained two sites (600m U/S North Cerney and North Cerney), two sites in Reach 3 (Cricklade and Cerney Wick). No monitoring sites were found for Reach 2.

Considering the spatial and temporal constraints on the baseline information, which are not considered to be sufficient to characterise the whole watercourse, care must be taken in their interpretation.

Observed MFR scores at Cerney Wick Gauging Station in 2013 of 1.94 (summer) and 2014 of 2.10 (summer) are indicative of a macrophyte community with a preference for slow to moderate flow velocities (see **Table 4.34**). The MTR score suggests the site is also likely to be either eutrophic or at risk of becoming eutrophic, with scores of 41.4 (summer 2013) and 39.4 (summer 2014) (see **Table 4.36**). Limestone streams are nutrient rich therefore, the MTR scores are consistent for this type of river and suggest the reaches are not significantly impacted by eutrophication. Nevertheless, Holmes[64] states that MTR scores less than 45 can indicate a possible risk of eutrophication and therefore the site could potentially be at risk of becoming eutrophic as suggested by the low 2013 and 2014 MTR scores recorded at Cerney Wick. Lower MTR scores were found at North Cerney and Cricklade in 2013; 38.0 and 36.8 respectively.

River Macrophyte Nutrient Index (RMNI) score is a measure of the macrophyte community's association with nutrient levels on a scale of 1 – 10. High scores are associated with species that dominate under nutrient enriched eutrophic conditions. The RMNI scores for sites on the River Churn range from 7.14 to 8.27 between 2013 and 2014, indicating a community with a preference for mesotrophic to eutrophic

[64] Holmes, N T H, Newman, J R, Chadd, S, Rouen, K J, Saint, L and Dawson, F H (1999) Mean Trophic Rank: A Users Manual. R&D Technical Report E38, Environment Agency, Bristol.

conditions. RMNI scores in Reach 5, River Coln, ranged between 7.32 to 8.27 and also indicate a community associated with mesotrophic to eutrophic conditions.

River Macrophyte Hydraulic Index (RMHI) is a measure of which plants are present within the community and their association with flow levels. High scores are associated with macrophytes present in low energy velocities. The RMHI scores for sites on the River Churn range from 7.06 to 8.11 between 2013 and 2014, indicating a community with a preference for low to moderate flow velocities. RMHI scores for sites in Reach 5 on the River Coln were also within this range indicative of communities associated with low to moderate flow velocities.

Table 4.34 Interpretation of MFR scores used for this Assessment (from Holmes *et al*., 1999[65])

MFR Score	Interpretation of Score
1	Community preferring slow flow velocity
2	Community preferring slow to moderate flow velocity
3	Community preferring moderate flow velocity
4	Community preferring moderate to fast flow velocity
5	Community preferring fast flow velocity

Table 4.35 Interpretation of MTR scores (from Holmes *et al*., 1999[66])

MTR Score	Interpretation of Score
<25	Site is badly damaged by eutrophication, organic pollution, toxicity or is physically damaged.
25 - 65	Site is likely to be either eutrophic or at risk of becoming eutrophic
>65	Site is unlikely to be eutrophic

Table 4.36 Observed MFR, MTR, RMNI and RMHI Scores from Environment Agency sites

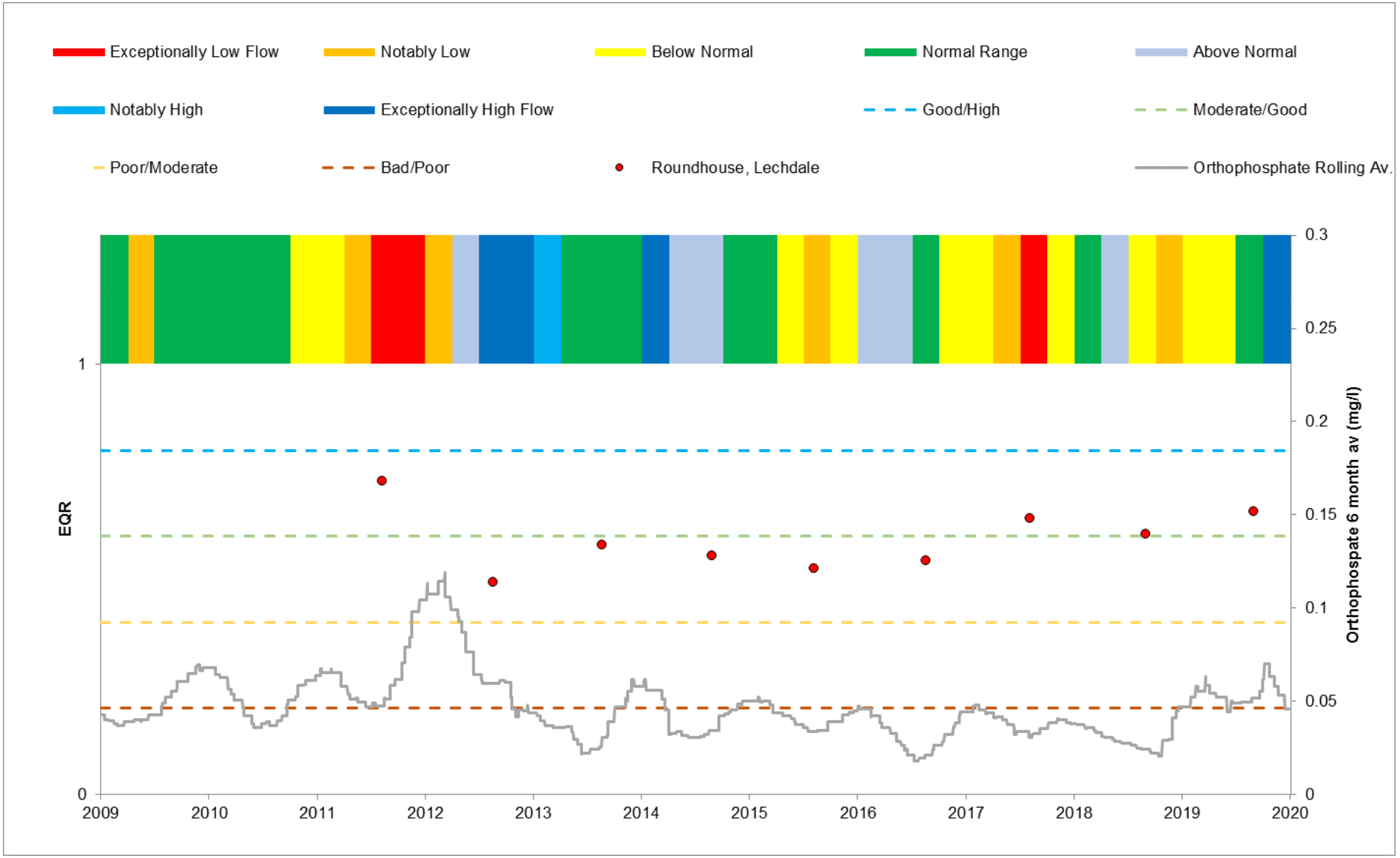
Site	Reach	Grid Reference	Year	MTR	MFR	RMNI	RMHI
North Cerney	1	SP0190807912	2013	38.0	2.09	7.14	7.06
600M U/S North Cerney	1	SP0173708365	2014	41.7	2.13	7.43	7.44
Cricklade	3	SU1040293811	2013	36.8	1.84	8.27	8.11
Cerney Wick	3	SU0783795983	2013	41.4	1.94	7.60	7.43
			2014	39.4	2.10	7.75	7.53
Roundhouse, Lechlade	5	SU2033698873	2010	28	1.78	7.76	7.46
			2011	35	1.88	7.44	7.3
			2012	27.2	1.45	8.17	7.77
			2013	30.5	1.88	7.69	7.37
			2014	30.5	1.86	7.75	7.46
			2015	28.8	1.82	8.06	7.73
			2016	-	-	7.59	8.01
			2017	-	-	7.56	7.76
			2018	-	-	7.64	7.84
			2019	-	-	7.58	7.72

[65] Holmes, N T H, Newman, J R, Chadd, S, Rouen, K J, Saint, L and Dawson, F H (1999) Mean Trophic Rank: A Users Manual. R&D Technical Report E38, Environment Agency, Bristol.
[66] Holmes, N T H, Newman, J R, Chadd, S, Rouen, K J, Saint, L and Dawson, F H (1999) Mean Trophic Rank: A Users Manual. R&D Technical Report E38, Environment Agency, Bristol.

Figure 4.29 Macrophyte EQRs for Reach 1

Figure 4.30 Macrophyte EQRs for Reach 3

Figure 4.31 Macrophyte EQRs for Reach 5



Assessment

The assessment of impacts on the macrophyte community should be considered in the context of the watercourse under baseline conditions. The River Churn in Reach 1 is perennial; however, it has been reported to dry up infrequently in drought conditions and will be more sensitive to a reduction in flow. Reach 2 is classified as an intermittent watercourse and therefore, considering it can dry up during dry summers, is less sensitive to a reduction in flow. Reach 3 has been reported to dry up during drought conditions and a reduction in flow contributions from Reaches 1 and 2 may be experienced during drought permit implementation.

There is no risk of water quality deterioration in Reach 1 and Reach 2, and a low risk of water quality deterioration in Reach 3, this is associated with a decrease in dissolved oxygen saturation. The risk of water quality deterioration as a result of changes in ammonia and SRP has been identified as negligible. Consequently, as the macrophyte community is not sensitive to a reduction in dissolved oxygen saturation and ammonia and SRP concentrations are at negligible risk, no water quality impacts on the macrophyte community are anticipated.

The main macrophyte growing season typically starts between April and extends until September. There will is a 2 month overlap with drought permit implementation from November to May. Therefore, potential impacts on macrophytes in Reach 1 are identified in April and May, but the impact is not expected to be outside a baseline of low flows occurring in naturally dry years. Impacts on the macrophyte community of Reaches 1 and 2 are therefore, considered to be low in April and May, and negligible throughout the rest of the year. Impacts on the macrophyte community of Reach 3 are considered to be negligible throughout the year.

Hydrological impacts within Reach 4 and 5 have been assessed as negligible and therefore the features will not be impacted within these reaches.

A summary of the impacts is provided in **Table 4.37.**

Table 4.37 Summary of Impacts on the Macrophyte Community

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 - River Churn				
Macrophytes	Reduction in growth as a result of impacts on water levels and flows	District	Low (April and May only)	Minor
	No effect from changes in water quality in this reach	District	Negligible (June to March)	Negligible
Reach 2 - River Churn				
Macrophytes	Reduction in growth as a result of impacts on water levels and flows	District	Low (April and May only)	Minor
	No effect from changes in water quality in this reach	District	Negligible (June to March)	Negligible
Reach 3 – River Churn				
Macrophytes	Reduction in growth as a result of impacts on water levels and flows	District	Low (April and May only)	Minor
	No effect from changes in water quality (macrophytes are not sensitive to changes in dissolved oxygen)	District	Negligible (June to March)	Negligible
Reach 3 – River Churn				
Macrophytes	Reduction in growth as a result of impacts on water levels and flows	District	Negligible (April and May only)	Negligible
	No effect from changes in water quality (macrophytes are not sensitive to changes in dissolved oxygen)	District	Negligible (June to March)	Negligible

During drought permit implementation, there is a risk of short-term deterioration in WFD status of the macrophyte component of the River Churn source to Perrott's Brook WFD waterbody (GB106039029810) and Baunton to Cricklade WFD waterbody (GB106039029750). However, no WFD macrophyte classification is given for the macrophyte component of these water bodies for RBMP1 and RBMP2 and it is therefore uncertain what the resulting effect (if any) is on WFD status. Impacts on the macrophyte communities have been summarised as minor adverse, short-term, temporary and reversible in April (in Reaches 1, 2 and 3), and negligible throughout the rest of the year. if the macrophyte component of the waterbody was classified, it is considered to be at **minor** risk of short-term deterioration. Impacts in Reach 5 are summarised as negligible. Consequently, the macrophyte component of the of the Coln (Source to Coln Rogers; GB106039029990) and the Coln (Coln from Coln Rogers and Thames Coln to Leach; GB10603902999) water bodies are at **negligible** risk of short-term deterioration in WFD status.

Fish

Baseline

The impacted reaches cover three WFD water bodies: The River Churn between its source and Perrott's Brook (GB106039029810), the River Churn between Baunton and Cricklade (GB106039029750) and the Frome - Ebley Mill to Severn confluence (GB109054032470)

The 2019 RBMP 2 status of Source to Perrott's Brook is classified as being of moderate ecological status for fish; a decline from 2015 RBMP 2 status of good. Under the same Cycle 2 classifications, Baunton to Cricklade in 2019 was considered good in relation to fish; an increase from bad in 2015. Reach 4, the Frome – Ebley Mill to Severn confluence (GB109054032470) recorded moderate biological quality for fish; a decline from good status in 2016.

Fish survey data have been provided by the Environment Agency for two sites in Reach 3, Cerney Wick and Siddington. This data was from 2005 to 2015. No survey data was available for Reaches 1 and 2 or from 2016 onwards see **Table 4.38**.

Species of individuals found indicates that both Reach 3 are dominated by rheophilic species; such as bullhead (*Cottus gobio*), trout (*Salmo trutta*), chub (*Leuciscus cephalus*) and dace (*Leuciscus leuciscus*). The invasive, but naturalised, rainbow trout (*Oncorhynchus mykiss*) was noted at Cerney Wick in 2010; however, this was a single individual.

In the absence of baseline information for Reaches 1 and 2, it is assumed that the fish species identified as present in Reach 3, extend their distribution to these upper areas of the River Churn. Additional fish survey data was collected by Thames Water as part of the baseline monitoring in 2016 at four sites in Reach 5 on the River Coln: Coln Rogers, Bibury, Coln St Aldwyn, and US Dudgrove Farm. Notable species recorded included perch, brown trout, eel and brook lamprey.

Table 4.38 Fish Community Composition and Species Abundance in River Churn 2005 to 2017 [67]

Site and ID	Species		2005	June 2006	Sept 2006	April 2007	Sept 2007	April 2008	Sept 2008	June 2009	Sept 2009	April 2010	Sept 2010	June 2011	Sept 2011	2012	2013	2014	2015	2017	Mean
Cerney Wick (8965)	Bleak	*Alburnus alburnus*	0	0	0	0	0	0	0	0	0	0	0	1	-	0	-	-	0	-	0.07
	Brown / sea trout	*Salmo trutta*	1	0	0	1	0	0	0	1	0	3	0	5	-	1	-	-	6	-	1.23
	Brook Lamprey	*Lampetra planeri*	0	0	0	0	0	0	0	0		0	Present	0	-	0	-	-	1 to 9	-	1 - 9
	Chub	*Leuciscus cephalus*	23	6	26	17	9	6	2	7	18	1	4	26	-	0	-	-	28	-	12.36
	Common bream	*Abramis brama*	0	0	0	0	0	0	0	0	1	0	0	0	-	0	-	-	2	-	0.21
	Dace	*Leuciscus leuciscus*	50	12	26	12	27	22	7	54	47	30	108	89	-	10	-	-	190	-	48.86
	Gudgeon	*Gobio gobio*	1	0	3	21	0	6	5	0	0	0	46	82	-	1	-	-	310	-	33.92
	Perch	*Perca fluviatilis*	26	6	18	13	60	4	3	18	13	0	14	9	-	2	-	-	71	-	18.36
	Pike	*Esox lucius*	9	3	2	2	5	1	0	0	1	1	2	4	-	5	-	-	4	-	2.79
	Rainbow trout	*Oncorhynchus mykiss*	0	0	0	0	0	0	0	0	0	1	0	0	-	0	-	-	0	-	0.07
	Roach	*Rutilus rutilus*	33	3	18	59	22	7	2	0	4	1	22	32	-	2	-	-	105	-	22.14
	Tench	*Tinca tinca*	0	0	0	1	0	0	0	1	0	0	0	0	-	0	-	-	0	-	0.14
Siddington (20925)	Brook lamprey	*Lampetra planeri*	-	Present	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1 to 9	-	1 - 9
	Brown / sea trout	*Salmo trutta*	-	16	-	-	-	-	-	-	-	-	-	-	-	59	-	-	67	-	47.3
	Bullhead	*Cottus gobio*	-	Present	-	-	-	-	-	-	-	-	-	-	-	100 to 999	-	-	10 to 99	-	100 to 999
	Pike	*Esox lucius*	-	2	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	1
Coln Rogers (Thames Water)	Brook lamprey	*Lampetra planeri*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	0.5
	Brown trout	*Salmo trutta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	54	55	54.5
	Bullhead	*Cottus gobio*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100 - 999	9	100 - 999
	Grayling	*Thylamus thylamus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	2	3.5
	Perch	*Perca fluviatilis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	1

[67] Where a dash denotes no survey and a zero denotes no catch. Data search has been extended from 2005-2017 due to 10 years of Environment Agency data (2005-2015). No recent (2015+) data was found.

Site and ID	Species		2005	June 2006	Sept 2006	April 2007	Sept 2007	April 2008	Sept 2008	June 2009	Sept 2009	April 2010	Sept 2010	June 2011	Sept 2011	2012	2013	2014	2015	2017	Mean
Bibury (Thames Water)	Stone loach	*Barbatula barbatula*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2	1
	Brook lamprey	*Lampetra planeri*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0.5
	Brown trout	*Salmo trutta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	65	39	52
	Bullhead	*Cottus gobio*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100 - 999	32	100 - 999
	Grayling	*Thylamus thylamus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	4	6
	Rainbow trout	*Oncorhynchus mykiss*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4	3
U/S Dudgrove Farm (Thames Water)	Brown trout	*Salmo trutta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	15	21
	Bullhead	*Cottus gobio*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	0.5
	Chub	*Leuciscus cephalus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0	1
	Dace	*Leuciscus leuciscus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	2	4.5
	Grayling	*Thylamus thylamus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	9	17
	Gudgeon	*Gobio gobio*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	3	10.5
	Perch	*Perca fluviatilis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	2	5
	Pike	*Esox lucius*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0	1
	Brown trout	*Salmo trutta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	15	21
	Bullhead	*Cottus gobio*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	0.5
	Chub	*Leuciscus cephalus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0	1
Coln St Aldwyns (Thames Water)	Brook lamprey	*Lampetra planeri*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	0.5
	Brown trout	*Salmo truta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55	64	60.5
	Bullhead	*Cottus gobio*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10-99	4	10-99
	Grayling	*Thylamus thylamus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	127	104	115.5

Freshwater fish species can be split into two main categories depending on their requirements or preference for river flow:

- Limnophilic species (i.e. organisms which prefer to live in lakes, ponds, marshes, pools or other slow moving, still or stagnant water), such as bream, carp, tench and European eel are adapted for slow flowing or still water environments and may generally be able to tolerate lower water quality and higher riverine temperatures than rheophilic (flow-loving) species. Spawning usually occurs in late May and June, although in cool summers spawning can be delayed into July. Water temperatures usually have to exceed 17°C or 18°C to stimulate spawning.
- Rheophilic species (also termed lithophils – organisms which prefer to live-in fast-moving water), such as trout, chub, dace and barbel, select stone and gravel on which to spawn. This generally requires a rapid flow to maintain the gravels free from fine sediments that may otherwise smother the eggs and starve them of oxygen. Spawning generally occurs earlier in the year than for limnophilic species where river temperatures are cooler. Dace generally spawn in late March or April on clean and unsilted gravels. Chub and barbel spawn later than dace in May or June when the water temperatures have risen.

Table 4.38 identifies the sensitive periods for those species identified as present in the River Churn.

The limited data indicates that both rheophilic and limnophilic species are present in the River Churn. The rheophilic species comprise a greater proportion of the community, and key species include; chub (*Leuciscus cephalus*) and dace (*Leuciscus leuciscus*). There are no obvious trends in the abundance of fish species in the data provided, with numbers fluctuating across the years surveyed. Brown trout (*Salmo trutta*) are present but, have been increasing abundance since 2006. There are no records of European eel (*Anguilla Anguilla*) in the data collected. Given the restricted spatial distribution of the data and the current decline of European eel, on a precautionary basis, its presence has been assumed.

The Thames Water survey data for Reach 5 suggests that rheophilic species (those with a preference for higher flows) dominate, with one NERC Act 2006 species present, brown trout. Brown trout was the dominant species present at three of the Thames Water survey sites, except for the Coln Aldwyn site where grayling (*Thymallus thymallus)* was dominant; grayling was also present at the other three survey sites but comprised a lower proportion of the population. Population estimates[68] in Reach 5 indicate that the Coln Aldwyn site had the highest overall fish population of 183 while the Coln Rogers site had the lowest, at 59. The species present typically require gravel substrates for spawning and are sensitive to changes in flow and water quality.

[68] Zippin, C. (1956) An Evaluation of the Removal Method of Estimating Animal Populations. Biometrics 12, 2, pp 163-189.

Table 4.39 Sensitive Periods (Spawning, Egg Incubation and Migration) for Common Freshwater Fish Likely to be Present in the River Churn

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Brown trout												
Bullhead												
Barbel												
Chub												
Dace												
European												
Pike												
Perch												
Roach												
Gudgeon												
Brook												
Stone loach												
Bream												
Tench												
Grayling												
Key												
Spawning and egg incubation							Migration					

Assessment

Information was not currently available to provide a quantitative assessment utilising the Fisheries Classification System (FCS2) to an equivalent WFD status. Therefore, assessment has been undertaken by professional judgement using baseline information provided by the Environment Agency.

The assessment of impacts on the fish community should be considered in the context of the watercourse under baseline conditions. The River Churn in Reach 1 is perennial, though is known to dry up during drought conditions, whereas in Reach 2 the River Churn is intermittent flowing, drying up in dry summers. Reach 3 has been reported to dry up during drought conditions and a reduction in flow contributions from Reaches 1 and 2 may be experienced during drought permit implementation.

In Reach 1, there is potential for refugia (e.g. deep pools) in which fish may remain during autumn. Fish may also move downstream into deeper water as the watercourse levels drop. The reduction in flows and water level could lead to increased stress in fish species. It is noted that if fish stranding occurs due to natural drought related impacts, it is likely that fish rescues by the Environment Agency will be undertaken to remove fish from isolated pool habitats. Conversely, Reach 2, which dries up more frequently is considered less sensitive to potential impacts identified for Reach 1.

The most significant impact is likely to occur during the drought permit is the period of spawning for brown trout (typically spawn in November, with egg incubation taking place up until March). However, the likelihood of reduced flows in the River Churn at the time of spawning for brown trout is high under natural drought conditions (without drought permit implementation). This could explain the low abundance of brown trout, indicative of poor recruitment, in the River Churn. Considering this, the drought permit is considered to have a medium impact on brown trout related to the prevention of spawning. The magnitude of impact considers the likelihood of desiccation, the impact likely to be attributable to a drought permit and the resilience of the population present to recover from this.

Most other species present will spawn in spring (see **Table 4.39**) Following the principle above, hydrological impacts on the spawning of fish species present are unlikely to occur. However, the potential for hydrological impacts to extend into this spawning period is possible, depending on rainfall during the hydrological winter, therefore any impacts are likely to be of greater magnitude as the spawning period of these species is not often affected by reduced flows. Although there is a likely impact

on the spawning habitat for fish species, the mobile nature of the species is likely to ensure the community recovers in the medium term. Overall, impacts due to delay to spawning in Reach 1, 2 and 3 are summarised as of medium and low magnitude respectively, during the spawning period (November to April) and negligible throughout the rest of the year.

Despite no records, delay to the upstream passage of migratory European eel (elver) into reaches may be affected if the delay to flow recovery extends into spring (April), with the possibility of individuals congregating at the downstream end of obstacles being at an increased predation risk.

Overall, the only risk of water quality deterioration has been identified as low due to changes in dissolved oxygen saturation in Reach 3. The impact has the potential to result in fish mortality or emigration from the impacted reaches, however, as this is likely to occur naturally in low flow/drought conditions without a drought permit, the species are likely to return to baseline levels quickly. Considering the baseline status of fish species and the likely resilience of species present as a result of the intermittent nature of flow in the reaches, the impacts of water quality deterioration on fish is considered likely to be of low magnitude in Reach 3 from November to May, and negligible throughout the rest of the year.

Hydrological impacts within Reach 4 and 5 have been assessed as negligible and therefore the features will not be impacted within these reaches.

Table 4.40 Summary of Impacts on Fish Community

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 - River Churn				
Fish	Loss of or reduction in extent of spawning habitat for different species	District	Medium (November to May)	**Minor**
	Increased stress and predation on species in refuges as a result of delay in recovery of flows	District	Negligible (June to October)	**Negligible**
Reach 2 - River Churn				
Fish	Loss of or reduction in extent of spawning habitat for different species	District	Medium (November to May)	**Minor**
	Increased stress and predation on species in refuges as a result of delay in recovery of flows	District	Negligible (June to October)	**Negligible**
Reach 3 – River Churn				
Fish	Reduction in species abundance or distribution as a result of changes in water quality, in particular dissolved oxygen.	District	Low (November to May)	**Minor**
		District	Negligible (June to October)	**Negligible**

During drought permit implementation, there is a risk of short-term deterioration in WFD status of the fish component of the River Churn (Source to Perrott's Brook) waterbody (GB106039029810) and River Churn (Baunton to Cricklade) waterbody (GB106039029750). Impacts of drought permit implementation on the fish community have been summarised as **minor** significant impacts medium adverse, short-term, temporary and reversible in November to May and **negligible** between June to October. The Source to Perrott's Brook waterbody is classified as moderate status for fish under 2019 RBMP2, an increase from the 2009 RBMP1 assessment which classified this waterbody as poor. Consequently, the fish component of the River Churn (Source to Perrott's Brook) waterbody is considered to be at **minor** risk of short-term deterioration. The River Churn (Baunton to Cricklade) waterbody is classified good status for fish under 2019 RBMP2. This represents an increase in ecological quality as in the 2009 RBMP 1 assessment, where this waterbody was previously bad. There is a **minor** risk of short-term habitat deterioration.

Diatoms

Baseline

The impacted reaches of the River Churn include two WFD water bodies: River Churn between its source and Perrott's Brook (GB106039029810) and the River Churn between Baunton and Cricklade (GB106039029750). The diatom component of both WFD water bodies have not been classified under the RBMP2 assessment, however, the diatom component of the former was classified as poor under RBMP1.

Two datasets from one Environment Agency monitoring station were provided for diatoms in the impacted reaches of the River Churn. The monitoring site South Cerney Outdoor Education Centre recorded diatom metrics in spring and autumn 2014. Results can be viewed on **Figure 4.31**.

Whilst the 2006 drought permit Thames Water EAR[69] did not provide any baseline information on diatoms, the walkover survey conducted for the 2006 drought permit noted epiphytic diatoms present on submerged vegetation, suggesting blanketing of macrophytes by diatoms can occur under natural conditions.

[69] Baunton Drought Permit Environmental Report Draft Final Report, Autumn Assessment Period (August 2006 to March 2007). Prepared by Scott Wilson on behalf of Thames Water, September 2006

Figure 4.32 Diatom EQRs for Reach 3

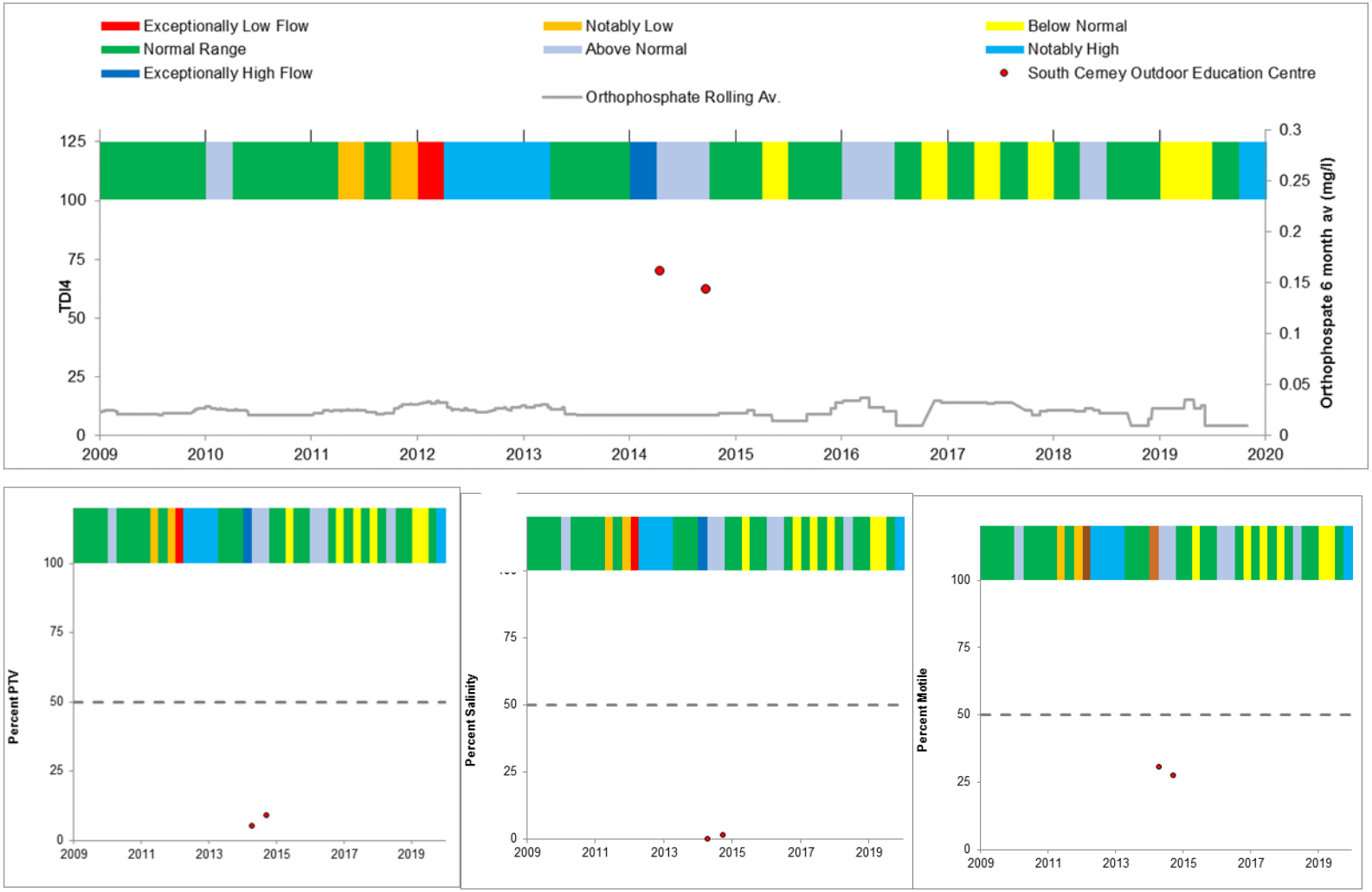
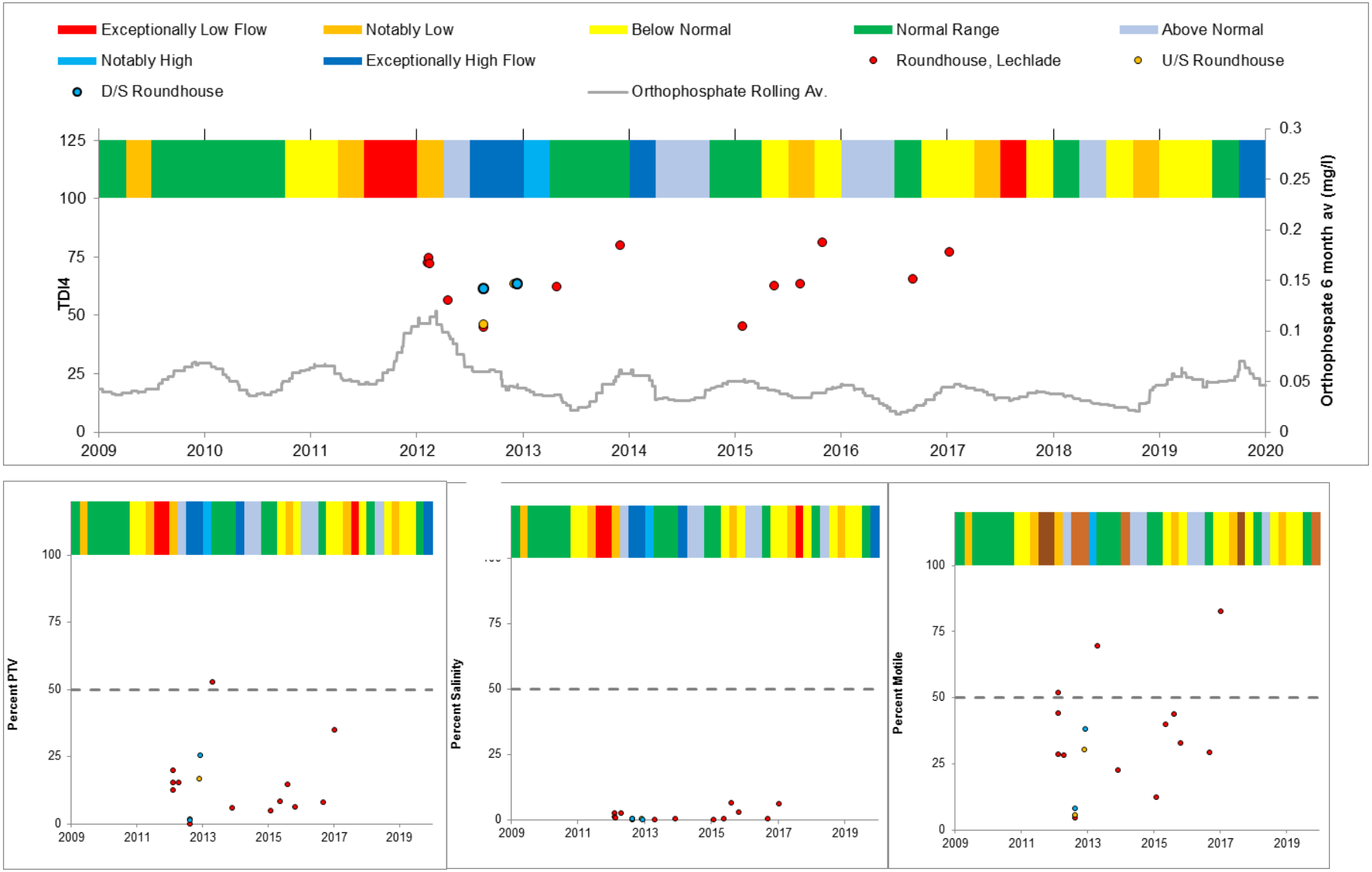


Figure 4.33 Diatom EQRs for Reach 5



Assessment

Species composition of the diatom community is most dependent on nutrient levels (notably SRP), whilst flow and grazing pressure (e.g. by invertebrates) governs the 'thickness' of the diatom biofilm. Slowing of flows can shift the community away from sessile towards more motile taxa (i.e. that are able to live in a thicker biofilm) and those that grow on stalks. In addition, changes in grazing pressure.

The principal concern regarding impacts on the diatom community is the potential for reduction in flow resulting in significantly increased areas of standing water where certain diatom taxa could proliferate. The water quality assessment suggests there is no risk of changes to the community as a result of changes in SRP.

The hydrological impact is associated over the hydrological winter. This impact could allow for an extended period where conditions allow for the proliferation of species, however, there will be a progressive recovery in the watercourse ensuring the diatom community returns to baseline conditions. The reduction in flow and velocity could impact the diatom community through an increase in standing or slow water in the impacted reaches potentially resulting in an alteration to the community present, increasing the thickness of the biofilm (as a result of reduced scour) and skewing the community to more motile taxa. This may result in short-term, temporary and reversible alteration to the diatom community. The overall value of the diatom community is considered to be of site-only value.

There is no risk to water quality deterioration in Reaches 1 and 2 and therefore no potential for impacts on the diatom community. The risk of water quality deterioration in Reach 3 could impact the diatom community. However, the principal risk is associated with a reduction in dissolved oxygen, which is identified as low, with a negligible risk to ammonia. Consequently, the impact magnitude in Reach 3 will be negligible, with the community returning to baseline conditions once flows have returned to normal.

Hydrological impacts within Reach 4 and 5 have been assessed as negligible and therefore, the features will not be impacted within these reaches.

A summary of the impacts is provided in **Table 4.41**.

Table 4.41 Summary of Impacts on Diatom Community

Species	Impact	Ecological Value of Feature	Impact Magnitude	Significance of Impact
Reach 1 - River Churn				
Diatoms	• Alteration to community composition as a result of delayed recovery of flows in the watercourse • No risk as a result of water quality	District	Low	**Minor**
Reach 2 - River Churn				
Diatoms	• Alteration to community composition as a result of delayed recovery of flows in the watercourse • No risk as a result of water quality	District	Low	**Minor**
Reach 3 – River Churn				
Diatoms	• Alteration to community composition as a result of reduced flow contributions from Reach 1 and Reach 2. • No risk as a result of water quality (dissolved oxygen levels do not affect diatoms)	District	Low	**Minor**

Impacts of drought permit implementation on the diatom community have been summarised as minor adverse, short-term, temporary and reversible. As the diatom status element has not been classified in the identified WFD water bodies, an assessment of the risk of deterioration in status is not applicable. However, if the diatom component of the water bodies were designated, the risk to short term deterioration in status is considered to be no more than minor.

Groundwater Body Status

WFD groundwater body status is a relatively 'coarse' feature to use for screening with respect to groundwater impacts. WFD groundwater bodies can be significant in size and the assessment for groundwater status involves the use of long term average data sets for the groundwater body as a whole. It is noted that the potential drought permits, and orders could result in a decrease in groundwater level and/or a delay in recovery of groundwater levels, but groundwater infiltration rates will not be impacted.

However, as groundwater levels could be impacted, the potential risk to WFD status in the context of GWDTEs has been considered.

North Meadow and Clattinger Farm SAC is located within reach three, close to the River Churn confluence with the River Thames. The North Meadow and Clattinger Farm SAC site represents an exceptional survival of the traditional pattern of management for hay meadows with unique vegetation communities. Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*) are an Annex I habitat. The site also contains a very high proportion of snake's head fritillary (*Fritillaria meleagris*) (greater than 90% of the surviving UK population), a nationally rare species highly characteristic of unimproved damp lowland meadows.

The Cotswolds Water Park SSSI is located within Reach 3 and is formed of over a hundred lakes within the Upper Thames floodplain in south-east Gloucestershire and north-west Wiltshire. There are two predominant types of lakes, one type which is rich in stoneworts, a group of large freshwater algae, and the second type which is associated with more nutrient-rich water. This second type is richer in species and is typified by Canadian waterweed (Elodea Canadensis) and common duckweed (*Lemna minor*).

The rich grassland found within the Wildmoorway Meadows SSSI is characterised by crested dog's-tail (Cynosurus cristatus) and common knapweed (Centaurea nigra). More than twenty species of grass and sedge are present including abundant quaking-grass (Briza media), and sweet vernal-grass (Anthoxanthum odoratum). Many herbs typical of old meadows occur, including cowslip (Primula veris), betony (Stachys officinalis), pepper saxifrage (Silaum silaus), ox-eye daisy (Leucanthemum vulgare) and green-winged orchid (Orchis morio). Locally, in wetter areas, meadowsweet (Filipendula ulmaria), reed canary-grass (Phalaris arundinacea) and ragged-robin (Lychnis floscuculi) are frequent together with southern marsh-orchid (Dactylorhiza praetermissa). Scattered scrub has developed in part of the site and several old trees of the native form of black poplar (Populus nigra var. betulifolia), occur in the hedgerows.

The North Meadow SSSI forms part of the North Meadow and Clattinger Farm SAC and is therefore also designated for its lowland meadow habitat. Over 250 species of higher plant occur on the meadow, including abundant grasses such as red fescue, perennial rye-grass, meadow foxtail, crested dog's tail and yellow oat-grass. meadow brome, meadow barley, adder's tongue, common meadowrue and ragged robin are also present, alongside herbs such as pepper saxifrage, yellow rattle, great burnet, and black knapweed. This SSSI contains a large population of snake's head fritillary, with approximately 500,000 plants flowering each year. It is estimated that this SSSI supports around 80% of the British population of wild fritillary plants.

Winson Meadows SSSI is a water meadow composed of neutral grassland and marshy areas. Marshy grassland occurs in two main areas, with vegetation dominated by jointed rush (Juncus articulates), and meadowsweet (Filipendula ulmaria). Yellow flag (Iris pseudacorus), ragged robin (Lychnis flos-cuculi), marsh marigold (Caltha palustris) and southern marsh orchid (Orchis praetermissa) are also present.

Due to the lack of information available for Perrott's Brook Marsh & Copse KWS (a non-statutory designated site), an assessment of aerial photography was undertaken, which identified the site supports a number of waterbodies immediately surrounded by woodland, with arable fields beyond. The site is likely to be hydrologically linked with local groundwater and surface water being a mixture of riparian and wetted habitats adjacent to the River Churn.

Due to the lack of information available about the Stratton Fooball Pitch Dew Pond KWS (a non-statutory designated site), an assessment of aerial photography was undertaken which identified that the site is surrounded by improved grassland with arable fields beyond. The site is not likely to be hydrologically linked with local groundwater (dew ponds have an impermeable base to hold water) although it may be linked to surface water flow (e.g. for replenishment) as the dew pond is located on the flood plain adjacent to the River Churn.

Due to the lack of information available for the River Thames or Isis LWS that has been available for this non-statutory designated site, an assessment of aerial photography was undertaken within the impacted reaches. Reach 3 is a tributary of the River Thames or Isis LWS which flows from WFD waterbodies Key (Source to Thames to Thames (Churn to Coln). Although the LWS will not be directly impacted by the impacts of the drought permit, the water course will receive reductions in flow from Reach 3 which may impact the LWS.

Cerney Wick Meadows LWS is located adjacent to River Churn and an unnamed watercourse which is a tributary of the River Churn. The section of the River Churn is an impacted reach of Baunton 1 drought option. The site consists of neutral grassland with marsh, bog, swamp and tall herb fen habitats. These habitats are water dependent. The site is located on rock with essentially no groundwater and mudstone bedrock.

Cotswold Water Park LWS (West) is a multipart site consisting of new, developing and well-established gravel pits and lakes, situated in the upper Thames Valley, south of Somerford Keynes and South Cerney. The lake complex continues over the border into Wiltshire and is adjacent to the River Churn. There are several areas of the LWS which are partially within the 100m buffer of the impacted reaches of River Churn. The LWS has bird and invertebrate interest. There is limited information on the species and habitats associated with the LWS, however, being lakes and gravel pits, these are likely to be water dependent.

Lake 6 Gateway (Cotswold Water Park) LWS is a multipart site consisting of new, developing and well-established gravel pits and lakes, situated in the upper Thames Valley, south of Somerford Keynes and South Cerney. The lake complex continues over the border into Wiltshire and is adjacent to the River Churn. There are several areas of the LWS which are partially within the 100m buffer of the impacted reaches of River Churn. The LWS has bird and invertebrate interest. There is limited information on the species and habitats associated with the LWS, however, being lakes and gravel pits, these are likely to be water dependent.

Crane Farm LWS is a mosaic of wetland vegetation and is of botanical interest. Habitats within the LWS are therefore, water dependent. The northern half of the LWS (furthest away from the River Churn) is located on a highly productive aquifer and the southern half is located on rocks with essentially no groundwater. The majority of the bedrock is mudstone with a small area limestone.

The River Churn LWS has riparian vegetation and qualifies as a LWS due to mammal interest (although no specific species is mentioned, it is assumed this is either water vole or otter). Therefore, habitats and species within the LWS are water dependent. The northern two thirds of the LWS are located on a highly productive aquifer, whilst the southern third is located on rocks with essentially no groundwater. There is a mixture of mudstone and limestone bedrock.

Assessment

The hydro-ecology of North Meadow and Clattinger Farm SAC and the impact of licensed abstractions were the subject of detailed study as part of Stage 3 Review of Consents. The study considered the impact of abstractions on flows in the River Thames and River Churn and used an existing model to predict the likely changes in vegetation composition given a range of stream flows. The conclusion was that the cumulative effect of all the abstractions licensed by the Environment Agency on North Meadow and Clattinger Farm SAC were insignificant, as the site is isolated from the influence of aquifer water levels by clays. Therefore, while the Review of Consents assessed the existing abstraction licence at

Baunton (rather than the Baunton drought permit), the hydrogeological situation remains the same: the Baunton abstraction is hydrologically isolated from the SAC site. The magnitude and significance of impact is therefore considered to be negligible.

Lakes in the Cotswold Water Park SSSI are hydrologically connected to the River Churn through superficial river terrace deposits. It is noted that at low flow periods the River Churn can lose some flow to the adjacent pits, confirming that they are in connectivity. The drought permit would lead to a reduction in flows that would manifest as a reduction in levels, velocities and wetted widths within the River Churn.. Uncertainty remains regarding impacts to the site and therefore, monitoring is recommended.

The Wildmoorway Meadows SSSI are unimproved species-rich neutral grassland which are underlain by alluvium and gravels of the Thames floodplain, with ridge and furrow visible over much of the site. Species associated with damp conditions are likely to depend on overland surface flow, which remain in the furrows, but not water levels from the River Churn. The magnitude and significance of impact is therefore considered to be **negligible**.

No impacts are anticipated on the lowland meadow habitat, including the population of snakehead fritillary, see North Meadow and Clattinger Farm SAC assessment above. There appears to be some connectivity between the diches that are associated with the SSSI and the River Churn, hence potential impacts on this habitat have been assessed in more detail.

Uncertainty surrounds the water level management practice at the site. Most aquatic plants highlighted as SSSI features are marginal and can withstand some degree of desiccation/periodic low water levels. There is, therefore, only a risk of an effect in case of a prolonged drought that could result in little to no water remaining in the ditches for a longer period of time. The aquatic macrophyte species highlighted are indicative of good water quality and suggest that the ditches are fed by wet flushes and/or surface water runoff but not groundwater or river water exclusively. It is also noted that most species are highly sensitive to increases in nutrient levels. The impacts will also occur outside of the aquatic macrophyte growing phase (between October and March). The potential impact on flows in the lower River Churn (Reach 3) is considered to be minor at most.

The magnitude and significance of impact is therefore, considered to be a precautionary low magnitude and reversible, therefore of **minor** significance (uncertain).

The Winson Meadows SSSI is upstream of the hydrologically impacted reach of the River Coln and therefore, will not be impacted by changes to flows and levels in this reach. The site lies on the Great Oolite aquifer, while the drought permit abstraction is from the Inferior Oolite aquifer. It has been identified that there is some connectivity between the two aquifers through fissures and therefore, it is possible that groundwater levels in the site could be affected by the drought permit. As the majority of the water levels are dependent on the Great Oolite aquifer which is not affected by the drought permit, any hydrological impact is considered to be of low or negligible magnitude, no significant impacts on the designated features of the site are anticipated.

The Whelford Meadows SSSI This site is located adjacent to the Reach 5 and there is uncertainty regarding the influence of the River Coln on the habitat and species assemblage of the Whelford Meadow SSSI. As it is does contain a number of water-dependent species, it is possible that the Whelford Meadow SSSI may be periodically inundated and therefore any drop in flow in the River Coln associated with the implementation of the drought permit may have an impact on the designated site. However, the hydrological assessment has concluded negligible impacts to the watercourse and therefore, the impact on the Whelford Meadows SSSI is likely to be low, short-term and reversible and is considered to be negligible.

No data is available for Perrott's Brook Marsh and Copse LWS. It is important to consider potential impacts in light of baseline conditions in which the movement of water from the aquifer to surface water bodies can stop in dry summers, as evident from the hydrograph data at Perrott's Brook (**Section 4.4.2.2**). Although there is uncertainty regarding the connectivity of the water dependent features of this

site to either surface water or groundwater, the designated site is likely to be resilient to some degree to the impacts of desiccation as a result of reduced surface water and groundwater levels. Consequently, the impact magnitude is not considered to be greater than medium, which equates to a **minor** significance of impact on this site of local value.

The impact on the Stratton Football Pitch Dew Pond needs to be considered in light of the baseline conditions, in which possible replenishment of the Dew Pond from surface water runoff is inconsistent, therefore, the likelihood the dew pond dries up intermittently is high. Although there is uncertainty regarding the connectivity of the water dependent features of this site to either surface water or groundwater, the designated site is likely to be resilient to some degree to the impacts of desiccation as a result of reduced surface water or groundwater input. Consequently, the impact magnitude is considered to be low, which equates to a negligible significance of impact on this site of local value.

Throughout its length, the River Thames lies on clay and is not in direct connectivity with the Great Oolite aquifer. Reach 3 is a tributary of the River Thames or Isis LWS, the water course will receive reductions in flow from Reach 3 as a result of the drought permit which may impact the LWS. The drought permit would lead to a reduction in winter flows that would manifest as a reduction in levels, velocities and wetted widths.

Flow in the River Ray (Ray at Eaton flow gauge) was examined and it was determined that flow in this river is normally at least 40Ml/d at all times. This is because Swindon STW discharges an average (between February 2005 and December 2015) of 45.6 Ml/d into the River Ray upstream of its confluence with the River Thames. The River Ray enters the River Thames approximately 1.2km downstream from the confluence with Ampney Brook. During dry periods, this would be the predominant flow in the downstream river and the river characteristics will reflect this level of relatively constant flow. Thus, any of the upstream impacts of the drought permit on the River Thames are considered to be negated downstream of the confluence with the River Ray. In addition, the size of the River Thames or Isis LWS will dilute impacts Reach 3 given the number of tributaries across the length of the watercourse. The magnitude and significance of impact is therefore considered to be **minor.**

The Cerney Wick LWS is located on superficial alluvium, sands & gravels overlying Oxford clay, as a result, no impacts on reduced groundwater availability is anticipated. However, as the site boundary includes the River Churn (Impacted Reach 3) it is uncertain if the marsh habitat relies on water supply from the river. The drought permit would lead to a reduction in winter flows that would manifest as a reduction in levels, velocities and wetted widths. This may impact the periodic inundation of the marsh, bog, swamp and tall herb fen habitats dependent on their position within the site. As such information is not available, impacts cannot be ruled out. The magnitude and significance of impact is therefore considered to be **minor** significance of impact on this site of local value.

Several areas of the Cotswold Water Park LWS are within close proximity to the impacted Reach 3 of the Baunton (1) drought option. The drought permit would lead to a reduction in flows that would manifest as a reduction in levels, velocities and wetted widths within the River Churn. Uncertainty remains regarding impacts to the site and therefore monitoring is recommended.

Lakes in the Lake 6 Gateway (Cotswold Water Park) LWS are hydrologically connected to the River Churn through superficial river terrace deposits. It is noted that at low flow periods the River Churn can lose some flow to the adjacent pits, confirming that they are in connectivity. The drought permit would lead to a reduction in flows that would manifest as a reduction in levels, velocities and wetted widths within the River Churn. Uncertainty remains regarding impacts to the site and therefore monitoring is recommended.

Crane Farm LWS is located on Superficial alluvium, sands & gravels overlying Kellaways Clay. The connectivity between the LWS and the River Churn (Impacted Reach 3) is uncertain if the wetland habitat relies on water supply from the river or groundwater influences. The drought permit would lead to a reduction in winter flows that would manifest as a reduction in levels, velocities and wetted widths.

As such information is not available, impacts cannot be ruled out. The magnitude and significance of impact is therefore, considered to be **minor** significance of impact on this site of local value.

Impacts within the River Churn are discussed in detail within **Section 4.5.2**. The drought permit would lead to a reduction in autumn and winter flows that would manifest as a reduction in levels, velocities and wetted widths. This would be limited to the period of drought permit implementation. Features assessments for species within the River Churn are discussed in **Section 4.7.2 to 4.7.4.** As a result, the impacts associated with the implementation of the drought option to the features assessed below the significance of impact to the River Churn LWS concluded as **Moderate**.

4.7.4.1 Summary

The assessment has indicated the implementation of the drought permit will result in minor impacts on the macroinvertebrate community for all reaches. The risk to the macrophyte community is considered to be minor from April to May in Reaches 1 and 2 and negligible for the remainder of the year, while the risk is negligible in Reach 3 for the whole year. The risk to the fish community is minor from April to May in all reaches and is considered to be negligible for the remainder of the year. The risk to the diatom community is considered to be minor for Reaches 1, 2 and 3.

The DP may, in the short-term, compromise the ability of planned programmes of measures to meet the objectives of features to be effective in their objectives, introducing a short-term delay in achieving objectives but not compromising their long-term effectiveness. In such circumstances the DP would not compromise the objectives of WFD Article 4.8 in terms of introducing permanent impediments to achieving Good Ecological Status.

4.7.5 Priority substances, priority hazardous substances and other pollutants

The screening exercise (**Section 4.4.2.7**) did not identify any reaches requiring further assessment for water quality impacts from priority substances, priority hazardous substances and other pollutants associated with discharges in relation to the Baunton (1) drought permit implementation.

4.7.6 Summary

Table 4.42 summarises the significance of impacts identified from the assessment of designated sites, NERC features and other ecologically significant receptors and their relevant reaches.

Table 4.42 Significance of Impact to Environmental Features Screened to be Assessed for the Baunton (1) Drought Permit

River Reach (Impact)	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Designated Sites					
North Meadow and Clattinger Farm SAC and NNR	N/A	N/A	Negligible	Negligible	N/A
North Meadow SSSI	N/A	N/A	Minor (uncertain), macrophytes only.	Negligible	N/A
Cotswold Water Park SSSI	N/A	N/A	Minor (uncertain)	Negligible	Negligible
Whelford Meadows SSSI	N/A	N/A	N/A	N/A	Negligible
Wildmoorway Meadows	N/A	N/A	Negligible	Negligible	N/A
Perrott's Brook Marsh LWS	Minor	N/A	N/A	N/A	N/A
Stratton Football Pitch Dew Pond KWS	N/A	Negligible	N/A	N/A	N/A
River Thames or Isis LWS	N/A	N/A	Minor	N/A	N/A
Cerney Wick Meadows LWS	N/A	N/A	Minor	N/A	N/A
Cotswold Water Park LWS (west)	N/A	N/A	Minor (uncertain)	N/A	N/A
Lake 6 Gateway (Cotswold Water Park) LWS	N/A	N/A	Minor (uncertain)	N/A	N/A
Crane Farm LWS	N/A	N/A	Minor	N/A	N/A
River Churn LWS	Moderate	Moderate	Moderate	N/A	N/A
Coastal and floodplain grazing marsh	Minor	Minor	N/A	N/A	N/A
WFD Status/Potential Receptors					
WFD Waterbody	River Churn (Source to Perrott's Brook) (GB106039029810)	River Churn (Baunton to Cricklade) (GB106039029750)		Frome - Ebley Mill to confluence River Severn (GB109054032470)	Coln (Source to Coln Rogers) GB106039029990 and Coln (from Coln Rogers) and Thames (Coln to Leach) GB106039029992
Macroinvertebrates	Minor	Minor	Minor	Negligible	Negligible
Macrophytes and phytobenthos	Minor	Minor	Minor	Negligible	Negligible
Fish	Minor	Minor	Minor	Negligible	Negligible
Burford Jurassic WFD groundwater body (GB40601G600400)					
Quantitative Dependent Surface Water Body Status	Negligible	Negligible	Negligible	Negligible	Negligible

River Reach (Impact)	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Quantitative GWDTEs test	Minor	Negligible	Minor	Negligible	Negligible
Quantitative Saline Intrusion	Negligible	Negligible	Negligible	Negligible	Negligible
Quantitative Water Balance	Negligible	Negligible	Negligible	Negligible	Negligible
Kemble Forest Marble WFD groundwater body (GB40602G600500)					
Quantitative Dependent Surface Water Body Status	Negligible	Negligible	Negligible	Negligible	Negligible
Quantitative GWDTEs test	Negligible	Negligible	Negligible	Negligible	Negligible
Quantitative Saline Intrusion	Negligible	Negligible	Negligible	Negligible	Negligible
Quantitative Water Balance	Negligible	Negligible	Negligible	Negligible	Negligible
NERC Receptors (based on reaches)					
Fine-lined pea mussel	Moderate	Moderate	Moderate	Negligible	Negligible
Brown trout	Moderate	Moderate	Moderate	Negligible	Negligible
Lamprey sp.	Moderate	Moderate	Moderate	Negligible	Negligible
European eel	Moderate	Moderate	Moderate	Negligible	Negligible
Ecologically Significant Receptors					
Ranunculus sp.	Minor (April and May only) Negligible (June to March)	Minor (April and May only) Negligible (June to March)	Negligible	Negligible	Negligible
R. cupreus, R. subviolaceus, Rhyacophila fasciata, T. unicolor, T. dives	Moderate	Moderate	Moderate	Negligible	Negligible
Bullhead	Moderate	Moderate	Moderate	Negligible	Negligible
Invasive species					
Potamopyrgus antipodarum	Minor (uncertain)	Minor (uncertain)	Minor (uncertain)	Negligible	Negligible
Zebra mussel	Minor (uncertain)	Minor (uncertain)	Minor (uncertain)	Negligible	Negligible
Crangonyx pseudogracilis	Minor (uncertain)	Minor (uncertain)	Minor (uncertain)	Negligible	Negligible
Dugesia tigrina	Minor (uncertain)	Minor (uncertain)	Minor (uncertain)	Negligible	Negligible
Pacifastacus leniusculus	Minor (uncertain)	Minor (uncertain)	Minor (uncertain)	Negligible	Negligible
Physa acuta	Minor (uncertain)	Minor (uncertain)	Minor (uncertain)	Negligible	Negligible
Japanese knotweed	Minor (uncertain)	Minor (uncertain)	Minor (uncertain)	Negligible	Negligible
Giant hogweed	Minor (uncertain)	Minor (uncertain)	Minor (uncertain)	Negligible	Negligible
Himalayan balsam	Minor (uncertain)	Minor (uncertain)	Minor (uncertain)	Negligible	Negligible
Other Receptors					
Other Abstractors	Negligible	Negligible	Negligible	Negligible	Negligible

4.8 Residual Impact

Should the identified mitigation measures be effectively applied in all situations in a timely manner, it is anticipated that the identified magnitude of impacts, and in some cases the significance of impacts, will be reduced (see **Chapter 6**). Should the application of mitigation measures applicable during the drought permit implementation period not reduce the impact magnitude or significance, compensatory measures such as restocking will be considered to help ensure pre-drought conditions return and reduce the significance of any post-drought permit impacts.

4.9 Environmental Monitoring Programme

Any monitoring and mitigation proposed for the impacts resulting from the implementation of the Baunton (1) drought permit are presented in **Chapter 6**.

4.10 Cumulative Impacts

Potential cumulative impacts between the SWOX WRZ drought permits with other drought permits in Thames Water DP and any other neighbouring Water Companies DP options are presented in **Chapter 7**.

5 Habitats Regulations Assessment

5.1 Introduction

The Environment Agency's DPG2020 specifies that a water company must ensure that its DP meets the requirements of The Conservation of Habitats and Species Regulations 2017. The DPG2020 refers to guidance relating to Habitats Regulations Assessment (HRA) that can be used which includes the UK Water Industry Research (UKWIR) report 'Strategic Environmental Assessment and Habitat Regulations Assessment - Guidance for Water Resources Management Plans and Drought Plans'[70]. The UKWIR report recommends that all DPs should be subject to the first stage of HRA, i.e. screening for Likely Significant Effects (LSEs).

Under Regulations 63 and 105 of the Habitats Regulations 2017, any plan or project which is likely to have a significant effect on a Habitats site (SAC, SPA or Ramsar site), either alone or in-combination with other plans or projects, and is not directly connected with, or necessary for the management of the site, must be subject to a HRA to determine the implications for the site in view of its conservation objectives.

A HRA has been undertaken in accordance with currently available guidance[71,72,73,74] and has been based on a precautionary approach as required under the Habitats Regulations. It has followed the staged HRA approach, commencing with the Stage 1 screening of all options considered within DP 2022. Where a significant effect is likely a Stage 2 Appropriate Assessment is undertaken of the drought option to determine whether this would adversely affect the integrity of the Habitats sites, either alone or in-combination with other plans and projects, taking into account available mitigation measures.

Where sites have been identified as potentially impacted, these have been included for full assessment in the EAR (**Section 4.7**). Information from these assessments has been used to inform the HRA.

This section summarises the outcomes of the Stage 1 Screening (**Section 5.2.1**), Stage 2 Appropriate Assessment (**Section 5.2.2**) and any in-combination effects resulting from implementing the proposed drought permit with other plans and projects (**Section 5.3**), as identified in the HRA.

More detail on the methodology for undertaking the HRA is described in the Thames Water Final Drought Plan 2022 Habitats Regulations Assessment - Screening Report[75].

5.2 Stage 1 – Screening

Thames Water has completed the first stage of the HRA process, screening, for all DP 2022 options. The screening stage identified whether any drought options have the potential to cause LSE on the integrity of a Habitats site(s). A summary of the conclusions of the Stage 1 Screening is presented in **Table 5.1.**Error! Reference source not found.

It should be noted that the information in **Table 5.1** is taken from the HRA (published August 2022). At the time of writing the HRA a drought permit implementation period of April to October was assumed. In light of a Baunton (1) drought permit application for the period November to May, this information has been reviewed. No variations from the summary of LSE provided in the HRA (and **Table 5.1**) resulting from the change in timing have been identified.

[70] UKWIR (2021) Environmental Assessments for Water Resources Planning (21/WR/02/15).
[71] Court of Justice for the European Union's ruling on People Over Wind and Sweetman ('Sweetman II') vs Coillte Teoranta, Case C-323/17.
[72] UK Government (2019). Guidance on the use of Habitats Regulations Assessment.
[73] UK Government (2019). Conservation of Habitats and Species Regulations (Amendment) (EU Exit).
[74] Natural England (2020). Guidance on how to use Natural England's Conservation Advice Packages in Environmental Assessments.
[75] Thames Water Utilities Ltd (2022). Thames Water Final Drought Plan 2022: Habitats Regulations Assessment - Screening Report – Prepared by Ricardo Energy & Environment (17 August 2022).

Table 5.1 Screening of Baunton (1) Drought Permit LSE on Habitats sites

Habitats site[76]	Potential for effects on qualifying features?	Is scheme likely to have a significant effect on Habitats site(s) alone?	Effect in-combination with existing consents?	Effect in-combination with other drought options?
North Meadow and Clattinger Farm SAC (12km)	Construction There is no construction phase associated with this drought option. Operation Lowland hay meadows are classified as groundwater dependent habitats, therefore, there is a potential impact pathway due to a reduction in groundwater level during operation. However, the borehole is located on a highly productive, great oolite group aquifer and the SAC is located on clays that confine the underlying aquifer. Therefore, no hydrological connectivity has been identified between the Habitats site and Baunton (1). No LSEs are anticipated from the operation of the Baunton (1) drought option alone on the North Meadow and Clattinger Farm SAC.	No	No	No

5.3 Stage 2 – Appropriate Assessment

The HRA Stage 1 screening assessment concluded that the Baunton (1) drought permit is not considered likely to have significant adverse effects on the qualifying features of Habitats sites. Therefore, Stage 2 Appropriate Assessment is not required.

5.4 Potential in-combination effects

A summary of the potential in-combination LSEs between the Baunton (1) drought permit with other plans and projects on Habitat sites, as identified in the HRA, are outlined in **Table 5.2** below.

[76] The distances given are to the nearest element of each scheme.

Table 5.2 Potential in-combination effects on Habitats sites as a result of implementing the Baunton (1) drought option with other plans and projects

Plans and projects with potential in-combination effects	In-combination LSE	Potential in-combination effects?
Other DP 2022 options	Potential in-combination effect with Baunton 2 drought permit. However, these would not be operated at the same time, therefore no in-combination effect. Potential in-combination effect with Latton drought permit. However, due to mudstone and clay bedrock, North Meadow and Clattinger Farm SAC is unlikely to be hydrologically connected to groundwater and therefore, no in-combination effects anticipated.	No
WRMP19	No likely significant in-combination effects between the Baunton (1) drought option and WRMP19 have been identified.	No
Environment Agency DPs	Given that the Environment Agency drought actions will have a positive effect on river flows and lake levels and, therefore, the natural environment and ecology, no in-combination effects have been identified and no LSEs anticipated.	No
Other Water Company DPs	No likely significant in-combination effects between the Baunton (1) drought option and other water companies DPs have been identified.	No
Other Water Company WRMPs	No likely significant in-combination effects between the Baunton (1) drought option and other water companies WRMPs have been identified.	No
Other Plans and Projects	No likely significant in-combination effects between the Baunton (1) drought option and other plans and projects have been identified.	No

5.5 Conclusions

To summarise, no Likely Significant Effect (LSE) on the integrity of a Habitats site(s) are anticipated from the implementation of the Baunton (1) drought permit.

6 Environmental Monitoring Plan and Mitigation

6.1 Background and basis of the Environmental Monitoring Plan

The Environmental Monitoring Plan (EMP) has been prepared in support of Thames Water's Drought Plan 2022 and in compliance with the requirements of Section 6 (Environmental Assessment, Monitoring and Mitigation) of the DPG.

Guidance states that in a Drought Plan, a water company must describe the measures they may need to take to restrain the demand for water within their water supply system, obtain extra water from other sources, and how the effects of an environmental drought and those resulting from the application of a drought permit are to be monitored and/or mitigated.

Table 6.1 identifies the specific monitoring and mitigation associated with the Baunton (1) drought permit option and its associated reaches. All monitoring and mitigation measures described are required if the impacts within the reaches identified are as a result of the drought permit rather than of the drought itself.

Where **negligible** or **minor** adverse impacts, from drought permit implementation, are anticipated for identified features, no further monitoring has been recommended in line with recommendations made by the Environment Agency DPG. This methodology can be viewed within the Ricardo Thames Water 'Drought Plan 2022 Environmental Assessment Methodology Report'[77] which has been agreed with the regulators. The environmental assessment has concluded that there are a number of features sensitive to the potential impacts of the drought permit, which are summarised which are summarised in the relevant sections of this EAR including the drought impact.

Control sites are crucial in assessing the ecological impact of flow pressure resulting from water resource activities. They can help determine whether any ecological impact being observed is a result of the water resource activity being investigated, rather than wider environmental influences.

Good control sites for hydroecological assessment should be chosen where there are no significant water quality problems or pressures which could undermine relationships between ecology and flow. Ideally, they must not be affected by the water resource activity being investigated nor have additional water resource activity upstream that could affect the flow regime, however, where baseline abstraction occurs upstream of a control this is also acceptable. It is imperative that they are as similar in nature to the baseline conditions of the impact sites as possible, most importantly in relation to stream size and channel gradient.

Appropriate control sites are listed below:

- Baunton (1) Walkover (Control) - US SP0163809167, DS SP0178308788

The final location of these control sites will be confirmed dependant on consultation with the Environment Agency prior to the application for the Drought Permit.

The final location of this control site has been confirmed prior to the application for the Drought Permit and is included as follows (see **Table 6.1**).

The monitoring programme has been updated from the "shelf copy" EAR to reflect discussions with the Environment Agency and Natural England at the time of application. The updates made to the EMP at the time of application (from "shelf copy" to "application ready" version) have considered:

[77] Ricardo Energy & Environment (2022) Thames Water Drought Plan 2022 Environmental Assessment Methodology, 23 September 2022. Report for Thames Water Utilities Limited

- Any potential changes in the assessment of the hydrological, water quality and geomorphological impacts based on baseline conditions at the onset of drought.
- Any potential changes in the assessment of impacts on environmental features based on baseline conditions at the onset of drought.
- Any changes in assessment and/or monitoring methodologies and biological indices. The iterated and agreed EMP also includes information on the agreed data format, field sheets (this comprises a "River Conditions Assessment Form', the content of which has been agreed with the Environment Agency and Natural England prior to the drought permit application) and quality control to ensure compatibility with Environment Agency systems.

6.2 Environmental Monitoring Plan Guidance

Guidance on the objectives and content of the EMP is given in Section 4 and 5 of the Environment Agency "Drought Plan Guideline Extra Information: Environmental Assessment for Water Company Drought Plans". The issues specified are addressed in subsequent sections of this report.

The guidance states that an EMP should include details of the monitoring required and states this should include:

Baseline monitoring – collection and maintenance of baseline monitoring datasets help understand the nature of the environment under 'normal' circumstances, along with establishing the sensitivity of the environment to changes in flow and any especially sensitive features of interest. Baseline monitoring is also essential in enabling understanding of the actual environmental impact of supply side drought management actions. It allows comparison between the environment under 'normal' conditions against observed environmental datasets during and after a drought.

Onset and In-drought monitoring - to help assess the immediate environmental impacts of drought action during a drought along with informing choices and implementation of mitigation measures. This can be split between pre-permit application (**Onset**) and post-permit implementation (**In-drought**) stages.

Post-drought (recovery) monitoring - to help assess any longer term environmental impacts of, or recovery from, the implementation of drought actions.

It may be possible to **mitigate** or reduce adverse effects on the environment. The guidance states a drought plan should, therefore, identify:

- pre-drought mitigation actions: actions you will implement before or whilst the drought is developing to reduce the likely environmental impact of your proposed actions
- in-drought mitigation actions: actions you will implement during a drought to minimise the environmental impact of your proposed actions
- post drought mitigation actions: actions you will implement following a drought to reduce any environmental impacts that may occur as a result of the actions you implement

The DPG also indicates that a drought plan should provide evidence that the mitigation measures that are proposed will be effective for the features that could be at risk from a drought option. The EMP should show how this will be monitored. The drought plan should also include details of any additional permits or approvals needed to carry out the mitigation measures.

In some cases, mitigation actions may be necessary to prevent derogation of other abstractions (for example, by providing alternative supplies if feasible).

6.3 Biosecurity

Biosecurity is a major issue across the UK to prevent disease and pathogen transfer and the spread of non-native invasive species; drought conditions can increase some of these risks but reduce others. It is important that prior to commencing any monitoring or implementing any mitigation measures, a

biosecurity risk assessment is completed to highlight the risks relating to the proposed activities and ensure good working practice is followed. A biosecurity plan should be prepared to set out the risks and the prevention measures (or mitigation measures should adverse effects arise). This will be implemented by documenting this (alongside other environmental and health and safety risks) in the "Site Visit Risk Assessment and Methodology" form that will be completed by the field surveyors prior to undertaking any fieldwork.

During a drought, Thames Water will work with the Environment Agency, Natural England, and, if necessary, landowners (e.g. CLA) and the agriculture sector (e.g. NFU) as appropriate to promote the importance of biosecurity measures at times of low flows. This could include joint press releases and website messages. A joint message is likely to have the greatest impact, rather than one organisation working in isolation.

6.4 Baseline Monitoring

6.4.1 Routine Baseline Monitoring

Baseline monitoring is required to assess the baseline sensitivity of the receiving environment outside of environmental drought conditions and to identify impacts of the drought options over and above the effects of environmental drought. A comprehensive review of existing baseline information relating to Thames Water supply-side drought options has been carried out in preparation of the Thames Water Drought Plan. The adequacy of these data has been reviewed and consideration has been made as to whether there is a need for further baseline monitoring to reduce uncertainty regarding the presence or distribution of important features, which will be updated through the review of the assessment.

The use of existing monitoring sites (for Environment Agency and Thames Water monitoring programmes) and standard methodologies applied in data collection are recommended, where possible. It should be noted, however, that not all existing monitoring sites are necessarily required to feed into Drought Permit assessments. This baseline monitoring programme is customised to the individual sites associated with a particular drought option and the sensitive features known to be present within proximity to the site. Where initial assessment of sensitive features (following the Environment Agency DPG) identified a lack of data to inform full assessment and subsequent sensitivity was classed as 'uncertain', further surveys have been recommended to inform detailed assessment (see section below).

To assist in the development of potential drought permit or order applications identified in its DP, to further inform the environmental assessments and to reduce uncertainty, Thames Water has made a commitment to undertake additional baseline environmental surveys, where appropriate.

Baseline monitoring has been ongoing since 2012 following the preparation of the EARs and comprised a walkover using a bespoke methodology developed by Cascade, Cascade Hydro-Ecology Walkover (CHEW) approach. The initial walkover survey also identified key 'monitoring/surveillance' reaches, based on selection of the most appropriate or significantly impacted reaches. Targeted macroinvertebrate and fisheries surveys have been undertaken and the results are outlined in the individual drought permit baseline sections for each environmental feature.

A number of Baseline Environmental Monitoring Reports (BEMRs) have been produced which are of relevance to the SWOX WRZ, these include:

- Baunton (1): 2015[78] (containing 2012-2015 data), 2017[79], 2018[80] and 2019[81]

On completion of the initial monitoring programme (2012 to 2015) and following review of the recommendations made in the EARs for DP 2017, it was recommended that monitoring should continue to be undertaken at appropriate intervals to ensure baseline information is robust to support any future application for drought powers. The baseline monitoring programme has been developed using best practice guidelines where appropriate, including JNCC Common Standards Monitoring Guidance[82] and WFD classification requirements[83]. This monitoring programme was developed based on the 2011 DPG[84] and also complies with the ecological monitoring methods in the DPG2020.

Future monitoring will be reasonable and practicable and will be subject to further discussion with the Environment Agency and Natural England. Baseline monitoring has been undertaken between 2020 and 2022, and further monitoring has been specified and is planned to continue to 2024.

The relevant monitoring approaches applied in the baseline monitoring programme have been set out in the sections below. It is noted that, where applicable, these methodologies will also be used for monitoring at the onset, in and post drought to inform the impacts associated with the implementation of a drought permit/order.

6.4.2 Physical Environment

6.4.2.1 Environment Agency Surveys

The Environment Agency routinely monitor a number of sites within identified potentially impacted reaches as part of EU Water Framework Directive (WFD) monitoring programmes. These monitoring surveys can also be utilised for in-drought and post-drought assessments. Monitoring includes the following key elements:

- River flow monitoring at a series of gauging stations
- Physico-chemical water quality monitoring at sites on all the main rivers for parameters outlined in the 2010 Defra Directions (carried out for WFD and other purposes).

6.4.2.2 Hydrology (River Flows and Water levels)

River flow data assist the baseline understanding of the river catchment, establish the zone of influence of the drought options and assist in the differentiation of drought-related impacts and drought options on hydrology and hydro-ecology.

To ascertain the hydrological impacts of the various drought options, a variety of different hydrological/hydrometric datasets were obtained. These generally came from either the Environment Agency, Thames Water or the Centre of Ecology and Hydrology's (CEH) national river flow archive website. The existence of each data type, around each of the drought options, was dependent on the site specific details of each of the drought options.

Long-term flow records show the typical variation of flow within a watercourse over time. Statistics on flow can be obtained for long term datasets. Typical statistics include median flow and infrequent high and low flows. Of relevance for drought studies are the low flow statistics, such as Q_{95} which represents flow equalled or exceeded for 95% of days in the measured record.

[78] Cascade Consulting (2016) Baseline Environmental Monitoring Report – Baunton Drought Permit, August 2016. Report for Thames Water Utilities Limited.
[79] Ricardo Energy & Environment (2019) Baseline Environmental Monitoring Report (2017) – Baunton Drought Permit. Report for Thames Water Utilities Limited
[80] Ricardo Energy & Environment (2019) Baseline Environmental Monitoring Report (2018) – Baunton Drought Permit. Report for Thames Water Utilities Limited
[81] Ricardo Energy & Environment (2020) Baseline Environmental Monitoring Report (2019) – Baunton Drought Permit. Report for Thames Water Utilities Limited
[82] JNCC (2014) Common Standards Monitoring Guidance for Rivers, ISSN 1743-8160
[83] European Parliament (2000) Directive 2000/60 EC The Water Framework Directive: Annex V
[84] Environment Agency (2011). Water Company Drought Plan Guideline. June 2011.

River stage/level measured data (obtained from the Environment Agency) are generally long-term measurements of the depth of a watercourse at a fixed location. Stage refers to elevation above ordnance datum whilst level is relative to a nearby local datum (such as bed level). Stage/level measurements are a coarser approximation of the variability of a river over time in that higher levels are generally associated with higher discharges. In the absence of local flow data, stage/levels have been used in the assessment generally to show if the variability in stage/level experienced nearer to a potentially impacted reach is similar to that of flow gauge further upstream/downstream. If the local stage/level is similar to the more distant flow gauge, then the measured flow gauge data may be used to derive approximate flows (through catchment apportioning) in the vicinity of where the drought option, and any impact of it, is focussed.

A combination of continuous and ad-hoc river level and flow gauging monitoring should be undertaken to inform the assessments and provide in-situ data pre/during and post implementation, as outlined below.

Continuous (auto data logging) surveys include:

- River level and flow gauging – Data is collected by the Environment Agency as part of routine monitoring of the physical environment. This data can be requested from the Environment Agency's regional data centres for analysis and many are located in the vicinity of water infrastructure.
- Standing water level logging - Data is collected by Thames Water (in-reservoir), the Environment Agency or other responsible body (Wetland trusts, etc.) as part of routine monitoring of the physical environment. This data can be requested from the Environment Agency's regional data centres for analysis.

Ad hoc surveys include:

- Spot flow gauging – Safe and effective spot flow gauging is dependent on the size and current flow of the water body. Common methods include:
    - In-channel measurements using Acoustic Doppler Current Profiler (ADCP). This can be undertaken with a hand held ADCP when the water is at a suitable flow and the user can safely wade across the wetted width of the water body. This involves the submersion of the ADCP unit to record measurements at particular locations/intervals to create a flow profile.
    - In-channel measurements using an Electromagnetic (EM) gauge. Such a technique is employed when stream flow is extremely low and involves the submersion of the EM unit into the flow, to take a measurement.
- Cross-sectional profile (depth and wetted width), flow and velocity data should also be collected within the impacted reaches at sites identified during walkovers.

6.4.3 Hydrology (Groundwater Level Monitoring)

Where available, borehole and well assessments should consider the feasibility of installing automatic water level logging devices, alternatively manual dip readings should be taken. The datum level should be carefully determined and noted and referenced to ground level datum or other appropriate local datum.

Where automatic logging devices are installed, a manual calibration dip should be taken once every 6 months (as a minimum) and compared to the logger data. Any discrepancies and re-calibration should be clearly identified in the data record. The manual calibration dip reading should be carefully recorded and retained for future reference.

If the groundwater level is being obtained from a borehole used for potable supply purposes, great care must be taken not to cause any contamination of the groundwater during installation of automatic logging equipment or manual dip readings.

6.4.4 River Habitats / Geomorphology

In order to understand the impacts of changes in flow on habitats and geomorphology, existing river habitat and geomorphological data was sought. Geomorphological information has been based on a series of walkover surveys undertaken for Thames Water by Ricardo in 2012 as part of the 2013 DP EMP using Ricardo's in-house assessment methodology called CHEW and bolstered, where necessary, using extant aerial imagery and OS mapping. It is proposed that up to date characterisation of the river habitats of the reaches is informed by bespoke walkover surveys in the form of River Habitat Surveys (RHS) undertaken by the Environment Agency with additional supplementary mapped/aerial imagery information, both before and after the implementation of the drought permit. It should be focussed on locations of bank poaching, surface water outfall input and also downstream of weirs where flows are likely to be particularly low in order to provide a suitable comparison to make a conclusion on deterioration or otherwise within the impacted reaches.

RHS data is collected along a 500m section of river using 10 spot sites and a "sweep-up" of the features within and around the river. The survey should contain a range of ecological, hydrological, geomorphological data for the channel bed and banks, flow and surrounding land. The survey also collects information on the anthropogenic modifications present within and around the channel and the land-use around the channel. This data can be generally semi-quantitative with some quantitative data describing channel width and depth.

Aerial imagery data of the impacted reaches can be reviewed using Google Earth. The aerial images can used to assess the impacted reaches by deriving counts of geomorphological features in the channel (e.g. sediment bars, riffles, pools, bank erosion etc.), the presence of anthropogenic structures in and around the channel, particularly weirs, bridges and reinforced or re-sectioned banks and the surrounding land use. In addition, the images can be used to acquire measurements of channel length and width and the width of weirs. Aerial imagery may be limited in some cases due to the presence of riparian vegetation obscuring the channel and water clarity at the time aerial images are taken, which means features and channel dimensions could not be directly assessed via this method. This limitation is of particular importance where there is no walkover or RHS data, hence no geomorphological interpretation can be undertaken at such sites. This can be more common in smaller rivers at altitudes between the steepest upland channels and the widest lowland channels.

In general, the river habitat data and aerial imagery is limited by the dates of survey/imagery. Due to the dynamic nature of rivers, it is expected that the data contained in the walkovers, RHS and aerial imagery is unlikely to be the most current data. This may lead to an assessment of the river habitats and geomorphology of the impacted river reach which is less representative than the current day. Walkover surveys will be undertaken at the on-set of environmental drought (see **Section 6.5.3**) in order to obtain up-to-date and representative data within each affected reach prior to the implementation of the Drought Permit.

6.4.5 Water Quality

Water quality surveys will include:

- In-situ spot measurements using a multi-meter probe to measure pH, temperature, electrical conductivity and dissolved oxygen (% saturation and mg/l).
- Water quality samples will be taken in the field and sent to an accredited laboratory for alkalinity, unionised ammonia, ammonia, hardness, nitrate, phosphate, suspended solids, total oxidised nitrogen, orthophosphate, temperature, and pH analysis.

The number and location of samples will be determined by the length of the EMP reach and specific water quality pressures identified within the reach, whilst accounting for the spatial distribution and results of all relevant Environment Agency historic water quality monitoring data. In addition, samples will be taken in areas that are targeted for ecological monitoring (particularly macroinvertebrates).

6.4.6 Ecology

6.4.6.1 Macroinvertebrate and Fish Monitoring Surveys

The Environment Agency routinely monitor a number of sites within impacted reaches as part of WFD and National Fisheries monitoring programmes. These monitoring surveys can also be utilised for in-drought and post-drought assessments. To ensure a sufficient dataset to inform the environmental baseline for environmental assessment Thames Water also carry out further macroinvertebrate and fish monitoring using the same methodologies. These datasets are used in the preparation of the EARs.

For all available macroinvertebrate data where environmental variables were available, EQRs should be calculated using RICT for $WHPTN_{TAXA}$ and $WHPT_{ASPT}$ indices which are directly relate the macroinvertebrate community to WFD status over the monitoring period. Baseline conditions for sites within the zone of influence of the drought option should also established through existing data. These included graphing the hydrology, water quality, habitat and macroinvertebrate (LIFE scores and WHPT EQRs) variation temporally over the monitored period. This information is used to inform the assessment of any potential impacts on the macroinvertebrate community (as per the RBMP2 status assessments in each EAR).

As part of the WFD assessment of the fish element the Environment Agency undertakes a FCS2 assessment for most WFD waterbodies. The assessment within each EAR considered the scale and longevity of any fish status impacts and determined the severity and duration of impacts to the physical environment as a result of the drought permit and the specific requirements of the fish population present. These assessments were informed by the last FCS2 data available for sites within impacted reaches associated with each drought option.

6.4.6.2 Ecology Records Search

Information obtained from the Environment Agency, National Biodiversity Network (NBN) and supplementary report and data from Thames Water has provided information on the distribution of NERC Act Section 41 Priority species.

6.4.6.3 Targeted Baseline Monitoring

Although potential impacts to NERC Act Section 41 Priority species would be considered, the requirement for further supplementary surveys where data gaps are apparent is only applicable for features identified as having a sensitivity of moderate or major.

Where gaps in data have been identified and discussed in each individual EAR, targeted surveys are recommended for specific reaches too gain sufficient data for baseline assessment.

6.5 On-set, In Drought and Post Drought Monitoring and Mitigation

6.5.1 Introduction

Section 4 of the DPG supplementary guidance states monitoring data is required to inform an environmental assessment in advance of a drought, and any in-drought and post-drought data requirements. This section of this EMP details the monitoring measures that will be undertaken during each progressive stage of a drought: on-set; in-drought; and post-drought. Section 7 of the DPG supplementary guidance states that it may be possible to mitigate or reduce adverse effects that drought actions have on the environment and the drought plan must identify in-drought and post drought mitigation measures.

In order to understand the impacts of changes in flow on habitats and geomorphology, existing river habitat and geomorphological data will be sought via walkover surveys and will monitor features such as river levels and habitat availability, providing qualitative information on the effects of the drought measures, and allow decisions to be taken quickly regarding further monitoring and/or mitigation

requirements. This type of walkover survey incorporates elements of the RHS, and will identify conditions of ecological features such as key fish habitats and risks. Data will be collated via the 'River Conditions Assessment Form', the scope and content of which has been agreed with the Environment Agency and Natural England prior to the application of the drought permit. Further targeted surveys will be undertaken where walkover surveys identify potential serious significant impacts. These targeted surveys may result in implementation of mitigation measures where required.

Quantitative and qualitative monitoring surveys are recommended for different stages of the drought process where a reliable data set is required in order to determine impacts to sensitive features and reduce uncertainty in environmental assessment. This monitoring will provide data necessary to satisfy the requirement of Section 4.3 of the DPG for water companies to review the environmental impacts of the drought by analysing baseline, in-drought and post-drought data (where post-drought monitoring has been required).

6.5.2 Monitoring methodologies and locations (general)

The baseline monitoring programme will continue during the on-set, in drought and post drought option implementation periods in order to provide robust data on environmental conditions during and after the implementation of drought options (locations are provided below in Table 6.1). Monitoring will be undertaken at those sites that are considered in (a) the baseline monitoring programme and/or (b) those sites considered in informing baseline conditions in this EAR to ensure a robust baseline for assessing any impacts both in future drought plans and in the event of a drought permit/order implementation. Survey methodologies noted in the sections above are applied to ensure that data is comparable.

In line with Environment Agency advice, no in stream monitoring will be undertaken during environmental drought, unless agreed otherwise, to prevent further harm to the aquatic communities through sampling.

Data collected in the baseline, on-set and in drought this period can be compared to data collected in post-drought conditions to determine the rates of recovery and any further appropriate mitigation required.

6.5.3 On-set of Environmental Drought Monitoring

6.5.3.1 On-set of environmental drought walkovers

The on-set drought monitoring locations are provided below in **Table 6.1.**

The identification of the extent and location of flow sensitive habitats using a walkover survey during the on-set of environmental drought prior to the implementation of drought options has been provided in the **Table 6.1** below. Walkover surveys during the onset of environmental drought will monitor the current hydrological, water quality and habitat conditions at the on-set of the drought permit implementation.

Walkover surveys will monitor features such as river levels and habitat availability, with data collated into the 'River Condition Assessment Form' (the scope and content of which has been agreed with the Environment Agency and Natural England prior to the application of the drought permit) providing qualitative information on the effects of the drought measures. This type of walkover survey incorporates elements of the RHS and includes identification of ecological features such as key fish habitats and risks. Walkover surveys will be conducted by experienced field surveyors, with knowledge and understanding of walkover surveys, river habitats and ecological features associated with this environment. These initial walkover surveys will identify the 'monitoring/surveillance' reaches, based on selection of most significantly impacted reaches, which will remain consistent throughout the subsequent walkover surveys.

Duration and Frequency
On-set drought monitoring will be undertaken on one occasion, prior to the implementation of the drought permit.

6.5.3.2 In Drought (During Drought Option Implementation) Monitoring

In-drought surveys will be undertaken to monitor changes to sensitive features during implementation of the drought option and to identify the need for mitigation measures at the same sites monitored during the on-set environmental drought walkovers. In drought monitoring should commence 2 days after the implementation of the drought option; Baunton (1) permit application 14/11/2022, therefore monitoring should begin 16/11/2022.

The in-drought monitoring locations are provided below in **Table 6.1** and will be consistent with those undertaken during the on-set monitoring to allow for comparison to baseline drought conditions to provide an assessment of any changes in ecological features. Monitoring methodologies will adopt the same methodologies as applied during on-set monitoring. No in stream monitoring will be undertaken during environmental drought, unless otherwise advised and agreed with the Environment Agency and Natural England, to prevent further harm to the invertebrate community through kick/ sweep sampling.

Walkover surveys will monitor features such as habitat availability, providing qualitative information on the effects of the drought measures, and allow decisions to be taken quickly regarding further monitoring and/or mitigation requirements. This type of walkover survey incorporates elements of the RHS, and will identify conditions of ecological features such as key fish habitats and risks, data will be collated via the 'River Conditions Assessment Form'.

Mitigation measures are provided in **Table 6.1** below based on the likely impacts to sensitive features. Further description of mitigation measures is provided in **Sections 6.5.5** and **6.5.6**. These measures should be updated where potential additional 'new' impacts are identified from walkover surveys.

Duration and Frequency
In-drought monitoring will be initiated immediately once the drought permit is implemented. The in drought surveillance walkovers will take place two days after the drought option implementation until the drought permit / order expires or is revoked, unless otherwise agreed by the Environment Agency. The frequency of the in-drought monitoring is assumed to be monthly for a period of six months from implementation (November), however expert judgement will be used to identify the severity of impacts as a result of the walkovers and therefore frequency may be increased as a result.

Method
The visual monitoring of the potentially affected reaches to detect any potential change in habitat will be recorded via the 'River Condition Assessment Form'. Photographs should be taken at recorded locations to be repeated during subsequent surveys.

Changes in fish habitat can be discreet and subtle as discharge reduces. Baseline conditions and images will be available in each survey reach taken during the on-set monitoring such that changes can be detected and reported by the field team.

Environmental Impacts
Environmental impacts observed may include:

- Fish in distress, for example gasping at the surface or leaping out of the water
- Dead or dying fish
- Concentration of fish in restricted areas/pools which could increase susceptibility to predation
- Exposure of key functional habitat, particularly where there are reduced flows over or siltation of brown trout redds
- Stranding of fish in marginal areas
- Signs of pollution
- Changes to geomorphology e.g. changes in wetted width and exposure or normally submerged marginal features

From general water quality spot surveys; low levels of dissolved oxygen below the boundary of WFD moderate and poor status or high values of ammonium (surrogate for total ammonia) in excess of boundary of WFD moderate and poor status; or high values of unionised ammonia in excess of 40µg/l.

For onset of drought walkovers, the good-moderate boundary will be used to provide an early warning of potential areas at risk. Baseline conditions, prior to the implementation of the Drought Permit will be taken into account within reaches where parameters are already below the good-moderate boundary. These are discussed within the main EAR above for each reach. Parameters to be included in water quality spot sampling analysis are outlined below.

Water Quality Monitoring
In-stream water quality monitoring will be undertaken in the form of spot sample measurements using handheld meters to identify environmental problems on the affected waterbodies that may be caused by the reduction in flow. These will be taken during each of the walkover locations (detailed below in **Table 6.1**).

Water quality monitoring should be undertaken during each walkover survey until the drought permit expires or is revoked.

In situ probe readings and spot water quality samples should be taken in the centre of the channel at mid-depth where appropriate. The following parameters will be recorded:

- Dissolved oxygen concentration (mg/l) and saturation (%)
- Conductivity
- Water temperature
- pH
- Turbidity
- Ammonium concentration
- Unionised ammonia
- Suspended solids

Reporting
Data will be collated in the field using the 'River Conditions Assessment Form'. Thames Water will provide the Environment Agency a briefing note after the completion of surveys, detailing:

- Inventory of walkover surveys undertaken: dates, locations and findings
- Summary of water quality measurements, where taken
- Completed datasheets from the surveillance walkover surveys of habitat quality and ecological stress
- Recommendations for the implementation of any mitigation measures
- Recommendations for the frequency of subsequent monitoring in the "during drought permit" period.

6.5.4 Mitigation Measures

If, during the visual and water quality monitoring there are significant environmental impacts observed (e.g. fish in distress/ low dissolved oxygen / reduced habitat availability etc.), then a mitigation response may be required. Mitigation measures are provided in **Table 6.1** below based on the likely impacts to sensitive features.

The mitigation recommendations have been made in a hierarchy of approach which follows the general principle of 1) reducing the pressure at source; 2) pressure management in the river; and 3) ecological action. The implementation of mitigations during the in-drought and post-drought periods should follow this principle, with movement to mitigation measures in the next hierarchy dependent upon the success or failure of mitigation in the lower hierarchy.

Thames Water have commissioned a project to identify potential options to enhance the environmental resilience of rivers within their operational area to improve their robustness in times of drought. This project is reviewing all potentially impacted reaches identified in the EARs and assessing what river restoration options might improve the environmental resilience in the area, should there be a drought and / or a need to implement drought options. This work is ongoing at the moment, therefore, outcomes

are not included in the EARs and will be incorporated at a later update. The extent, location and type of mitigation measures will also be informed by walkovers that are completed at the onset of drought.

6.5.5 In Drought Mitigation Options

The surveillance walkovers incorporate visual and water quality monitoring. This includes a number of suggested signs of environmental distress which may be observed during the visual observations and the water quality sampling. If the monitoring identifies signs of environmental distress Thames Water would notify the Environment Agency and review and assess a remedial course of action to address the signs of environmental distress, where possible. The frequency of the in-drought monitoring is assumed to be monthly for a period of six months from implementation (November), however expert judgement will be used to identify the severity of impacts as a result of the walkovers and therefore frequency may be increased as a result.

Where water level impacts have been identified; the creation of alternative refuges in deeper water where walkover surveys identify the loss of important deep water habitat or high densities of fauna in refuges (fish) may be considered. Placing stones or logs in a main river to enhance habitats is permitted under flood risk activity (FRA) exemption FRA18[85] where installation of habitat structure made of natural materials (but not including weirs and berms) is permitted on a main river.. Placing these items may assist in creating alternate refuges in the event that identified refuges are insufficient or not retained during the implementation of the drought permit. These structures should be permitted assuming:

- stones must be less than 400mm in any dimension and of a type that occurs naturally in the main river
- logs must be of less than 2m in length, less than 400mm in diameter and oriented to within 45° of the flow of water
- logs must be from a tree species that occurs naturally in the vicinity of the main river; and it must be securely pinned to the bed or bank of the main river to prevent wash out and congregation downstream
- the stones or logs are placed in the channel over no more than 20m of the length, and 20% of the width, of the main river
- no stones or logs are placed within 100m of a non-agricultural building in the floodplain, a natural channel habitat structure, an existing emplacement of stones or logs placed in the main river for habitat enhancement or a man-made structure on or in the main river
- material may remain in place post drought permit if allowed under exception.

Provision of in-stream structures and flow baffles to create functional refuges to support flow sensitive species where walkover surveys identify a projected loss of habitat inundation (macroinvertebrates, fish) It may be necessary to introduce in-stream structures at sites to create functional refuges to support displaced fish stocks. Installing habitat structures made of natural materials (excluding weirs and berms) is permitted under exemption FRA15[86] which allows installation of structures made of natural materials (but not including weirs and berms).

These structures should be ready to be installed at suitable sites and would be permitted as long as:

- the structure occupies no more than half the width of the cross-sectional area of the channel in the main river and no more than 20m of the length of the main river
- no part of the structure is higher than 0.3m above the level of the river bed or 25% of the height of the bank (excluding any wall or embankment), whichever is greater
- the structure is made from naturally occurring woody material and is securely fastened to the bed of the main river, the bank or both

[85] https://www.gov.uk/government/publications/environmental-permitting-regulations-exempt-flood-risk-activities/exempt-flood-risk-activities-environmental-permits
[86] https://www.gov.uk/government/publications/environmental-permitting-regulations-exempt-flood-risk-activities/exempt-flood-risk-activities-environmental-permits

- no works take place within 100m of a non-agricultural building in the floodplain, another natural channel habitat structure, stones or logs placed in the main river for habitat enhancement or a man-made structure on or in the main river
- all structures should be removed within 1 month of the expiry of the drought permit.
- Artificial channel narrowing to provide functional refuges and support habitat requirement for species, enabling a quick natural recolonisation of the reach post-drought (fish, macroinvertebrates)

A combined approach should be used to capture any fish, either isolated from the main flow of the river or showing signs of distress from the DP implementation process. Standard methods should be used including electric fishing to capture fish from cover features and also manual searches (under cobbles etc.) using hand nets to manually capture fish. Any fish captured should be relocated to a suitable area of habitat less affected by the reduction in flow. All electric fishing should be undertaken by fully trained fisheries scientists following standard electric fishing practice for operators and equipment, as developed by the European Standards Committee and detailed in the Environment Agency Code of Practice and Electric Fishing Equipment Annex A and B, Issue II regulations

If fish continue to show signs of distress, they should be captured and held for a short period, allowing recovery of both the fish and the levels of instream dissolved oxygen. In the case that these levels fail to recover, the fish should be moved to a suitable release site downstream where appropriate conditions exist on the day. It may also be necessary to relocate fish across barriers where movement between two areas as a result of an instream barrier is restricted.

Any eel captured should be kept in a separate tank to all other fish species as they secrete mucus which can infest the gills of other fish. Dissolved oxygen concentration should be monitored and optimum concentrations maintained by continuous infusion, using an oxygenation unit.

- Implementation of navigation controls in the channel to reduce disturbance damage upon vulnerable species and/or populations (Environment Agency).
- For CSOs identified as significant water quality pressures, prioritise planned maintenance work on and reactive pollution prevention work, including visits by operators.

The identification of appropriate mitigation to be implemented during a drought needs to take into account all of the species present in the reach, as the implementation of some mitigation measures for the benefit of one species could be at the detriment of another.

6.5.6 Post Drought Monitoring

In order to assess whether the implementation of the drought options has any long-term effects on any environmental features, monitoring after implementation of drought options will be necessary for certain features. This is specified in **Table 6.1**.

This monitoring will provide a quantitative dataset to assess whether the implementation of the drought option has had any long-term effects on any sensitive environmental features within the extent of hydrological influence associated with the Baunton (1) drought permit and to demonstrate recovery where appropriate.

The frequency and duration of the post-drought monitoring will be agreed with the Environment Agency and Natural England.

6.5.6.1 Data Analysis

In order to assess whether the implementation of the drought options has any long-term effects, monitoring after implementation of drought options will be necessary for certain features. Comparison of the post-drought monitoring results to monitoring data from (a) baseline monitoring locations, (b) monitoring of control sites and (c) in-drought monitoring locations (where available), will provide a quantitative dataset to determine whether the implementation of drought options has had any long-term

effects on any sensitive environmental features within the extent of hydrological influence associated with each of the drought options, demonstrate recovery where appropriate, and identify the need for further monitoring and mitigation.

Identifying any long-term effects on ecological features and an assessment of the efficacy of any in-drought and post drought mitigation measures should be initially informed by a direct comparison of the relevant biological metrics/indices.

For macroinvertebrate communities this includes a direct comparison of the EQRs calculated using RICT for $WHPT_{NTAXA}$ and $WHPT_{ASPT}$ indices and a direct comparison of the total WHPT score, LIFE scores and PSI scores as obtained for a specific monitoring site (i.e. where monitoring has been completed pre-drought and post drought from the monitoring site.). A drought option is considered to have resulted in an impact on the macroinvertebrate community where EQRs have reduced by one biological band[87] when comparing the results of a minimum of five-year baseline monitoring data against a control site. Comparison against a long-term data set is required to allow for natural variation in community structure.

For fish communities the assessment should consider a direct comparison of the species assemblage, density, biomass and standing crop density and biomass for a specific monitoring site (i.e. where monitoring has been completed pre-drought and post drought from the monitoring site.). The data analyses should also include a comparison of length-frequency distribution plots to identify any impacts on recruitment. A drought option is considered to have resulted in an impact on the fish community where EQRs have reduced when comparing the results of a minimum of five-year baseline monitoring data. Comparison against a long-term data set is required to allow for natural variation in community structure It is noted that monitoring results could vary naturally as a result of changes in habitat availability following a severe natural event (e.g. drought or flood). As such, the assessment of any impacts on the ecological features, and the subsequent need for further post drought mitigation, should also consider the result of the baseline, in-drought and post drought monitoring results at control sites. For example, the overall biomass of the fish community with a river reach associated with a drought option may have reduced by 10%, however, a similar observation could be made at a control site. As such, the 10% reduction could be considered to be as a result of natural variations/drought impacts and not necessarily as a result of the implementation of a drought option. It is noted the this will require calculations of EQRs using the Environment Agency's FCS2 tool. Should this not be possible, the assessment should rely on expert judgment of the relevant metrics and data.

Biological indices and metrics are mostly informative and basic representations of a biological community's condition and represents a summary of complex ecological data. To reduce any uncertainty in the assessments it is, therefore, recommended that the assessment is further supported by a statistical analysis of the macroinvertebrate and fish community data using an appropriate software package (e.g. Primer or R) to complete a similarity analysis. The statistical analyses should be used to identify which species typified survey sites pre- and post-drought option implementation and whether there has been a statistically significant difference in either the diversity and/or abundance of the ecological communities. The statistical analyses should include the comparison between sites and with control sites and should consider a minimum of five-year baseline monitoring data (where available) to allow for natural variation.

6.5.7 Post Drought Mitigation Options

Some mitigation options are considered to be most effective when applied following removal of drought option measures (i.e. post drought) where adverse impacts, as a result of the drought permit, have been identified.

[87] See Part 4, Section 1 of the Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015)

The recommended post-drought mitigation options could include any of the following suite of mitigation options:

- Enhancement of habitat within the impacted reach (macroinvertebrates, fish).
- Capture and relocate across barrier (taking migratory period into account) where significant numbers of migratory fish congregate at obstacle (fish).
- Relocation of juveniles where walkover surveys identify the likely desiccation of marginal habitats or loss of water depth at important habitats (fish)
- Restocking using offspring from broodstock from the catchment where monitoring indicates loss of fish abundance or recruitment (fish).
- Restocking of coarse fish from the catchment where monitoring indicates loss of fish abundance or recruitment (fish).

The requirement for the implementation of any potential post-drought mitigation options will be discussed with the Environment Agency and Natural England.

6.5.8 Monitoring and mitigation measures: ensuring environmental protection

The monitoring and mitigation measures set out in this EMP have been based on previous experience and evidence from droughts in other parts of the UK and/or from water management experiences more broadly from water companies and the Environment Agency (for example, aeration of waterbodies by United Utilities on the Manchester Ship Canal or by the Environment Agency and Thames Water on the lower River Thames). Some of the mitigation measures do carry a level of risk and for this reason full consultation with the Environment Agency and Natural England will take place to agree whether a particular mitigation action is the best option in the prevailing drought situation and that it will have the greatest chance of success. Whilst no mitigation measure can claim to provide a 100% success rate, there is good evidence from across the UK that the measures set out in this EMP will likely have a positive, beneficial effect for the environment.

Table 6.1 Baunton (1) drought permit: Baseline, During and Post Drought Permit Monitoring Recommendations

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
Macroinvertebrates	Minor impacts within Reach 1, 2, 3. No on-set drought/during drought sampling will take place)	Last undertaken in 2019-2021 as part of existing baseline monitoring programme. Reach 1: Perrotts Brook SP0204206071 Reach 2: Stratton SP0207803291 Reach 3: Gauging station, Cerney Wick SU0755796305	N/A- No instream monitoring is to be undertaken during	N/A- No instream monitoring is to be undertaken during	N/A	Post drought baseline monitoring will be undertaken in spring (May) summer (July) and autumn (October) 2023 at the following locations to provide insight into community changes post implementation. Reach 1: Perrotts Brook SP0204206071 Reach 2: Stratton SP0207803291 Reach 3: Gauging station, Cerney Wick SU0755796305
Perrott's Brook Marsh LWS River Thames or Isis LWS Cerney Wick Meadows LWS Crane Farm LWS	Habitat degradation as a result of decreased river levels, velocity and connectivity to surface water.	To establish a baseline, monitoring should incorporate Surveillance walkover of aquatic habitats and investigate if hydrological connectivity is lost during drought order implementation, if not already lost due to antecedent environmental drought conditions Obtain any available site-specific water level/flow monitoring evidence.	Walkovers should be undertaken to record habitat conditions and connectivity to surface water during 'on-set' of the permit using the 'River Conditions Assessment Form'. Walkovers are to be undertaken at the following locations. Perrott's Brook Marsh LWS SP0203105954 River Thames or Isis LWS	Methodology criteria for assessing habitat condition on an assumed monthly basis, however expert judgement should be used in order to assess severity of impacts which may result in more frequent walkovers.	Specific mitigation for the LWS is not considered feasible.	In June 2023 following drought permit implementation carry out walkovers using the 'River Conditions Assessment Form'. If existing habitats have been lost or damaged due to permit, consider scope for replanting / re-creation of habitats or consider compensatory habitat options, in dialogue with Natural England.

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
River Churn LWS			Centre NGR: SU1430895689) One location in Walkover 5, and one additional location (to be detemined based on access). Cerney Wick Meadows LWS SU0758996370 Crane Farm LWS SU0600297435 River Churn LWS Undertaken during 1 walkover within Reach 1, Reach 2 and Reach 3.			Perrott's Brook Marsh LWS SP0203105954 River Thames or Isis LWS Centre NGR: SU1430895689) One location in Walkover 5, and one additional location (to be detemined based on access). Cerney Wick Meadows LWS SU0758996370 Crane Farm LWS SU0600297435 River Churn LWS Undertaken during 1 walkover within Reach 1, Reach 2 and Reach 3.
North Meadow Cricklade SSSI	Two offtakes from the River Churn appear to provide most of the flow through the central ditch system supporting a macrophyte community, but uncertainty surrounds the	Available baseline macrophyte data within North Meadow Cricklade SSSI is limited. Wiltshire County Council and the Nature Conservancy Council who manage the site can provide local knowledge of the ditch systems. To establish a baseline, monitoring should incorporate:	Walkovers should be undertaken to record habitat conditions and connectivity to surface water during 'on-set' of the permit using the 'River Conditions Assessment Form'. North Meadow Cricklade SSSI: Site centre NGR: SU0943494591	Repeat walkover surveys on an assumed monthly basis, however expert judgement should be used in order to assess severity of impacts which may result in more frequent walkovers.	Mitigating impacts to the macrophyte community from implementation of this drought permit is not feasible during implementation. Mitigating this impact should be triggered by post drought macrophyte community assessments to implement post drought mitigation measures.	Monthly walkover surveys of ditch network to understand how ditch network is recovering from drought permit implementation. LEAFPACs macrophyte survey for following two years at same location

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
	water level management practice at the site.	Walkover[88] to assess the water level management practice that supplies the ditch system in the SSSI. Ascertain how drought permit implementation might affect the site. Also identify key locations within the ditch system which are susceptible to low flow impact. LEAFPACS2[89] macrophyte survey of susceptible location(s) within ditch system to better determine macrophyte community composition pre-drought. To be carried out June – September.	In addition, carry out LEAFPACS2 macrophyte survey of susceptible location(s) within ditch system. To be carried out June – September.			North Meadow Cricklade SSSI: Site centre NGR: SU0943494591 Determining any influence of drought permit on macrophyte community composition. If existing macrophyte community has been irreversibly damaged then consider replanting where possible to promote recovery. Replanting of macrophyte community composition to be informed by pre-drought community
Coastal and floodplain grazing marsh	Habitat degradation as a result of decreased river levels and velocity within Reach 1 and 2	To establish a baseline, monitoring should incorporate Surveillance walkover of aquatic habitats and investigate if hydrological connectivity is lost during drought order implementation, if not already lost due to antecedent environmental drought conditions Obtain any available site-specific water level/flow monitoring evidence.	The habitat extends throughout Reach 1, Reach 2. Walkovers should follow a three-step procedure. Determine (if applicable) the connectivity of the habitat to surface water. If there is connectivity- undertake a habitat condition assessment. Provide a list of wetland indicator species present at	Methodology criteria for assessing habitat condition on an assumed monthly basis, however expert judgement should be used in order to assess severity of impacts which may result in more frequent walkovers.	Specific mitigation for the habitat is not considered feasible.	In June 2023 following drought permit implementation carry out walkovers using the 'River Conditions Assessment Form'. Walkovers should follow a three-step procedure. Determine (if applicable) the connectivity of the habitat to surface water.

[88] Refer to Appendix B of this document for a detailed methodology to be used for walkover surveys
[89] Environment Agency (2011).Surveying freshwater macrophytes in rivers. Operational instruction 131_07. (Unpublished procedures manual)

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			the site that would be impacted by the impacts of the drought permit. Data will be collated using the 'River Conditions Assessment Form'. Walkovers are to be undertaken at the following locations. <u>Reach 1</u> Walkover 3: US SP0216504512, DS SP0221404124 <u>Reach 2</u> Walkover 1 US SP0196603230, DS SP0198102764			If there is connectivity- undertake a habitat condition assessment. Provide a list of wetland indicator species present at the site that would be impacted by the impacts of the drought permit. If existing habitats have been lost or damaged due to permit, consider scope for replanting / re-creation of habitats or consider compensatory habitat options, in dialogue with Natural England. <u>Reach 1</u> Walkover 3: US SP0216504512, DS SP0221404124 <u>Reach 2</u> Walkover 1 US SP0196603230, DS SP0198102764
Fine-lined pea mussel	Reduction in species abundance as a result of increased stress in vulnerable habitats Reduction in species abundance or	Location of suitable pea mussel habitat and their susceptibility to drying up is known as a result of: CHEW walkover undertaken in 2012 by Ricardo. Data from routine Environment Agency/ Thames Water monitoring sites for invertebrates. Fine lined pea	No in stream monitoring is advised during environmental drought to prevent further harm to the invertebrate community through kick/ sweep sampling. Walkover of key sections (detailed below) known to be	No in stream monitoring is advised during drought permit implementation to prevent further harm to the invertebrate community through kick/ sweep sampling. Surveillance walkover of key sections on an	Mitigating the impact of the drought permit on macroinvertebrate species through direct intervention is not feasible. In extreme circumstances habitat improvements post drought can aid in natural recolonisation of fine-lined	In July 2023, targeted sweep sampling of silty habitat and submerged macrophytes in monitoring sites (detailed below) to ascertain population quality post drought. Laboratory sorted to

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
	distribution as a result of changes in water quality	mussels have been recorded from three sites. Targeted sweep sampling of silty habitat and submerged macrophytes in key locations to better ascertain distribution in affected reaches. Laboratory sorted to identify presence of fine-lined pea mussel.	susceptible to lower flows. Assessments of sediment cover will be undertaken within each walkover section. Reach 1 Walkover 1: US SP0190107934, DS SP0207007552 Walkover 2: US SP0204306061, DS SP0222305607 Walkover 3: US SP0216504512, DS SP0221404124 Walkover 4 (Control): US SP0163809167, DS SP0178308788 Reach 2 Walkover 1 (US Reach 1): US SP0196603230, DS SP0198102764 Walkover 2: US SP0240602468, DS SP0279902178 Walkover 3: US SP0374600311, DS SU0387599982 Reach 3 Walkover 1 (US Reach 1): US SU0406098329, DS SU0409897965	assumed monthly basis. However, following the review of the on-set drought monitoring, expert judgement should be used to determine if the frequency of monitoring the impacts of drought should increase given the conditions recorded during the on-set walkovers. Continue walkovers, and measure dissolved oxygen, conductivity and temperature in the field using calibrated handheld equipment. Reach 1 Walkover 1: US SP0190107934, DS SP0207007552 Walkover 2: US SP0204306061, DS SP0222305607 Walkover 3: US SP0216504512, DS SP0221404124 Walkover 4 (Control): US SP0163809167, DS SP0178308788 Reach 2 Walkover 1 (US Reach 1): US SP0196603230, DS SP0198102764	pea mussel and depressed river mussel.	identify presence of fine-lined pea mussel. Reach 1: Perrotts Brook SP0204206071 Reach 2: Stratton SP0207803291 Reach 3: Gauging station, Cerney Wick SU0755796305 Measure dissolved oxygen, conductivity and temperature in the field using calibrated handheld equipment. Collect water samples for analysis of Orthophosphate as PO4 and Total Oxidised Nitrogen (Total nitrogen (Nitrite as NO2 and NO3) concentrations as species abundance is linked to reduced concentrations at key locations- North Cerney (SP0190807912) Perrot's Brook (SP0205406012) Rivercourt, Cirencester (SP0301201797) South Cerney Outdoor Education Centre (SU0673296807)

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Walkover 2: US SU0398197684, DS SU0426597336 Walkover 3: US SU0499697236, DS SU0546497375 Walkover 4: US SU0744596493, DS SU0779796216 Walkover 5: US SU1026394008, DS SU1058893772 Reach 5 Walkover 1 (US Reach 1): US SP1233806486, DS SP1210906057 Walkover 2: US SP1228405823, DS SP1267005562 Walkover 3: US SP1363205385, DS SP1406405242 Walkover 4: US SP1497905150, DS SP1502004722 Walkover 5: US SP1503201544, DS SP1508301070 Walkover 6 (Control): US SP1011607765, DS SP1047707501	Walkover 2: US SP0240602468, DS SP0279902178 Walkover 3: US SP0374600311, DS SU0387599982 Reach 3 Walkover 1 (US Reach 1): US SU0406098329, DS SU0409897965 Walkover 2: US SU0398197684, DS SU0426597336 Walkover 3: US SU0499697236, DS SU0546497375 Walkover 4: US SU0744596493, DS SU0779796216 Walkover 5: US SU1026394008, DS SU1058893772 Further assessment of sediment cover. Collect water samples for analysis of Orthophosphate as PO4 and Total Oxidised Nitrogen (Total nitrogen (Nitrite as NO2 and NO3) concentrations as species abundance is linked to reduced concentrations at key locations-		

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Measure dissolved oxygen, conductivity and temperature in the field using calibrated handheld equipment within each walkover section. Collect water samples for analysis of Orthophosphate as PO4 and Total Oxidised Nitrogen (Total nitrogen (Nitrite as NO2 and NO3) concentrations as species abundance is linked to reduced concentrations at key locations- North Cerney (SP0190807912) Perrot's Brook (SP0205406012) Rivercourt, Cirencester (SP0301201797) South Cerney Outdoor Education Centre (SU0673296807)	North Cerney (SP0190807912) Perrot's Brook (SP0205406012) Rivercourt, Cirencester (SP0301201797) South Cerney Outdoor Education Centre (SU0673296807)		
Brown trout Bullhead Brook Lamprey	Reduction or loss of spawning habitat due to desiccation of habitat	Fish populations are well understood as a result of: • CHEW walkover undertaken in 2012 by Ricardo • Environment Agency Rare and Protected Species database • Data from Environment Agency and Thames Water fish monitoring sites	No in stream monitoring is advised during environmental drought to prevent further harm to the fish community through sampling. Walkovers are to be undertaken at the following locations. Reach 1	Walkovers undertaken at those locations during the "on-set" monitoring are assumed to be repeated on a monthly basis. However, following the review of the on-set drought monitoring, expert judgement should be used to determine if the frequency of monitoring the impacts of drought	Targeted installation of woody debris features to provide fish with the habitat required to support feeding and development (growth). Consider modifying any impacted fish passes (where possible) to ensure passage is maintained during key migration periods (e.g. agree to provide an appropriate	Post-drought and year 3 fish population surveys if needed at Environment Agency monitoring sites (corresponding with a control and impact site/s) to determine any changes in population dynamics both temporally and spatially.

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
		• Local knowledge from Environment Agency fisheries and ecology teams Undertake walkover surveys to focussed on locations of bank poaching, surface water outfall input and also downstream of weirs where flows are likely to be particularly low in order to provide a suitable comparison to make a conclusion on deterioration or otherwise within the impacted reaches.	Walkover 1: US SP0190107934, DS SP0207007552 Walkover 2: US SP0204306061, DS SP0222305607 Walkover 3: US SP0216504512, DS SP0221404124 Walkover 4 (Control): US SP0163809167, DS SP0178308788 Reach 2 Walkover 1 (US Reach 1): US SP0196603230, DS SP0198102764 Walkover 2: US SP0240602468, DS SP0279902178 Walkover 3: US SP0374600311, DS SU0387599982 Reach 3 Walkover 1 (US Reach 1): US SU0406098329, DS SU0409897965 Walkover 2: US SU0398197684, DS SU0426597336 Walkover 3: US SU0499697236, DS SU0546497375	should increase given the conditions recorded during the on-set walkovers. Fish passage assessment of barriers /obstructions to fish passage and any associated fish passes should be undertaken to ascertain if they pose an increased risk to the free movement of fish will be undertaken during each walkover survey with data collated in the 'River Conditions Assessment Form'.	proportion of flow into the pass to enable passage). Consider 'Trap & Transport' of concentrated abundances of migrating fish accumulated below impassable barrier/s to spawning grounds upstream of the impacted reach (where environmental parameters such as dissolved oxygen and temperature allow). Alternatively, mitigation should seek to protect any populations 'trapped' as a result of the barrier/s until flows increase for example by using aeration (if dissolved oxygen levels are low) or preventing predation.	<u>Reach 1</u> No baseline monitoring sites are currently undertaken by EA or TWUL, this should be agreed before the post drought period <u>Reach 2</u> No baseline monitoring sites are currently undertaken by EA or TWUL, this should be agreed before the post drought period <u>Reach 3</u> Cerney Wick SU0783096000 <u>Reach 5</u> No baseline monitoring sites are currently undertaken by EA or TWUL, this should be agreed before the post drought period Results of the fish population surveys should help inform mitigation targeting habitat restoration where deemed to be

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Walkover 4: US SU0744596493, DS SU0779796216 Walkover 5: US SU1026394008, DS SU1058893772 Reach 5 Walkover 1 (US Reach 1): US SP1233806486, DS SP1210906057 Walkover 2: US SP1228405823, DS SP1267005562 Walkover 3: US SP1363205385, DS SP1406405242 Walkover 4: US SP1497905150, DS SP1502004722 Walkover 5: US SP1503201544, DS SP1508301070 Walkover 6 (Control): US SP1011607765, DS SP1047707501 Riverbed substrate composition, connectivity, water quality, fish barrier assessments and habitat fragmentation will all be undertaken during each walkover survey.			appropriate to support and enhance affected populations

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Data collated during the walkovers will be collated using the 'River Condition Assessment Form'			
Brown trout, brook lamprey, bullhead and European Eel	Increased stress and predation on species in refuges as a result of delay in recovery of flows	Fish populations are well understood as a result of: • CHEW walkover undertaken in 2012 by Ricardo • Environment Agency Rare and Protected Species database • Data from 3Environment Agency and Thames Water fish monitoring sites (including analysis of growth rates for trout species using fish scales) • Local knowledge from Environment Agency fisheries and ecology teams Undertake walkover surveys to focussed on locations of bank poaching, surface water outfall input and also downstream of weirs where flows are likely to be particularly low in order to provide a suitable comparison to make a conclusion on deterioration or otherwise within the impacted reaches.	No in stream monitoring is advised during environmental drought to prevent further harm to the fish community through sampling. Walkovers are to be undertaken at the following locations. Reach 1 Walkover 1: US SP0190107934, DS SP0207007552 Walkover 2: US SP0204306061, DS SP0222305607 Walkover 3: US SP0216504512, DS SP0221404124 Walkover 4 (Control): US SP0163809167, DS SP0178308788 Reach 2 Walkover 1 (US Reach 1): US SP0196603230, DS SP0198102764 Walkover 2: US SP0240602468, DS SP0279902178	Walkovers undertaken at those locations during the "on-set" monitoring are assumed to be repeated on a monthly basis. However, following the review of the on-set drought monitoring, expert judgement should be used to determine if the frequency of monitoring the impacts of drought should increase given the conditions recorded during the on-set walkovers. Fish passage assessment of barriers /obstructions to fish passage and any associated fish passes should be undertaken to ascertain if they pose an increased risk to the free movement of fish will be undertaken during each walkover survey with data collated in the 'River Conditions Assessment Form'.	Targeted installation of woody debris features to provide fish with the habitat required to support feeding and development (growth). Consider modifying any impacted fish passes (where possible) to ensure passage is maintained during key migration periods (e.g. agree to provide an appropriate proportion of flow into the pass to enable passage). Consider 'Trap & Transport' of concentrated abundances of migrating fish accumulated below impassable barrier/s to spawning grounds upstream of the impacted reach (where environmental parameters such as dissolved oxygen and temperature allow). Alternatively, mitigation should seek to protect any populations 'trapped' as a result of the barrier/s until flows increase for example by using aeration (if dissolved oxygen levels are low) or preventing predation.	Post-drought and year 3 fish population surveys if needed at Environment Agency monitoring sites (corresponding with a control and impact site/s) to determine any changes in population dynamics both temporally and spatially. <u>Reach 1</u> No baseline monitoring sites are currently undertaken by EA or TWUL, this should be agreed before the post drought period <u>Reach 2</u> No baseline monitoring sites are currently undertaken by EA or TWUL, this should be agreed before the post drought period <u>Reach 3</u>

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Walkover 3: US SP0374600311, DS SU0387599982 Reach 3 Walkover 1 (US Reach 1): US SU0406098329, DS SU0409897965 Walkover 2: US SU0398197684, DS SU0426597336 Walkover 3: US SU0499697236, DS SU0546497375 Walkover 4: US SU0744596493, DS SU0779796216 Walkover 5: US SU1026394008, DS SU1058893772 Reach 5 Walkover 1 (US Reach 1): US SP1233806486, DS SP1210906057 Walkover 2: US SP1228405823, DS SP1267005562 Walkover 3: US SP1363205385, DS SP1406405242 Walkover 4: US SP1497905150, DS SP1502004722			Cerney Wick SU0783096000 <u>Reach 5</u> No baseline monitoring sites are currently undertaken by EA or TWUL, this should be agreed before the post drought period Results of the fish population surveys should help inform mitigation targeting habitat restoration where deemed to be appropriate to support and enhance affected populations

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Walkover 5: US SP1503201544, DS SP1508301070 Walkover 6 (Control): US SP1011607765, DS SP1047707501 Riverbed substrate composition, connectivity, water quality, fish barrier assessments and habitat fragmentation will all be undertaken during each walkover survey. Data collated during the walkovers will be collated using the 'River Condition Assessment Form'			
Brown trout, brook lamprey, bullhead and European eel	Reduction in species abundance or distribution as a result of changes in water quality	Water quality is well understood as a result of water quality monitoring undertaken by the Environment Agency. In addition, discharges which are likely to be key locations for water quality pressure into the reach have been identified in **Section 4.4.2.7.** Populations of brown trout and bullhead are well understood as a result of: Data from routine Environment Agency monitoring sites for fish and ecology Local knowledge from Environment Agency fisheries and ecology teams	Surveillance walkover of key sections (identified above) with known water quality pressures and sections known to be susceptible to lower flows. Measure dissolved oxygen, conductivity and temperature in the field using calibrated handheld equipment within each walkover. Known areas of dry habitats are typically avoided during the walkover but recorded where observed to confirm and/or confirm existing knowledge.	Surveillance walkover of key sections (identified above) with known water quality pressures and sections known to be susceptible to lower flows are assumed to be repeated on a monthly basis. However, following the review of the on-set drought monitoring, expert judgement should be used to determine if the frequency of monitoring the impacts of drought should increase given the conditions recorded during the on-set walkovers.	Deployment of aeration equipment in key reaches that have standing or slow flowing water with low oxygen levels.	No action required outside of routine monitoring programmes identified above. (Post-drought and year 3 fish population surveys if needed, at Thames Water/Environment Agency monitoring sites (corresponding with a control and impact site/s) to determine any changes in population dynamics both temporally and spatially.

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
		Undertake walkover surveys to focus on locations of bank poaching, surface water outfall input and also downstream of weirs where flows are likely to be particularly low in order to provide a suitable comparison to make a conclusion on deterioration or otherwise within the impacted reaches.	Data to be collated via the 'River Condition Assessment Form'.	Measure dissolved oxygen, conductivity and temperature in the field using calibrated handheld equipment. Data to be collated via the 'River Condition Assessment Form'.		
European Eel	Habitat fragmentation due to increased significance of obstacles	No records of European eel exist in Reaches 1 and 2. Key monitoring locations can be established by: Environment Agency Rare and Protected Species database Local knowledge from Environment Agency fisheries and ecology teams CHEW walkover undertaken in 2012 by Ricardo, which identified suitable habitats Baseline fish monitoring required for Reaches 1 and 2. Four electric fish surveys, to be carried out to provide a baseline, using invert monitoring sites 1-4 as locations with suitable access to the river. Undertake walkover surveys to focus on locations of bank poaching, surface water outfall input and also downstream of weirs where flows are likely to be particularly low in order to provide a suitable comparison to	No in stream monitoring is advised during environmental drought to prevent further harm to the fish community through sampling. Walkovers are to be undertaken at the following locations. Reach 1 Walkover 1: US SP0190107934, DS SP0207007552 Walkover 2: US SP0204306061, DS SP0222305607 Walkover 3: US SP0216504512, DS SP0221404124 Walkover 4 (Control): US SP0163809167, DS SP0178308788 Reach 2	Walkovers undertaken at those locations during the "on-set" monitoring are assumed to be repeated on a monthly basis. However, following the review of the on-set drought monitoring, expert judgement should be used to determine if the frequency of monitoring the impacts of drought should increase given the conditions recorded during the on-set walkovers. Fish passage assessment of barriers /obstructions to fish passage and any associated fish passes should be undertaken to ascertain if they pose an increased risk to the free movement of fish will be undertaken during each walkover survey with data collated in the 'River	Targeted installation of woody debris features to provide fish with the habitat required to support feeding and development (growth). Consider modifying any impacted fish passes (where possible) to ensure passage is maintained during key migration periods (e.g. agree to provide an appropriate proportion of flow into the pass to enable passage). Consider 'Trap & Transport' of concentrated abundances of migrating fish accumulated below impassable barrier/s to spawning grounds upstream of the impacted reach (where environmental parameters such as dissolved oxygen and temperature allow). Alternatively, mitigation should seek to protect any populations 'trapped' as a	Post-drought and year 3 fish population surveys if needed at Environment Agency monitoring sites (corresponding with a control and impact site/s) to determine any changes in population dynamics both temporally and spatially. <u>Reach 1</u> No baseline monitoring sites are currently undertaken by EA or TWUL, this should be agreed before the post drought period <u>Reach 2</u> No baseline monitoring sites are currently undertaken by EA or TWUL, this should be

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
		make a conclusion on deterioration or otherwise within the impacted reaches.	Walkover 1 (US Reach 1): US SP0196603230, DS SP0198102764 Walkover 2: US SP0240602468, DS SP0279902178 Walkover 3: US SP0374600311, DS SU0387599982 Reach 3 Walkover 1 (US Reach 1): US SU0406098329, DS SU0409897965 Walkover 2: US SU0398197684, DS SU0426597336 Walkover 3: US SU0499697236, DS SU0546497375 Walkover 4: US SU0744596493, DS SU0779796216 Walkover 5: US SU1026394008, DS SU1058893772 Reach 5 Walkover 1 (US Reach 1): US SP1233806486, DS SP1210906057 Walkover 2: US SP1228405823, DS SP1267005562	Conditions Assessment Form'.	result of the barrier/s until flows increase for example by using aeration (if dissolved oxygen levels are low) or preventing predation.	agreed before the post drought period <u>Reach 3</u> Cerney Wick SU0783096000 <u>Reach 5</u> No baseline monitoring sites are currently undertaken by EA or TWUL, this should be agreed before the post drought period Results of the fish population surveys should help inform mitigation targeting habitat restoration where deemed to be appropriate to support and enhance affected populations

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Walkover 3: US SP1363205385, DS SP1406405242 Walkover 4: US SP1497905150, DS SP1502004722 Walkover 5: US SP1503201544, DS SP1508301070 Walkover 6 (Control): US SP1011607765, DS SP1047707501 Riverbed substrate composition, connectivity, water quality, fish barrier assessments and habitat fragmentation will all be undertaken during each walkover survey. Data collated during the walkovers will be collated using the 'River Condition Assessment Form'			
Rhyacophila fasciata *Riolus cupreus* *Riolus subviolaceus*	Reduction in species diversity and abundance as a result of reduced recruitment Alteration to community composition as a	Distribution of these three species is established based on Environment Agency data collected between 2013 and 2015. See **Section 4.7.3**. Rapid bankside assessment of the invertebrate community is not feasible. Laboratory analysis of the invertebrate community is required to determine presence	No in stream monitoring is advised during environmental drought to prevent further harm to the invertebrate community through kick/ sweep sampling. Walkover of key sections (detailed below) known to be susceptible to lower flows. Assessments of sediment	No in stream monitoring is advised during drought permit implementation to prevent further harm to the invertebrate community through kick/ sweep sampling. Surveillance walkover of key sections on an assumed monthly basis. However, following the	Mitigating the impact of the drought permit on macroinvertebrate species through direct intervention is not feasible. In extreme circumstances habitat improvements post drought can aid in natural recolonisation of fine-lined pea mussel and depressed river mussel.	In July 2023, targeted sweep sampling of silty habitat and submerged macrophytes in monitoring sites (detailed below) to ascertain population quality post drought. Laboratory sorted to identify presence of the

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
	result of changes in water quality	of these three species. As such baseline monitoring of these species should be based on existing sites and consists of three minute kick sampling methodology, with species level analysis of *Rhyacophilidae* and *Elmidae* specimens.	cover will be undertaken within each walkover section. Reach 1 Walkover 1: US SP0190107934, DS SP0207007552 Walkover 2: US SP0204306061, DS SP0222305607 Walkover 3: US SP0216504512, DS SP0221404124 Walkover 4 (Control): US SP0163809167, DS SP0178308788 Reach 2 Walkover 1 (US Reach 1): US SP0196603230, DS SP0198102764 Walkover 2: US SP0240602468, DS SP0279902178 Walkover 3: US SP0374600311, DS SU0387599982 Reach 3 Walkover 1 (US Reach 1): US SU0406098329, DS SU0409897965	review of the on-set drought monitoring, expert judgement should be used to determine if the frequency of monitoring the impacts of drought should increase given the conditions recorded during the on-set walkovers. Continue walkovers, and measure dissolved oxygen, conductivity and temperature in the field using calibrated handheld equipment. Reach 1 Walkover 1: US SP0190107934, DS SP0207007552 Walkover 2: US SP0204306061, DS SP0222305607 Walkover 3: US SP0216504512, DS SP0221404124 Walkover 4 (Control): US SP0163809167, DS SP0178308788 Reach 2 Walkover 1 (US Reach 1): US SP0196603230, DS SP0198102764		macroivertebrate species Reach 1: Perrotts Brook SP0204206071 Reach 2: Stratton SP0207803291 Reach 3: Gauging station, Cerney Wick SU0755796305

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Walkover 2: US SU0398197684, DS SU0426597336 Walkover 3: US SU0499697236, DS SU0546497375 Walkover 4: US SU0744596493, DS SU0779796216 Walkover 5: US SU1026394008, DS SU1058893772 Reach 5 Walkover 1 (US Reach 1): US SP1233806486, DS SP1210906057 Walkover 2: US SP1228405823, DS SP1267005562 Walkover 3: US SP1363205385, DS SP1406405242 Walkover 4: US SP1497905150, DS SP1502004722 Walkover 5: US SP1503201544, DS SP1508301070 Walkover 6 (Control): US SP1011607765, DS SP1047707501	Walkover 2: US SP0240602468, DS SP0279902178 Walkover 3: US SP0374600311, DS SU0387599982 Reach 3 Walkover 1 (US Reach 1): US SU0406098329, DS SU0409897965 Walkover 2: US SU0398197684, DS SU0426597336 Walkover 3: US SU0499697236, DS SU0546497375 Walkover 4: US SU0744596493, DS SU0779796216 Walkover 5: US SU1026394008, DS SU1058893772		

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Measure dissolved oxygen, conductivity and temperature in the field using calibrated handheld equipment within each walkover section.			
Invasive non-native species (INNS) *Crangonyx pseudogracilis,* *Potamopyrgus antipodarum* *Dugesia tigrina, Pacifastacus leniusculus Physella acuta* *Fallopia japonica* *Heracleum mantegazzianum* *Impatiens glandulifera*	Increasing the distribution of invasive non-native species (INNS)	Locations of INNS species within Reach 1 is to be ascertained by assessment of open-source data and liaising with local Environment Agency biodiversity and ecology teams. **To establish a baseline:** Investigatory surveys to be informed by open-source data and Environment Agency knowledge around key locations within Reach 1 (including back pumping operations and known any known obstacles to INNS spread) INNS surveys are to be undertaken using multispecies methods in order to capture known and potential unknown species within the area.	No in stream monitoring is advised during environmental drought to prevent further harm to the aquatic communities through sampling. Surveillance walkovers have been selected and will be undertaken at the following locations: Reach 1 Walkover 1: US SP0190107934, DS SP0207007552 Walkover 2: US SP0204306061, DS SP0222305607 Walkover 3: US SP0216504512, DS SP0221404124 Walkover 4 (Control): US SP0163809167, DS SP0178308788 Reach 2	Monthly walkovers of the sites identified in the on-set monitoring programme have been assumed for the duration of the implementation. During these walkovers, surveyors will note the presence, and extent, where possible, of any INNS species found during the walkover surveys; this includes the mapping of localities where INNS were observed and photographs. All INNS surveys should be carried out in compliance with biosecurity guidance[91].	Mitigation for the spread of INNS should be centred around preventative measures by following best practice protocols and biosecurity guidance[92] . INNS survey results should be used to inform the biosecurity protocol and mitigate for the potential for further spread of INNS during additional monitoring and mitigation tasks.	All INNS records to be provided to the Environment Agency. Monitoring should commence in June 2023 following the drought and should continue for at least two years in order to assess the impact of drought permit implementation on the INNS species identified during monitoring. The results of these surveys should be used to inform the requirement for biosecurity protocols and monitoring during subsequent drought permit implementation period. INNS surveys are to be undertaken using multispecies methods in order to capture known

[91] GB non-native species secretariat - Biosecurity in the field. Accessed 2nd March 2022. http://www.nonnativespecies.org//index.cfm?pageid=174.
[92] GB non-native species secretariat - Biosecurity in the field. Accessed 2nd March 2022. http://www.nonnativespecies.org//index.cfm?pageid=174.

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Walkover 1 (US Reach 1): US SP0196603230, DS SP0198102764 Walkover 2: US SP0240602468, DS SP0279902178 Walkover 3: US SP0374600311, DS SU0387599982 Reach 3 Walkover 1 (US Reach 1): US SU0406098329, DS SU0409897965 Walkover 2: US SU0398197684, DS SU0426597336 Walkover 3: US SU0499697236, DS SU0546497375 Walkover 4: US SU0744596493, DS SU0779796216 Walkover 5: US SU1026394008, DS SU1058893772 Reach 5 Walkover 1 (US Reach 1): US SP1233806486, DS SP1210906057 Walkover 2: US SP1228405823, DS SP1267005562			and potential unknown species within the area.

Baunton (1)						
Feature and reach	Potential Impact identified in EAR	Pre-drought	On-set of environmental drought	During Drought Permit Implementation Period		Post Drought Permit
		Key locations	Monitoring and trigger setting	Trigger and monitoring to inform mitigation action	Mitigation actions	Monitoring and post-drought mitigation (where applicable)
			Walkover 3: US SP1363205385, DS SP1406405242 Walkover 4: US SP1497905150, DS SP1502004722 Walkover 5: US SP1503201544, DS SP1508301070 Walkover 6 (Control): US SP1011607765, DS SP1047707501 Surveyors will note the presence and extent, where possible, of any INNS species found during the walkover surveys; this includes the mapping of localities where INNS were observed and photographs with data collated via the 'River Condition Assessment Form'. All INNS surveys should be carried out in compliance with biosecurity guidance[90].			

[90] GB non-native species secretariat - Biosecurity and Pathways. Accessed 12th September 2022. https://www.nonnativespecies.org/biosecurity/.

7 Cumulative Impacts

7.1 Introduction

The focus of this EAR is the Baunton (1) drought permit. The assessment, as described in previous sections, has considered how the proposed drought permit may affect the environment in combination with the effects of existing licences and consents. In accordance with the DPG, and further to consultation with the Environment Agency during the development of **the Methodology**, the assessment has also considered the potential cumulative effects of Thames Water implementing other drought permits within a similar timeframe. Consideration has also been given to the potential for cumulative impacts of drought options implemented by neighbouring water companies. This is discussed further in **Sections 7.2** and **7.3** below.

7.2 Interaction with Other Thames Water Drought Options

Thames Water's Drought Plan comprises a number of drought permits, which are identified on **Figure 2.1**. During the time of writing the “shelf copy” EAR, the cumulative impacts of implementing the Baunton (1) drought permit at the same time as the Meysey Hampton and Latton drought permits were assessed. At the time of application for the Baunton (1) drought permit, the Meysey Hampton drought permit application is also being made. Therefore, cumulative impacts have been assessed and presented below.

7.2.1 Interaction between Baunton (1) Drought Permit with Meysey Hampton Permits

The Baunton (1) and Meysey Hampton drought permit applications were made on the 6th October 2022 as part of a programme of drought permit applications required to address the risk to supply caused by the drought leading to reduction in storage at Farmoor Reservoir. At the time of application, the Latton drought permit is not being applied for. The cumulative impact assessment below is an over representation of any impacts of implementing the Baunton (1) and Meysey Hampton drought permits simultaneously, as it assumes the Latton drought permit is also in operation.

Introduction

The Baunton (1) groundwater abstraction lies in close proximity to the Meysey Hampton groundwater abstraction, albeit from different aquifers.

For the Baunton (1) drought permit, there are five potentially impacted reaches over three rivers: Reaches 1 to 3 are located on the River Churn, Reach 4 on the Gumstool Brook and Reach 5 on the River Coln (from Ablington to its confluence with the River Thames). Assessment of the hydrological impact of implementing the Baunton (1) drought permit indicates a **moderate** hydrological impact in Reaches 1 to 3 and a **negligible** hydrological impact in Reaches 4 and 5.

For the Meysey Hampton drought permit, there are six potentially impacted reaches over six rivers: Reach 1 is located on the Ampney Brook, Reach 2 is located on the Poulton Stream (a tributary of the Ampney Brook), Reach 3 is located on the Marston Meysey Brook, Reach 4 is located on the Blackford Barn Stream (a tributary of the Marston Meysey Brook), Reach 5 is located on the River Thames and Reach 6 is located on the River Coln (from Fairford to its confluence with the River Thames). Assessment of the hydrological impact of implementing the Meysey Hampton drought permit indicates a **major** hydrological impact in Reaches 1 to 4 and a **negligible** hydrological impact in Reaches 5 and 6.

Therefore, there is one reach with potential cumulative impacts: the River Coln, from Ablington to its confluence with the River Thames (cumulative Reach 1).

Potential Groundwater Drawdown from Implementation of the Drought Permits

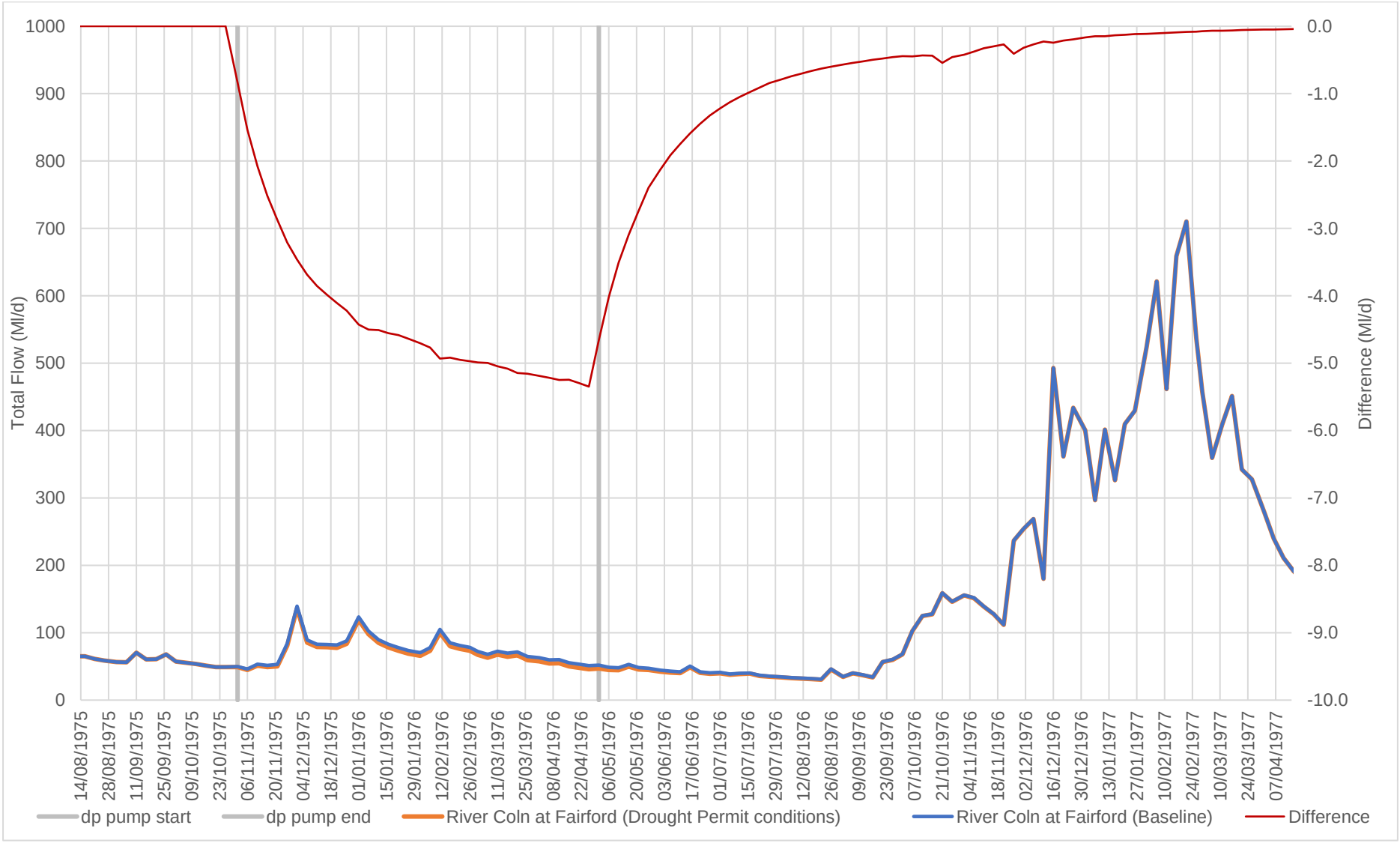
The Baunton (1) drought permit would allow additional water to be abstracted from the Inferior Oolite aquifer. Conversely, the Meysey Hampton drought permit would allow additional water to be abstracted from the Great Oolite aquifer. Therefore, no cumulative effect on groundwater drawdown is anticipated as a result of implementing the Baunton (1) and Meysey Hampton drought permits at the same time.

Potential Changes to Hydrology from Implementation of the Drought Permits

The Baunton (1) and Meysey Hampton drought permits operating individually have both been identified as having a negligible impact on flows in the River Coln. Potential cumulative effects on stream flows resulting from implementing the Baunton (1) and Meysey Hampton drought permits have been assessed using the Cotswolds Groundwater Model. The modelling outputs include stream flows for a baseline (without drought permit) scenario and under Baunton (1), Latton and Meysey Hampton drought permit conditions. Therefore the assessment is an over representation of effects on hydrology. For the purpose of this assessment the year 1975/1976 has been focussed on.

Modelling results for the baseline and drought permit scenario for Cumulative Reach 1 (River Coln) are based on modelled flow at the Coln at Fairford gauge. Modelling results for flow in Cumulative Reach 1 (River Coln) are presented for 1975/1976 on **Figure 7.1** below.

Figure 7.1 Coln at Fairford assessment gauge: Modelled baseline flow vs Baunton (1), Latton and Meysey Hampton drought permit conditions



For an assessment point in Cumulative Reach 1, baseline flow without a drought permit is considered to be represented at the Coln at Fairford assessment gauge. The modelling results for the Coln at Fairford show that Cumulative Reach 1 (River Coln) is a perennial reach.

Based on the modelled data, the baseline (without drought permit) reference conditions flow at Coln at Fairford would be as follows: summer Q95 of 32.6 Ml/d, summer Q99 of 31.3 Ml/d, annual Q50 of 63.8 Ml/d and annual Q95 of 33.9 Ml/d.

The modelling results show that with the Baunton (1) and Meysey Hampton drought permits in place there would be a reduction in the summer Q95 and Q99 flows of 2% at the Coln at Fairford assessment gauge. The modelling results also indicate that with the drought permit in place there would be a reduction in the annual Q50 and Q95 flows of 7% and 2% respectively. The modelling results indicate following the drought permit cessation flows will be up <1 Ml/d lower until the following winter recharge period.With the exception of the last 4.6km of the reach whose elevation is slightly below 80mAOD, the majority of the reach is above 80mAOD. This indicates the reach should be considered as an upland reach in the perennially flowing watercourses hydrological impact assessment methodology (see **the Methodology**). Given the potential impacts discussed above (<10% reduction in summer Q95 and summer Q99, <10% reduction in annual Q50 and Q95), the potential cumulative hydrological impact of implementing the Baunton (1) and Meysey Hampton drought permits at the Coln at Fairford assessment gauge is considered to be **negligible**[93].

Hydrological Impact Summary

The potential cumulative hydrological impact of implementing the Baunton (1) and Meysey Hampton drought permits simultaneously is summarised in **Table 7.1** below:

Table 7.1 Cumulative hydrological Impact of the Drought Permits

Hydrological Reach	Reach Map Ref		Reach Boundary	Reach Length (km)	Hydrological Impact
River Coln	Cumulative Reach 1	Ablington	Confluence with River Thames	25.0	**Negligible**

Water quality

The hydrological impact resulting from implementing the Baunton (1) and Meysey Hampton drought permits has been assessed as negligible. The cumulative impact of the Baunton (1) and Meysey Hampton reaches on water quality is therefore considered to be **negligible** in Cumulative Reach 1 (River Coln).

Environmental pressures

An overview of flow pressures within the area of influence of the Baunton (1) and Meysey Hampton drought permits indicates that there are no significant risks to river flows in the River Coln from groundwater abstractions (other than from the Thames Water abstractions themselves) or surface water abstractions. The cumulative risk from flow pressures with both the Baunton (1) and Meysey Hampton drought permits in place is hence considered to be **low**, and there is no additional risk to the operation of these abstractions from having both drought permits in place.

A review of water quality pressures within the area of influence of the Baunton (1) and Meysey Hampton drought permits (based on discharge permit data received from the Environment Agency) indicates that there is a **negligible** risk to water quality in Cumulative Reach 1 (River Coln) associated with discharges.

[93] 'winter period' is the period once wet conditions trigger recharge, expected to occur within the period November to March. This overlaps with hydrological winter (1 October to 31 March), and hydrological conditions during this period correspond to hydrological winter.

Environmental Features Assessment

The hydrological assessment of the cumulative impacts of implementing the Baunton (1) and Meysey Hampton drought permits simultaneously has identified negligible impacts on hydrology in the River Coln (Cumulative Reach 1). Risks to water quality from flow and water quality pressures are also considered negligible. Therefore, impacts on features in Cumulative Reach 1 (River Coln) are not anticipated.

7.3 Interaction with Other Water Companies' Drought Options

The assessment of the potential for cumulative impacts of Thames Water's supply side and drought permit/order options with drought options listed in neighbouring water companies' drought plans has been undertaken as part of the Thames Water Final Drought Plan 2022: Strategic Environmental Report - Environmental Report [94]. The SEA was informed by the most recent information available on the neighbouring water companies' drought plans.

The SEA considered the following neighbouring watering company DPs:

- Anglian Water (2022)
- Severn Trent (2022)
- Southern Water (2022)
- Wessex Water (2021)
- Bristol Water (2022)
- Essex and Suffolk Water (2022)
- South East Water (mid Kent) (2022)
- SES (2021)
- Affinity Water (2022)

The SEA did not identify any drought permit/order options in other water company drought plans that could result in cumulative effects with the Thames Water Baunton (1) drought permit.

[94] Thames Water Utilities Ltd (2022). Thames Water Final Drought Plan 2022: Strategic Environmental Report - Environmental Report – Prepared by Ricardo Energy & Environment (17 August 2022).

Appendix A – Technical note: Cotswolds Hydrogeology and Groundwater Modelling

Appendix

For Baunton, Latton, Meysey Hampton and Bibury
Environmental Assessment Reports

Thames Water Utilities Limited

25 October 2022

T1.02

Appendix

Prepared for

Thames Water Utilities Limited

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Contents

FIGURES

TABLES

1 Introduction

1.1 Background

This appendix note is an amalgamation of the former Appendix A (Ricardo) and Appendix B (ESI) which were last updated in 2016. It forms a supporting document for the SWOX Resource Zone Drought Permit Environmental Assessments Report (EAR) as part of Thames Water's current Drought Plan (DP) 2022.

The appendix presents a technical note describing the hydrogeological conceptual model for four Thames Water public water supply sources (Baunton, Latton, Meysey Hampton and Bibury), These sources all draw groundwater from the Jurassic limestone aquifer system in the Cotswolds near Cirencester.

The hydrogeology of the Cotswolds is complex: layered, faulted and karstic. This means that the standard tools used by hydrogeologists for predicting impacts from changes in abstraction are unlikely to be reliable. A sound conceptual model is an essential starting point for any detailed assessment. The conceptual understanding has been used in the past in conjunction with observed groundwater level and surface water flow responses to abstraction changes as a basis to estimate water resource implications using the Environment Agency's Catchmod model. This approach has been replaced by the use of the Cotswolds Limestone regional groundwater model.

The Cotswolds Limestone groundwater model was developed in 2012-13 by ESI for the Environment Agency in close consultation with relevant stakeholders (particularly Thames water). The model is considered by the Environment Agency to be the most appropriate tool for making technical, quantitative decisions regarding the management of the groundwater resources of the aquifer system. The study area, Cotswolds Limestone groundwater model area and the location of the PWS abstractions are shown in Figure 1.

1.2 Approach

The approach adopted here is first to present a concise summary of the conceptual understanding of the local aquifers (Section 2). Analysis of the existing datasets is then presented as there have been substantial changes in abstraction rate at these sources over recent years (both as part of formal pumping tests and as a result of sustainability reductions). Review of the response of groundwater levels and river flows to these changes in abstraction (Section 3) will give a more reliable indication of potential location and duration of impacts of the proposed Drought Permit abstraction than theoretical groundwater calculations, particularly given the complex hydrogeology. Section 4 presents the latest (October 2021) modelling results using the Cotswolds Limestone groundwater model.

The presentation of figures and tables in this appendix is handled as a combination of in text figures and tables referenced as with chapter and figure number (e.g., Figure 1-1) and figures kept externally in the 'Appendix Figures' folder which are referenced as Appendix Figures in the text (e.g., Appendix Figure 1). This approach stems from the combination of the two appendices which each adopted a different method.

2 Conceptual Understanding

The conceptual model of the aquifer is described in this section. This is the technical basis behind the groundwater model as developed and should therefore be generally assumed to be embedded within the calibrated model.

2.1 Study Area

The study area is shown on Appendix Figure 1. The land surface in the area generally dips gently to the southeast towards flatter land along the course of the Thames. Along river valleys the gently sloping Cotswolds Plateau is steeply incised by rivers in places. The land is predominantly used for arable farming with some managed pasture. Cirencester is the largest town, located to the northwest of the sources being considered for the Drought Permits.

2.2 Geology

The geology of the study area is dominated by a sedimentary sequence of Lower to Middle Jurassic Limestones and mudstones (Appendix Figure 2). Superficial deposits are composed of Pleistocene River terrace deposits and recent alluvial deposits which are largely restricted to the valleys. The main formations of relevance to this study are concisely described in Table 2-1.

The stratigraphic sequence of the Jurassic strata in the Cotswolds is complex: the lateral variability of the various Formations and Members that comprise the Great and Inferior Oolite Formations is illustrated in Figure 2-1 below.

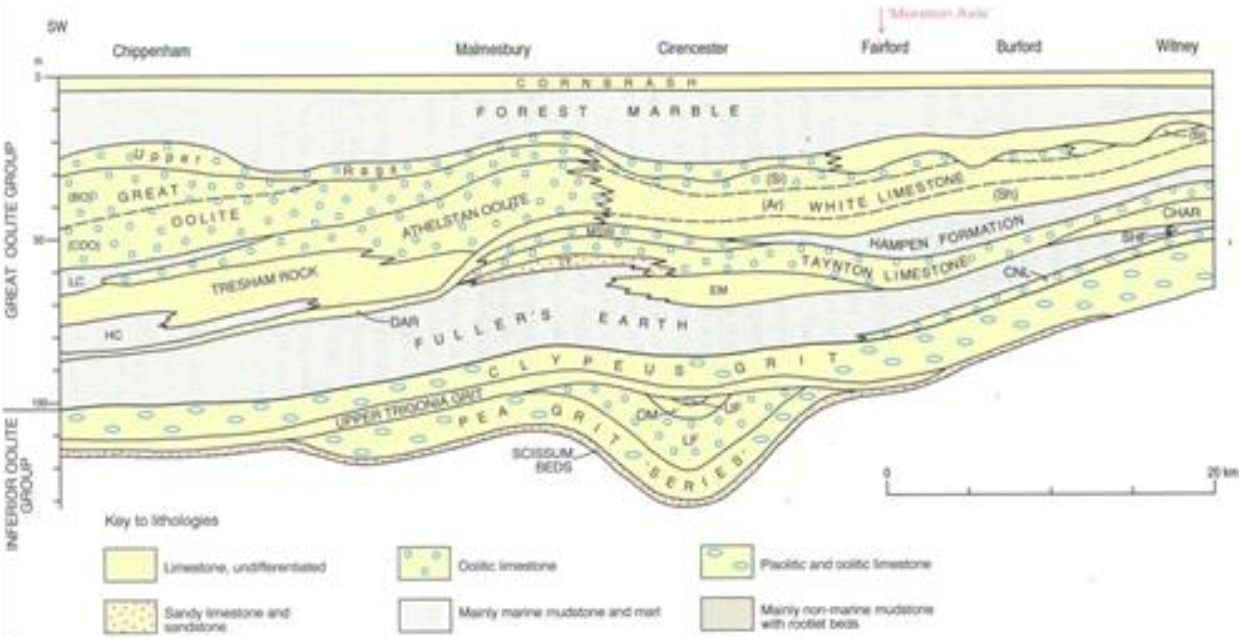

Figure 2-1 Jurassic stratigraphy in the Cotswolds (Sumbler, 1996)

Table 2-1 Stratigraphy of the study area (see notes at table foot for key to colours)

Chronostratigraphy			Lithostratigraphy			Description	
Era	**Period**	**Epoch**	**Group**	**Formation**	**Member**	**Lithology**	**Thickness (m)**
Cenozoic	Quaternary					Alluvium, clay, silt, sand and gravel	Up to 6m
		Pleistocene		Thames Valley Formation	Northmoor Sand and Gravel Member	Sand and gravel	Up to 6m
					Summertown-Radley Sand and Gravel Member	Sand and gravel	Up to 6m
					Hanborough Sand and Gravel Member	Sand and gravel	Up to 6m
Mesozoic	Jurassic	Middle	Ancholme Group	Oxford Clay Formation		Mudstone.	Up to 23
				Kellaways Formation	Kellaways Sand Member	Calcareous sandstones	5 – 9
				Kellaways Formation	Kellaways Clay Member	Mudstone	2 – 4
			Great Oolite Group	Cornbrash Formation		Calcarenitic limestone	2 – 6
				Forest Marble Formation		Mudstone with beds of shelly, ooidal limestone	10 – 25
				White Limestone Formation	Signet Member	Sandy or clayey peloidal wackstones	2-3
					Ardley Member	Limestone, peloidal wackstones and packstones	12

Chronostratigraphy			Lithostratigraphy			Description	
Era	**Period**	**Epoch**	**Group**	**Formation**	**Member**	**Lithology**	**Thickness (m)**
					Shipton Member	Limestone, peloidal wackstones and packstones	4 – 10
				Hampen Formation		Sandy and ooidal limestone with clay and marl beds	1 – 20
				Taynton Limestone Formation		Shelly ooidal grainstone	0 – 15
				Fuller's Earth Formation	Eyford & Througham Member	Fine ooidal grainstone	0 – 5
					Lower Fuller's Earth	Calcareous mudstones	0 – 10
				Chipping Norton Limestone Formation		Sandy, ooidal limestone	0 – 6
			Inferior Oolite Group	Salperton Limestone Formation	Clypeus Grit Member	Ooidal, shelly packstone	7 – 16
					Upper Trigonia Grit Member	Shelly, ooidal grainstone and packstone	0 – 5
				Aston Limestone Formation	Rolling Bank Member	Shelly, sandy, ooidal limestones. Ferruginous peloids	0 – 1
					Notgrove Member	Poorly sorted, peloidal and ooidal grainstone	0 – 10
					Gryphite Grit Member	Shelly, sandy, peloid (often ferruginous) grainstones, packstones and wackstones	3 – 5
					Lower Trigonia Grit Member	Shelly, sandy, peloid wackstones, packstones and grainstones	1 – 2

Chronostratigraphy			Lithostratigraphy			Description	
Era	**Period**	**Epoch**	**Group**	**Formation**	**Member**	**Lithology**	**Thickness (m)**
				Birdlip Limestone Formation	Harford Member	Ooidal, sometimes sandy limestone with sandy clay layers	0 – 90
					Scottsquar Member	Peloidal/ooidal, shelly packstone and grainstone	0 – 30
					Cleve Cloud Member	Ooidal grainstone	0 – 40
					Crickley Member	Ooidal shelly, grainstone	0 – 8
					Leckhampton Member	Peloidal /ooidal sandy, muddy limestone. Basal conglomerate	0 – 10
		Lower	Lias Group	Bridport Sand Formation		Sandy mudstones at base. Fine-grained micaceous sandstone	0 – 10
				Whitby Mudstone Formation		Mudstone with subordinate limestone beds at base	12 – 98

Notes: After Jones et al., (2000), Neumann et al., (2003) and Owen et al., (2005).

Colours represent the main two aquifer units in the area and are grouped according to their lithostratigraphic hydraulic connectivity. Grey/shaded formations are aquitards

Great Oolite aquifer

Inferior Oolite aquifer

In the south of the study area the relatively impermeable Oxford Clay Formation (Ancholme Group) occurs. This is underlain by the Great Oolite Group and Inferior Oolite Group which consist of a ~100 m thick sequence predominantly of limestones. The oolitic limestones are underlain by the mudstones of the Lias Group.

The Jurassic strata dip gently between 0.5° and 1.5° towards the south and southeast. Faulting of the Jurassic sedimentary sequence results in blocks of strata dipping locally in different directions to the regional trend. Fault planes trend predominantly north to south and WNW to ESE and may have throws of up to 50 m.

Superficial Deposits

Along the Thames Valley the Jurassic strata are overlain by Pleistocene River deposits. These predominantly comprise flat lying spreads of uniform, sandy gravel formed of sub rounded grains of sandy and shelly oolitic limestones with smaller quantities of ironstone, chert and quartzite. A few cobbles of oolite and chert are present. Most of the deposit is classified as gravel (gravel 50%, sand 45% and fines 5%).

2.3 Hydrogeology

The Cotswolds Jurassic Limestone groundwater body comprises two main aquifers: the Great Oolite and the underlying Inferior Oolite. These are separated by the intervening, low permeability Fuller's Earth.

Great Oolite

The Great Oolite Group is composed of limestones and calcarenitic limestones and includes the Fuller's Earth Formation. The Fuller's Earth Formation comprises a lower clay rich unit (Lower Fuller's Earth) and overlying calcareous sandstones, often locally decalcified to loose sand, and with minor beds of limestone, marl or mudstone (Eyford and Througham Members). The clay rich Lower Fuller's Earth, where present, forms the base of the Great Oolite aquifer.

The Cornbrash Formation (the uppermost formation of the Great Oolite Group) is classified as a Secondary A aquifer. This is due to the underlying Forest Marble Formation Clay Member which generally forms a hydraulic barrier between the Cornbrash and the underlying Great Oolite aquifer.

The top of the Inferior Oolite aquifer (where confined) is the base of the overlying Fuller's Earth Formation.

Overlying the uppermost part of the Inferior Oolite Group is the Chipping Norton Limestone Formation of the Great Oolite Group followed by the Fuller's Earth Formation; thus, the Chipping Norton Limestone Formation forms part of the Inferior Oolite aquifer as it is in direct hydraulic continuity.

Inferior Oolite

The Inferior Oolite Group is predominantly composed of limestones and rests on the Bridport Sandstone Formation (Lias Group), thus, the Bridport Sandstone Formation forms part of the Inferior Oolite aquifer unit as it is in direct hydraulic continuity. The Bridport Sandstone Formation is likely to be thin in the study area (<5 m).

The base of the Inferior Oolite aquifer is the interface between it and the underlying Whitby Mudstone Formation, which is underlain by the Marlstone Rock Formation, Dyrham Formation and the Charmouth Mudstone Formation (all pertaining to the Lias Group). The Whitby Mudstone Formation forms the base of the Inferior Oolite aquifer.

Hydraulic Connectivity of Inferior Oolite and Great Oolite aquifers

The Inferior Oolite and the Great Oolite aquifers are separated by the Fuller's Earth clay which is generally considered to be an aquiclude resulting in two independent aquifers (Allen et al., 1997; Environment Agency, 2007a). Water levels in the two aquifers are often significantly different, with those in the Great Oolite generally higher than those in the Inferior Oolite (University of Birmingham, 1987a). Neumann et al., (2003) also suggest that locally water levels in the Great Oolite are several tens of metres higher than those in the Inferior Oolite. Where the Fuller's Earth is thick, clayey and undisturbed, there can be steep vertical hydraulic head gradients across it (e.g. 15 m head difference at Meysey Marston).

As the Great Oolite becomes confined to the south of the Cotswolds study area the groundwater levels in the Inferior Oolite are generally higher than those in the Great Oolite. This is discussed further below. Geophysical borehole logging results for the Meysey Hampton borehole indicate a clay rich unit (interpreted as the Fuller's Earth Formation) around 10 to 15 m thick between the Inferior Oolite and Great Oolite. Test pumping at Meysey Hampton in 1973 did not indicate any leakage from one aquifer to another (Thames Water, 1973). Figure 2-2 below shows a conceptual cross section of the two aquifers.

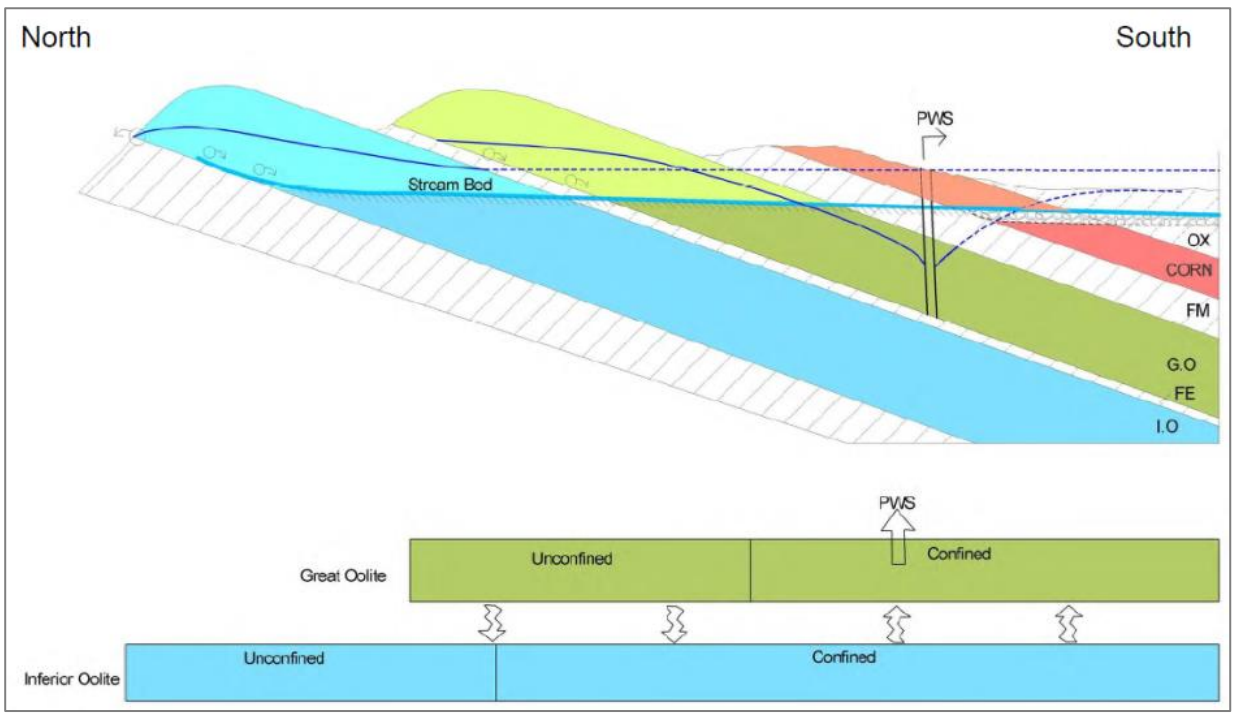

Figure 2-2 Hydrogeological conceptual cross section of Great and Inferior Oolite

Figure 2-7 shows modelled vertical conductance between Forest Marble to Great Oolite and conductance across the Fuller's Earth Formation.

Several reports have suggested that there may locally be connectivity between the Great Oolite and the Inferior Oolite, via leakage through the Fuller's Earth due to faulting. Thinning of the Fuller's Earth Formation and faulting may result in the two aquifers being hydraulically connected and may result in locally similar groundwater levels.

In summary, the hydraulic connectivity between the Inferior Oolite and Great Oolite is locally variable and dependent on the:

- Lateral argillaceous lithological variations in the Fuller's Earth Formation;
- Thickness of the Fuller's Earth Formation (there is localised and regional pinching and swelling. The Fuller's Earth Formation is around 14m thick in the study area; and
- Degree of faulting and downthrow (some faults have displacements of 10s of metres which juxtapose the Inferior Oolite and Great Oolite).

There is some uncertainty as to the nature of the upper parts of the Great Oolite aquifer system. The Forest Marble Clay is a potentially confining layer. However, scoping calculations and modelling by the University of Birmingham, 1987 suggested that there may be significant leakage through the formation from the overlying Cornbrash and this may support the major PWS abstractions in the confined zone during dry weather. If this is the case, the Kellaways Clay that overlies the Cornbrash would form the top of the Great Oolite aquifer system.

Gravel aquifer

There is no direct contact between the Thames Valley Formation gravel aquifer where it overlies the Oxford Clay. However, as shown on Appendix Figure 2, in some places the gravels overlap onto the upper parts of the limestone sequence (Cornbrash and Kellaways Formation) and provide a discharge route for groundwater from those formations. The gravels have been extensively worked for aggregates and restored as open water bodies and this has generally had a detrimental effect on summer groundwater levels in the gravels which in turn leads to losses from the tributaries of the Thames as they cross the gravels.

2.4 Hydraulic properties

Extensive testing of the main PWS abstractions in the confined zone has provided a large data set of aquifer parameters for the Great and Inferior Oolite. However, it is equally clear that the aquifer properties are highly variable and the response of the aquifers to abstraction, recharge and groundwater flow is strongly controlled by factors such as faulting.

Regional Context

The Inferior and Great Oolite aquifers are composed of generally well cemented limestones which give the aquifer matrix a low permeability, low effective porosity and thus a low storage potential. The bulk of groundwater flow and storage is considered to be largely within fractures and fissures (Maurice et al., 2007).

The Inferior Oolite aquifer strata are generally more fractured than the Great Oolite aquifer and this is understood to be due to its lower clay content. However, the Great Oolite generally has a transmissivity which is twice that of the Inferior Oolite (Allen et al., 1997).

In general, within the main limestone sequence, there is little evidence of particular formations providing zones of higher permeability. Birmingham University (1987) indicated that there was some evidence of variable permeability with depth (VKD) in the upper parts of the Great Oolite.

Local Data

CCTV inspection of boreholes at Meysey Hampton indicate that fissures in the Great Oolite aquifer were largely associated with bedding planes and flow logging suggested that the bulk of groundwater flow was from these larger bedding plane fissures. Both horizontal and vertical fissures were present in core samples from the Meysey Hampton boreholes. Significant flow was detected from bedding plane fissures close to the top of the Fuller's Earth Formation and at the base of the Inferior Oolite Group.

Test pumping has been carried out on a number of nearby public water supply (PWS) abstractions:

- Baunton, (NGR 402025, 204835);
- Latton (NGR: 408015, 196941);
- Ashton Keynes (NGR: 404160, 194110); and
- Meysey Hampton which has two PWS abstractions: one abstracting from the Inferior Oolite aquifer and the other from the Great Oolite aquifer (NGR: 411347, 198844).

However, quantitative analysis of these pumping tests to derive aquifer hydraulic properties has been undertaken for only a select number of pumping tests; many of the pumping tests were undertaken to delineate the extent of drawdown in the wider area and monitor river flow and loss. A summary of the hydraulic properties obtained from test pumping at these sites is presented in Table 2-2.

Table 2-2 also presents results of pumping tests prior and post acidisation development of the Meysey Hampton boreholes. It is evident that development by acidisation of the Great Oolite aquifer increased transmissivity and storage by around 20% and improved well performance.

Table 2-3 presents a summary of hydraulic properties for the varying lithostratigraphic units that are present in the study area. These hydraulic properties are derived from pumping tests, slug tests and laboratory core testing.

Role of faults

Geological structures are understood to affect the hydraulic properties of the aquifers. Some faults in the Cotswolds area have substantial throws (up to 50 m) and these result in the juxtaposition of the Inferior and Great Oolite aquifers, thereby connecting them hydraulically. Faults may affect groundwater flows in several ways:

- They may disrupt strata that act to separate different formations thus allowing/enhancing vertical flow between the formations. This may either be by means of placing the two formations in contact or by providing a zone of enhanced permeability through the intervening aquitard.
- They may offset a low permeability unit wholly or partially against a more permeable unit thus reducing transmissivity.
- They may affect the permeability of aquifers by physically altering the strata (either increasing or reducing it). In particular, some faults appear to act as partial barriers to flow.

Test pumping at Ashton Keynes PWS was seen to affect different boreholes to those affected by test pumping at Latton PWS which suggests that faulting reduces transmissivity in the area (Allen et al., 1997).

Groundwater level contours compiled by the University of Birmingham (1987) show faults influencing groundwater levels. Pumping tests at Latton and Marston Meysey suggest that Marston Meysey and Down Ampney Faults have some effect on groundwater flows but do not act as barriers to flow.

The Ampney Park Fault may act to limit impacts on groundwater levels (and baseflows) to the north of this, as cited in the 1997 and 2006 Drought Permit Report (SWK, 2006).

Table 2-2 Summary of pumping test results in the study area

Aquifer	Location	Date of testing	Test	T (m^2/d)	S	Q (Ml/d)	Drawdown (m)	Notes
Great Oolite Group	Meysey Hampton	2 July to 7 July 1973	24 hour steps over 6 days	*879	*4.0×10^{-4}	-	-	Pre acidisation
Great Oolite Group	Meysey Hampton	10 July to 16 July 1973	7 day constant	859	4.2×10^{-4}	4.320	43.5	Pre acidisation
Great Oolite Group	Meysey Hampton	26 July to 31 July 1973	24 hour steps over 6 days	*1,445	*3.8×10^{-4}	-	-	Post acidisation
Great Oolite Group	Meysey Hampton	6 August to 20 August 1973	14 day constant	*1,012	*5.2×10^{-4}	10,050	31	Post acidisation
Great Oolite Group	Meysey Hampton	August 1982	2 day constant	*1,432	*0.7×10^{-5}	-	-	-
Great Oolite Group	Meysey Hampton	8 August to 1 September 1983	25 day constant	*562	*2.1×10^{-4}	9,400	38.3	-
Great Oolite Group	Meysey Hampton	July/August 1996	Variable					29 July to 22 August- abstraction off (8.274 to 8.321 Ml/d prior) 22 August- to 29 August- approx. 8 ML/d
Inferior Oolite Group	Meysey Hampton	19 October to 23 October 1973	2 & 24 hour steps over 5 days	506	-	7,820	70	Pre acidisation

Aquifer	Location	Date of testing	Test	T (m^2/d)	S	Q (Ml/d)	Drawdown (m)	Notes
Inferior Oolite Group	Meysey Hampton	29 October to 4 November 1973	2 & 24 hour steps over 6 days	*454	*3.2 x 10^{-4}	-	-	Post acidisation
Inferior Oolite Group	Meysey Hampton	5 November to 19 November 1973	14 day constant	395	1.8 x 10^{-4}	9,245	61	Post acidisation
Inferior Oolite Group	Meysey Hampton	1 August to 2 August 1978	2 hour steps over 2 days	*603	-	-	-	-
Inferior Oolite Group	Meysey Hampton	3 August to 26 September 1978	54 day constant	*455	2.9 x 10^{-4}	-	-	-
Inferior Oolite Group	Meysey Hampton	July 1982	2 day constant	*530	*1.2 x 10^{-4}	-	-	-
Inferior Oolite Group	Meysey Hampton	July/August 1996	Variable					
Great Oolite Group	Latton	1964-1965	Using average values from operational data	592	-	-	-	-
Great Oolite Group	Latton	July/August 1996	Variable rate	592	-	-	-	Intermittent pumping 29 August- Approx 10 Ml/d

Aquifer	Location	Date of testing	Test	T (m^2/d)	S	Q (Ml/d)	Drawdown (m)	Notes
Inferior Oolite Group	Baunton	4th to 18th November 1969	14 day constant + geophysical logging	**3690	**1.1 x 10^{-4}	17,150	1.7 (additional ~1.9m total)	2 boreholes in the IO
Inferior Oolite Group	Baunton	3rd August to 3rd October 1978	61 day constant + tracer test			12,200	0.3 (additional ~1m total)	2 boreholes in the IO
Inferior Oolite Group	Baunton	1981				28,425 (combined)		2 additional boreholes in the IO
Inferior Oolite Group	Baunton	29th May to 15th July 1996	25 day Winter rate, 21 day Peak rate			Winter rate: 6,000 Peak rate: 15,000		Variable rate

Notes:

* Asterisk denotes average of test results. ** Denotes best of two results (poor results)

Source: Thames Water (1973), Thames Water (1978), Thames Water (1980), Robinson (1982) and Robinson and Allan (1983), Burton (1967).

Great Oolite aquifer

Inferior Oolite aquifer

Table 2-3 Hydraulic properties of lithostratigraphic units in the Cotswolds area

Stratigraphic Group	Lithostratigraphic unit		Porosity %	Effective porosity %	T (m^2/d)	S	K (m/d)	Sy
Ancholme Group	Kellaways Sand Member	Min. Ave. Max.	4.3 34	- - -	- - -	- - -	5.5×10^{-6} - 1.4×10^{-3}	- - -
Great Oolite Group	Cornbrash Formation	Min. Ave. Max.	- - -	- - -	- - -	2.2×10^{-6} - 2.2×10^{-2}	1×10^{-2} - 1.9	- - -
Great Oolite Group	Not defined	Min. Ave. Max.	5 14.5 25	3 (fissure) - 8.6	4 *212 5,900	6×10^{-5} - 4×10^{-3}	3.5×10^{-2}	1.4%
Inferior Oolite Group	Not defined	Min. Ave. Max.	12 19.1 24	12.1	- *139 700	7×10^{-5} - 1×10^{-4}	4×10^{-4} - 6×10^{-4}	1.8%

Notes: All averages are given as arithmetic mean unless marked with * denoting a geometric mean. Source: Allen et al., (1997) and Jones et al. (2000)

2.5 Groundwater Levels

The Inferior and Great Oolite aquifers are considered to be two independent aquifers with significantly different groundwater levels due to the presence of the Fuller's Earth Formation. In the unconfined zone, groundwater levels in the Great Oolite are generally higher than those in the overlying Inferior Oolite aquifer (Maurice et al., 2007). Groundwater contour maps, indicating maximum and minimum levels in both the Great and Inferior Oolite aquifers are presented in Appendix Figures 3 and 4 respectively. The regional direction of groundwater flow is towards the southeast in both aquifers although there are minor deviations due to faulting and in the unconfined parts as a result of topography.

In the unconfined zone, heads in the Great Oolite exceed those in the Inferior Oolite whilst, in the confined zone, groundwater levels in the Inferior Oolite tend to be higher than those in the Great Oolite reflecting the slow upwards flow towards ground surface via the Great Oolite (groundwater levels in the latter may also be locally depressed by abstraction e.g. at Latton). At the confluence of the Poulton Stream and the Ampney Brook, for example, the groundwater levels in the Inferior Oolite are approximately 110 m AOD (above Ordnance Datum) whereas the groundwater in the Great Oolite aquifer varies between 80 and 90 mAOD.

Groundwater hydrographs and the effect of abstraction on groundwater levels are discussed in more detail in Section 3.

2.6 Groundwater-Surface Water Interaction

Figure 2-4 shows the spatial distribution of gaining and losing reaches in average and dry conditions as simulated by the Cotswolds Limestone groundwater model for the period after abstraction reductions around Latton. The model was well calibrated to most of the surface water gauges and so the accretion and periods of low flow should be well represented by the model. Note that the model doesn't simulate the gravel aquifers and so the zero gain/loss (yellow cells) doesn't reflect the effect of the Cotswolds Water Park for instance.

Stream flows in the area are very 'flashy'; hydrographs are characterised steep rises in flow in winter due to rapid recharge processes. Figure 2-5 shows surface water flow at Cirencester gauging station which is typical for other hydrographs, combined with groundwater elevations. Figure 2-6 shows the difference in surface water summer flows between the Recent Actual and naturalised groundwater model runs (both in Ml/d and in proportional flow reduction).

2.6.1 River Churn

The River Churn, normally perennial, rises on the Inferior Oolite/Upper Lias boundary at Seven Springs at SP968169 and then flows in a generally southerly direction towards Cirencester (Figures 1 and 2). Between the source and Marsden (SP010 120) the river flows over Upper Lias and inputs are from springs in the Inferior Oolite in the valley sides (Environment Agency, 1997).

Appendix Figure 7A shows typical accretion profiles of the river including showing the geological formation over which the stream flows. Note however that, due to the steeply incised valleys, in places the streams may receive spring flow from higher formations (e.g. whilst the stream flow over the Fuller's Earth it may receive spring flow from the Great Oolite. However, in this reach it cannot leak to the Great Oolite). The groundwater elevation data shows that upstream of Baunton where heads are being controlled by springs in the valley sides, minimum groundwater levels in the Inferior

Oolite are generally close to the stream bed elevation. Downstream of Marsden to just south of Perrott's Brook, the river flows over an increasing thickness of Inferior Oolite. University of Birmingham (1987a) suggest that during recession periods the Churn loses to the Inferior Oolite between Marsden and North Cerney whilst the Environment Agency (1997) suggest that between Marsden and Perrott's Brook gauging station there are losses during most of the year although there may be gains during periods of high groundwater levels. In addition, there may be gain via the Bagendon Brook on this reach.

Between Perrott's Brook gauging station and Trinity Farm (SP020 050), the river flows over the Fuller's Earth and between April and August 1996 it gained flow (Environment Agency, 1997). This gain was thought to come from Great Oolite springs in the valley sides. For about 1 km south of Baunton the river loses to the Great Oolite and water levels in the Great Oolite are rarely above riverbed level (Environment Agency, 1997). Environment Agency (1997) notes that between Baunton and Cirencester the river does not gain flow from the Great Oolite, and it is possible that this stretch is permanently losing. During dry weather periods, the Churn typically dries at Cirencester gauging station. No flow at the gauging station has been recorded in 1990/91, 1995, 1996/7 and 2003.

The two public water supply abstractions within this catchment are Baunton, pumping from the Inferior Oolite aquifer and Latton, pumping from the Great Oolite aquifer. Abstraction from these sources has been reduced significantly since 2004, as a result of low flow investigations, resulting in a measurably increase in flows in the River Churn particularly under drier conditions.

Before pumping began at Latton, the Boxwell Springs issued from the Great Oolite and provided flow to the Churn at South Cerney (also to the Cotswolds Canal), but these are now generally dry (University of Birmingham, 1987).

Pumping from the Inferior Oolite at Baunton has been shown to impact flows in the Churn. This includes impacts on groundwater levels and flows north of Perrott's Brook. In the 1981 test flows at Cirencester were reduced by 12% of the abstraction rate (28 Ml/d) (Hunter and Davis, 1997).

Between Baunton and Latton, Inferior Oolite heads are variable relative to stream bed (possible abstraction impacts) but downstream of Latton they are substantially above the stream bed reflecting the confined nature of the aquifer. Groundwater elevations in the Great Oolite however, were generally well below stream bed elevation until the recent reductions in PWS abstraction since when they have occasionally been above stream bed level.

South of Cirencester, from South Cerney (SU 046972) to Cerney Wick (SU 078958)) the River Churn is understood to receive a significant inflow from the superficial gravel deposits, especially from the extensive area of submerged quarry voids (forming the Cotswolds Water Park) around South Cerney. However, during dry periods, the water levels in the submerged quarry voids fall due to evaporative losses. Given the hydraulic continuity between the lakes and the gravel deposits this is likely to result in a corresponding fall in groundwater levels in the gravels and a reduction in flow in the River Churn.

Analysis of the elevation of groundwater and surface waters at the Cotswold Water Park shows that the elevation of the lakes of the Cotswolds Water Park are in places lower than adjacent streams and groundwater levels, including the River Churn. This causes water from up gradient surrounding

areas (including adjacent rivers) to migrate into the lakes. Recharge-runoff modelling using 4R suggests that an increased evapotranspiration rate from the open water bodies can cause a significant loss to the River Churn (as shown in Table 2-4). Another mechanism for the loss is thought to be the control of water levels in the lakes by downstream discharge points.

Spot flow data taken from the River Churn also suggests that the Cotswolds Water Park causes a potentially significant reduction in the flow of the River Churn as it passes through it. This applies both for whole year data, as well as both low flows (below 30th percentiles) and high flows (above 30th percentiles). The overall picture when comparing the spot flow gauging sites and the Cerney Wick permanent gauging station downstream (all located on the gravels) was that there was a slight reduction in flow on average. The degree to which this was occurring was small (-0.0084 m3/s on average (0.7 Ml/d)). The effect was greatest in the low flow period (-0.014 m3/s (1.2 Ml/d)). Comparison of permanent flow gauges of Cirencester and Cerney Wick indicated an increase in mean monthly flow when averaged for each year, although losses were noted in the low flow summer months. Overall, this suggests a slight reduction in flow for the Churn over the reach passing the gravels.

The results of a walkover survey along the Churn in Cirencester and South Cerney in autumn 1996 are presented in Appendix A (taken from Hunter and Davis, 1997). This shows several dry reaches in these areas.

The two main tributaries to the River Churn are the Bagendon Brook, flowing on Inferior Oolite outcrop, which joins the Churn just upstream of Perrott's Brook gauging station, and the Dunt which joins the Churn at Cirencester. The Dunt is ephemeral, gaining water in its upper reaches but losing water below Daglingworth and, therefore, does not provide a large contribution to the Churn (University of Birmingham, 1987a and b).

2.6.2 River Coln

The River Coln rises from springs emanating from the Inferior Oolite aquifer in the Brockhampton and Sevenhampton area. In its upper reaches it flows over Lias through deeply incised valleys. As the River Coln flows downstream, accretion occurs due to groundwater discharge from the Great Oolite, initially via springs in the valleys sides and then through the stream bed. The stream itself is perennial on this reach. At Bibury, there is a substantial increase in flow because of major springs (see discussion below). Between Bibury and Fairford, where the river flows on Forest Marble clays, the gain in flow is very small during most summers. Appendix Figure 7B shows the accretion profile of the river including showing the geological formation over which the stream flows. Note however that, due to the steeply incised valleys, in places the streams may receive spring flow from higher formations (e.g. whilst the stream flow over the Fuller's Earth it may receive spring flow from the Great Oolite. However in this reach it cannot leak to the Great Oolite).

Groundwater levels in the Great Oolite tend to be close to or above stream level in winter but below in summer, whereas in the Inferior Oolite they are generally 10 m above stream level. During test pumping of the confined Inferior Oolite aquifer at Meysey Hampton in 1973, flow from artesian springs (Swan Springs) at the village of Bibury (SU 113 690) reduced within 24 hours of pumping at Meysey Hampton and showed an overall reduction in flow of 1.7 Ml/d to 1.9 Ml/d – equivalent to 20% of the abstraction rate at Meysey Hampton (Thames Water, 1973). A similar response was observed in test pumping in 1978 at Meysey Hampton with the springs decreasing in flow rate by around 4.7

Ml/d equivalent to 66% of the test pumping abstraction rate of 7.1 Ml/d. The impact on flows in the River Coln is greater than this, indicating that additional springs are affected.

Despite the Bibury springs being situated on Great Oolite they are affected by abstraction from the Inferior Oolite. University of Birmingham (1987a) suggested that water from Bibury springs has chemical characteristics of unconfined Great Oolite water. However, Allen et al. (1997) suggested that the springs may be derived from the Inferior Oolite via a fault. There is no suggestion in the Environment Agency (1997) report that abstraction from the Great Oolite at Meysey Hampton impacts on the springs at Bibury.

Meysey Hampton's old "summer" licence, which was revoked in 2002, required groundwater abstraction to switch from the Inferior Oolite aquifer to the Great Oolite aquifer, when the flow rate in the River Coln fell below the threshold of 68 Ml/d at Bibury (Robinson, 1983). This allowed the recovery of flow from the springs at Bibury. Groundwater heads in the Inferior Oolite in this area tend to be higher than those in the Great Oolite, therefore, flow from the Inferior Oolite to the Great Oolite is possible.

A 4R recharge-runoff model has been run for the Cotswold Water Park near the River Churn (ESI, 2013c). Using this modelling, it is possible to interpolate that the Cotswolds Park East area, containing open water to approximately 4 km2 might cause additional evaporative losses of around 1.1 Ml/d, which would otherwise flow to the River Coln. Table 2-4 shows the potential losses from the three rivers due to evaporative loss caused by the Cotswold Water Park. Compared to the River Churn and Ampney Brook the Cotswold Water Park only has a marginal effect on the River Coln, potentially due to the larger flows at Fairford.

2.6.3 Ampney Brook

The Ampney Brook is a winterbourne stream which rises on the Great Oolite (Figures 1 and 2). Springs feeding the stream move up and downstream, depending upon the rise and fall of groundwater level within the Great Oolite aquifer. During the spring and summer, flows in the brook recede south eastwards, until the brook completely dries. It generally dries over some of its length on an annual basis.

Appendix Figure 8 shows the geology and elevation of the stream bed of the Ampney Brook with distance from the confluence with the River Thames. Key features of interest such as abstractions, discharges and faults are shown for reference. Groundwater elevations for the Great and Inferior Oolite from the contours shown on Appendix Figures 3 and 4 have been added. The profile for the adjacent Poulton Stream is probably similar (generally less than 1 km to the east).

The winter source of the stream is the Winterwell Stream which occupies the Winterwell Valley to the north of Ampney Park and is fed by Great Oolite springs issuing from the interface between the White Limestone and Forest Marble Formations, 800 m west of Barnsley at SP068052. It flows across the Great Oolite to Ampney Park, where, it is fed by further springs at Ampney Park Springs. The Ampney Park Fault downthrows the less permeable strata against the Great Oolite aquifer in this area which accounts for the presence of the springs and may also explain why abstraction from the confined Great Oolite does not affect flows to the north of the fault (Hunter and Davis, 1997). The Ampney Brook flows over outcrops of the Cornbrash Formation between the villages of Ampney St. Peter (SP 078013) and Driffield (SU084, 994). South of this, the river flows on the clays, first the Kellaways for about 500m, and then the Oxford Clay, until its confluence with the Thames.

Winter flows in the order of 300 Ml/d have been recorded at the Sheepen Bridge gauging station on the Ampney Brook, but it dries along much of its length in the summer, largely due to its elevation; the upper reaches being 30m higher than the River Coln less than 3 km west (Rushton et al, 1992). Flow is lost downstream of the Ampney Park Fault.

The Poulton Stream rises, and flows, mostly over the mudstones of the Forest Marble Formation joining the Ampney Brook at Down Ampney.

Abstraction at Latton has not been clearly shown to affect flows in the Ampney Brook. However, it is believed to affect groundwater levels in the Great Oolite as far east as Fairford (on the Coln) and therefore some reduction in flow seems likely. Since the reductions in abstraction at Latton and Meysey Hampton there appears to have been a reduction in summer losses between Ampney St Peters and Sheepen Bridge (confluence with Thames).

Modelling studies by University of Birmingham (1987) showed that it was feasible for vertical flow from the Cornbrash to support abstraction at Latton. Previous studies (Hunter & Davis, 1997, and Scott Wilson Kirkpatrick, 2006a-c) have indicated that the restarting of flow in the Ampney Brook in the autumn/winter each year is principally determined by the timing of the first winter rains and that the impact of abstraction is relatively insignificant unless the winter rainfall is extremely low.

Downstream of the Ampney Park Fault, where it flows over the Forest Marble Formation, the stream may gain or lose water to the Great Oolite aquifer by downwards leakage through this less permeable strata. However, there is flow at Ampney Park in all but the driest years (University of Birmingham, 1987).

During the summer, groundwater elevations in the Great Oolite aquifer are generally well below stream bed elevation, pre and post the 2005 reductions in PWS abstractions, and so, during a drought could be in the order of 20 to 30 m below bed level, hence resulting in drying of the stream. However, further south at Ampney St Mary, when groundwater levels are high, i.e. after significant recharge, there may be a contribution to stream flow from the Great Oolite. Heads in the Inferior Oolite are substantially higher than this. Great Oolite groundwater levels are typically well below equivalent bed level in the upper reaches of these streams and consequently there can be no groundwater contribution to stream flow.

It has also been suggested (Hunter & Davis, 1997) that storage in the gravels aquifer may support flow in the reach south of Ampney St Peter. Further downstream, the Ampney Brook flows on to the Cornbrash and then onto the Kellaways Beds. There is no influence on changes in the Great Oolite groundwater levels after the Ampney Brook flows onto the Kellaways Beds.

Similar to the River Churn, Ampney Brook experiences a potentially significant reduction in river flows due to a reduction in baseflow from the gravels at the Cotswold Water Park. Table 2-4 indicates that evaporative losses are a potential cause for this loss.

Table 2-4 Potential evaporative losses realised by rivers

River	Proportion of gravel groundwater flow received from CWPw (%)	Amount lost to evaporation (Ml/d)	Q95 flows (Ml/d)
Churn	25	0.39	1.1 Cerney Wick
Ampney Brook	5	0.078	0.0 Sheepen Bridge
Coln	-	1.1	57 Fairford

2.7 Summary of the conceptual model

The principal aquifers in the area are the Inferior Oolite and Great Oolite aquifers. These aquifers are generally hydraulically isolated by an interbedded, lower permeability, clay rich formation (Fuller's Earth Formation). The Fuller's Earth Formation is around 15m thick in the area and the Inferior Oolite and Great Oolite aquifers are considered to be generally hydraulically isolated here. The throws on the faults in the study area do not seem to be large enough to juxtapose the aquifers but may provide zones of enhanced vertical permeability through the Fuller's Earth in places.

Regional groundwater flow in the Inferior Oolite and Great Oolite aquifers is to the southeast which is the dip direction of the strata. Groundwater flow direction is influenced by faults and by groundwater abstractions. Faults either appear to restrict movement of groundwater, (although they do not form complete hydraulic barriers), or act as conduits for groundwater flow between the Inferior Oolite and Great Oolite aquifers; the springs at Bibury village are understood to flow from the confined Inferior Oolite via a fault system.

Groundwater flow and storage is influenced predominantly via secondary porosity features such as fractures and fissures. The Great Oolite aquifer is considered to have a transmissivity which is around twice that of the Inferior Oolite.

It is considered that there is negligible hydraulic continuity between the limestone aquifers and surface water features in the south of the study area due to intervening confining strata (i.e. Forest Marble and Oxford Clay Formation). In this area the streams are strongly influenced by interaction with the overlying Thames Valley gravels aquifer. This has been extensively worked for gravels with old mineral working being restored as open water. This lowers the summer water table with the result that many of the tributaries of the Thames lose water as they flow over the gravels.

Figure 2-3 shows a schematic illustration of the conceptual model.

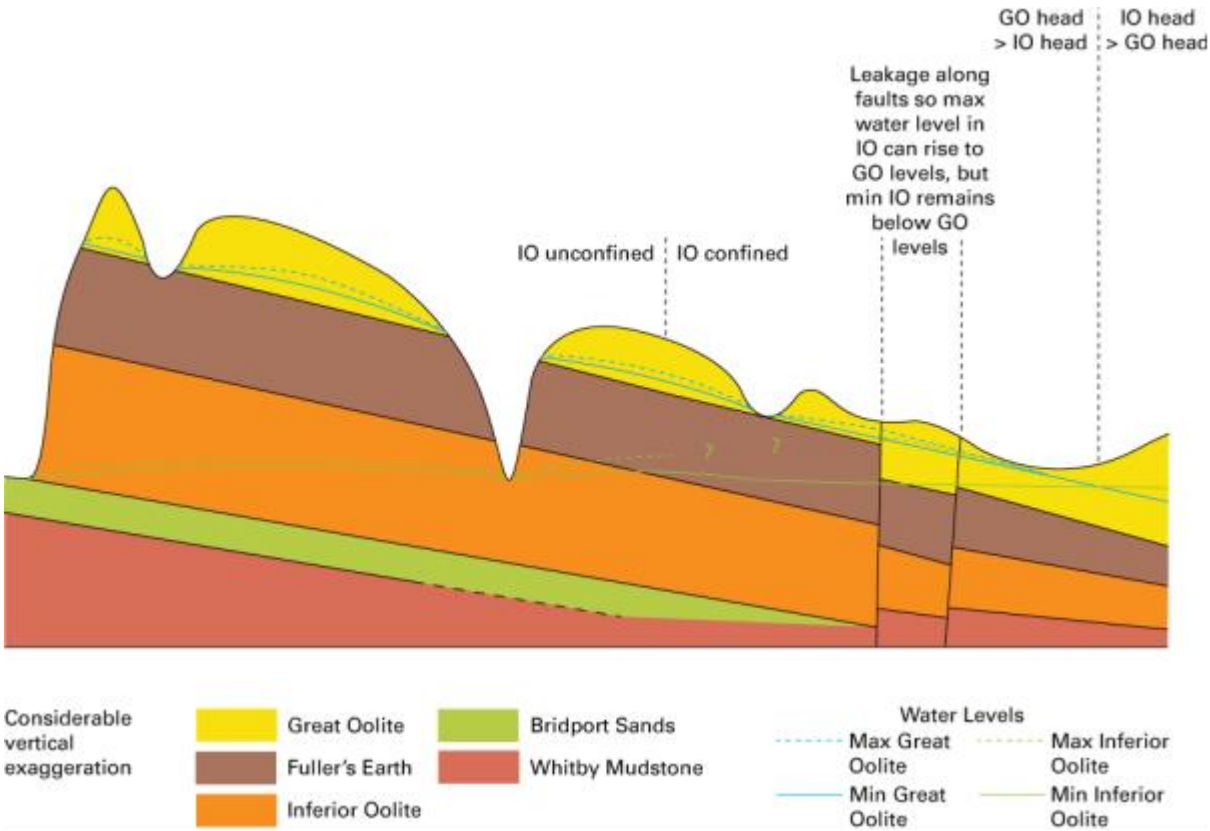

Figure 2-3 Schematic illustration of the conceptual model is provided below (BGS).

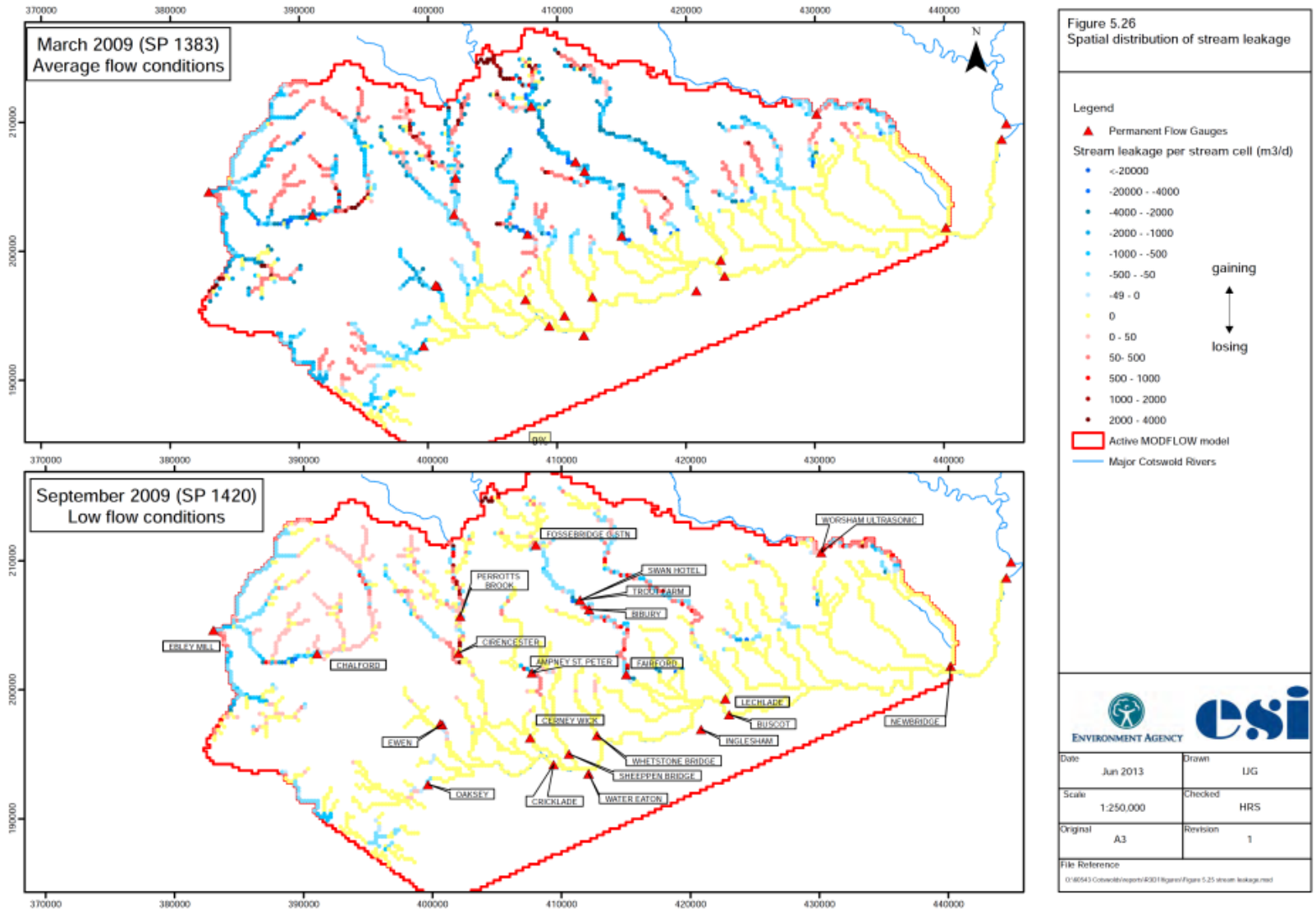

Figure 2-4 Spatial distribution of simulated stream leakage in average (top) and low (bottom) flow conditions

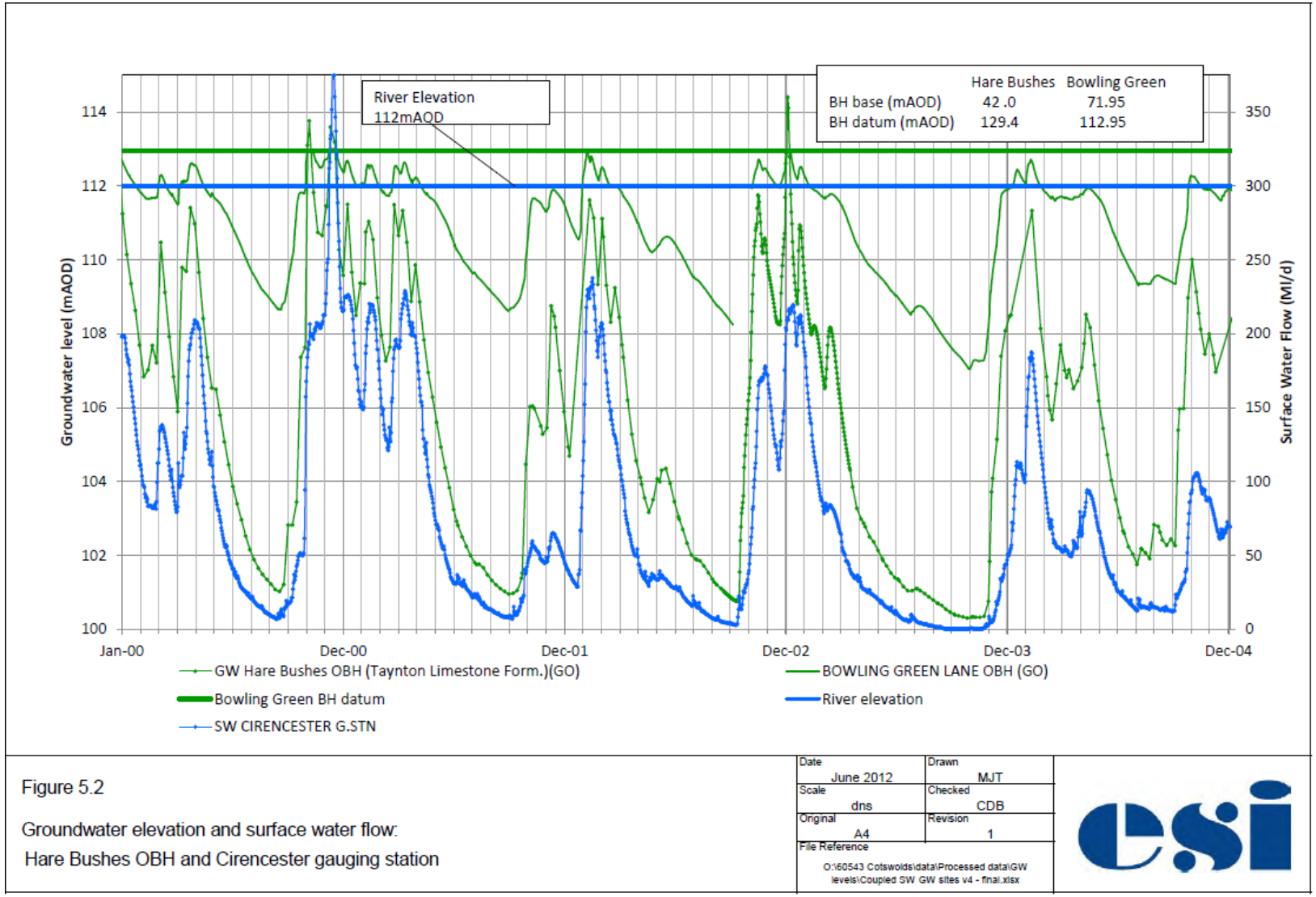

Figure 2-5 Cirencester gauging station hydrograph with groundwater levels 2000-04

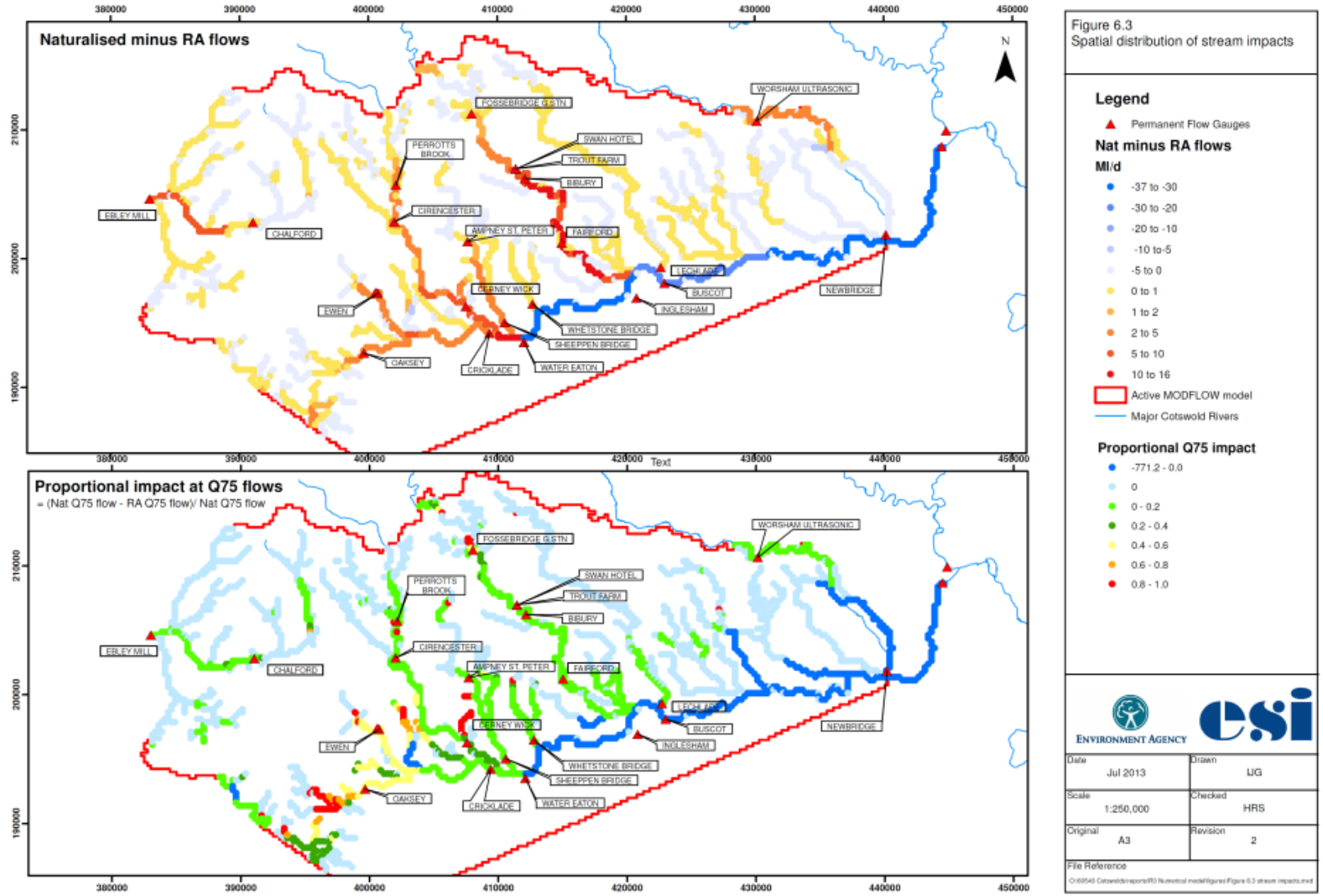

Figure 2-6 Difference between recent actual and normalised groundwater flows, in Ml/d (top) and proportional flow reduction (bottom)

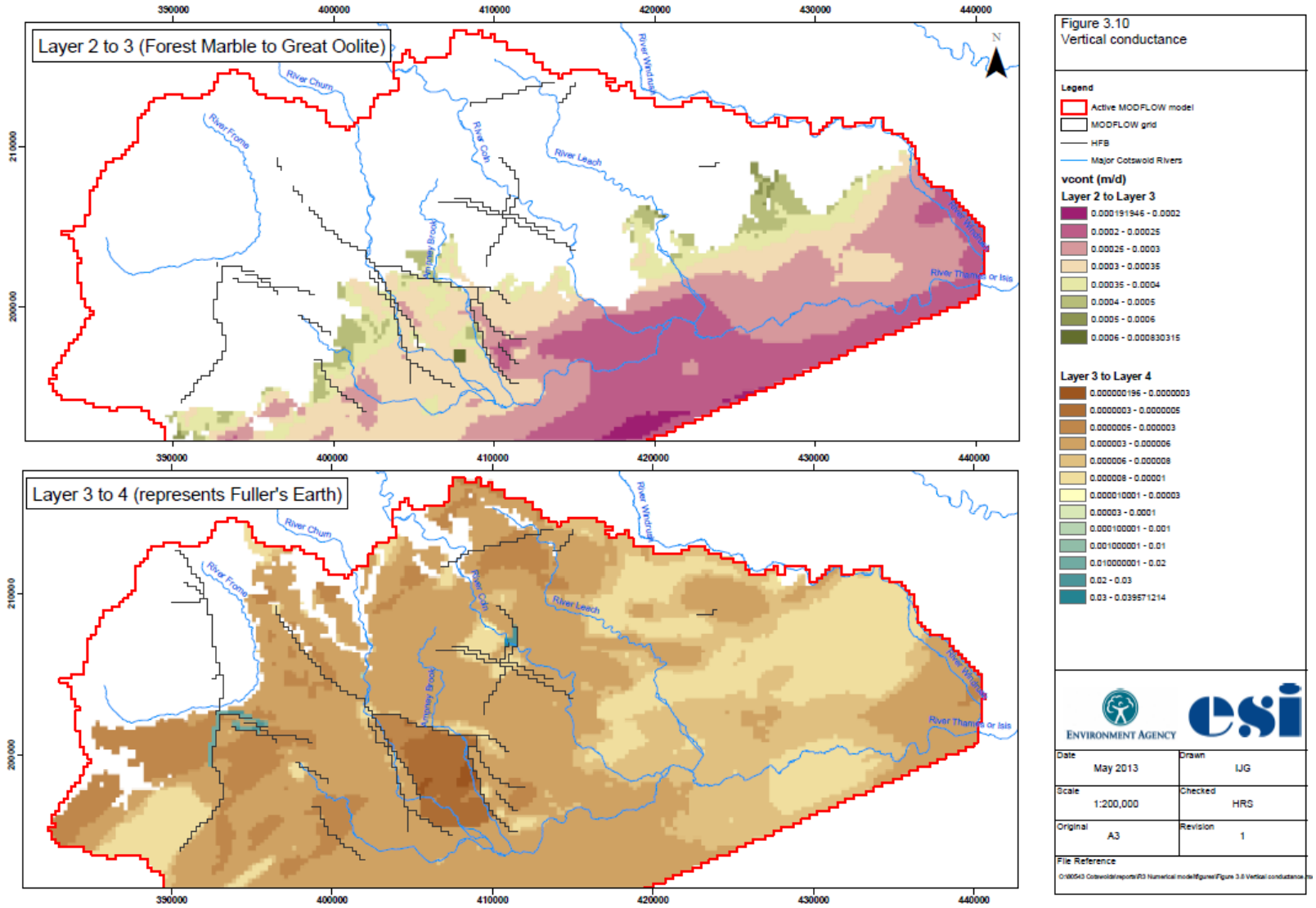

Figure 2-7 Modelled Vertical Conductance

3 Review of Impacts of Previous Periods of High Abstraction

The current rate of total abstraction from the Latton, Meysey Hampton, Bibury and Baunton PWS sources is substantially lower now than previously (Appendix Figure 9) with Bibury being the only PWS that sustained roughly the same abstraction rate. Comparing the groundwater and surface water conditions at prior to 2004 with those currently prevailing provides a useful indication of the likely extent of impacts from the proposed Drought Permits. This exercise represents a 'worst case scenario' with drought permit impacts expected to be lower than the results of this comparison as it is not proposed to increase abstraction rates to pre-2004 levels.

3.1 Previous Elevated Abstraction Rates

Appendix Figure 9 shows that the rate of PWS abstraction from Latton, Baunton, Bibury and Meysey Hampton has dropped from 35-55 Ml/d prior to 2004 to around 20-35 Ml/d over recent years. Changes in abstraction are summarised as follows:

	Average of Latton	Average of Baunton	Average of Meysey Hampton GO	Average of Bibury	Average of Grand Total
Pre 2004	23.08	7.81	2.16	7.20	40.25
Post 2004	13.73	4.55	0.09	8.08	26.44
Change	-9.35	-3.26	-2.07	+0.87	-13.81

This substantial change in abstraction has had a marked effect on groundwater levels in some places as discussed in the following section. Effects on flows are much harder to discern in the data but analysis of the time series flow data is also discussed. It should be noted that both Baunton and Meysey Hampton operate under HoF conditions which will influence the likely impact from Drought Permits during low flow conditions. The constraints on the deliverable output on those sources are listed in Table 3-1 below.

Table 3-1 Deliverable Output Constrains on Sources

Source	DO constraints
Baunton	Licensed rate except when flow constraint active. Average licence 16.59 Ml/d. Peak licence 21.59 Ml/d. Flow constraint: no abstraction when average of mean daily flows of immediately preceding five consecutive days ≤ 32 Ml/d in River Churn at Cirencester (SP 02013 02863).
Meysey Hampton (Inferior Oolite Boreholes)	Licensed rate except when flow constraint active. Average licence 7.95 Ml/d. Peak licence 10.14 Ml/d. Flow constraint: no abstraction when average of mean daily flows of immediately preceding five consecutive days ≤ 68 Ml/d in River Coln at Bibury (SP 12147 06228).

Groundwater Levels

Hydrographs of local groundwater levels and relevant abstraction rates are shown on Appendix Figures 10 and 11 (Great and Inferior Oolite respectively). The effects of the reductions in PWS abstraction are summarised in Table 3-2. The locations of the observation boreholes are shown on Appendix Figures 3 and 4.

In summary, this analysis shows that reductions in the rate of abstraction by 15- 20 Ml/d had a marked effect on groundwater levels within several kilometres of the PWS abstractions being considered for the Drought Plan with more subdued effects beyond this. It is difficult to completely disentangle the effects of the individual abstractions as the rate of abstraction was reduced at all three PWSs over similar timescales.

Table 3-2 Effect on Groundwater Levels from PWS Abstraction Reductions

Observation Bh	Range pre 2004 (mAOD)	Range Post 2004 (mAOD)	Rise in mins (m)	Rise in maxs (m)	Probable PWS	Comment
Great Oolite Sites						
Down Ampney	55-80	63-86	8	6	Meysey Hampton	
Ampney Crucis OBH	100-103	100-103	0	0		No real change
Box Bush	60-80	70-88	10	8	Latton	near the Churn
Meysey Hampton	65-95	84-94	19	-1	Meysey Hampton	
Sheephouse Farm	111-115/118	111-118				on the Ampney Brook (0.5 m drop in 1976)
Crane Bridge	60-83	70-90	10	7	Latton	
Siddington	76/78-87	79-96	2	9	Latton	
Inferior Oolite Sites						
Meysey Hampton	96-109	93-112	-3	3	Meysey Hampton	
Perrott's Brook	119-123/124	117-126	-2	2	Baunton	near Baunton
Baunton	119-125 (116 in 1976)	-			Baunton	No recent data
Siddington	80-92	83-96	3	4	Meysey Hampton (& Latton?)	

Stream Flows

Churn

The difference in flows between Cerney Wick (lower reaches on Thames gravels) and Cirencester is shown on Appendix Figure 12. This reach will primarily be affected by changes in abstraction at Latton (changes in abstraction at Baunton would occur upstream of this). Visually Appendix Figure 12 appears to show relatively little change between the periods before and after the change in abstraction: during winter months there is generally a substantial gain but during summer months (typically July to September but occasionally including May, June or September) there are losses of 0.9 to 4.3 Ml/d (0.01 to 0.05 m3/s).

It is difficult to directly compare the periods before and after 2004 as the rainfall during these periods is quite different. However, looking at the low flow months (July to September), pre 2004 there was an average loss of flow of around 0.9 Ml/d (0.01 m3/s) over this reach whereas post 2004 there was an average increase in flows of 2.6 to 7.8 Ml/d (0.03 to 0.09m3/s)) (0.9 Ml/d (0.01 m3/s) if you exclude 2008 which seemed to have atypical summer flows).

This would suggest that the reduction in abstraction rates at Latton (9.35Ml/d) has had a small but discernible effect on low flows (plus around 1.8 Ml/d). However, even pre 2004, monthly average losses never exceeded 4.3 Ml/d (0.05 m3/s). The change in abstraction rates at Latton may also have impacted the reaches upstream of Cirencester.

Ampney Brook

The difference in flows between Sheepen Bridge (confluence with Thames) and Ampney St Peters is shown on Appendix Figure 13. Visually this appears to show relatively little change between the periods before and after the change in abstraction: during winter months there is generally a gain but during summer months (typically July to September but occasionally including May, June or September) there are losses of 0.9 to 3.5 Ml/d (0.01 to 0.04m3/s).

It is difficult to directly compare the periods before and after 2004 as the rainfall during these periods is quite different. However, looking at the low flow months (July to September), pre 2004 there was an average loss of flow of 0.9 to 1.7 Ml/d (0.01 to 0.02m3/s) whereas post 2004 there was an average increase in flows of 2.6 to 3.5 Ml/d (0.03 to 0.04m3/s) (1.7 Ml/d (0.02m3/s) if you exclude 2008 which seemed to have atypical flows).

This would suggest that the reduction in abstraction rates at Latton (9.35Ml/d) had has a small but discernible effect on low flows (2.6 to 3.4 Ml/d). However, even pre 2004, monthly average losses never exceeded 3.5 Ml/d (0.04 m3/s). A small amount of this improvement may be due to the reduction in Inferior Oolite abstraction at Meysey Hampton by 1.9 Ml/d. However, most of the impact from the latter source was inferred to occur at the Bibury Springs on the Coln and so is unlikely to benefit the Ampney Brook significantly.

3.2 Pumping Tests

A series of pumping tests have been carried out at the PWS sources in this area over the last 30-40 years. Appendix B presents a summary of the pumping tests. Environmental monitoring during this period provides an important indication of the effects of PWS abstraction and thus the potential effects of the proposed Drought Permits.

The conclusions of these tests with respect to each source and stream are summarised in the following sections.

Baunton

Approximately 1km south of Perrott's Brook gauging station, groundwater is abstracted from the Inferior Oolite at Baunton, within 100 m of the River Churn. Inferior Oolite abstractions from Baunton were shown in the 1969 and 1978 pumping tests to impact flows in the Churn south of the Perrots Brook gauging station (Thames Water, 1980). Groundwater levels at Baunton rarely fall below the river bed and the 1978 tracer test showed a rapid but minimal flow of river water to the Baunton abstractions; tracer introduced into the river 25m upstream of the abstraction borehole was detected at the pumping borehole seven minutes after injection. It was inferred, but not proved, that the abstraction at Baunton impacts a natural outlet of groundwater to the River Churn, rather than inducing flow from the river to the aquifer (Thames Water 1980).

Pumping tests in 1981 and 1996 further defined the extent and mechanisms of impacts from Baunton on the River Churn (Environment Agency, 1997). Impacts from the 1981 pumping test were estimated to deplete river flow by 12% of the pumping rate (see Table 2 for test details) whereas in 1996 the loss of flow in the River Churn due to the abstraction at Baunton was calculated to be only 1.5% of the change in abstraction rate.

The licensed quantity at Baunton was reduced substantially in January 2008.

Meysey Hampton

Ampney Brook

The drying of sections of the Ampney Brook downstream of Ampney St. Peter is considered to be due to natural losses to the superficial deposits as there is no evidence to suggest any continuity between the Great Oolite aquifer and the Ampney Brook (Environment Agency, 1996). This finding appears to contradict the findings of the Inferior Oolite test pumping of 1973 at Meysey Hampton.

The 1973 pumping test at Meysey Hampton had an effect on the Great Oolite borehole (SP00SE24) at Ampney St. Peter (SP0770120) although no reduction was observed in the flow of the Great Oolite springs at Ampney Park (SP0610233). These results have been used to infer a zone of low transmissivity associated with the decrease in aquifer thickness along the Ampney Park Fault, an east-west fault between Ampney St. Peter and Ampney Crucis (Allen et al., 1997).

Marston Meysey Brook

During test pumping in 1973, a loss in stream flow of around 0.6 Ml/d was observed in the Marston Meysey Brook between Meysey Hampton pumping station and Whetstone Bridge (SU12769647). This was interpreted as natural leakage into the gravels during times of low flow and not as a result of the abstraction from the deeper Inferior Oolite aquifer (Thames Water, 1973).

Latton

River Churn

Test pumping at Latton during 1996 showed that increases in pumping rate at Latton were detected in the unconfined Great Oolite aquifer north of Cirencester, over 8.5km to the NNW. Groundwater levels were below the River Churn streambed elevation in the unconfined Great Oolite aquifer north of Cirencester throughout 1996 resulting in no groundwater contribution to river flows in this area (Environment Agency, 1996). This would likely have been the case irrespective of pumping test.

Poulton Stream

The cone of depression extending from the Latton abstraction is understood to reach as far as Poulton Stream.

3.3 Summary of Effects of PWS Abstraction on Stream Flow

Table 2-2 summarizes the main PWS pumping tests.

Latton

Previous investigations (Hunter & Davis, 1997) and (SWK, 2006) have suggested that it is possible that flows in the River Churn are affected by abstractions at Latton by:

- Leakage to the unconfined Great Oolite north of Cirencester.
- Induced leakage through the Forest Marble through Cirencester.
- Possible delayed long-term recovery of spring flow from the Boxwell Springs. These springs used to issue from the contact of the Cornbrash and the Kellaways Beds at South Cerney, until the head in the Great Oolite aquifer fell below this level.

The Great Oolite abstraction at Latton clearly has an impact on flows in the River Churn between the point where it flows onto the Great Oolite north of Cirencester and South Cerney, where the river flows onto the Kellaways Beds. Downstream of South Cerney stream flows are strongly influenced by interaction with the Thames Gravels which makes the stream more prone to drying.

The permanent flow gauging data shows that a reduction in abstraction of 9.35Ml/d at Latton and Meysey Hampton meant that the rate of loss between Cirencester and South Cerney benefited by around 2 Ml/d. Some further benefit may have occurred in the reach immediately north of the Cirencester gauge, but this is not easily established from the available data: it is likely that the impact is to some degree proportional to flow (i.e. larger impacts at high flows and smaller impacts at low flows).

Impacts on the Poulton Stream and Marston Meysey Brook from abstraction from the Great Oolite at Latton are less clear due to limited flow data. They are largely sourced from the overlying Cornbrash so should be less vulnerable.

Baunton

Previous investigations (Hunter & Davis, 1997) and (SWK, 2006) have suggested that abstraction from the Inferior Oolite at Baunton, impacts flows in the River Churn between Perrott's Bridge gauging station and the Great Oolite outcrop immediately south of Baunton by:

- a loss to the unconfined Inferior Oolite north of Perrott's Brook at times of low groundwater levels
- induced leakage through the Fuller's Earth between Perrott's Brook and Baunton PS
- a depletion of a 'natural outlet' of Inferior Oolite water where the aquifer is confined by Fuller's Earth between Perrott's Brook and Baunton.

In the short term, the rate of depletion is likely to be between 1.5% and 12% of the abstraction rate (SWK, 2006). In the longer term, as storage in the aquifer is diminished, all additional abstraction will be at the expense of stream flows. However, it is likely that the rate of depletion will be higher under high flow conditions.

Meysey Hampton

Previous investigations (Hunter & Davis, 1997) and (SWK, 2006) have suggested that there will not be on effect from increased abstraction at Meysey Hampton upstream of the Ampney Park Fault since it acts as a barrier to groundwater flow. Once the Ampney Brook flows onto the Kellaways Beds, and the Great Oolite aquifer becomes confined, abstraction at Meysey Hampton will not have any influence the stream. Therefore, there is a 2 kilometre stretch between the Ampney Park Fault and Charlham Farm House (where the stream flows onto the Kellaways Beds) which may be affected by a Drought Order abstraction at Meysey Hampton.

Marston Meysey Brook was monitored during the Meysey Hampton Great Oolite pumping test and no impact was detected. However, the potential for some impact on this stream should be retained in the assessment process.

4 October 2022 Groundwater modelling support SWOX EAR update

4.1 Introduction

4.1.1 Background

Thames Water Utilities Limited (TWUL) have a requirement to update and extend previous modelling work carried out to support their Drought Plan 2022. This work utilised the Cotswolds regional groundwater model to assess the impact on groundwater (GW) levels of GW abstractions operating at drought permit (DP) rates.

The project comprised model-based assessments of the individual and cumulative impacts of TWUL abstractions on GW levels under a range of scenarios. Post-processing of model outputs was undertaken to provide maps of predicted drawdown from each model run and other metrics as agreed. The results will inform the TWUL programme and the outcomes of the modelling will be used by TWUL's environmental consultant Ricardo to update the EAR for the SWOX resource zone.

This report represents an initial set of 5 priority drought modelling scenarios covering Latton, Meysey Hampton & Baunton 1 Winter drought permits and will be followed by additional drought modelling work covering the remaining sources.

4.1.2 This report

A summary of the Cotswolds groundwater model runs undertaken in support of the DP operation is given in Section 2. Methodology and model QA are briefly presented in section 3. Model results are presented in Section 4. Section 5 provides a descriptive list of the project deliverables.

4.2 Model runs

The Cotswolds numerical model simulates the Jurassic limestones of the Cotswolds (the Great and Inferior Oolite) which form an important aquifer that supports the headwaters of the River Thames, a number of important public water sources, and several SAC and SSSI wetland sites.

For the purposes of this DP assessment a shortened model run time was chosen, focussed around the reference drought period of 1976. All model runs (baseline and scenarios) were set up to simulate the period from 01/01/1970 (start date of the standard Cotswolds model) to 31/12/1986 (10 years after the 1976 drought).

4.2.1 Recent Actual Baseline

The Recent Actual (RA) baseline is a standard predictive scenario which represents recent to current abstraction rates in the model domain. The latest Cotwolds Recent Actual scenario uses surface and groundwater abstractions rates as constant rates calculated as an average over the period 2009-2014.

Recent actual abstraction rates for the five abstractions sources Latton, Meysey Hampton, Baunton 1, Baunton 2 and Bibury were provided by TWUL and are detailed in Table 4-1. All other sources in the model are represented at baseline recent actual rates.

Table 4-1 TWUL Recent Actual Baseline Rates

Source	RA Baseline run (Ml/d)	RA DP run (Ml/d)
Latton	12.67	17***
Meysey Hampton	0.00002	0
Baunton 1	2.52	0-9**
Baunton 2*	0	0
Bibury	7.57	9

* Baunton 2 Drought Permit is of shorter duration as it follows on from Baunton 1; the impact from Baunton 2 is cumulative with Baunton 1.
** Rates for each stress period supplied by TWUL. Rates switch from 0 to 9 Ml/d, according to the modelled (historical) River Churn flow at Cirencester and the flow constraint.
*** Changed from 15Ml/d to its current varied licence 17Ml/d – October 2022

Using the abstraction rates listed in Table 4-1 and the shortened model run time described above a MODFLOW Recent Actual DP baseline was created and used as reference run for comparison with the scenario runs. It was not necessary to re-run the Cotswolds recharge model as the model sources of interest are exclusively groundwater boreholes rather than surface water sources.

4.2.2 Scenario Runs

Each scenario run is based on the Recent Actual DP baseline and varies only in that one or more abstractions from groundwater will be altered for the winter DP period, November 1975 to April 1976 respectively.

Scenario abstraction rates for the abstraction sources were provided by TWUL and are detailed in Table 4-2. The abstraction rates for all other sources remain at baseline recent actual rates.

Table 4-2 Winter DP abstraction rates

Scenario Number	Scenario Type	Source(s)	Rates for Nov 1975-Jan 1976	Rates for Feb-Apr 1976
1	**Individual Permits**	**Latton**	20	20
2		**Meysey Hampton**	11.37	11.37
3		**Baunton 1**	6.3	6.3
4	**Cumulative Impacts**	**Latton & Meysey**	31.37	31.37
5		**Latton, Meysey & Baunton 1**	37.67	37.67

4.3 Methodology and Model run QA

The model set-up, running of the models and post-processing was done using a run automation tool developed by Stantec. The tool reads the scenario rates from a prepared spreadsheet, builds the scenario WEL files, runs the model scenario and extracts the required post-processing output once the model run has finished. Model runs are automatically simulated in sequential order and can be run in parallel providing an efficient way to complete a great number of scenario runs in a short time. This approach also provides a more error proof process for model setup and processing as all steps are coded and simply repeated for each scenario thus assisting with and reducing the necessary post QA effort.

After all scenarios had finished a complete QA process carried out by the modeller and checked by the model reviewer. The QA checks included:

- The correct setup of the model WEL files and any other input files that have changed.
- The model run has used the correct input files.
- The model ran successfully to completion with no errors.
- The differences between the model output and the baseline output are reasonable and as expected.

Results of these checks showed expected model behaviour and indicated that the model runs had been completed successfully and without error.

4.4 Model results

The simulated changes in groundwater levels and stream flow as a result of the DP scenario run 02 (Individual Permits, Meysey Hampton) in comparison to the Recent Actual DP baseline are presented as an example in the following sections.

The section covers the following agreed post-processing maps and figures:

1. Time series of modelled groundwater levels before, during and after the drought period, for baseline and scenario run, for selected locations.
2. Time series of SW flow before, during and after the drought period, for baseline and scenario run, for selected locations.
3. Time series of GW-SW interaction before, during and after the drought period, for baseline and scenario run, for selected locations.

4.4.1 Groundwater level time-series

Time series of simulated difference in groundwater levels between the DP baseline run and DP scenario run 02 (scenario minus baseline) are presented in Figure 4-1. Modelled DP abstraction difference at Meysey Hampton is shown for comparison.

The drawdown simulated at Meysey Hampton peaks at around 10.75 m and recovery to baseline levels occurs within about 3-4 months after the DP abstraction ceases. The abstraction borehole (ABH) at Latton simulates a delayed maximum drawdown (end of April 1976) of 0.5 m and recovers to baseline similarly delayed (March – May 1977).

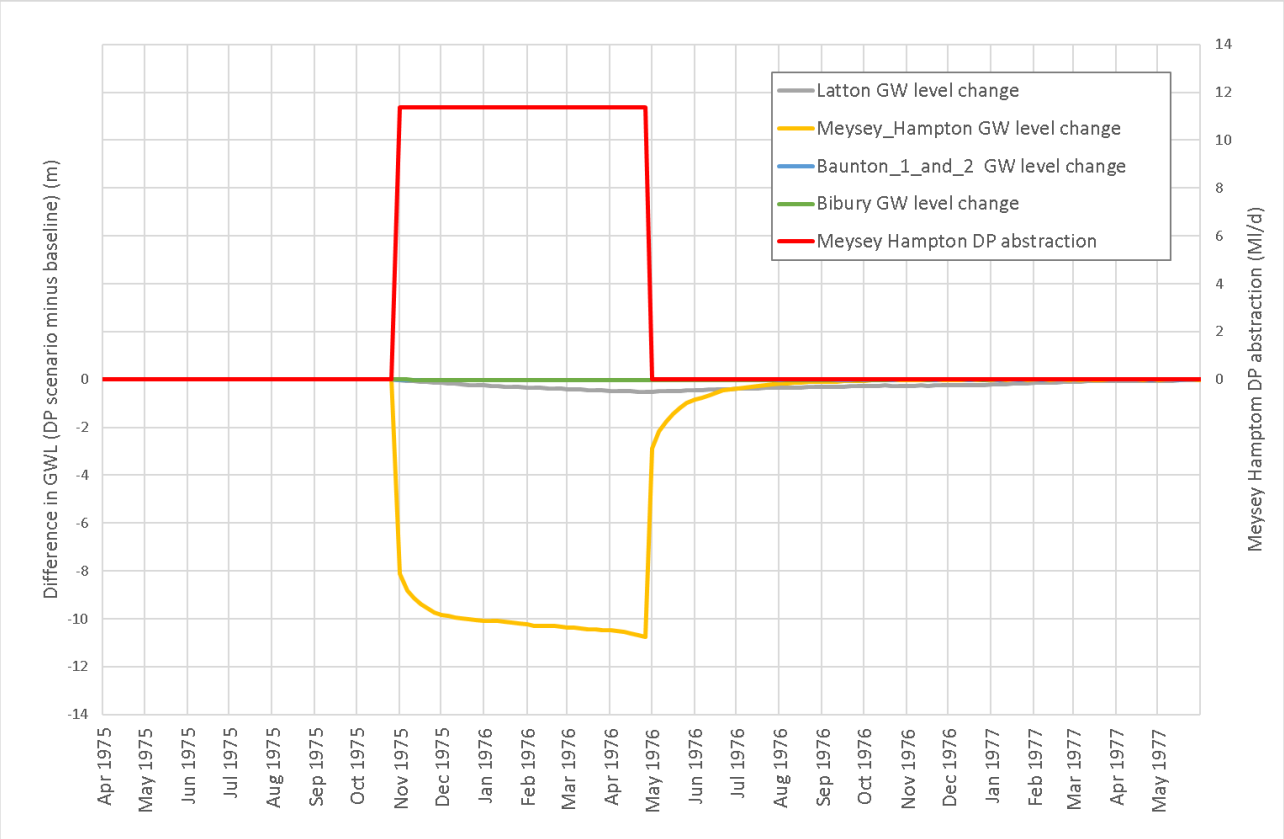

Figure 4-1 Difference in simulated groundwater levels at ABH's and modelled DP abstraction

4.4.2 Surface Water flow time-series

Time series of simulated difference in surface water flow between the DP baseline run and DP scenario run 02 (scenario minus baseline) are presented in Figure 4-2. Modelled DP abstraction difference at Meysey Hampton is shown for comparison. Time series of simulated stream flow have been output for ten locations in the project area. The greatest impact can be seen on the gauges in closer proximity of Meysey Hampton, especially Ampney Brook at Sheepen Bridge and River Coln at Fairford. Flow reductions of up to 4 Ml/d are simulated with recovery to baseline levels taking 3 – 4 months after the DP abstraction ceases.

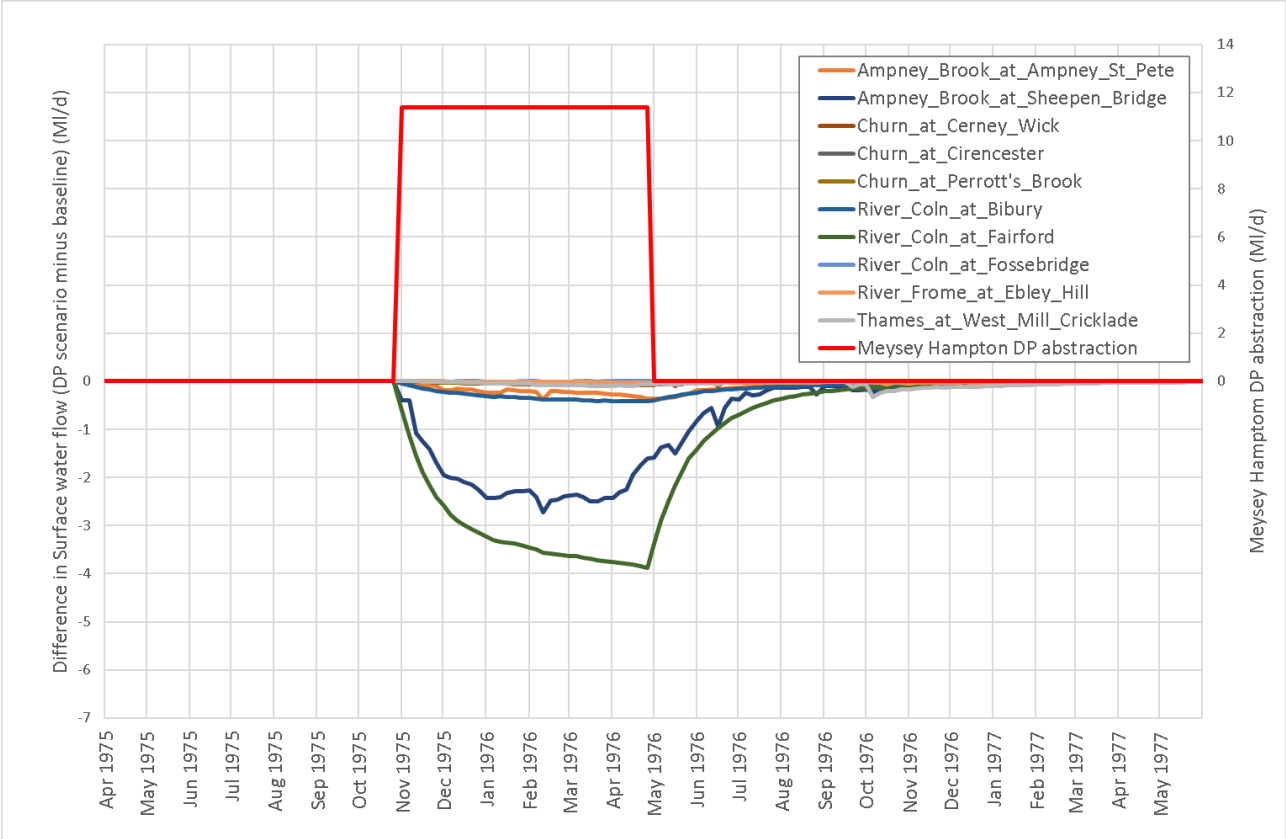

Figure 4-2 Difference in simulated surface water flows and modelled DP abstraction

4.4.3 GW-SW flow time-series

Time series of simulated difference in GW-SW flow between the DP baseline run and DP scenario run 02 (scenario minus baseline) are presented in Figure 4-3. Modelled DP abstraction difference at Meysey Hampton is shown for comparison. Time series of simulated GW-SW flow have been output for Perrott's Brook Marsh KWS. Two further locations were suggested (Down Ampney Pits KWS and North Meadow, Cricklade SSSI) but these are located on the Oxford Clay and are therefore simulated as disconnected from the aquifer (i.e. no GW-SW flow).

Figure 4-3 illustrates increasing stream losses from the onset (start of November 1975) of the DP pumping. The stream sustains maximum stream loss from June 1976 to end of November 1976 during normal operations therefore showing no difference when compared to the DP scenario run. Reduced stream losses and baseflow recovery in the wet season are delayed due to the DP pumping which can be seen as a spike of GW-SW flow impacts in early December 1976. Recovery to baseline levels occurs around April – May 1977.

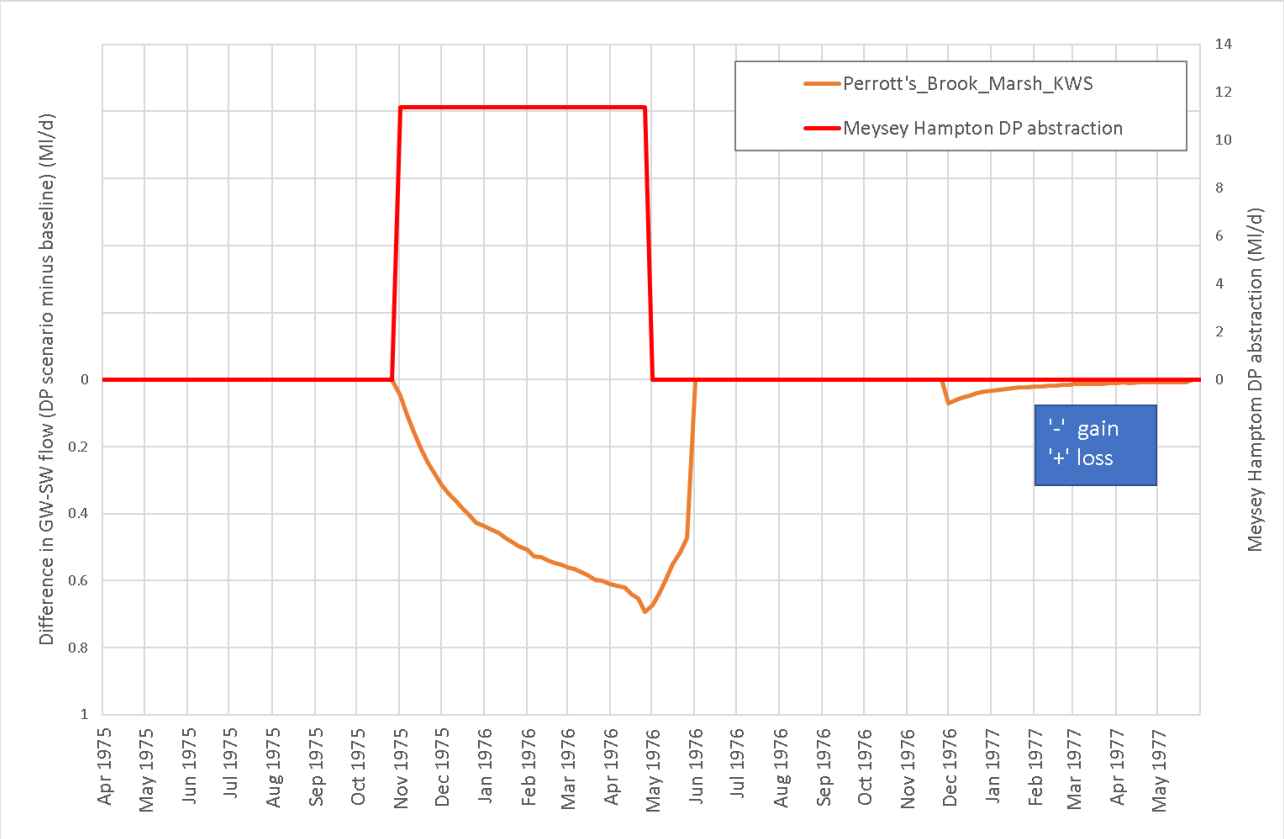

Figure 4-3 Difference in simulated GW-SW flows and modelled DP abstraction

4.4.4 Low flow model calibration

The Cotswolds groundwater model is generally considered well calibrated, however, as all groundwater models, it holds uncertainties, it is wrong locally and it will inevitably fail to provide exact answers to questions requiring a particular level of detail. Therefore, model results should always be presented with caveats.

The hydrological impact assessment of drought permits for EAR update uses two different approaches:

1. Perennial systems: assess % change in Q95 and Q99 flows
2. Ephemeral systems: assess flow recovery (additional days reaches dry, new drying reaches)

To accurately pursue the second approach (for intermittently flowing systems) a baseline historic simulation is required that reflects the ephemeral nature of intermittent water courses exactly to the duration (days) they dry out. This will not be possible with the Cotswolds model in its current form as the temporal resolution is set up to 6 days per stress period, which is already relatively high.

However, it has been found that some water courses which are considered to be intermittent (from observed data) do not dry out in the historic groundwater model and vice versa (see Table 4-3 below lists the 10 assessment gauges, information on observed and modelled flow characteristics as well as the low flow correction in the column furthest right. This correction volume has to be applied (deducted) to the modelled flow output send prior for baseline and scenario results and the flow

impact reassessed. This will obviously only make a difference for the assessment of intermittent reaches and the duration of dry conditions.

Table 4-3, discrepancies highlighted orange). This fundamental difference in the way water reaches are represented in the groundwater model simulation compared to how they are actually observed impedes the hydrological impact assessment for EAR update.

The Cotswolds groundwater model calibration, precisely the representation of low flows, was therefore reviewed and correction volumes for the 10 assessment gauges calculated to adjust the initial results and take calibration offset into account. For this, the flow duration curves (FDC) were analysed and historically modelled and observed low flows compared, taking only time periods into account with available observed data. The lowest non-zero flow volume (either modelled or observed) was taken and the difference to its counterpart calculated. This factually represents the difference in low flow volume over the entire observed data period compared to modelled flow volumes.

Figure 4-4 below illustrates the approach using Ampney Brook at Sheepen Bridge as example. The overall flow calibration looks decent across the high and mid-range flows but modelled flows deviate from observed flows visibly in the lower flow range. The lowest flowing Q was observed at the 95 percentile with 0.07Ml/d at which point 9.18 Ml/d are modelled which indicates a difference in low flows of 9.11Ml/d. This represents the correction needed to be applied (deducted) to the modelled low flow data at this gauge and is illustrated as a blue arrow in Figure 4-4.

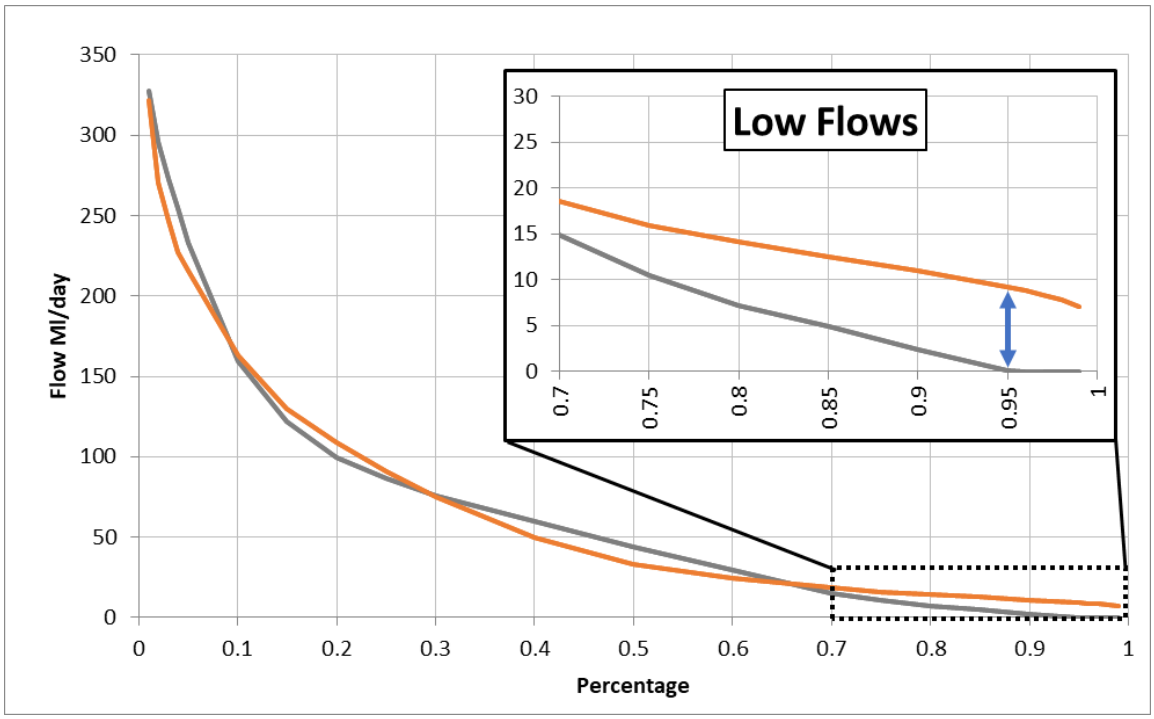

Figure 4-4 Low flow correction approach (example: Ampney Brook at Sheepen Bridge)

The correction was applied to the DP scenario flows for the entire model scenario period. This is an important point to note: the calculated difference only represents a correction of the low flows yet was applied to all flows and therefore only the corrected low flows should be taken forward from this exercise.

Figure 4-5 illustrates the effect of the correction volume on the total flows at Ampney Brook at Sheepen Bridge. The flow time-series for the original RA baseline (blue) and DP scenario (red) are shown in lighter colours alongside their darker corrected counterparts. For the year 1976 the corrected baseline (dark blue) shows 21 dry stress periods whereas the corrected DP scenario (dark red) shows a total of 25 dry stress periods indicating an earlier onset of drying conditions.

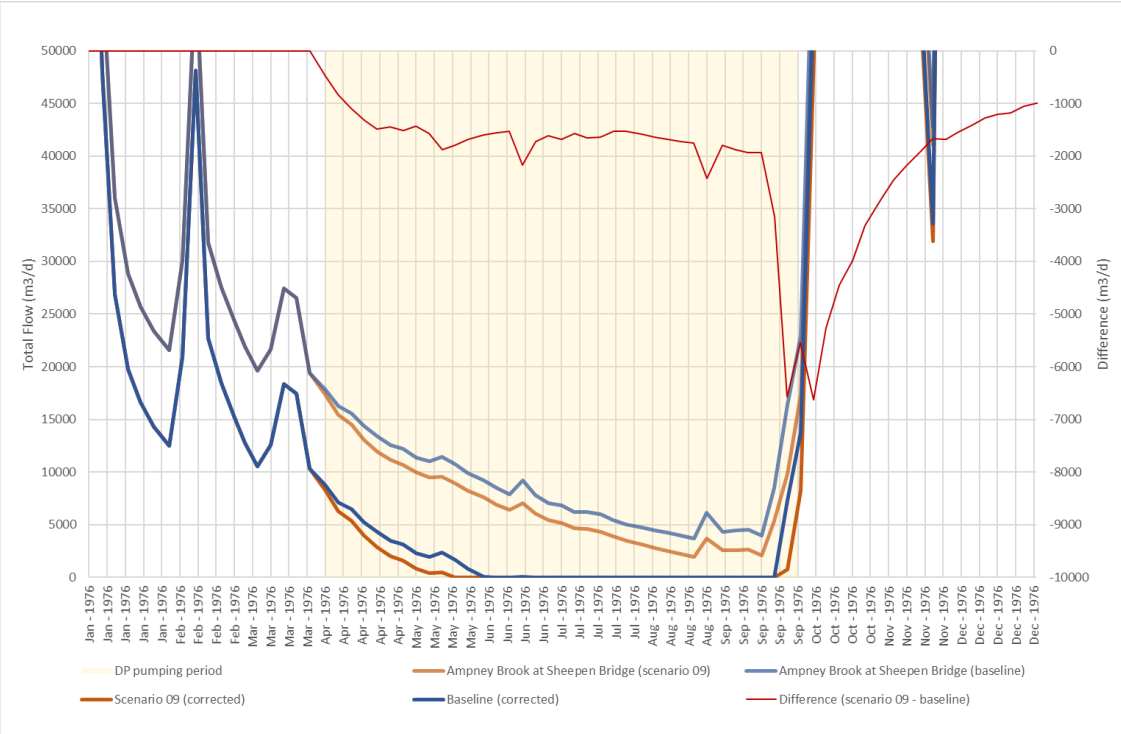

Figure 4-5 Total Flow scenario vs baseline, low flow correction

Table 4-3 below lists the 10 assessment gauges, information on observed and modelled flow characteristics as well as the low flow correction in the column furthest right. This correction volume has to be applied (deducted) to the modelled flow output send prior for baseline and scenario results and the flow impact reassessed. This will obviously only make a difference for the assessment of intermittent reaches and the duration of dry conditions.

Table 4-3 Flow gauge low flow assessment

River Reach	Ephemeral in SWOX Report?	Ephemeral in the GW model?	Lowest flowing Q	Modelled historic (Ml/d)	Observed (Ml/d)	Correction Volume (Ml/d)
Ampney Brook at Ampney St Peter	No	No	97	4.67	0.22	4.45
Ampney Brook at Sheepen Bridge	Yes	No	95	9.18	0.07	9.11

Churn at Cerney Wick	Yes	No	98	0.65	0.14	0.51
Churn at Cirencester	No	Yes	98	0.64	1.04	-0.40
Churn at Perrott's Brook	No	No	99	1.94	0.64	1.30
Coln at Bibury	No	No	99	37.14	21.51	15.63
Coln at Fairford	No	No	99	37.44	44.94	-7.49
Coln at Fossebridge	Yes	Yes	85	0.11	6.48	-6.37
Frome at Ebley Hill	Unspecified	No	99	67.92	55.68	12.24
Thames at West Mill Cricklade	Unspecified	No	99	13.16	3.67	9.50

General Notes on low flow calibration

Surface water flows along Ampney brook are generally well calibrated. However, low flows are overestimated in the model with Ampney St Peter showing a small low flow error which is exacerbated further downstream at Sheepen Bridge. Low flows and flows in general are very well calibrated along the Churn. Low flows of the River Coln are well represented in the model towards the bottom of its catchment (at Fairford) but show some notable discrepancies further upstream at Bibury and more so at the most upstream gauge at Fossbridge. The River Frome is well calibrated especially for low flows.

The modelled flow residuals are discussed further in the Cotswolds Model report (ESI, 2018). This report also discusses the quality of the permanent gauge data, including EA's gauging station data quality (GDSQ) score which for instance flags 'Caution' for low flows at Ampney St Peter, Sheepen bridge, Cerney Wick, Fossebridge, and Fairford St Peter.

4.5 Deliverables

Post-processed data for the RA DP baseline and 5 scenario runs has been provided in a GIS-compatible format (shapefile, raster or XYZ files) in the case of spatial data, or as Excel files in the case of time series. The complete list of delivered model outputs and figures can be viewed in Table 4-4 below. The specific locations and time periods requested for the post processing outputs are presented in section 4.5.1 and 4.5.2.

Table 4-4 Deliverables

Number	Name	Items	Format
1	Time series of modelled groundwater levels at 4 locations for the RA DP baseline and 5 DP scenarios. Additional modelled groundwater levels at 3 OBH locations.	12	CSV files/spreadsheets
2	Spatial GWL maps of 6 specified stress periods in 2 layers for the RA DP baseline and 5 DP scenarios and their difference	72	ASCII grids
3	Time series of modelled surface water flows at 10 locations for RA DP baseline and 5 DP scenarios	6	CSV files/spreadsheets
4	Spatial stream flow output of 6 specified stress periods for all stream cells for the RA DP baseline and 5 DP scenarios and their difference	72	CSV files/spreadsheets
5	Time series of modelled GW-SW flow at 1 location for RA DP baseline and 5 DP scenarios	6	CSV files/spreadsheets

4.5.1 Time-series data locations

The locations for time-series datasets were provided by Ricardo and are listed in Table 4-5, Table 4-6 and Table 4-7.

Table 4-5 Requested Surface Water Flow locations

Number	Name	NGR
1	Ampney Brook at Ampney St Peter	SP 07700 01300
2	Ampney Brook at Sheepen Bridge	SU 10500 95000
3	Churn at Cerney Wick	SU 07500 96200
4	Churn at Cirencester	SP 02000 02800
5	Churn at Perrott's Brook	SP 02100 05700
6	River Coln at Bibury	SP 12100 06200
7	River Coln at Fairford	SP 15000 01200
8	River Coln at Fossebridge	SP 08000 11200
9	River Frome at Ebley Hill	SO 83000 04600
10	Thames at West Mill Cricklade	SU 09400 94200

Table 4-6 Requested GW level locations

Number	Name	NGR
1	Latton ABH	SU 07500 96750
2	Meysey Hampton ABH	SU 13300 98900
3	Baunton - 1 and 2 ABH	SP 01900 04850
4	Bibury ABH	SP 11300 07100
5	Ampney Crucis OBH (L3)	SP 05875 01875
6	Jackaments Bottom OBH (L4)	ST 96875 97375
7	Perrott's Brook OBH (L4)	SP 01875 06125

Table 4-7 Requested GW-SW flow locations

Number	Name	NGR	Comments
1	Down Ampney Pits KWS	SU 11187 95549	This surface location is separated from the aquifer as it sits on the Oxford Clay (i.e. no GW-SW flow).
2	North Meadow, Cricklade SSSI	SU 09263 94484	This surface location is separated from the aquifer as it sits on the Oxford Clay (i.e. no GW-SW flow).
3	Perrott's Brook Marsh KWS	SP 02025 05971	OK.

4.5.2 Spatial plots time periods

The six time periods for spatial maps were provided by Ricardo and are presented in Table 4-8.

Table 4-8 Spatial assessment stress periods

Number	Winter DP scenarios	
	Date	Stress Period
1	11/11/1975	423
2	11/01/1975	435
3	11/03/1976	447
4	11/05/1976	459
5	11/07/1976	471
6	21/09/1976	485

The stress periods were specifically chosen to provide results that give a good overview of the DP pumping impact progression, covering the increased pumping period (first three stress periods) and the recovery period (remaining 3 stress periods).

Geological and hydrological features: River Churn

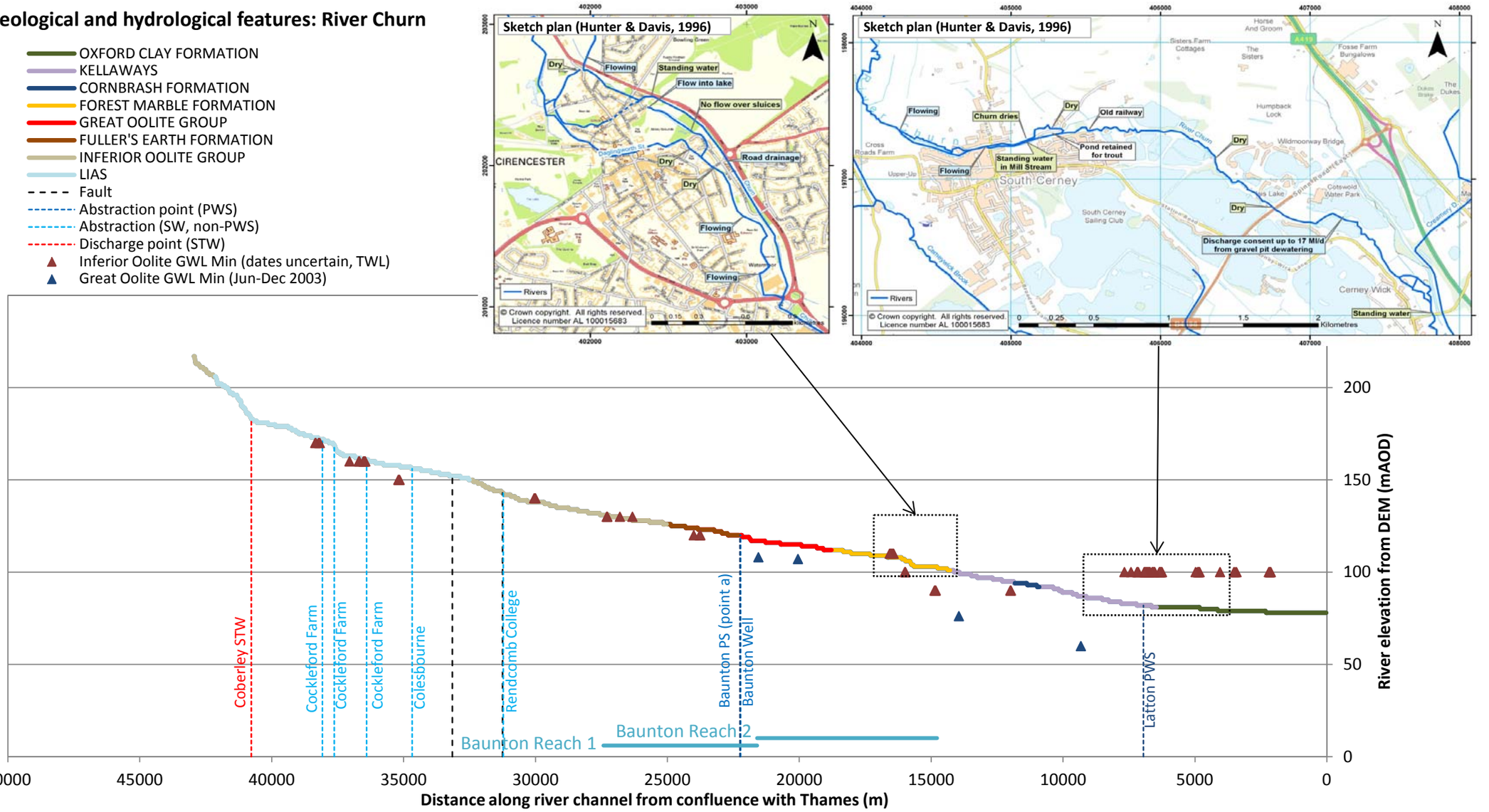

Figure 6.0

Geological and hydrological features: River Churn

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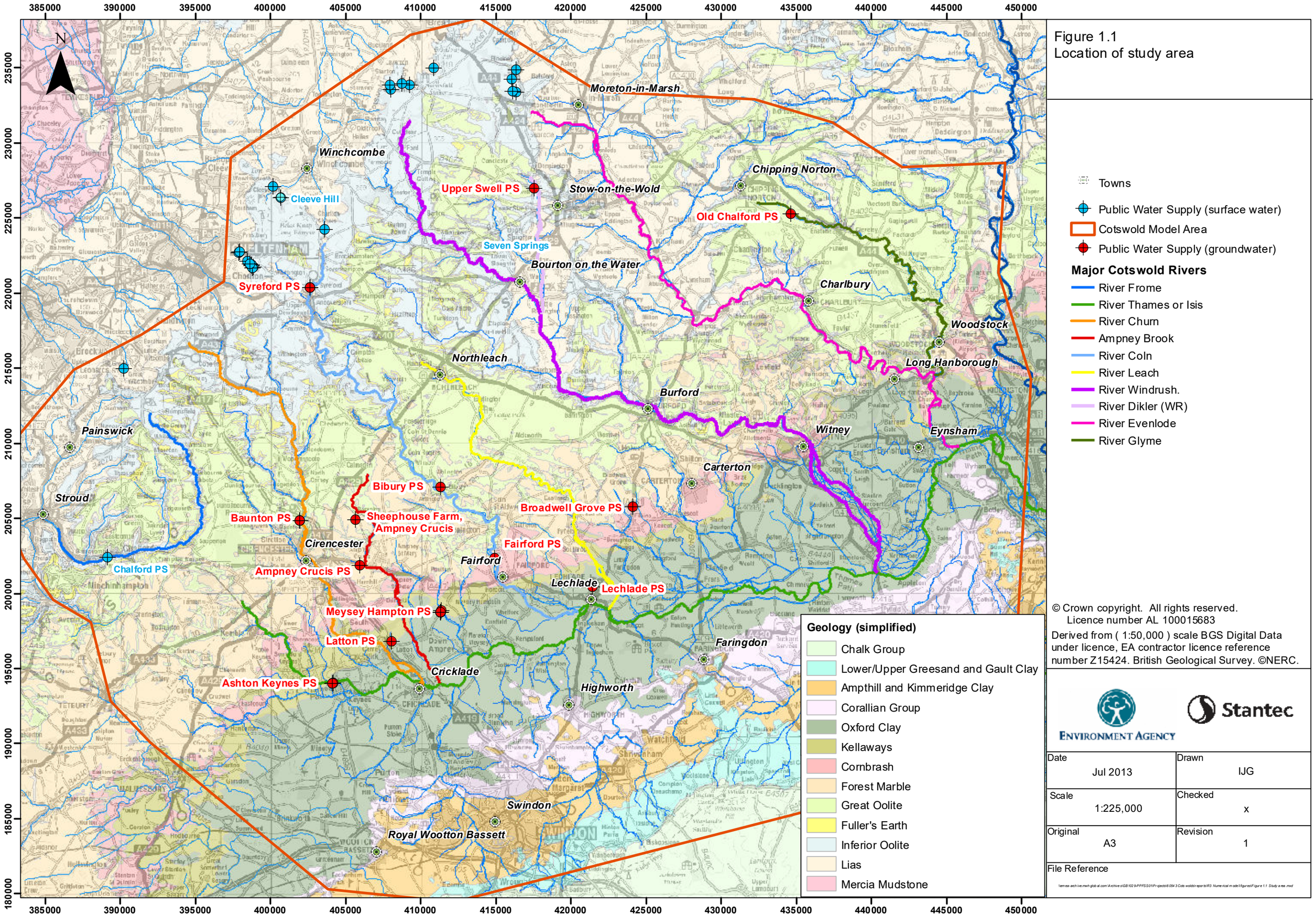

Figure 1.1
Location of study area

ENVIRONMENT AGENCY

Stantec

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File Reference

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405000
410000
415000
205000
200000
195000

N

Perrott's Brook
River Churn
BAUNTON PWS
Cirencester
Bibury
Poulton Stream
Marston Meysey Brook
Ampney St. Peter
Ampney Brook
Blackford Barn Brook
Fairford
R. Coln
MEYSEY HAMPTON PWS
Ewen
R. Thames
Cerney Wick
LATTON PWS
Whetstone Bridge
Marston Meysey Brook
Ampney Brook
Sheepen Bridge
West Mill Cricklade
Water Eaton

Kilometers
0
5
10

Figure 2
Baunton, Latton and Meysey Hampton Pumping Stations

- Pumping Station
- Gauging Station
- Brooks
- Rivers

Geology
- UPPER FORMATIONS
- OXFORD CLAY
- KELLAWAYS
- GREAT OOLITE
- INFERIOR OOLITE

esi

Date: March 2012	Drawn: KXM
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Original: A3	Revision: 1

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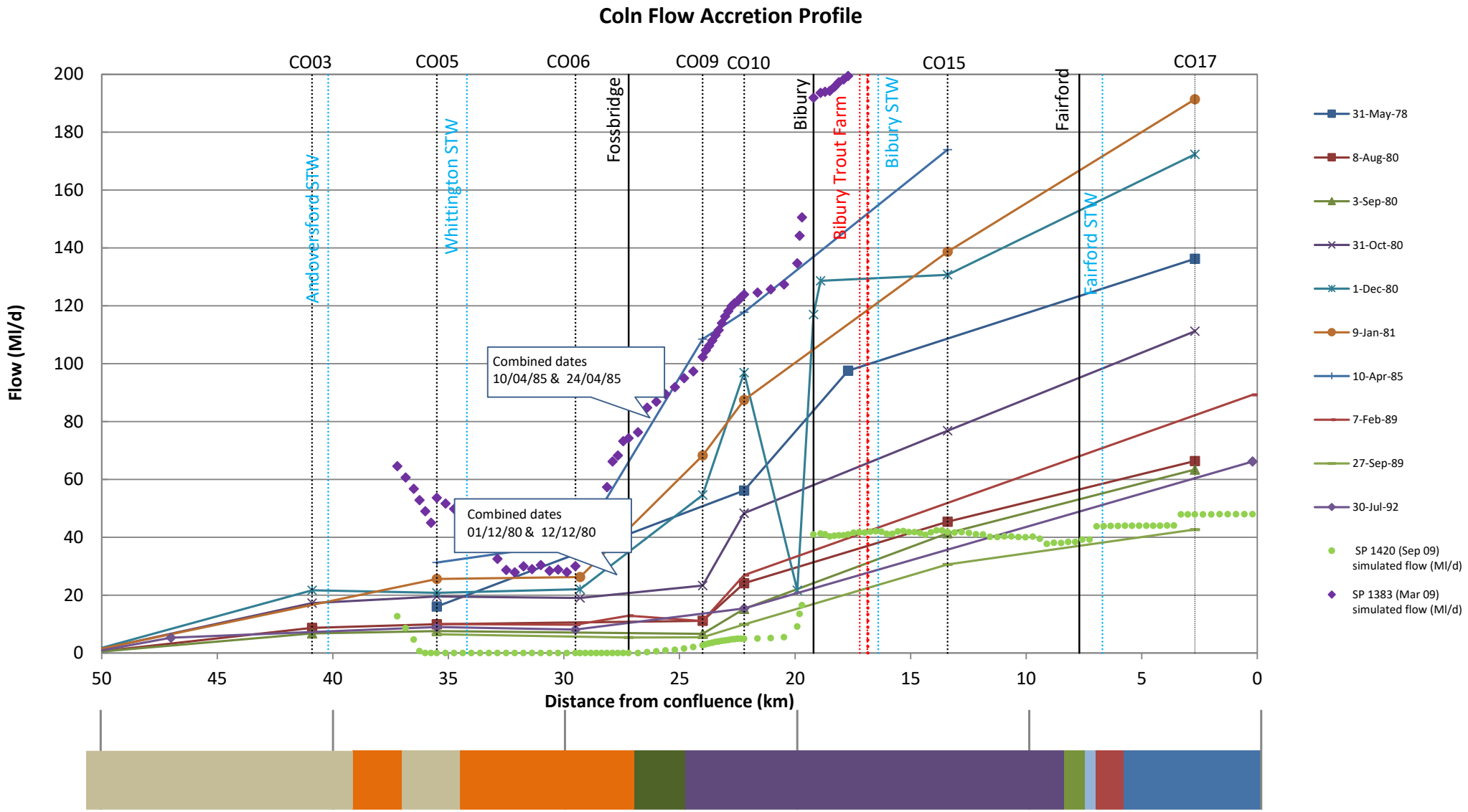

Figure 7B

Coln accretion profile

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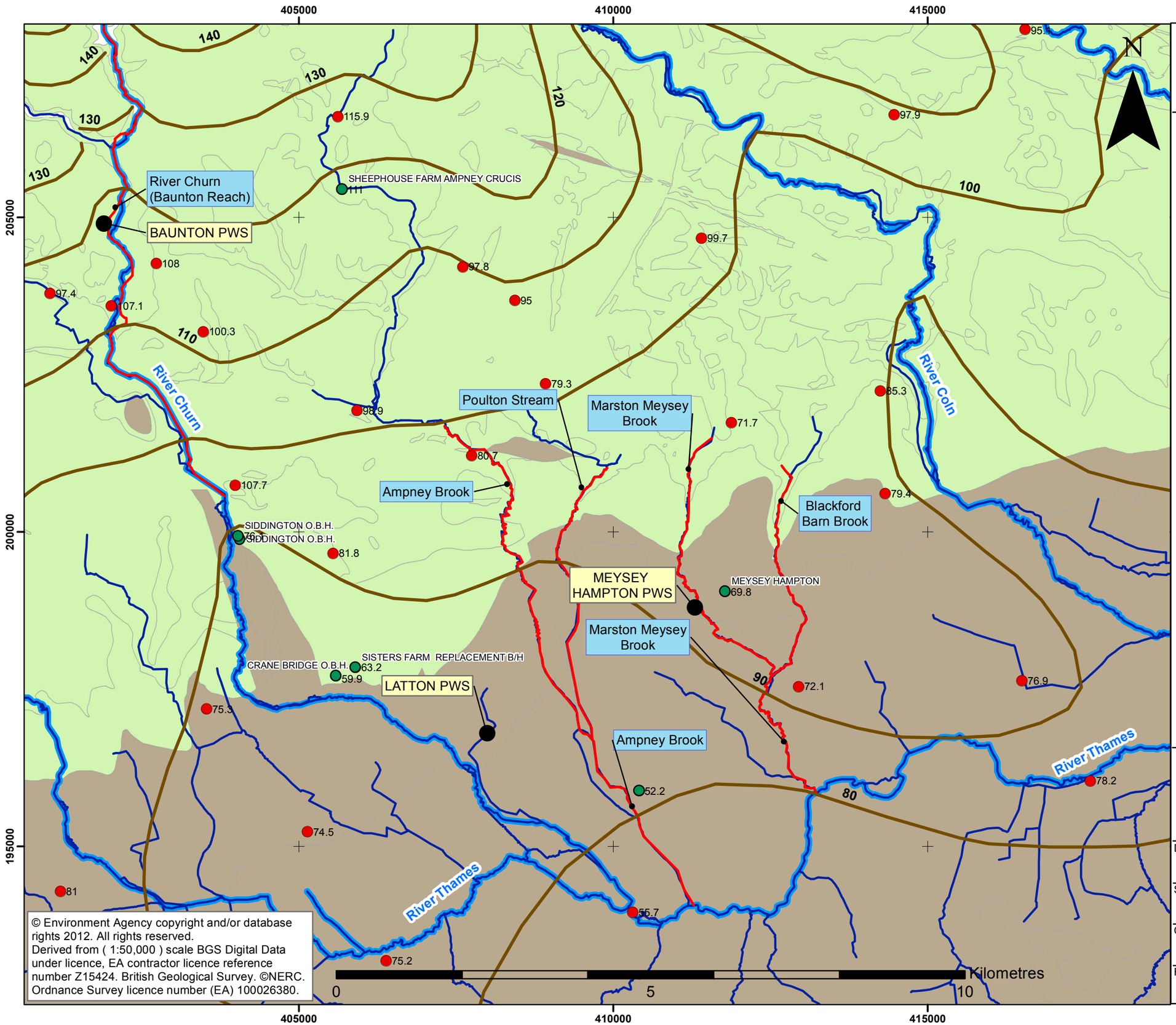

Figure 3.0
Great Oolite Groundwater Contours/Levels

- Rivers (all)
- Rivers (major)
- River Reach Identified in Scoping Study
- Pumping Station
- Observation Borehole
- Max Groundwater Level Contour
- Min Groundwater Levels

Geology

- Confined Great Oolite
- Unconfined Great Oolite

Labels:

- Watercourse
- Public Water Supply

esi

Date: March 2012	Drawn: KXM
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Original: A3	Revision: 1

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405000
410000
415000
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N
River Churn (Baunton Reach)
BAUNTON PWS
Poulton Stream
Marston Meysey Brook
Blackford Barn Brook
Ampney Brook
R. Coln
MEYSEY HAMPTON PWS
LATTON PWS
Marston Meysey Brook
Ampney Brook
R. Thames
Kilometers
0
5
10

Figure 5
Baunton, Latton and Meysey Hampton River Reaches and Groundwater Impacts

- Extent of Baunton GW Impact
- Extent of Latton GW Impact
- Extent of Meysey Hampton GW Impact
- Reaches Identified in Scoping Study
- Faults

Rivers

- Pumping Stations

Geology

- UPPER FORMATIONS
- OXFORD CLAY
- KELLAWAYS
- GREAT OOLITE
- INFERIOR OOLITE

esi

Date: April 2012	Drawn: KXM
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File Reference
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Figure 4.0
Inferior Oolite Groundwater Contours

N

- Rivers (all)
- Rivers (major)
- River Reach Identified in Scoping Study
- Pumping Station
- Observation Borehole
- Max Groundwater Contour
- Min Groundwater Contour

Geology (Inferior Oolite)

- Confined Inferior Oolite
- Unconfined Inferior Oolite

Labels:

- Watercourse
- Public Water Supply

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Kilometres
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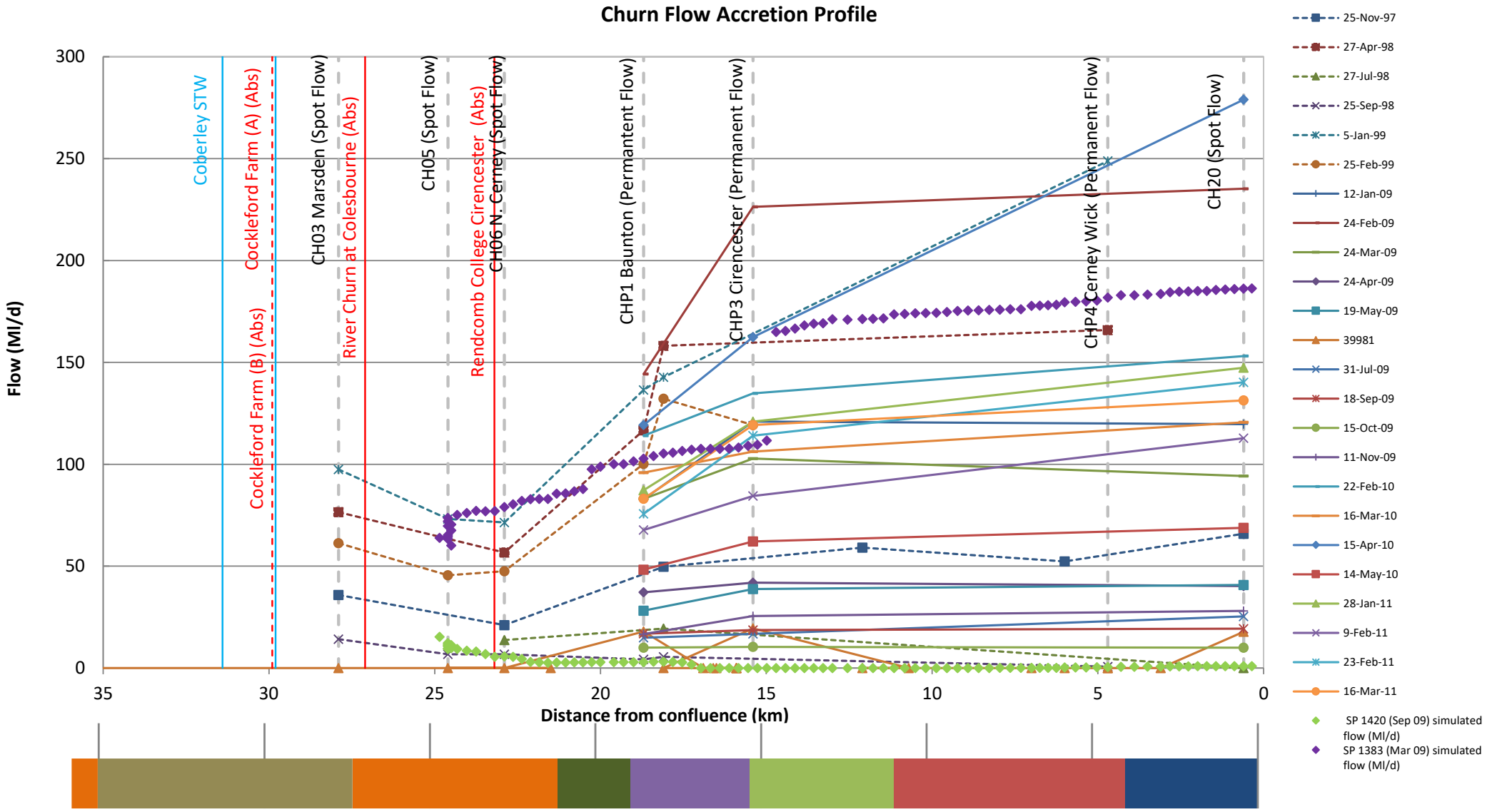

Figure 7A

Churn accretion profile

OXFORD CLAY FORMATION
KELLAWAYS
CORNBRASH FORMATION
FOREST MARBLE FORMATION
GREAT OOLITE GROUP
FULLER'S EARTH FORMATION
INFERIOR OOLITE GROUP
LIAS

Date: May-13	Drawn: IJG
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Geological and hydrological features: Ampney Brook

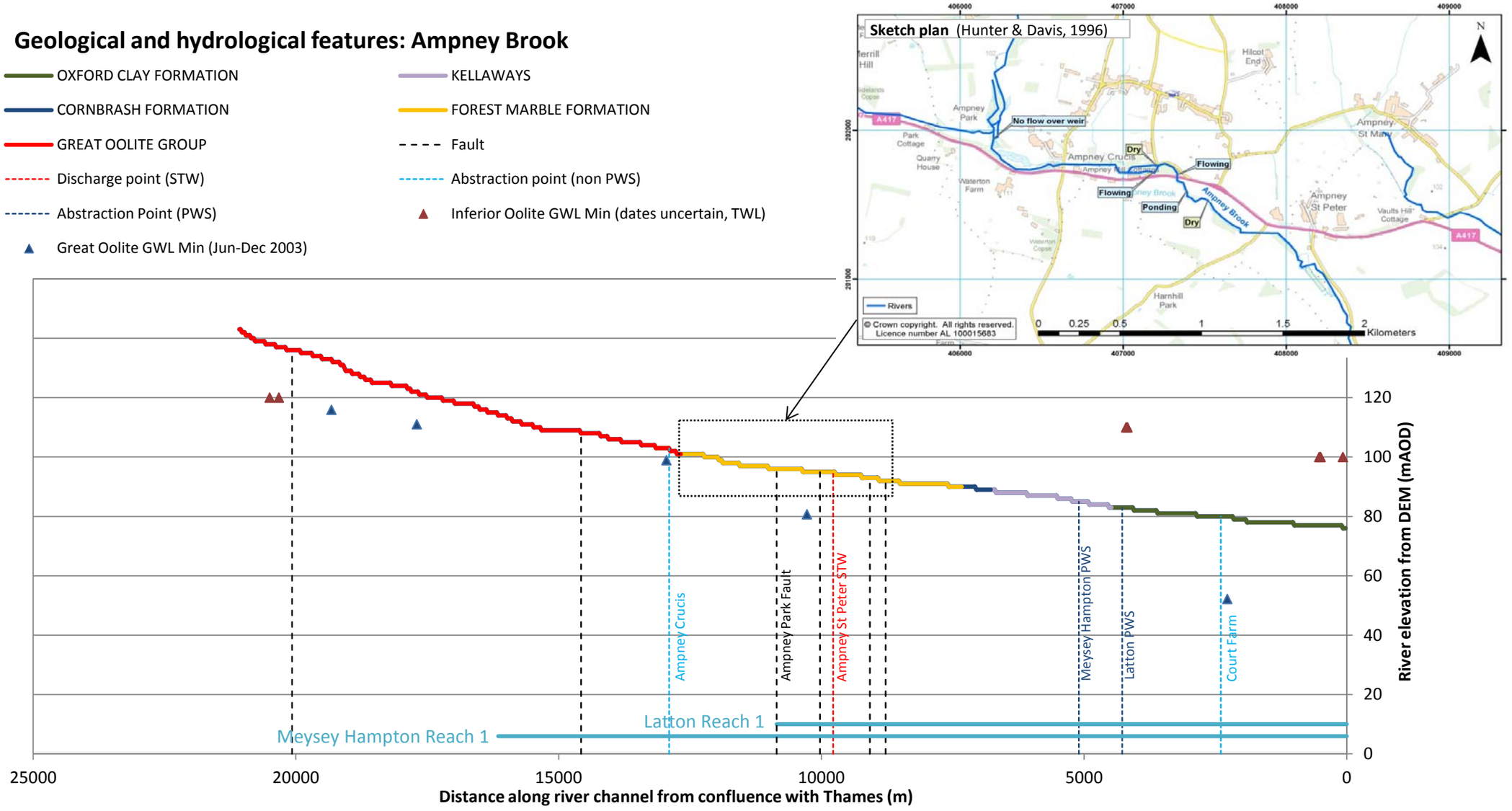

Figure 8.0

Geological and hydrological features: Ampney Brook

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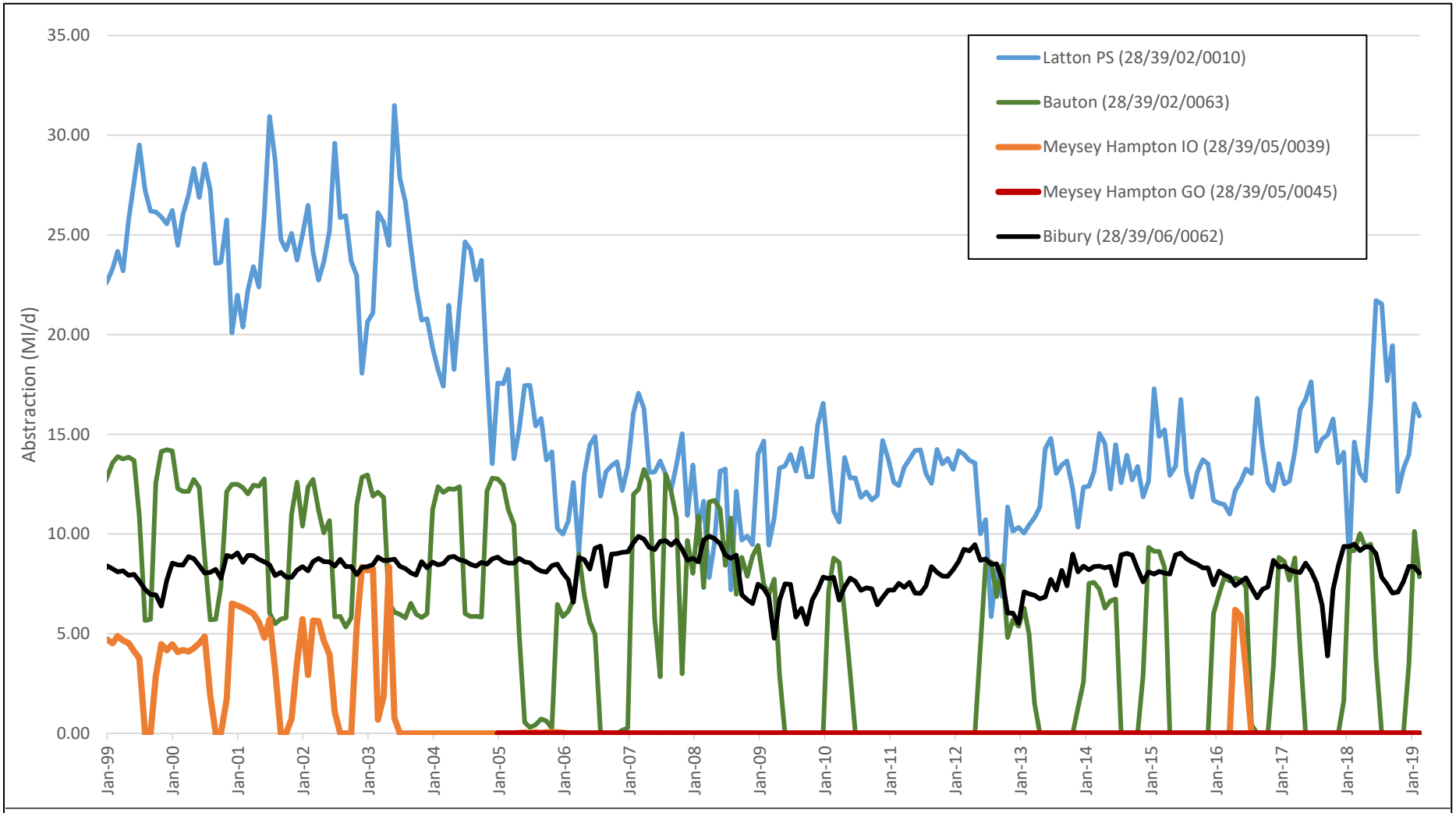
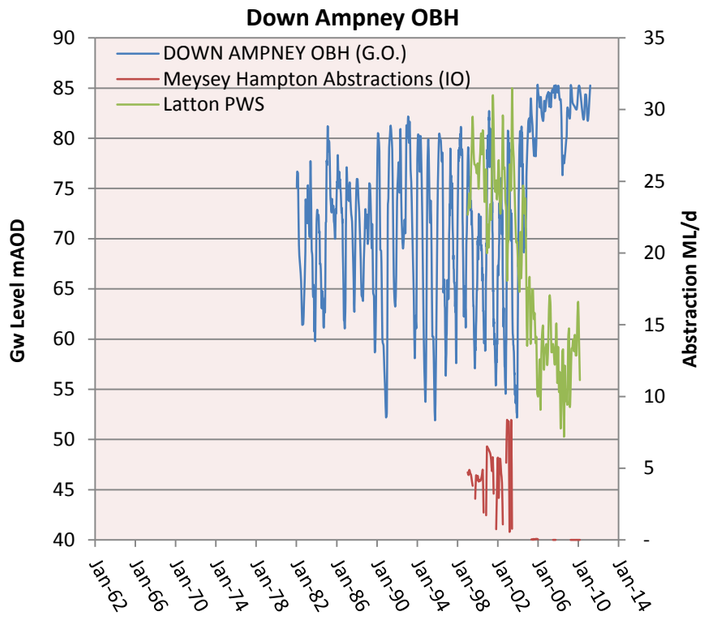


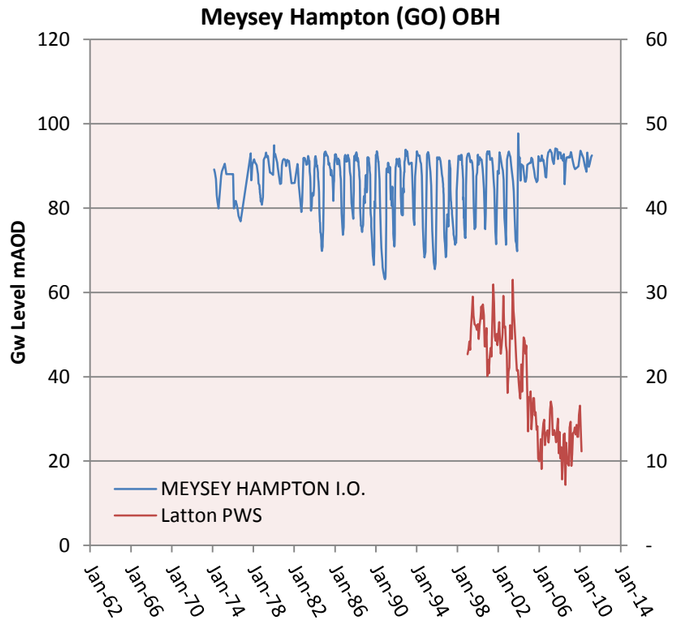
Figure 9

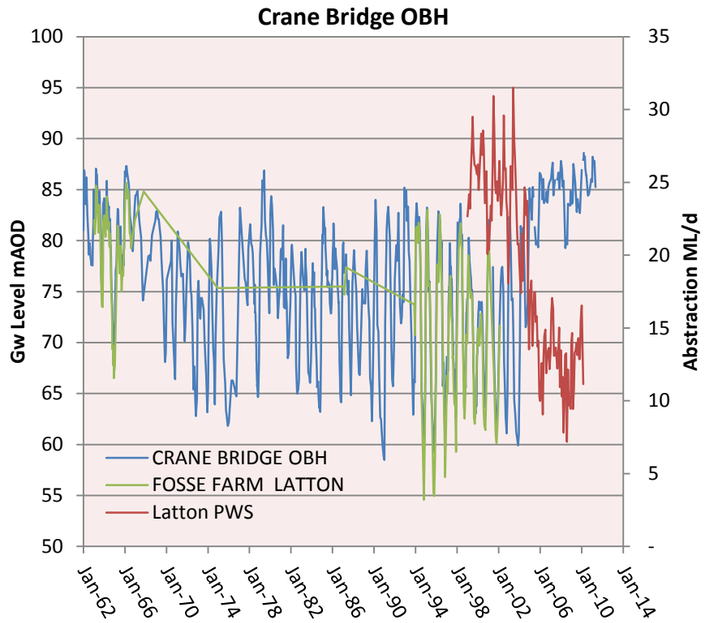
Rates of PWS abstraction in the Churn, Coln and Ampney Area

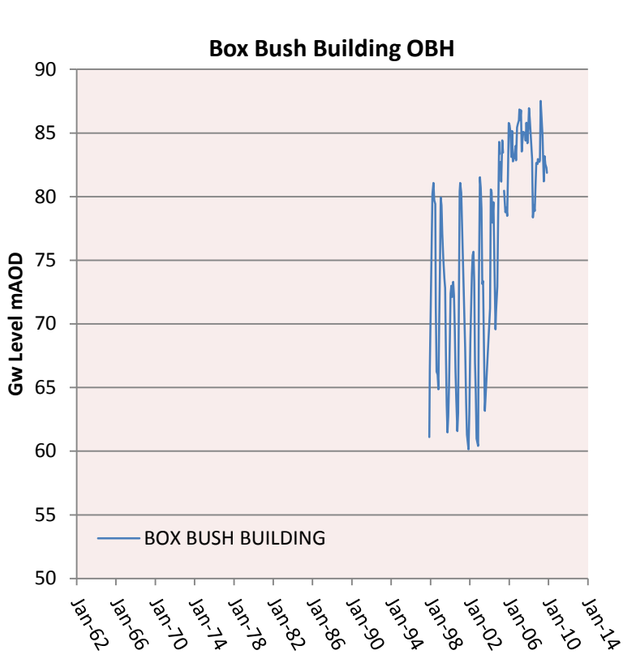
Stantec

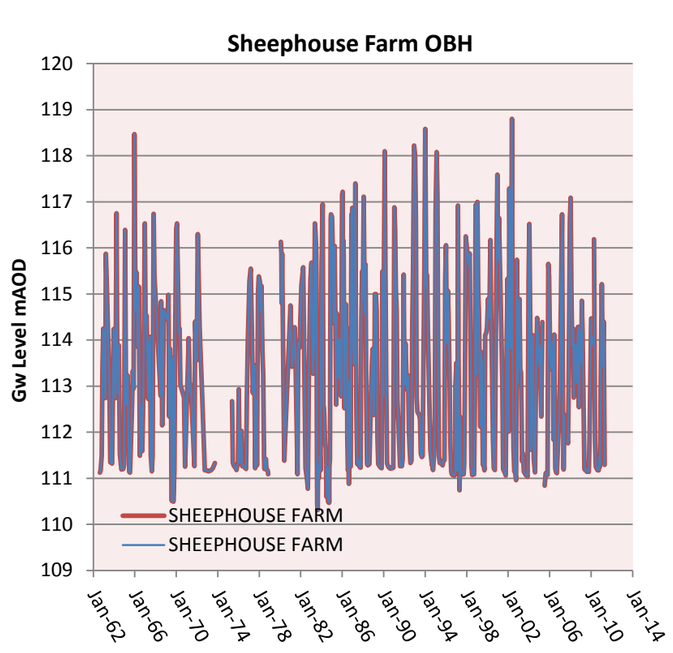
Date: April 2022 Drawn: SB











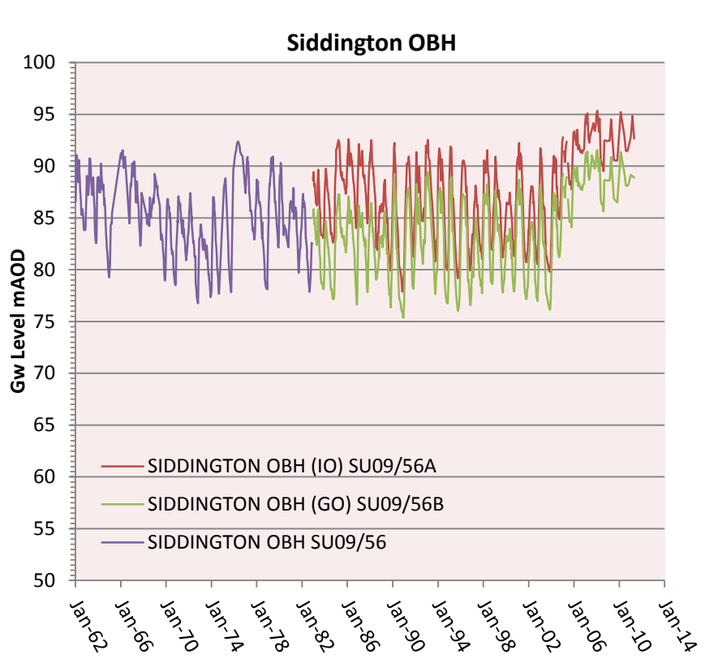


Figure 10

Hydrographs for observation boreholes in the Great Oolite, Cotswolds

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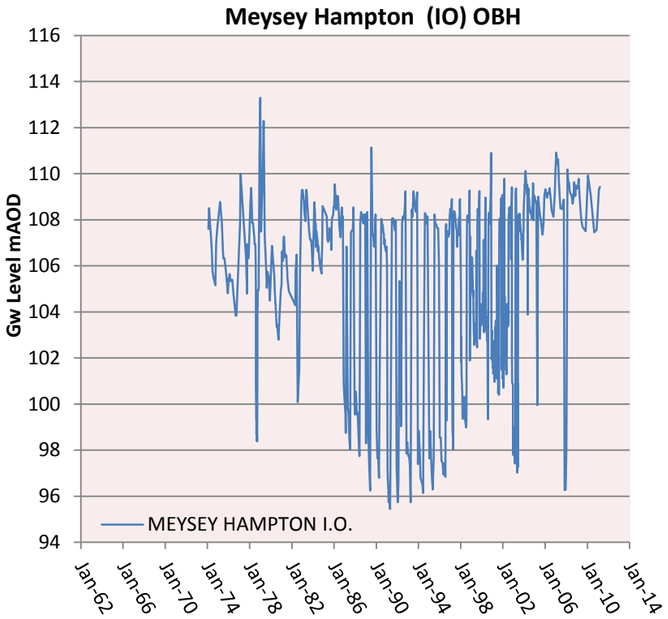

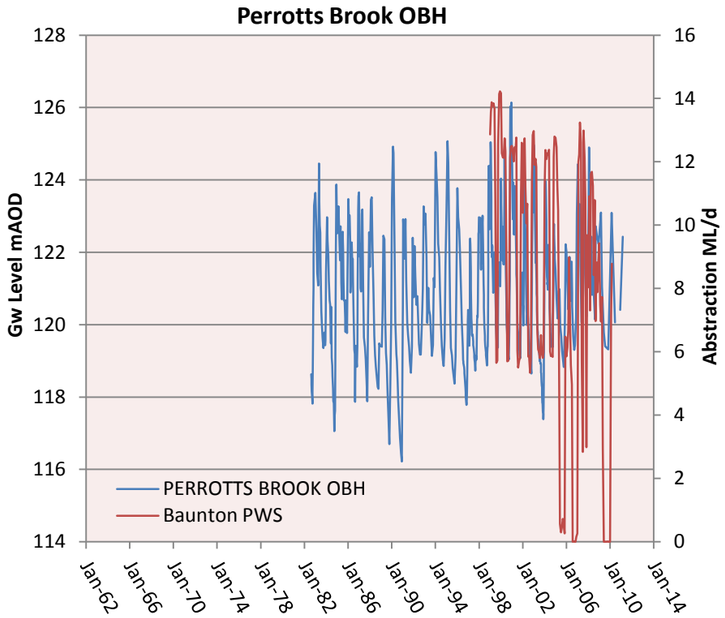

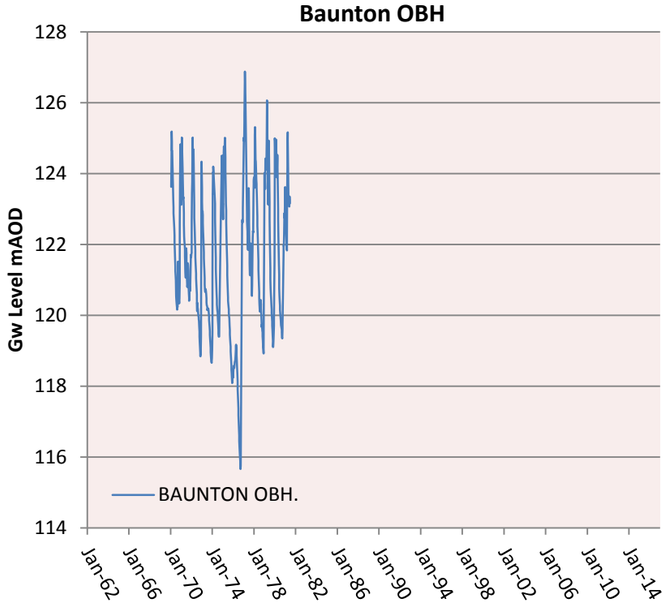

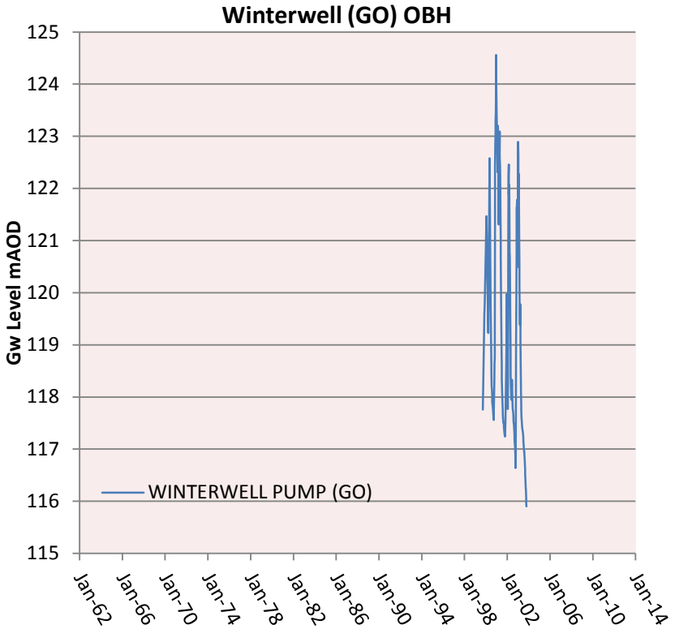

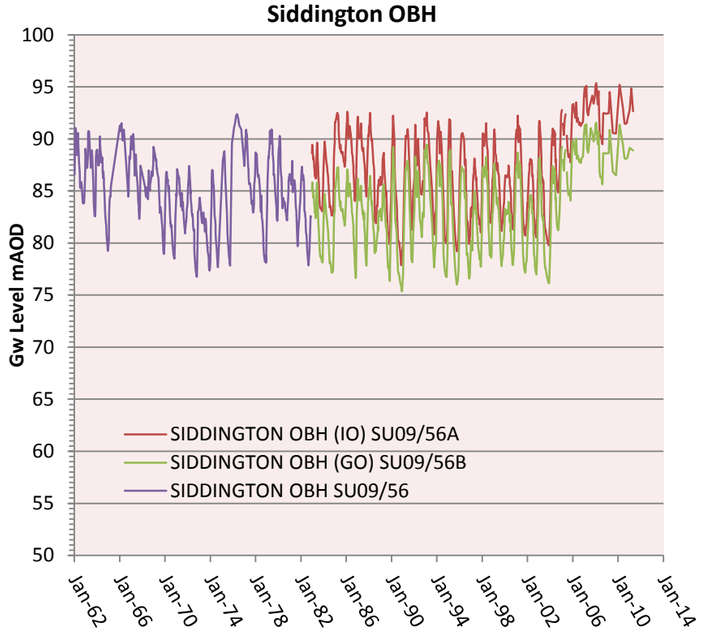

Figure 11

Hydrographs for obseravtion boreholes in the Inferiror Oolite, Cotswolds

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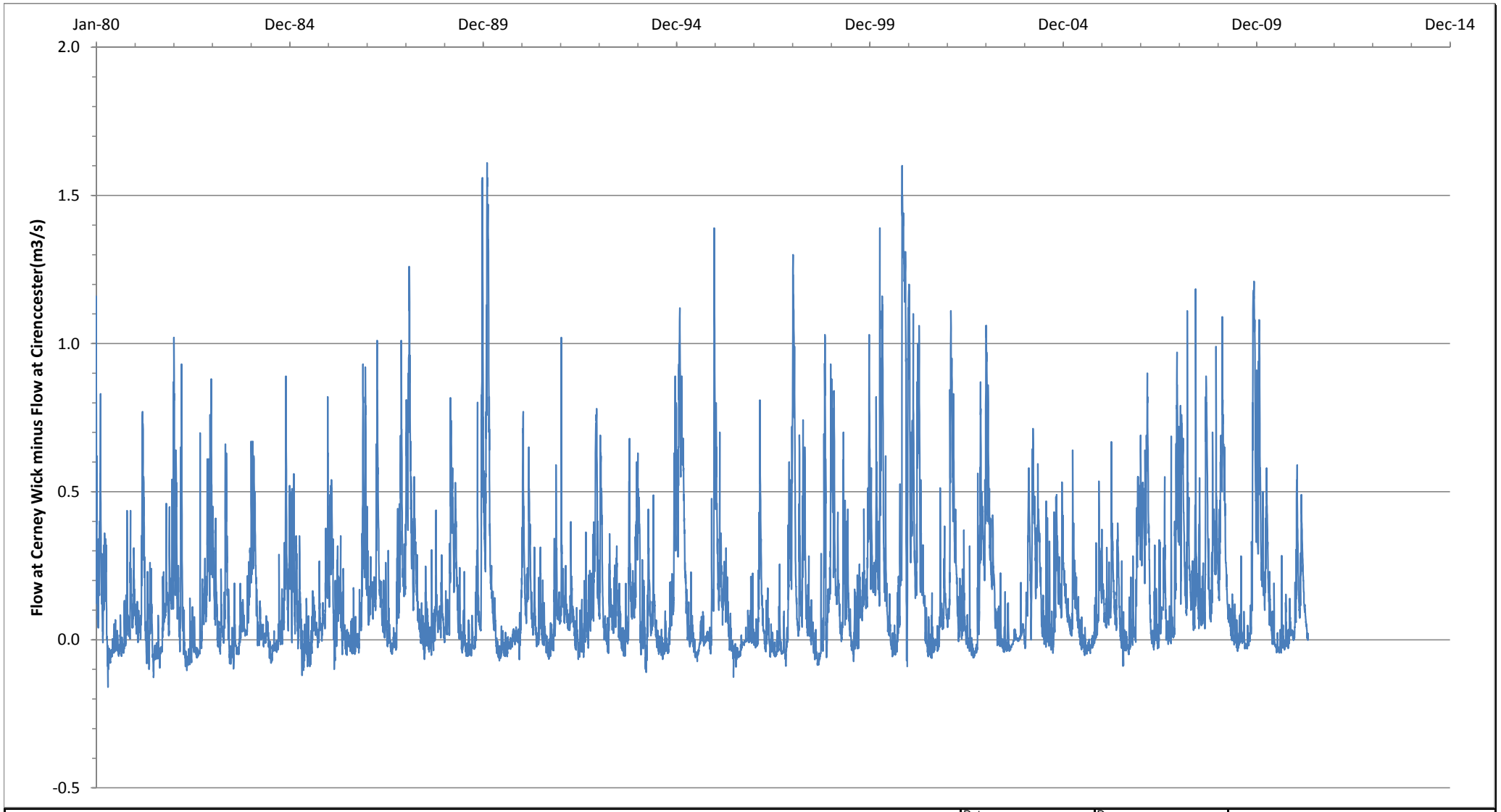

Figure 12

Difference in Flows in River Churn at Cerney Wick and Cirencester

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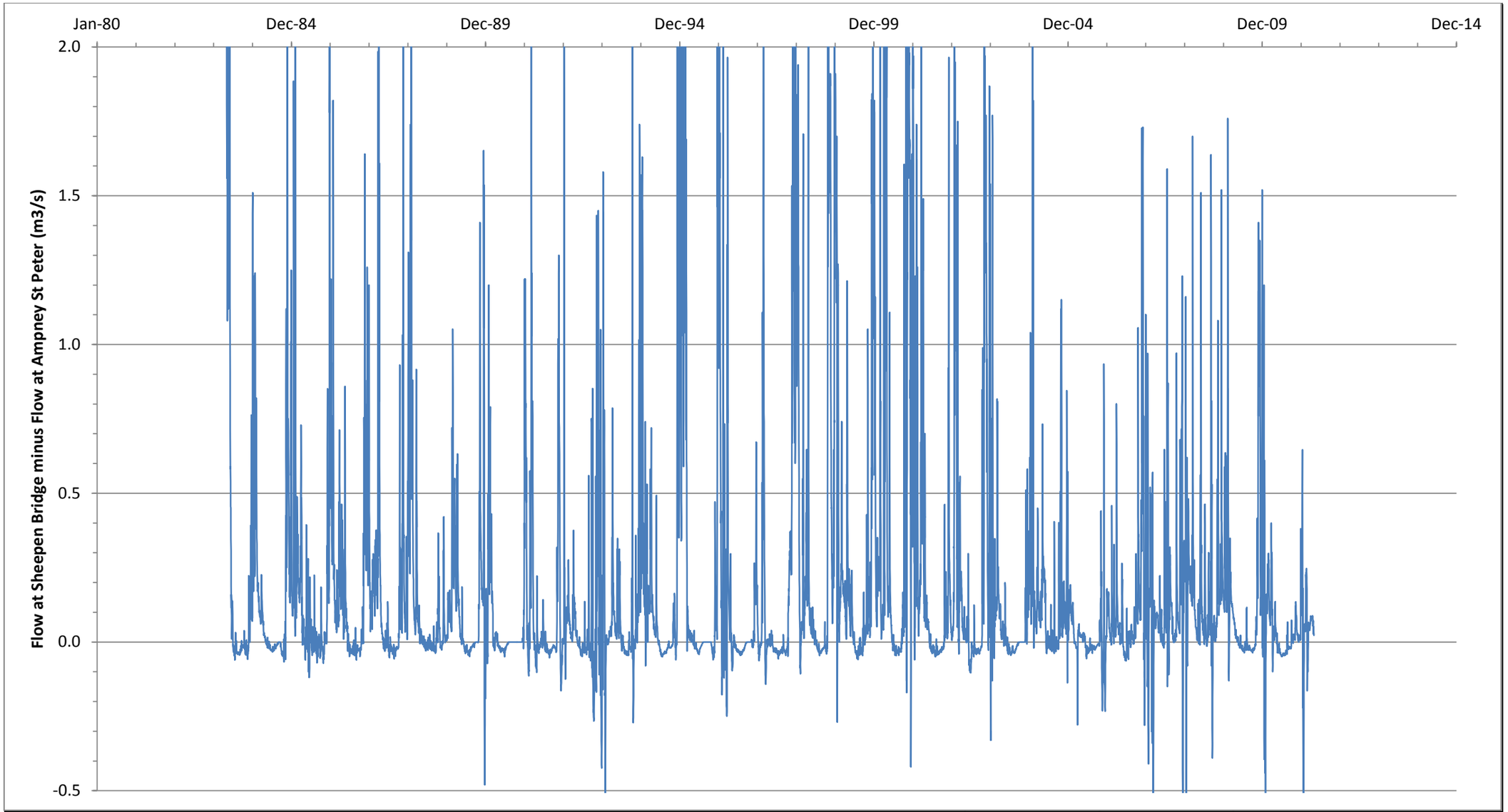

Figure 13

Difference in flows in Ampnet Brook between Ampney St Peter and Sheepen Bridge

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Scale: dns	Checked: MJS
Original: A4	Revision: 1
File Reference: O:\60710 TWUL Cotswolds Drought Permit\calculations\Sheepen Bridge and Amp ST peter.xlsx	

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