# Drought Permit Environmental Assessment Report: Derwent Valley Reservoirs

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# 1 Introduction

## 1.1 Derwent Valley Reservoirs DP application requirement

Severn Trent Water Ltd (STWL) are applying for a Derwent Valley Reservoirs Drought Permit (DP) in order to vary the compensation release requirement stipulated in the Derwent Valley abstraction licence.

This application is necessary due to an exceptional shortage of rainfall in 2022, which has resulted in low storage levels in the Derwent Valley Reservoirs. The drought triggers set for the Derwent Valley Reservoirs in STWL's drought plan were reached in 2022 as follows:

- Trigger 1 – level 1a (set at 85.9% storage) on the 25th April 2022
- Trigger 2 – level 1b (set at 66.5% storage) on the 13th June 2022
- Trigger 3 – level 2 (set at 38.6% storage) on the 22nd August 2022

STWL have commenced the actions associated with the drought trigger 3 (level 2) as set out in their drought plan, which involves preparing a DP application.

Drought permits are a precaution against a worsening situation. Due to the time involved in the application, public inspection and determination period, drought permits are often applied for but not implemented due to rain arriving in the meantime.

There is a threat that storage in the Derwent Valley Reservoirs will continue to decline if it remains dry and there is a risk that they may not refill if autumn/winter rainfall is insufficient. Drought permits have a duration of 6 months; however, if storage in the Derwent Valley Reservoirs improves, the drought powers may be lifted earlier.

The area affected by the drought permit is the River Derwent downstream of Ladybower reservoir. The environmental impacts of the drought permit, including the area impacted, are described in this Environmental Assessment Report (EAR).

## 1.2 Background

STWL abstracts water from the Derwent Valley Reservoirs for the purpose of public water supply. This is a strategically important source and as such, STWL undertakes extensive planning to prepare for times of drought.

DPs can be applied for where the main issue is variation of an abstraction licence condition such as the maximum annual abstraction limit or a compensation flow requirement. DPs are enacted through the Water Resources Act 1991 as amended by the Environment Act 1995, which confirms the EA as the relevant authority to determine the application.

As required under Section 39B(7) of the Water Industry Act 1991 and The Drought Plan (England) Direction 2016, there is a statutory duty for water companies to publish publicly available Drought Plans that are consulted upon with the Environment Agency (EA), the Secretary of State, the Water Services Regulation Authority (still commonly referred to as Ofwat) and other statutory bodies. Drought Plans are a requirement under Section 39B of the Water Industry Act 1991 (WIA), as introduced by the Water Act 2003. The purpose of a Drought Plan is to deliver sustainable management of water resources at times of limited natural reserves, thereby maintaining the balance between the needs of the public and the environment.

Prospective DP options are identified in STWL's Drought Plan (STWL, 2022). This document details the range of actions that STWL will consider implementing during drought conditions in order to maintain essential water supplies to its customers whilst minimising environmental impact. DPs may be granted to allow STWL to vary its operation within the terms of the permit for a period of six months. A review is conducted after five months with the possibility of a renewal of DP operation for a further six months after the end of the initial period. Thus, a DP could potentially be in place for up to 12 months.

Such actions to manage infrequent natural events such as drought are recognised within the European Water Framework Directive (WFD) as transposed into UK law by The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017. The WFD aims to ensure 'no deterioration' in the ecological status of water bodies, but temporary deterioration allowances, allow for temporary deterioration as a 'result of circumstances of natural cause which are exceptional or could not reasonably have been foreseen, in particular extreme floods and prolonged droughts.' This applies to situations where it is necessary to make use of the water environment in ways that result in a temporary deterioration of status (e.g. supplying the public with drinking water during prolonged drought).

## 1.3 Severn Trent Water Limited's Drought Plan

The Derwent Valley Reservoirs site is listed as a potential DP site within STWL's Drought Plan (STWL, 2022). In total the plan identifies six surface water abstractions where applications for a DP or a DO may be made (Table 1.1).

The environmental and ecological implications of potential DPs are investigated in advance, so that these assessments are in place should drought conditions arise. Each potential DP site requires an EAR. These reports provide details of likely changes to the flow regime due to implementation of the DP and an assessment of any potential impacts upon river ecology and river users arising from these changes. Potential impacts associated with a DP are assessed against a baseline of normal operation under drought conditions. Where impacts are determined to have **Moderate** significance or above, mitigation measures are required. An Environmental Monitoring Plan (EMP) is also set out to support the requirement for baseline, during and post DP monitoring. EAR's must be kept up to date with changes to operation of the Water Resource System and be consistent with STWL's Drought Plan (STWL, 2022).

**Table 1.1 STWL Drought Permit sites**

| Catchment | Potential STWL DP site |
|---|---|
| Derwent (Derbyshire) | - Derwent Valley Reservoirs; and<br>- River Derwent at Ambergate |
| Leam & Avon | - River Leam and River Avon (one single drought permit) |
| River Churnet | - Tittesworth Reservoir and River Churnet |
| Severn | - River Severn at Site G |
| Dove | - Dove Reservoirs (Staunton Harold and Foremark) |

## 1.4 This report

This report constitutes an application-version EAR for the Derwent Valley Reservoirs DP site and provides an environmental assessment of potential STWL drought actions within the Derwent catchment. Where potential impacts are identified, appropriate mitigation measures are presented to reduce impacts where possible. The report also includes an Environmental Monitoring Plan (EMP) detailing monitoring recommendations for the periods prior to, during and post DP implementation.

Following this background section, this report is structured as follows:

- Section 2 outlines the current study site and baseline operation, before describing the proposed DP operation;
- Section 3 presents the assessment method - where changes in assessment approach relative to the previous EAR have been made, these are set out in Section 3.4;
- Section 4 presents the baseline environment of the River Derwent;
- Section 5 sets out an assessment of changes to physical pathways and the assessment of impacts on ecological and other receptors, with regards the Derwent Valley Reservoirs DP;
- Section 6 provides a discussion of the previous EAR conclusions, to allow changes to be readily identified;
- Section 7 presents a summary of predicted the pathway changes and potential effects on ecological receptors associated with proposed DP operation
- Section 8 discusses possible mitigation measures;
- Section 9 outlines the environmental monitoring plan; and
- Section 10 provides the conclusions and recommendations.

For ease of reading, the report presents a technical summary of the detailed assessments that are subsequently presented as a series of Appendices.

# 2 The Derwent Valley Reservoirs drought permit

## 2.1 Baseline Operation of the Derwent Valley Reservoirs Water Resources System

### 2.1.1 Water sources

The major licensed abstractions and related operations undertaken within the Derwent catchment by STWL for public water supply are outlined below:

- The **Derwent Valley Reservoirs** system comprises three impounding reservoirs, Howden, Derwent and, Ladybower, situated upstream to downstream respectively, on the upper River Derwent. Inflows to these reservoirs are augmented by transfers on the River Noe, River Ashop and Jagger's Clough. Water abstracted by STWL from the Derwent Valley Reservoir system is treated at the nearest Water Treatment Works (WTW). Raw water is also transferred from the reservoirs to Sheffield and is covered by a bulk supply agreement with Yorkshire Water.

- **Ogston Reservoir** is situated on the River Amber and is augmented by abstractions from the River Derwent at Ambergate and Carsington Reservoir. The water treatment works for this source supplies parts of Derbyshire and Nottinghamshire.

- **Carsington Reservoir** impounds Henmore Brook, a tributary of the River Dove that is therefore outside of the Derwent Valley. However, the Henmore Brook accounts for only 12% of the water in the reservoir and the remainder is sourced by abstractions from the Derwent at Ambergate during periods of average to high flow. Carsington Reservoir is used to support flows in the Derwent and supplies to Ogston Reservoir during periods of low flow.

- There are four other licensed abstractions from the Derwent for public water supply.
  - **Ambergate** supplies water to Carsington and Ogston Reservoirs.
  - **Little Eaton** provides water to the water treatment works supplying Derby.
  - **Draycott** provides water to the water treatment works supplying Nottingham.
  - Abstraction from **Meerbrook Sough** (tributary of the Derwent) at the water treatment works feeding the Derwent Valley Aqueduct and also supplying the Wirksworth area. This abstraction is regarded as a Derwent abstraction due to proximity to the main river and because the licence has restrictions pertaining to Derby St Mary's Bridge gauging station.

The abstraction from the **Derwent Valley Reservoirs** system is the location for which an application for DP operation is being made. This is described in more detail below.

### 2.1.2 The Derwent Valley Reservoirs Abstraction Licence

The Derwent Valley Reservoirs abstraction licence permits the abstraction of a daily average rate of 245 Ml/d from three reservoirs for the purpose of public water supply. The abstraction is split, serving STWL's public water supply area via the Derwent Valley Aqueduct, and; serving the Sheffield area under a bulk supply agreement to Yorkshire Water.

A compensation flow to the River Derwent must be maintained downstream of Ladybower Reservoir:

- When the daily mean flow measured at Derby St Mary's Bridge gauging station (DSM) is at or below 340 Ml/d then the minimum quantity to be discharged from Ladybower Reservoir shall not be less than 72 Ml/d.
- When the mean daily flow measured at DSM is above 340 Ml/d the minimum quantity to be discharged shall not be less than 54 Ml/d.

In practice, STWL allow a margin of error to ensure compliance with the compensation requirement (a 10% margin of error).

There are no separate requirements to maintain flows downstream of Howden Reservoir (which spills directly into Derwent Reservoir) or Derwent Reservoir (which is separated from Ladybower Reservoir by only a very short reach). There are licensed requirements associated with the River Ashop, River Noe and Jagger's Clough abstractions (compensation release). These requirements may be summarised as:

- 10 Ml/d compensation requirement, when diverting water for abstraction, in the River Noe downstream of the abstraction point;
- 5 Ml/d compensation requirement, when diverting water for abstraction, in the River Ashop downstream of the abstraction point; and
- Between 10 and 17 Ml/d to be discharged (or maintained) in Jaggers Clough downstream of the Noe diversion.

A further control imposed on the Derwent Valley Reservoirs system considers the combination of compensation discharges from Ladybower Reservoir and the River Noe. The control/compensation flow requirements are as follows:

- When the mean daily flow measured at DSM is at or below 340 Ml/d then the minimum combined quantity referred to above shall not be less than 92 Ml/d.
- When the mean daily flow measured at DSM is above 340 Ml/d the minimum combined quantity referred to above shall not be less than 74 Ml/d.

## 2.2 Previous Drought Order/Permit Applications and Licence Variations

Historically, STWL applied for the following Drought Orders and licence variations within the Derwent catchment:

- Drought Order (DO) for the Derwent in 1976;
- DO for reducing compensation flows from Ladybower Reservoir in 1989/90;
- DO relating to refilling of Derwent Valley and Carsington in 1995/96;

In addition, DP applications were made in 1996 and 2003 for the Derwent catchment, but these applications were subsequently withdrawn due to changed weather conditions.

From April 1983 to December 1993 (inclusive) compensation flow to the River Derwent downstream of Ladybower Reservoir was also reduced to 39 Ml/d at times when the flow at Derby St Mary's Bridge was greater than 340 Ml/d. This was related to construction works at Carsington Reservoir.

## 2.3 Proposed Drought Permit Operation

### 2.3.1 Drought Permit scenario

Operation of the Strategic Grid East (which includes the Derwent Valley Reservoirs abstraction) is described in STWL's Drought Plan (STWL, 2022).

Drought Permits for the Derwent Valley Reservoirs must be justified by an exceptional shortage of rain, but are triggered by reservoir storage crossing control lines relating to the volume of storage remaining in the reservoirs at any given time of year, along with prescribed flows measured at Derby St Mary's Bridge.

The Derwent Valley Reservoirs DP applies to compensation releases from the Ladybower Reservoir (and does not involve changes to Ashop and Noe compensation releases). Table 2.1 summarises the changes sought to controls on the Derwent Valley Reservoirs licence.

The proposed DP scenario therefore allows for the following changes:

- Regardless of whether the daily mean flow measured at Derby St Mary's Bridge gauging station (DSM) is above or below 340 Ml/d, when storage in the Derwent Valley Reservoirs is sufficiently low, the minimum quantity to be discharged from Ladybower Reservoir shall not be less than 34 Ml/d, with at least 51 Ml/d being maintained immediately downstream of the Noe-Derwent confluence.

**Table 2.1 Derwent Valley Reservoirs Drought Permit variation**

| System | Mean daily flow controls (normal/drought permit) at St Mary's Bridge Derby (Ml/d) | | Permissible Abstractions (Ml/d) | Total Upper Derwent compensatory flow requirements (normal/drought permit) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Yorkshire Bridge | | Below Noe Confluence | |
| | Normal | Drought Permit | Normal & Drought Permit | Normal | Drought Permit | Normal | Drought Permit |
| Derwent Valley Reservoirs System | ≤ 340 | ≤ 340 | 245 (daily average value) | ≥ 72 | ≥ 34 | ≥ 92 | ≥ 51 |
| | > 340 | > 340 | | ≥ 54 | ≥ 34 | ≥ 74 | ≥ 51 |

## 2.4 Summary of the scenario

The DP scenario therefore allows for the following changes from baseline operation:

- The **Derwent Reservoir DP scenario** simulates a minimum quantity to be discharged from Ladybower Reservoir of not less than 34 Ml/d, with at least 51 Ml/d being maintained immediately downstream of the Noe-Derwent confluence; this DP scenario does not involve change to any compensation requirement beyond the Ladybower Reservoir release e.g. those compensation requirements on the Rivers Ashop and Noe.

# 3 Assessment method

## 3.1 EAR production guidance

The environmental assessment of a potential DP is undertaken in recognition of the following principal guidance from the EA and Defra:

- Defra (2015). Drought permit guidance: https://www.gov.uk/guidance/apply-for-a-drought-permit (published November 2015).
- Environment Agency (2017). Drought plan guideline extra information; Environmental Assessment for Water Company Drought Plans (last updated September 2017).

The environmental assessment carried out and reported here to support the Derwent drought options is not a statutory Environmental Impact Assessment (EIA), as recognised, for example, within the Town & Country Planning regime and its enabling regulations. However, the EAR assessment method has been developed in accordance with best practice EIA guidance wherever applicable.

The guidance dictates that the environmental assessment process should involve definition of the baseline, followed by three stages:

- EAR Stage 1: Hydrological, hydrogeological and geomorphological impact assessment;
- EAR Stage 2: Environmental sensitivity assessment; and
- EAR Stage 3: Identifying any additional evidence/data requirements.

The baseline conditions are those that exist in the absence of the proposed drought actions. Baseline data (historical and recent) are gathered and described according to the latest classification techniques (e.g. WFD Cycle 2 classifications).

The staged EAR approach is consistent with the Environmental Impact Assessment (EIA) 'source'-'pathway'-'receptor' concept. The EAR Stage 1 (above) constitutes a 'pathways' assessment. Pathways are the means by which an effect reaches or is propagated upon the receiving 'receptor'; so, pathways with respect to Drought Permit EARs are typically changes to river discharge, water quality and physical habitat. Effects on these pathways are assessed in Stage 1 with respect to their likely scale, timing, duration and spatial extent, but not to their importance (or value).

EAR Stage 2 defines how the predicted pathway changes (from EAR Stage 1) may cause an 'effect' on receptors, ultimately characterising the significance of each identified effect. With respect to Drought Permit EARs, these are typically flow-sensitive biota and other water users. Compliance with regulatory requirements can also be considered a receptor. As for pathways, impacts on receptors have been assessed with respect to their likely scale, timing, duration and spatial extent. However, as receptors, their importance (or value) is also considered to establish to overall significance of the impact.

There are many independent and linked characterisations undertaken in the overall assessment of significance and the process has been defined for this project having cognisance of the latest CIEEM guidelines (CIEEM, 2016). Figure 3.1 illustrates (in schematic form) the overall process of defining significance of individual effects. All individual, component assessments are recorded; Table 3.1 provides the assessment component categories and definition guidance.

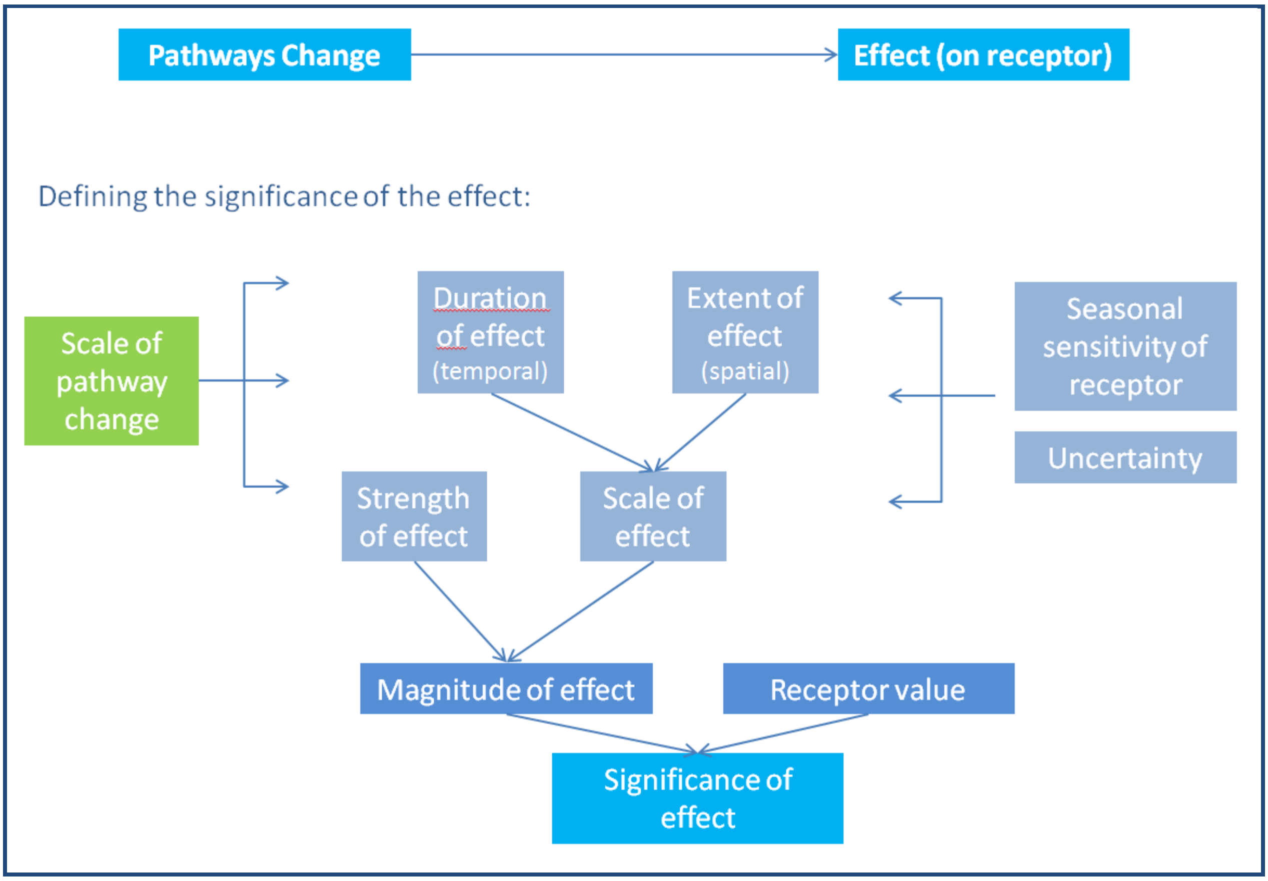


**Figure 3.1 Schematic of the EAR stage 2 process, defining the significance of each effect**

**Table 3.1 Assessment component categories and definition guidance**

| Component | Categories | | | | | | | | | Commentary |
|---|---|---|---|---|---|---|---|---|---|---|
| **Seasonal sensitivity** | High | Medium | Low | None | | | | | | Assessed on an individual species / life-stage / receptor basis for individual months e.g. salmon juveniles may have High sensitivity in some calendar months and Low sensitivity in other calendar months. |
| **Uncertainty** | Confirmed | Probable | Suspected | Unknown | | | | | | Receptor and site specific; may depend on data availability; knowledge of receptor etc. Defined for information/ consideration within all other component assessments. |
| **Duration** | Permanent | Long Term | Medium Term | Short Term | | | | | | Receptor and site specific; defined for example in relation to ecological characteristics such as species' life-cycle. |
| **Extent** | Extensive | Moderately extensive | Localised | Negligible | | | | | | Spatial or geographical area over which the impact/effect may occur. |
| **Scale** | High | Medium | Low | Negligible | | | | | | Matrix combination of duration and extent. |
| **Strength** | Large -ve | Moderate -ve | Small -ve | Negligible | Small +ve | Moderate +ve | Large +ve | | | Receptor and site specific; incorporates positive and negative change |
| **Magnitude** | High Negative | Medium Negative | Low Negative | Negligible | Low Positive | Medium Positive | High positive | | | Matrix combination of scale and strength. |
| **Receptor value** | International | National | Regional / County | District / Parish | Negligible | | | | | As adapted from CIEEM 2016. |
| **Significance** | Critical | Major | Moderate | Minor | Negligible | Minor Benefit | Moderately beneficial | Highly beneficial | Very highly beneficia | Matrix combination of receptor value and magnitude. |

## 3.2 Assessment Points

Characterisation of major rivers efficiently necessarily means that long lengths of river must be represented with data collected at a series of single locations or along shorter reaches. The spatial extent of the River Derwent presents a particular problem because it drains a large proportion of the county of Derbyshire (Figure 3.2). It is approximately 106 km long to its confluence with the River Trent near Sawley, with a catchment area of 1210 km².

For the purposes of the Water Framework Directive (WFD) the river has been split into four waterbodies separated at the confluences of major tributaries.

The River Derwent from Westend to Wye waterbody (GB104028057880) comprises the upper Derwent and marks a transition in character from an energetic, upland stream to a sizeable intermediate river. Rising on the eastern flank of Bleaklow, the upper Derwent catchment drains the Millstone Grit and peat moorland of the Dark Peak and includes the Derwent Valley Reservoirs. Between the reservoirs and the River Wye confluence, the valley opens out and the catchment receives drainage from both Millstone Grit/ peat moors and from the Carboniferous Limestone/ pasture of the White Peak. Urban land use is minimal, but is concentrated along the river, including the villages of Bamford, Hathersage, Grindleford and Baslow.

The Derwent from Wye to Amber (GB104028052390) and the Derwent from Amber to Bottle Brook (GB104028052310) waterbodies comprise the Middle Derwent. This includes the Ambergate abstraction and marks the transition to a mature lowland river, via flow through incised limestone topography. The Derbyshire Wye adds a substantial component of limestone/ pasture-derived drainage, with an increasing (though still fairly modest) urban component from Matlock, Cromford and Belper on the River Derwent itself, and from Buxton and Bakewell on the River Wye. These reaches include Ogston Reservoir and associated abstraction locations.

The Derwent from Bottle Brook to Trent (GB104028053240) waterbody is a mature lowland river more open in character, flowing over Coal Measures and Triassic sandstones and marls. These reaches drain pasture, some arable land and the substantial urban area of Derby, with abstractions made from the watercourse as described in Section 2.1.1.

Eight Assessment Points (APs) were selected to characterise these reaches, as detailed in the following table and shown on Figure 3.2.

**Table 3.2 Derwent Assessment Points**

| AP | Name | Relevance |
|---|---|---|
| D1 | Yorkshire Bridge | Immediately d/s Derwent Valley Reservoirs |
| D2 | Leadmill Bridge | d/s the Noe confluence |
| D3 | Baslow Bridge | |
| D4 | Matlock Bath | d/s Wye confluence |
| D5 | Whatstandwell | u/s Ambergate |
| D6 | Belper | d/s Ambergate |
| D7 | Allestree | |
| D8 | Derby St Mary's Bridge | Key control point for drought management actions |

NB: AP prefix 'D' included here and Figure 3.2 for consistency with hydrological modelling works undertaken. Elsewhere in this EAR, the prefix is not reported.

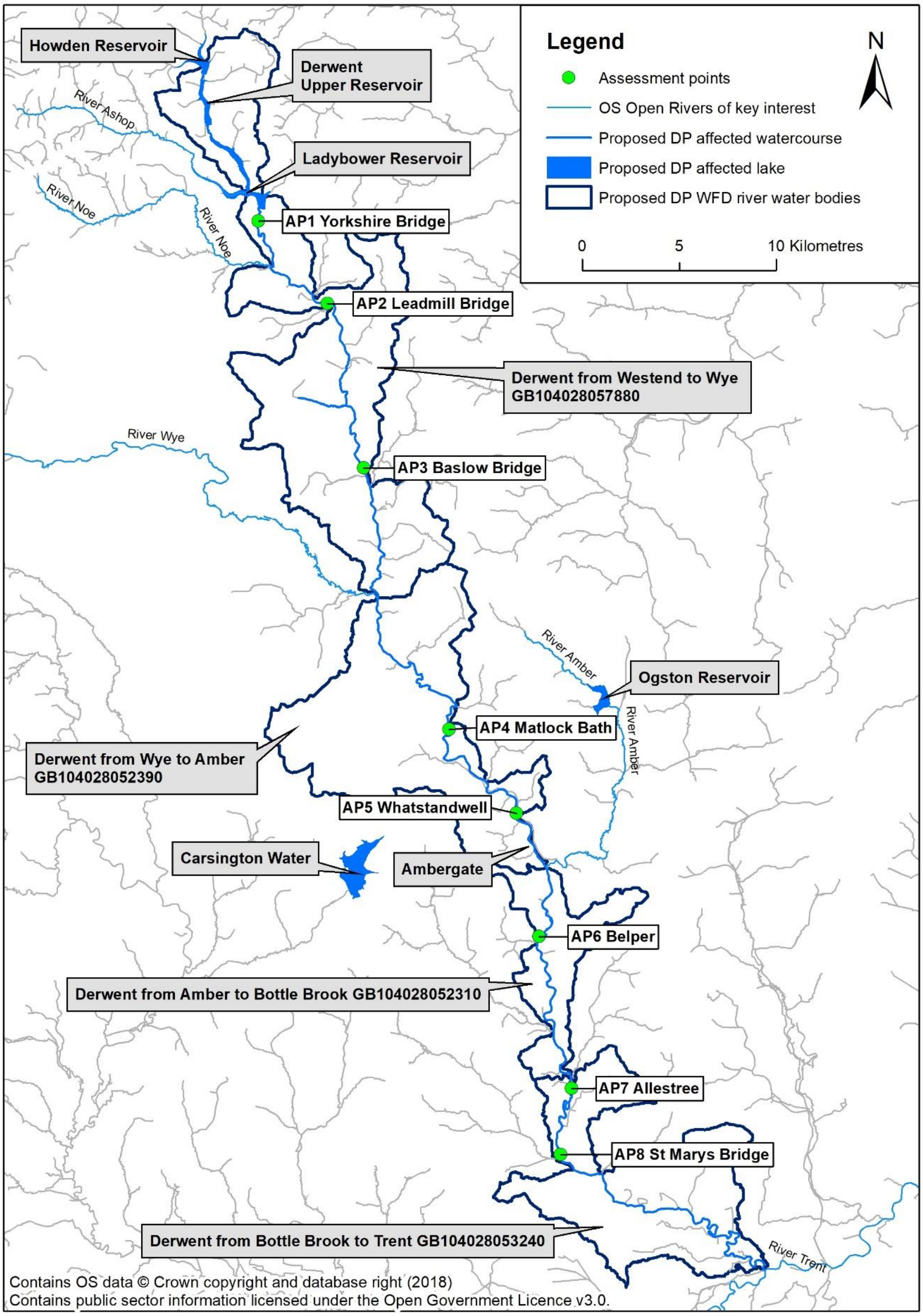


**Figure 3.2 WFD water bodies and Assessment Point locations**

The selection of APs was originally made in consultation with STWL, the EA and APEM at a meeting held for the previous DP EAR (ESI & APEM, 2012) on 19 August 2010. Selection of APs was based on ecological and hydrological considerations to represent reaches of distinct hydrological, hydraulic or water quality characteristics, although compromises were also made in selecting transects that were a) also suited to reliable flow estimation and b) safely and easily accessible. Consideration was also given to the locations with existing long-term ecological datasets and those used for WFD classification, as these were considered likely to be most useful to allow comparison and analysis of current and historical monitoring data.

No new APs have been added for this update, following critical review, but examination of hydraulic response was undertaken in greater detail for the Derwent: Westend to Wye waterbody (Section 3.3.1, Appendix C). The coverage afforded by the three transects within the Derwent: Westend to Wye waterbody was greatly increased by hydraulic modelling along the entire river length between Ladybower Reservoir and the River Wye confluence, thus markedly improving the representation of hydraulic behaviour, capturing the effects of structures (weirs and bridges) and of a number of the gravel shoals present in the Derwent: Westend to Wye waterbody.

## 3.3 Impacts at Assessment Points

At each AP, the operation of STWL's water supply network has been linked to impacts on biological receptors and water users via water quality and physical habitat pathways. This is summarised in Figure 3.3. Changes to river discharge resulting from abstraction are typically not the only stressor in the water body and are often not the most important stressor. As the assessment of DP operation is made against baseline conditions, this must therefore include consideration of the effect of other pressures. Other pressures may act independently of abstraction pressure or interact with abstraction pressure, acting in combination either to exacerbate (or compound) impacts on ecology, or to alleviate their effect. Other pressures considered in this report include diffuse and point source pollution inputs, changes to channel morphology, barriers to fish migration and invasive species.

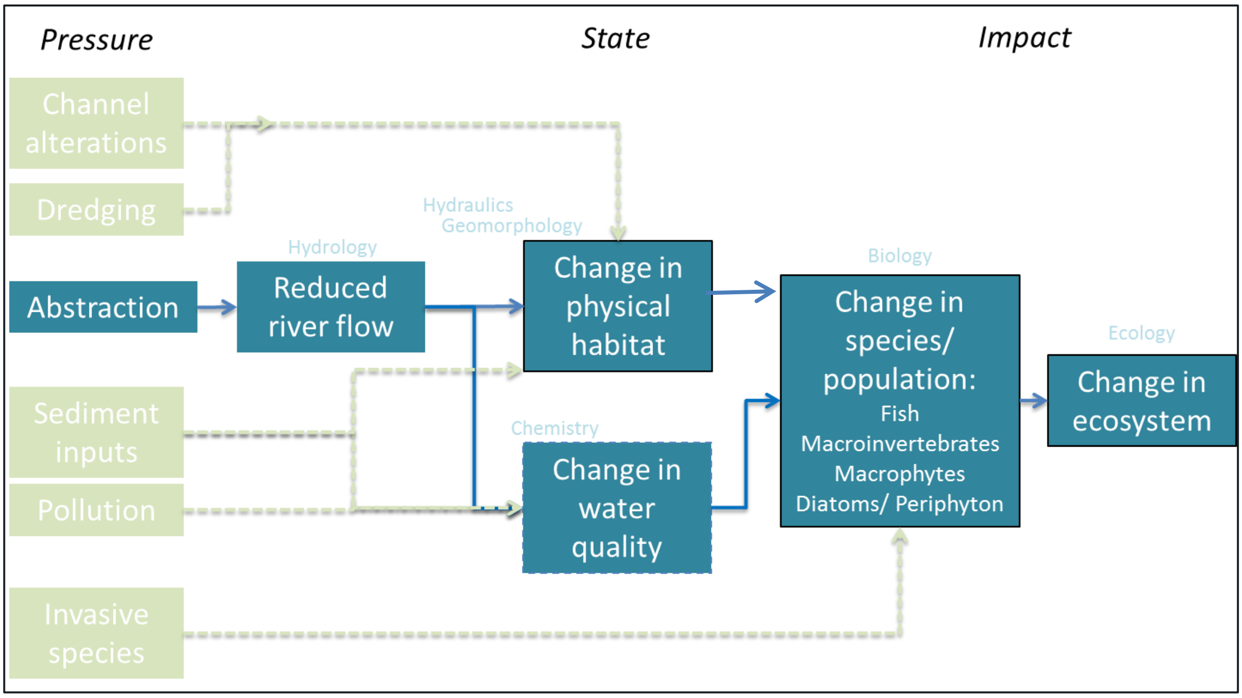


**Figure 3.3 Conceptual linkage of abstraction to impacts on biological quality elements.**
**Blue-green boxes show the pathway between abstraction and its possible effect in an otherwise pristine river. Green boxes indicate the potential effects of other pressures.**

### 3.3.1 Pathways

The pathways considered as part of this EAR study are:

- **Hydrological** – reservoir storage, low flows; spate and flood flows; flow variability and rate of change;
- **Hydromorphological** - size of wetted habitat; connectivity; character; diversity and reservoir level;
- **Water quality** – e.g. WFD physico-chemical elements.

Pathways effects have been modelled in sequence.

*Hydrology*

The operation of STWL's water supply network has been modelled within Aquator™ for STWL's Water Resources Management Plan (STWL, 2019) and Drought Plan (STWL, 2022). Aquator™ models the behaviour of STWL's water resources system based on estimated inflows and a set of rules that govern the operation of STWL's water resource system (and third-party influences). Using these, Aquator™ outputs flow and reservoir storage.

Aquator™ outputs represent the best estimate of drought flows and system behaviour available at the time of modelling (which was undertaken in 2018). It should be acknowledged that the representation of inflows and of STWL's supply system have been upgraded since, but (particularly as they are intended as a 'snapshot' of likely operation within a continually evolving water resources system), the 2018 simulations are considered of acceptable accuracy for the purposes of this report[1].

The scenarios for DP operation were simulated with relevant drought operations enabled. Baseline scenarios were simulated with drought operation disabled, such that outputs show how the water supply system would perform without recourse to drought operation. These baseline flow time series represent a modelled estimate of the flows that would have occurred during historic droughts had STWL's water supply system operated as it did at the time of modelling, with demands as they were at the time of modelling[2]. The most severe of the simulations undertaken at that time has been used to illustrate potential DP/ DO effects throughout this report[3].

Aquator™ outputs flow and reservoir storage at key points (model nodes) in STWL's supply system, including several locations along the River Derwent. However, the assessment of DP impacts has been undertaken at a finer resolution than allowed by Aquator™ nodes alone[4]. As such, the accretion of flows down the River Derwent has been interpolated between Aquator™ nodes to derive flows appropriate to points of interest in the catchment. This is described in Appendix A.

*Hydraulics and geomorphology*

The assessment of hydraulics and geomorphology used River Habitat Survey (RHS) and habitat walkover collected at co-located sampling locations to characterise physical habitat within the reaches of interest. Aerial imagery was also used to help interpret these data in the context of the remainder of the river, and structures of potential importance to fish passage or to the character of river habitat were also identified. Background to RHS and to the walkover method used is given in Appendix B.

Likely DP effects on reservoir levels have been estimated from reservoir storage (output by Aquator™) using reservoir bathymetry data. Likely DP effects on the character of flow along the River Derwent has been

[1] They are primarily used here for context, establishing, for example, the likely timing and frequency of DP operation. The DP EAR is instead based upon specified release conditions at Ladybower Reservoir.
[2] As such, and because Aquator™ also assumes perfect application of the operating and licence rules, the river flows generated by Aquator™ are not directly comparable with measured historical river flows.
[3] This was the Modelled Stochastic 1959/60 drought – a synthetic 'worse than recorded' drought which was based upon historic droughts but perturbed to represent the potential effects of climate change.
[4] Aquator nodes are not intended to capture environmental differences and Aquator™ models STWL's entire Strategic Grid, not just the River Derwent.

modelled at two levels of complexity. Hydraulic modelling allows predicted changes in river discharge (hydrological changes) to be translated to changes of hydraulic variables that collectively describe the water environment, thereby adding a temporal dimension to the spatial description achieved through habitat walkover mapping or RHS. Two levels of complexity were used for the hydraulic analysis and are described below:

- For a higher-level analysis, empirical relationships have been established between measured hydraulic parameters and discharge at a single transect representing each AP. Each of these transects is independently-assessed (i.e., unlinked), meaning that this is a simple, high-level hydraulic modelling approach that furthers the hydrological assessment, but (in the numbers deployed) does not offer a high density of coverage and may not represent hydraulic complexities (such as backwater effects at structures or variability in roughness with depth). As such, this approach relies upon site selection to characterise potentially sensitive habitats, and extrapolations also tend to be less certain. Because of this, this "independent transect" approach has been used primarily to confirm a likely absence of effect where hydrological changes are relatively modest.
- Secondly, an integrated hydraulic model has been created in the Derwent: Westend to Wye waterbody. This approach makes use of an existing flood model to greatly expand the coverage of transects, increasing confidence that diverse habitats are represented. Moreover, as the transects are linked within a hydraulic description that also incorporates structures and an improved treatment of variability of varying roughness, extrapolations can be made with greater confidence. This has been applied to the Derwent: Westend to Wye waterbody because this is where hydrological effects at low flows are greatest, where depths are lowest (and hence more prone to variability in roughness) and where habitat is most diverse (i.e., benefiting most from greater density of coverage). This is termed an "integrated model" approach.

The following hydraulic parameters have been assessed in both the independent transect and integrated model approaches: Maximum depth, wetted perimeter, transect averaged velocity, flow intensity (Froude Number[5]) and bed shear stress (estimated from bed slope). Together, these have been used to assess changes to the habitat size (wetted perimeter), habitat character (velocity and flow intensity) and habitat connectivity (maximum depth). Changes to habitat diversity and juxtaposition of habitats have also been considered, as has the potential longer terms effects of any DP-induced geomorphological changes (via velocity and shear stress). Depth of flow was also used qualitatively as a potential control on connectivity with the floodplain (lateral connectivity), and with the subsurface environment (vertical connectivity). These have not been quantitatively assessed. Further detail on the independent transect and integrated model approaches to hydraulic assessment is given in Appendix C.

*Water quality*

Water quality in the River Derwent may be affected directly by releases from storage, or via a reduced capacity to dilute pollutants. The EA's Derwent SIMCAT model was interrogated to provide an approximation of the discharge load and contributions for common Sewage Treatment Works (STW) discharge parameters throughout the catchment. Effects have been screened using expert judgement (e.g. consideration of long-term data series in the context of low flow periods) and, for phosphate and total ammonia, mass balance calculations have been used to explore potential effects of changes to dilution in more detail. The assessment has included all WFD physico-chemical elements and those water quality WFD supporting elements that have been identified (through Environment Agency WFD classifications) as currently at less than Good status, which are zinc (bioavailable) and cadmium. This is described further in Appendix D.

### 3.3.2 Receptors

Assessment of potential impacts on ecological receptors mainly relied upon expert assessment of the estimated effects on pathway variables in parallel with historical receptor data. Direct observations of receptors'

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[5] Froude number can differentiate between standing and flowing (lentic and lotic) waters, and between types of flowing water environment, and has been shown to correlate to biotic communities (e.g., Harding et al, 2009).

responses to DP operation are limited because of the need to extrapolate beyond the measured baseline conditions for DP assessment.

*Macroinvertebrates*

Consideration of macroinvertebrate data has been informed by expert judgement based upon hydraulic and water quality pathways, as well as by observed effects during the 1995/96 drought, during which DP operation was implemented according to the DO relating to refilling of Derwent Valley and Carsington in 1995/96. Macroinvertebrate sampling captured the response of macroinvertebrate communities to a reduction of the Ladybower compensation flow to 34 Ml/d between the end of January and the end of April 1996. These provide a useful analogue with which to assess potential effects of the proposed Derwent Reservoirs DP. However, the limited dataset – one period of DP operation, impedes quantitative examination of 1995/96 effects.

Macroinvertebrate data were summarised as a suite of biotic indices, calibrated to detect the biological effects of low flows and water pollution:

- Lotic Invertebrate index for Flow Evaluation (LIFE; Extence *et al.*, 1999) is the average of abundance-weighted flow groups that indicate the preferences of each taxon for higher water velocities and clean gravel/cobble substrata or slow/still water velocities and finer substrata. LIFE is used to index the effect of flow variations on macroinvertebrate communities.
- Whalley Hawkes Paisley Trigg (WHPT, UKTAG 2014) is an index of overall biological quality using macroinvertebrates. WHPT ASPT and WHPT NTAXA are the current indices used to determine WFD status during classifications for macroinvertebrates and are also useful for distinguishing the direct effects of water abstraction from the effects of water pollution.

Species lists from macroinvertebrate sample records have also been interrogated to assess the potential for impacts on rare species (e.g. Species of Principal Importance under the Natural Environment and Rural Communities Act 2006). Assessment of potential impacts on macroinvertebrates is detailed further in Appendix E.

*Fish*

The baseline fish populations of the River Derwent and the habitat upon which they depend has been assessed using:

- Fish survey data
- Habitat walkover data
- Information on the passability of structures

Historical fish survey data have been used to determine species composition. Habitat walkover data and passability of structures have been used to understand the likely ecological function of each reach.

Many fish species require access to a variety of habitats and conditions at different stages of their lives, such that their utilisation of the environment changes on a seasonal basis. For example, salmonids and certain cyprinid species (e.g., barbel, dace) require the use of riffle and shallow run habitat to fulfil essential life stage requirements such as spawning, egg incubation and nursery functions (termed rheophilic species). Other species, such as perch and roach, demonstrate greater plasticity in their habitat requirements (termed eurytopic species). Yet other species occupy specialist niche habitats such as the utilisation of marginal silts by lamprey ammocoetes. Because of this dependence upon the river's habitat, the impact of flow changes upon different fish species has been assessed by examining hydraulic and water quality changes in the light of established migration requirements and seasonal sensitivity and habitat preferences for individual species and life stages.

In line with the hydraulic analysis, assessment of impacts on fish habitat have been undertaken at two levels. Because of the small scale of hydraulic change predicted downstream of the River Wye confluence, changes to habitat in these reaches have been assessed by expert judgement based upon hydraulic parameters. These have been assessed collectively, but without explicit quantification of habitat suitability based upon depth and velocity requirements. Effects at structures have likewise been assessed from predicted changes in depth but not through explicit modelling.

The following species or functional guilds have been assessed:

- Atlantic salmon (*Salmo salar*);
- Brown/sea trout (*Salmo trutta*);
- Rheophilic coarse fish (comprising barbel (*Barbus barbus*), chub (*Leuciscus cephalus*), dace (*Leuciscus leuciscus*), grayling (*Thymallus thymallus*));
- Eurytopic coarse fish (comprising perch (*Perca fluviatilis*), pike (*Esox lucius*), roach (*Rutilus rutilus*), ruffe (*Gymnocephalus cernua*), gudgeon (*Gobio gobio*), tench (*Tinca tinca)*, bleak (*Alburnus alburnus*) and common bream (*Abramis brama*);
- Minor coarse fish species (comprising minnow (*Phoxinus phoxinus*), stone loach (*Barbatula barbatula*), spined loach (*Cobitis taenia*) and three-spined stickleback (*Gasterosteus aculeatus*));
- Bullhead (*Cottus gobio*);
- European eel (*Anguilla anguilla*); and
- Brook lamprey (*Lampetra planeri*).

Hydraulic changes arising from the Derwent Valley Reservoirs DP are greatest in the Derwent from Westend to Wye waterbody and hydraulic changes were modelled at higher resolution between Ladybower Reservoir and the Wye confluence. Combined depth and velocity outputs of the hydraulic modelling were screened against literature-derived habitat preferences for relevant fish species. (Note, however, that depth and velocity changes have been treated independently of substratum composition, which has not been mapped.) Modelled changes in habitat suitability are presented for this reach across the entire model domain. However, because of barriers to migration, no fish species can access habitat along the entire reach between Ladybower Reservoir and the Wye confluence, and for some species or species-lifestages, habitat is fragmented by a number of intervening structures. As such, habitat suitability has been assessed both collectively across the model domain, and discretely, within the following reaches:

- Ladybower to Bamford Weir
- Bamford Weir to Hathersage Leadmill Bridge
- Hathersage Leadmill Bridge to Calver
- Calver to Baslow Weir
- Baslow to Chatsworth Weirs
- Chatsworth to Rowsley (Wye confluence).

To assess the impacts of a drought permit upon migration, structures that are considered impassable under baseline conditions have not been considered as an additional impact under a DP as they would remain impassable during the DP/DO implementation. However, barriers which are negotiable under all or certain flow conditions during baseline conditions may pose an increased barrier during a DP[6]. Structures that are deemed impassable to salmon migrating upstream have been considered impassable to the majority of other species. That said, there may also be additional barriers not considered an impediment to upstream migrating salmon

[6] For example, a reduction in flow may increase the hydraulic head drop over a weir, reduce water depths over the crest or face of a weir or decrease the depth of water on the approach to a structure, each of which have the potential to pose a greater obstruction to migration. Similarly, where fish passes are present adjacent to weir structures a reduction in river flow may decrease the depth of water through the fish pass – depending on the magnitude of the reduction this may be sufficient for a fish pass to fall outside of the design parameters required for effective operation.

which would act as barriers to other species. Assessment of potential impacts on fish is detailed further in Section 5.6 and Appendix F.

*Amenity and protected rights*

Amenity use was assessed via a desk-based assessment using publicly available information. With the exception of Protected Rights, potential impacts on water users, legislative compliance and the risk of spreading Invasive Non-Native Species (INNS) also relies upon expert assessment of the estimated effects on pathway variables.

Protected Rights (Appendix H) are numerically defined by abstraction licence and discharge consent conditions and are therefore amenable to quantitative comparisons. These were made with reference to Aquator™ output scaled where necessary as explained in Appendix A. Protected Rights have been screened for two mechanisms of impact:

- Mechanism 1: causing flows and levels at St Mary's Bridge and other control points to fall below trigger thresholds to reduce or cease abstraction; or
- Mechanism 2: reducing flows and levels so there is insufficient water available for abstraction.

The first mechanism would impact protected rights both upstream and downstream of the DP site if they have control points downstream of a DP but will not impact rights with no control point downstream of a DP. The second mechanism will only impact rights downstream of a DP whether or not they have a control point. Note that in some instances, licences include local controls that cannot be related to Aquator™ output, without recourse to expert judgement.

## 3.4 Changes since the previous Drought Permit Environmental Assessment

The structure and many of the component methods used in this DP EAR are consistent with those quoted in the previous DP EAR (ESI & APEM, 2012), with the following exceptions:

The assessment of drought frequency and hydrological changes has benefitted from the following improvements to the representation of STWL's water supply system within Aquator™ in 2018:

- Changes to the large-scale model structure and definition of water resource zones; the previous DP EAR (ESI & APEM, 2012) used the East Midlands model, this update uses the strategic grid water resource zone.
- Better representation of the operation of individual sources, including addition of Ogston and Carsington control curves.
- Updating and rationalisation of control curves throughout STWL's supply zones.
- Revision, rationalisation and extension of Hysim (WRA, 2018) generated historical inflow series.
- Updated deployable output analysis, leading to a lower deployable output than previously used.
- Inclusion of DP actions within the model code.
- Allowance for climate change effects.

The hydromorphological assessment benefits from analysis of subsequent gaugings (for the unlinked transect approach at APs) and from integrated hydraulic modelling throughout the Derwent: Westend to Wye waterbody.

The water quality assessment has included interrogation of the EA's SIMCAT model of the River Derwent, has investigated the thermal effect of the Ladybower compensation and has investigated the effect of the DP coinciding with theoretical permit maximum phosphate discharges at Derby STW.

Consideration of ecological receptors (macroinvertebrates and fish) has incorporated new data but has not extended former statistical analyses (macroinvertebrates only).

Consideration of effects on designated sites has been extended to include other users.

This report includes a quantitative assessment of effects on protected rights, taking into account Hands Off Flow (HOF), levels (where data is available) and daily abstraction values for individual abstractions. The previous report only undertook a qualitative assessment.

## 3.5 Uncertainties

The purpose of the DP EAR is to undertake a proportionate risk assessment, the foundation of which is the comparison of baseline and DP/DO scenarios. Uncertainties in such an assessment cannot be eliminated. The uncertainties in the assessment methods are summarised below, with further detail given in relevant appendices. These inform a wider consideration of the certainty of impacts arrived at using expert judgement.

All assessments are underpinned by the same methods, based on the same assumptions and are thus comparable for the purposes of impact assessment.

### 3.5.1 Hydrology

Aquator™ simulations use models to simulate runoff generation from rainfall and potential evapotranspiration inputs. These are consistent with those used for STWL's Water Resources Management Plan (STWL, 2019) and Drought Plan (STWL, 2022), but neither the rainfall inputs themselves, nor the characterisation of runoff generation processes are free of error. Models may not always characterise extreme low flows well, particularly where these are lower than in the historical record. Accounting for climate change is likewise problematic. This may affect contextual information, such as the predicted likely frequency or timing of DP operation but is not considered a big effect on the assessment of environmental impacts.

The assessment of drought flows using Aquator™ simulated operation of STWL's water resource network to pre-defined rules and demands, as extant in 2018 Aquator™ output, represented the best estimate of drought flows and system behaviour available at the time of drafting of STWL's Water Resources Management Plan (STWL, 2019). The representation of inflows and of STWL's supply system has been upgraded since this modelling, but the DP EAR is intended as a 'snapshot' of likely operation within a continually evolving water resources system. Within this context, the 2018 Aquator™ representation of STWL's abstraction is considered to remain an acceptable representation.

### 3.5.2 Hydraulics

The limitations of the intentionally high-level analysis at APs downstream of the River Wye confluence mean that the estimation of hydraulic behavior during severe drought events is of only medium certainty. However, given the low degree of change to flows in reaches downstream of the River Wye confluence, this uncertainty is not considered to cast significant doubts on the impacts on receptors in those reaches:

- Hydromorphological effects have sought to characterise baseline habitat over long river reaches using walkover and other data centered upon eight APs. The walkover sections surveyed were discrete lengths of 1 km, and are therefore a representative sample, rather than a comprehensive description, of the entire channel.
- The high-level hydraulic analysis downstream of the River Wye confluence presented here is based upon various extrapolations. Specifically, extrapolation at a transect to flows lower than the gauged range and extrapolation spatially to use these results to infer more general behavior of the river reaches in general. The first of these extrapolations is an unavoidable consequence of compensation flows not being sufficiently low in recent times. The second was countered to some extent by selecting transects to be representative of the hydraulic character of the River Derwent.
- There are also inevitable uncertainties in the measurements taken at the APs. Transects have not been surveyed. Hydraulic relationships were instead derived from gauging transects and represent a

typical transect taken from gaugings conducted over several years. The gaugings were taken at a fixed location, but differences between gauged transects inevitably occur depending on the precise path taken by the ADCP. The practical limitations of ADCP gauging also mean that velocity measurements are not available on shallows, including shallow margins. This has limited appraisal of hydraulic behavior in these areas, the ecology of which can be sensitive to flow reductions.

Upstream of the Wye confluence, in the River Derwent Westend to Wye waterbody, the high-level approach was augmented by integrated 1D modelling. The model is considered to capture the main controls on hydraulic behaviour (including numerous structures) and has greatly increased coverage of cross sections (145 in total, not including interpolates, of which nearly 100 are not associated with structures), including at complex channel features. Sensitivity analysis has also demonstrated that conclusions are not likely to be unduly sensitive to the model parameterization. Such a modelling approach is more comprehensive than often deployed in DP EAR assessments and the model substantially increases the certainty of the hydraulic assessment in the River Derwent Westend to Wye waterbody.

Overall, the assessment of habitat changes based on the integrated hydraulic modelling approach is considered robust, but even so, some uncertainty must be acknowledged even in the integrated model assessment. Outputs are dependent upon calibration, which reflect data recorded during baseline operation (in the absence of detailed records during former DP operation) and therefore require extrapolation to the DP scenario. Some caution must also exercised in the interpretation of the 1D hydraulic model outputs. As a 1D model implementation in FloodModeller Pro, outputs are also restricted to surveyed cross sections and did not allow detailed examination of hydraulic variation across the channel width; rather, inference was drawn from outputs of maximum depths, transect-averaged velocity and derivatives of these. Thus, the 1D model outputs provide high resolution along the river channel, but do not provide commensurate detail across the channel.

### 3.5.3 Water quality

The water quality assessment benefits from 20 long-term Environment Agency monitoring locations distributed along the River Derwent within the study area. Of these, nine correspond with ongoing Environmental Monitoring Plan (EMP) locations where water quality data have been collected since 2011. The data allow a comprehensive characterisation of the current (and recent year) water quality conditions, at a resolution (generally monthly data) allowing seasonal change to be described with confidence. It was not deemed appropriate to extend the analyses of background water quality conditions as far back as low flow 1995/96 years on account of sewage treatment improvements since this period (which are evident in the water quality data) and on account of the availability of Environment Agency data (available from 01/01/2000 onwards).

The Environment Agency's SIMCAT model is used - to indicate water quality parameter source apportionment at particular locations within the catchment for example. Although it is noted that a number of large industrial discharges contained in this version of SIMCAT are suspected to have been revoked/discontinued in recent years (with the general decline of heavy industry around Derby) the results of this EAR assessment are not reliant upon this level of detail.

### 3.5.4 Receptors

Macroinvertebrate data provide a good quality record of macroinvertebrate community composition along the River Derwent downstream of Ladybower Reservoir. As at many sampling locations there are some gaps in the historical record, including during some historic droughts, and summer sampling was historically patchy. However, spatial coverage is good, data extend as far back as the mid 1980's at some locations[7] and recent data is comprehensive, having been augmented by baseline monitoring undertaken by STWL. The main limitation of the macroinvertebrate data is that DP operation has rarely been captured in the data record, as it

[7] Note, however, that quality assurance procedures were not fully established within the EA prior to the early-mid 1990's.

has not often been enacted. There is also no ‘unimpacted’ control river; given there are no unimpacted rivers of equivalent size and type in the area.

Historical fish survey data provide good spatial and temporal coverage; they are sufficient to provide a comprehensive assessment of species assemblages and therefore target fish species, which is the principal requirement for the EAR assessment. However, it should be acknowledged that, in common with much baseline fish surveillance data, they have limitations for fully quantitative treatment. In particular, data are affected by stocking activity of both salmonids and coarse fish and survey type tends to be variable, with for example data collection at different times not allowing natural mortality to be characterised.

The likely response of fish populations to DP implementation has primarily been assessed with reference to physical habitat changes. When used alongside habitat preferences, combinations of depth and velocity may overstate or understate habitat suitability by assuming that depth and velocity are suitable or unsuitable across the whole transect when in fact suitability may vary. This can be exacerbated when binary suitability criteria are applied (as for this assessment), because a small change close to the criteria boundary can cause an entire cross section to be considered suitable or unsuitable. These limitations are appropriate to the level of assessment, which is intended to consider effects at a reach scale (i.e. aggregating effects across several transects).

Passability of structures has been assessed with reference to historical information gathered in 1985, albeit subsequently updated. It has been assessed with reference to Atlantic salmon and if a structure is impassable to salmon migrating upstream it has been considered impassable to the majority of other species. Structures passable for salmon may be impassable for other fish species, particularly weaker swimming coarse fish species such as perch and bream.

If environmental conditions change as a consequence of the potential DP actions, this can allow opportunities for INNS, which are competitive and opportunistic, to expand their range or increase numbers. The assessment of INNS has focussed on those INNS with defined high impact (Defra, 2015) and those INNS that are already present under baseline conditions. INNS may be affected by the predicted changes in river flows and by associated low water levels.

It is routine practice to assess amenity receptors using a qualitative approach.

# 4 Baseline

## 4.1 Derwent Valley Reservoirs - Water levels

Presentation of the baseline is shown in Figure 5.1[8]. Levels in the Derwent Valley Reservoirs, and in Ogston and Carsington Reservoirs, are dependent upon inflows and demands and as such they vary appreciably between years. Even so, in all but the wettest years they follow a predictable pattern of recession, refill and recovery to maximum storage over the course of the year:

- Derwent Reservoir is often drawn down earliest and furthest (in level terms) given its gravity feed into supply. Even so, with recent modelled demands and the 2018 configuration of the water supply system, Derwent Reservoir is predicted to be full, on average, 38% of the time (based on Aquator™ modelled storage, 1920 – 2014).
- During short dry spells, a modest degree of drawdown can occur in any month in all reservoirs. Sustained drawdown, however, tends to be lagged from inflows. This is because inflows tend to exceed demand until April and conversely, the autumn recovery in flows may not cause immediate increases in storage if they do not exceed demands.
- Notably, the Derwent Valley Reservoirs refill even during the most severe of the Modelled Stochastic droughts. This is not true of Ogston and Carsington. These reservoirs are filled in part by STWL pumping from the River Derwent and as such pumping is only used where necessary.

## 4.2 River flows

The effect of the water supply system on river flows is illustrated (for the 1959/60 stochastically modified drought) in Figure 4.1.

Natural river flows reflect rainfall inputs, losses from interception and evapotranspiration and storage in soils, groundwater and (sometimes) snow. As is typical of the flashy impermeable uplands of the UK, the river flows are naturally very variable but although they may vary in their precise timing, in all but the most exceptional years baseflows show a reliable trend of spring recession and autumn rise, with a summer or early autumn minimum. These are punctuated by episodic, rapidly rising spates and flood flows, with a late autumn or winter maximum in most years.

Downstream of the Derwent Reservoirs, the baseline regime deviates substantially from this general pattern. (all APs are shown) and can be summarised as follows:

- Immediately downstream of the Derwent Valley Reservoirs at Yorkshire Bridge (AP1, within the River Derwent from Westend to Wye waterbody), there are long periods of unvarying flow for much of the year - the compensation flow released from Ladybower Reservoir. The compensation flow released at Yorkshire Bridge (AP1) is lower than would naturally have occurred during the late spring/ early summer recession, but from mid-summer to early autumn is higher than would have naturally occurred during a drought year.
- Variations in flow during the late spring to early winter are normally restricted to short term changes to a higher, but equally unvarying state. In periods of high storage these may be precipitated by releases for Hydroelectric Power (HEP), and flows may be quite high. The much smaller flow elevations evident during drier periods may be prompted by operational requirements further downstream, such as the need to maintain flows at Derby St Mary's Bridge, or downstream of the Noe confluence. (Operationally, these may

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[8] This is based upon modelled flows output from STWL's 2018 Aquator™ model (i.e. representing STWL's Strategic Grid in 2018) with a synthetic rainfall sequence intended to represent worse than historic drought (termed the Modelled Stochastic No DP scenario). This is used here to illustrate the effect on reservoir levels in the Derwent Valley Reservoirs during the 1959/60 stochastic drought (i.e. a drought statistically perturbed to allow for climate change) and although STWL's supply system, Aquator™ model and therefore flow outputs have all been upgraded since, the broad patterns illustrated here are likely to be the same.

also be due to 'put and take' operation, although these have not been modelled for this report.) Note that spills do appear to occur in every year, but after drought years such as 1959/60, may be restricted to a few short weeks in late April or early May.

- During periods of full storage in the upstream reservoirs, late winter or early spring spills are evident and during wet years, such spills may occur outside of this period. However, spate flows are smaller and less frequent than would be the case in the absence of upstream storage. Spate flows are important geomorphologically and ecologically; for erosion, and transport of sediment, and for maintaining the quality of river habitat. Large flow events initiate river-bed sediment transport and flush the river-bed of fine sediments and mobilise and reorganise coarser bed sediments. This maintains clean, loose river-bed particles, which are essential for spawning and egg incubation for many fish species.
- At Hathersage Leadmill Bridge (AP2, also in the River Derwent from Westend to Wye waterbody), flows are higher due to contributions from the River Noe and from the intervening catchment, but for most of the time, the abstraction of mid-range flows at the Noe catchwater and the small area of unregulated catchment ensure a similar lack of variability to that seen at Yorkshire Bridge[9] (in modelled flows variability is mainly seen as occasional spate flows that are sufficiently large to pass the Noe impoundment, mostly in the late autumn to late spring).
- By Baslow Bridge (AP3), the additional unregulated catchment is sufficient to provide a modest variation in baseflow and a few minor spates, but variability is still much suppressed from its natural state.
- The contribution of the River Wye upstream of Matlock Bath (AP4) and Whatstandwell (AP5) introduces a far greater flow, and a more natural pattern; a damped version of the natural pattern of spate flows overlain on baseflows following a spring recession and autumn rise appears restored. However, even here it is only in late winter/ early spring (when the upper Derwent Reservoirs fill) that there are large flood peaks.
- In the Derwent from Amber to Bottle Brook and Derwent from Bottle Brook to Trent water bodies, more modest changes to the flow regime are also evident from the abstraction at Ambergate, with flow at Belper (AP6), Allestree (AP7) and Derby St Mary's Bridge (AP8) remaining above 340 Ml/d as a target of management of the water resource system, even whilst flows at Matlock Bath (AP4) and Whatstandwell (AP5) continue to recede.

The effect of the water supply system on the long-term annual flow duration curves is shown for all APs in Figure 4.2, with seasonal effects differentiated by the long-term monthly flow duration curves at Yorkshire Bridge (AP1). For brevity, monthly effects are not shown at APs further downstream, but propagate downstream in a similar way to the long-term annual flow duration curves.

Effects on the flow duration curve are summarised thus:

- On the annual flow duration curves, the changes to the flow regime at the Upper Derwent APs are evident as a marked flattening – below median flows show the compensation flow plus operational margin at Yorkshire Bridge, and the Yorkshire Bridge release plus the Noe/ Jaggers compensation immediately downstream of the Noe confluence[10]. This pattern is only slightly modified at Baslow Bridge (AP3) and there is no reduction in the compensation flow even at extreme low flows (Q99). (This is because the Modelled Historical flow series used for the illustration does not trigger DP operation.)
- By contrast, the annual flow duration curves of the Middle and Lower Derwent APs follow a more consistent gradient, which is roughly parallel to that of the natural inflows except at extreme low flows (likely due to the support to the river at the lowest flows).

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[9] Note variability and accretion may be slightly underestimated here as contributions from the Peakshole Water and Bradwell Brook are not separately represented in Aquator.

[10] Note also a flattening at higher flows, which are of less interest to drought operation. These flows represent releases from the operation of the HEP scheme at Ladybower. Note also that catchment inputs between the Noe-Jaggers compensation and the Derwent confluence are not included in flows immediately downstream of the Noe confluence, resulting in a conservative estimate of flow accretion.

- The monthly flow duration curves at Yorkshire Bridge (AP1) show pronounced seasonal differences. Under baseline operation of the current water supply system to current demands, compensation flows unaugmented by spills are expected for more of the time than not in late spring to mid-autumn (May to October inclusive). Spills are predicted only 17% of the time (i.e. compensation flows are experienced 83% of the time) in June. Compensation flows unaugmented by spills are experienced 50% of the time in September and November (close to the annual average). In contrast, compensation flows unaugmented by spills are predicted far less often in the December to April period (comprising only 12% of flows in February). Hydropower releases are also far more common.

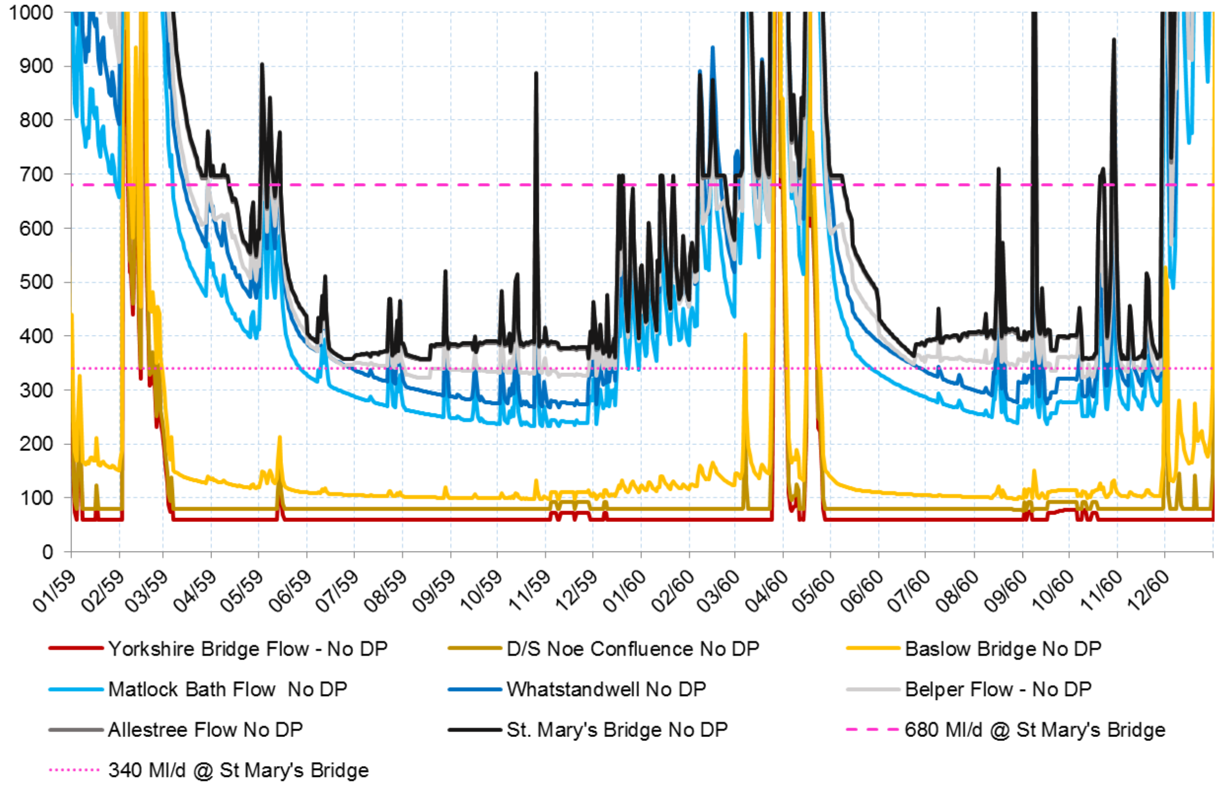



**Figure 4.1 Modelled flows, Baseline operation 1959-1960. Y axis = flow in Ml/d**

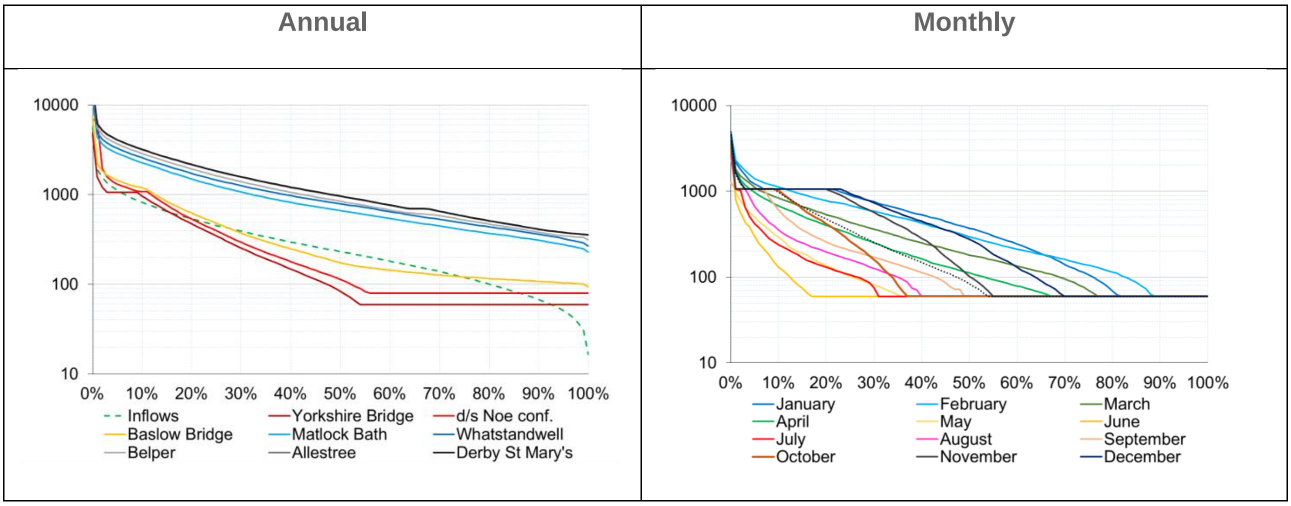



**Figure 4.2 Long term annual and monthly flow duration curves.**

**Based on Modelled Historical No DP scenario. Log scale on y axis used to highlight low flows. X axis denotes flow percentile. Y axis denotes discharge in Ml/d. Monthly flow durations shown for Yorkshire Bridge (AP1) only.**

## 4.3 Hydromorphology

Generally, spates play the main role in maintaining morphological function, but the lower flows of interest to the DP constitute the prevailing hydraulic habitat.

River Habitat Survey (RHS), walkover and transect data collected at APs provide a consistent picture of baseline physical habitat during low flows. Data collected at gauging transects support the RHS and walkover data by indicating the dominance of slow, deep, glide-type flows at most APs. Where RHS sites coincide with APs, computed indices of habitat quality and physical modification are broadly in line with average values for all sites in the area of interest.

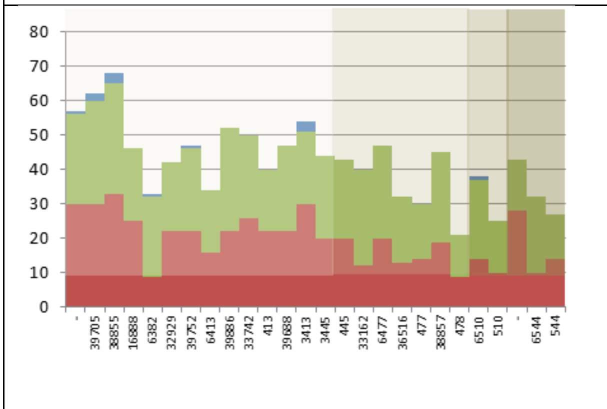
RHS data suggest that physical habitat ‘quality’ (a measure of diversity) is average or slightly below average at all surveyed sites, and that diversity decreases with distance downstream. This is in broad agreement with the walkover data, which demonstrate limited variability of flow types within all surveyed reaches.

At lower flows, glide is the dominant flow type in all surveyed reaches within the Derwent: Westend to Wye waterbody, although hydraulic analysis at APs suggests a mixture of run or glide/pool flow type. The available data (including hydraulic modelling output within the Derwent: Westend to Wye waterbody) also suggest that physical habitat diversity decreases with distance downstream (although not uniformly) and that the dominance of glide increases with distance downstream (particularly in the middle and lower reaches a predominance of glide might be expected). This is illustrated by both RHS and walkover data in Figure 4.3.

RHS data also indicate that physical habitat modification is common on the River Derwent downstream of Ladybower Reservoir – sometimes to a degree considered severe. (Only 15% of RHS sites were classified as ‘pristine’ and 54% of sites were classified as either ‘significantly’ or ‘severely’ modified.) Except in the River Derwent from Wye to Amber, point modifications (weirs, fords, culverts, outfalls/ deflectors and bridges), rather than linear features (re-sectioning, embankments, reinforcements) tend to be the main type of alteration. However, the effect of some point features – weirs in particular, is extensive.

The effect of weirs (and bridges) is illustrated in Figure 4.4, which shows modelled depth and mean transect velocity along the Derwent from Westend to Wye waterbody. The presence of numerous weirs and mill structures creates areas of markedly deeper flow, which are well outside the range of depth variation in reaches not affected by these structures. Such reaches also tend to be notably slower, wider (with higher wetted perimeter) and of lower flow intensity, exacerbating the predominance of glide/ pool habitat and creating depositional zones (low shear stress). This effect, together with the barrier effect of the structure, are likely to create a series of temporary barriers to downstream sediment movement. On the downstream face of the weirs, the inverse holds (albeit over a much lesser spatial extent), with fast, shallow flow down the high gradient combining to create potential barriers to upstream fish movement. Bridges tend to have a lesser and more localised hydraulic effect.

| Habitat Quality (RHS) | Flow and habitat types (walkover) |
| --- | --- |



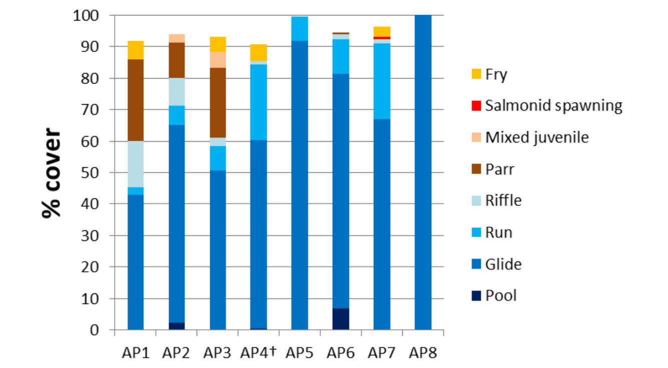




**Figure 4.3 Decrease of habitat diversity with distance downstream.**

**Sites arranged upstream to downstream (left-right) with grey shading indicating different waterbodies. RHS key: Red = in-channel habitat; green = riparian habitat; blue = RHS features of special interest (Environment Agency, 2003)**

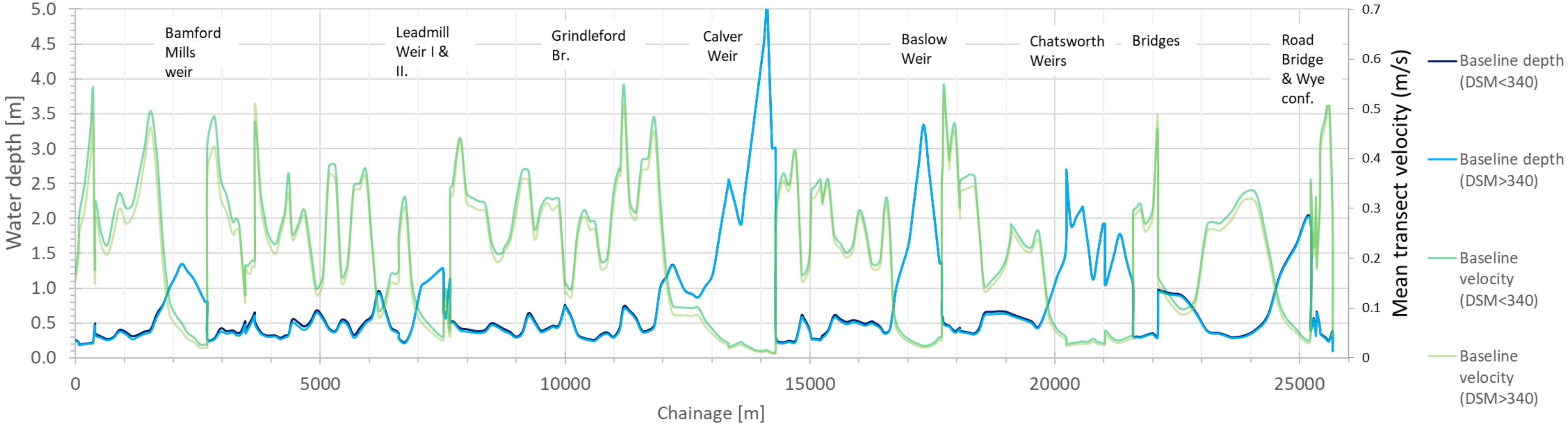



**Figure 4.4 Modelled maximum cross section depth and mean transect velocity along the River Derwent, Ladybower Reservoir to Wye confluence.**

## 4.4 Water Quality

### 4.4.1 Temperature and dissolved oxygen

Water quality data demonstrate a range of expected natural characteristics, on which is superimposed the effect of the reservoirs and other anthropogenic inputs (Appendix D).

The Derwent Valley Reservoirs appear to cause localised storage effects on river water temperature that do not appear to be entirely mitigated for, despite the infrastructure at Ladybower offering flexibility in the depth from which compensation flows and HEP releases are made. Figure 4.5 shows long-term average seasonal water temperatures at the eight APs relative to the annual average water temperature. At most APs, peak summer water temperatures are approximately 5°C higher than the annual average for that location. Spring warming above annual average is well established by May, as is cooling below average by November.

At Yorkshire Bridge, however, peak summer temperatures are deferred until September and the relative difference is much smaller in magnitude than further downstream, a result of summer cooling (of around 1.5°C) due to the compensation release. Winter temperatures at Yorkshire Bridge appear slightly warmer relative to annual average than further downstream; spring warming is less established and water temperatures do not fall markedly below annual average temperature until December. These effects are still present at Hathersage Leadmill Bridge (AP2) and in historical EA data from Grindleford but are much diminished and are not noticeably increased during times of low flow. By Baslow, the natural pattern has reasserted itself, with a gradual increase in temperatures to Derby St Marys Bridge (a natural consequence of reduced altitude (c.0.5°C with a 50m fall)) not obviously interrupted by baseline operation at Ambergate or releases from Ogston and Carsington Reservoir.

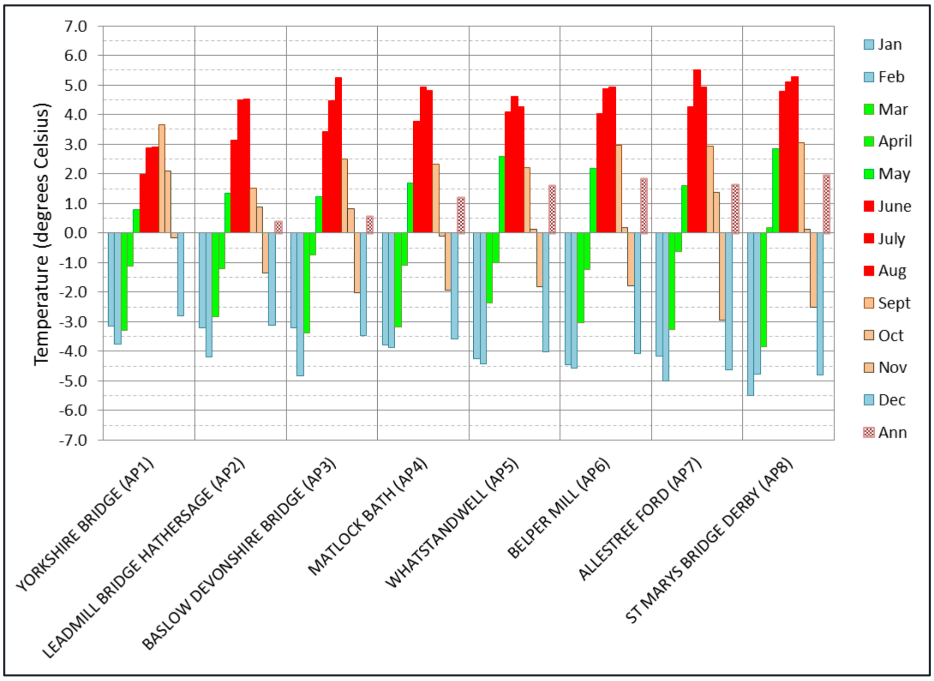
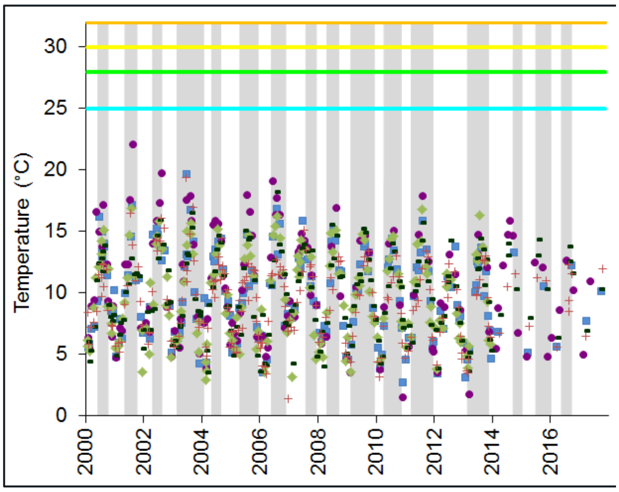



**Figure 4.5 Average seasonal water temperatures relative to annual average (temperature differences).**

**Annual average relative to the Yorkshire Bridge annual average [of 9.1°C].**

Water temperatures are not elevated anywhere in the catchment relative to the Water Framework Directive (WFD) Good status threshold. The natural seasonal pattern dominates the long-term average temperature regime; the long-term temperature graphs (Appendix D, with example provides as Figure 4.6) demonstrate a clear sinusoidal seasonal temperature curve at all sites. The summer peak temperature might be expected to be exaggerated during hot, dry, sunny summers, however, when filtered for periods of low accretion, long term average water temperatures in the River Derwent from Westend to Wye suggest that this additional effect (evident only in the upper catchment) is not great (<1°C).

Dissolved oxygen concentration (as mg/l) also clearly follows seasonal trends, peaking in mid-winter and with troughs in mid-summer (long-term dissolved oxygen graphs are presented in Appendix D). This seasonal trend is likely to be driven by temperature changes[11], which is reflected by the trends in the long-term data. There is also some decrease in percentage oxygen saturation with distance downstream, with an increased spread of results in the lower river. Even so, dissolved oxygen conditions are healthy throughout the catchment (consistent with High WFD status throughout the catchment) and the localised temperature effect of the Ladybower compensation does not appear to noticeably influence dissolved oxygen concentrations.



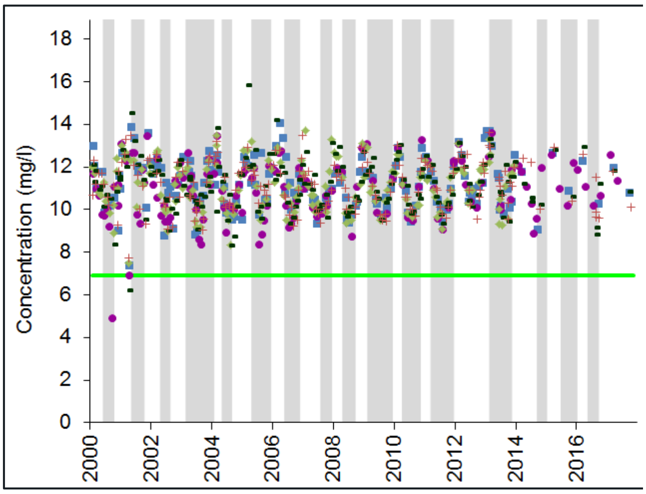




**Figure 4.6 Water temperature (left) and dissolved oxygen concentrations (right), 'Derwent from Westend to Wye' water body.**

**WFD temperature classification thresholds are shown as Environment Agency standard WFD colours and low flow periods at Yorkshire Bridge denoted by grey shading. Green line on right hand chart denotes the salmonid guideline threshold (minimum) defined by the now repealed Freshwater Fish Directive (for information). Different colours denote different sampling locations.**

### 4.4.2 Dilution of other pollutants

Anthropogenic pollutant inputs include those from Sewage Treatment Works (STW), mining, industry and urban and agricultural runoff. Following historical improvements in effluent quality and reductions in industrial discharges, baseline water quality of the River Derwent has improved in recent years and is consistent with at least Good status for many WFD water quality determinands (Catchment Data Explorer[12]). Even so, the River Derwent from Westend to Wye is the only waterbody with all water quality parameters consistent with at least Good status.

The status of the middle catchment (Derwent from Wye to Amber water body and Derwent from Amber to Bottle Brook water body) is affected by zinc and cadmium discharges. These are a legacy of mining and quarrying as well as natural mineralisation (EA, 2015).

The middle and lower catchment also record elevated phosphate concentrations, from both point (sewage discharge) and diffuse sources (livestock and road drainage) (EA, 2015). Phosphate is classified by the

[11] As temperature increases, the solubility of a gas (including oxygen) decreases (given consistent pressure).
[12] All WFD classifications in this section are Cycle 2, 2016.

Environment Agency at Moderate status in the ‘Derwent from Amber to Bottle Brook’ and ‘Derwent from Bottle Brook to Trent’ waterbodies. Visual analysis of phosphate time series plots finds increased phosphate concentrations correspond with low flow periods (Figure 4.7).

The most downstream waterbody (Derwent from Bottle Brook to Trent) also shows some relationship between zinc concentration and low flow periods, with zinc concentrations within the lower catchment noticeably lower during low flow periods. This supports the assumption that zinc contributions are derived mainly from diffuse sources.

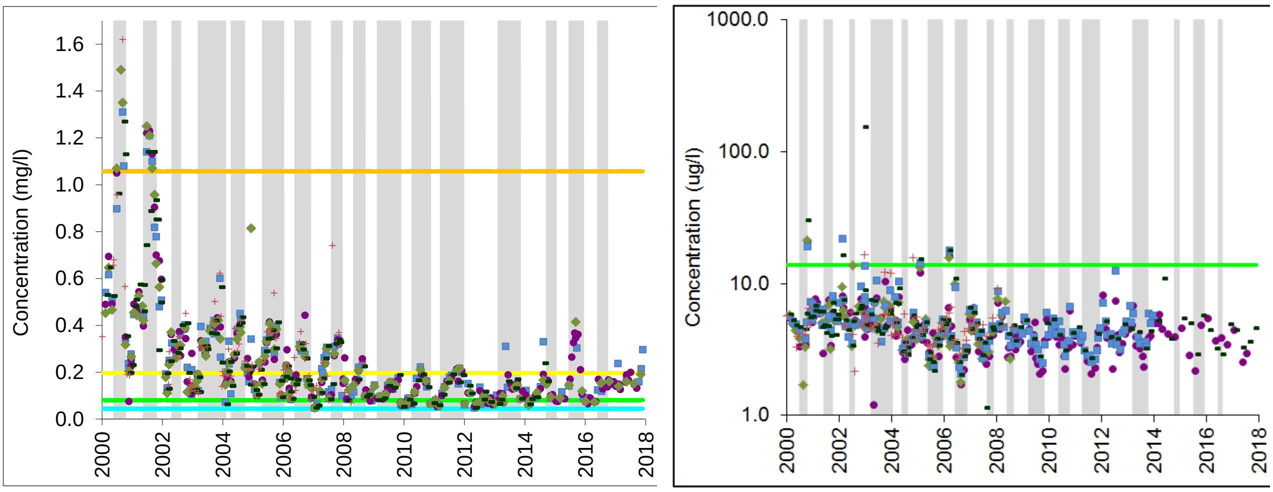



**Figure 4.7 Phosphate concentrations (left) and bioavailable zinc (as Zn) concentrations (right), Derwent from Bottle Brook to Trent.**

**Note only low concentration data are shown on the left-hand chart. WFD classification thresholds (annual mean) illustrated with standard Environment Agency WFD colours. Low flow periods at Yorkshire Bridge denoted by grey shading.**

**WFD Specific Pollutant EQS (annual mean incorporating ambient background concentration) are shown by green line on the right-hand chart. Low flow periods at Yorkshire Bridge denoted by grey shading.**

The source apportionment of ammonia, Biochemical Oxygen Demand (BOD) and nitrate (TON) throughout the study area has also been investigated (presented within water quality technical appendix). The load proportion contributed by point sources relative to diffuse sources increases with distance down the catchment, most notably with regards total ammonia (the River Derwent changes from a diffuse dominated system (~79%) at AP2 to a heavily point dominated system (~87%) at AP8).

The loading contribution of those point sources entering the river around Derby are of a much greater scale than elsewhere in the system. For example, nutrient loads deriving from Matlock STW (which are significant at AP5) are small compared to those deriving from Derby STW.

## 4.5 Macroinvertebrates

Macroinvertebrate community composition on the River Derwent broadly follows the expected gradual transition from species preferring fast-flowing, well oxygenated water and a coarse substratum in the River Derwent from Westend to Wye, to those more tolerant of more sluggish flows and finer sediment further downstream.

Indices designed to detect impacts of organic pollution, flow stress and excessive fine sediment deposition generally compare favourably with those from similar UK reference rivers in data from samples collected from the River Derwent from Westend to Wye and River Derwent from Wye to Amber waterbodies. As a result, these anthropogenic pressures are considered not to have impacted macroinvertebrate community composition in these waterbodies. However, at Yorkshire Bridge (directly downstream of Ladybower Reservoir) date to 2018 appear to show declining scores and score consistently less well relative to reference conditions than do samples taken from Hathersage Leadmill Bridge (and Baslow Bridge) in the same waterbody downstream (Figure 4.8 and Appendix E). This suggests an effect of Ladybower Reservoir, although this is not confirmed as flow-related (effects on water quality or sediment may also play a role).

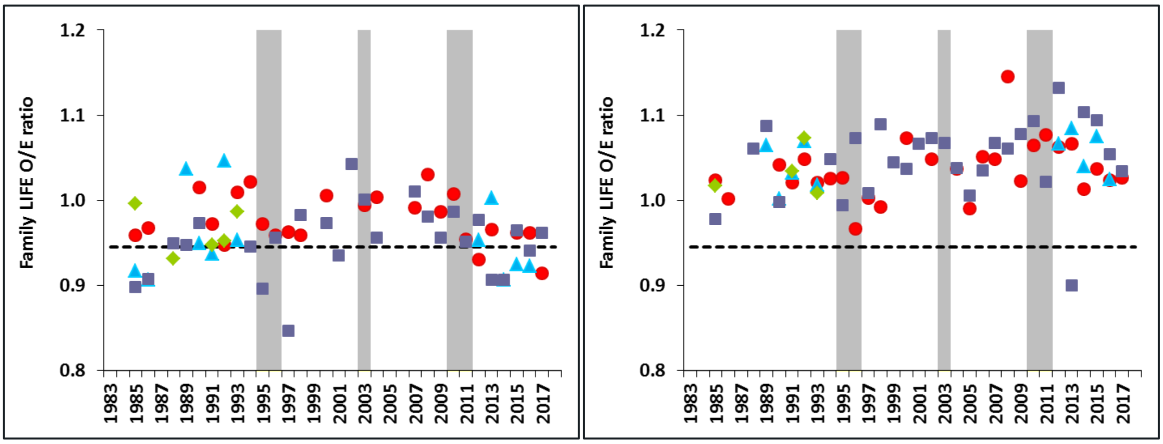



**Figure 4.8 LIFE (Family) O/E ratios at Yorkshire Bridge (left) and Leadmill Bridge (right). Where green=winter, red=spring, blue=summer, purple=autumn.**

Over time, macroinvertebrate communities might be expected to respond to flow variability under baseline conditions. This is most likely to be evident where flow changes are most severe and in the relative absence of other pressures in the River Derwent from Westend to Wye and River Derwent Wye to Amber waterbodies. However, visual inspection of local data does not indicate a strong effect (e.g. Figure 4.8; all sites Appendix E). Rather, and as observed in the previous DP EAR (ESI & APEM, 2012)[13], in the upper Derwent reductions in biotic indices are apparent during some dry periods and not during others, and effects are less apparent further downstream. From visual assessment of the available data, it also appears evident that any changes are likely to be short-lived.

Downstream of Whatstandwell, in the River Derwent Amber to Bottle Brook and Bottle Brook to Trent, deterioration in biotic scores is evident, although these waterbodies also achieve High status for macroinvertebrates under the WFD (Cycle 2). Different pressures are evident at two of the downstream locations. At Raynesway, nutrient and organic pollution pressures are evident (e.g. WHPT ASPT results - Figure 4.9). At Derby St Marys Bridge, poor habitat and inorganic pollution were indicated, which is broadly consistent with the prevalence of channel modifications and of metals pollution at this location (e.g. WHPT NTAXA results - Figure 4.10).

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[13] Attempting a quantitative, statistical examination, the previous DP EAR used ANalysis Of VAriance (ANOVA) to test the significance of reductions in the LIFE index during recent dry periods. That study noted a modest degree of explanatory power regressing the LIFE O/E ratio (the macroinvertebrate index intended to identify possible flow stress) with a low flow metric comprising minimum flows and the duration of flows below the 72 Ml/d and 54 Ml/d thresholds. However, any such analysis can only be treated as preliminary and analysis of the 1995-1998 period (a drought, in 1995, followed by drought permit implementation in 1996) found no difference in LIFE scores between drought (1995) and drought permit (1996) years.

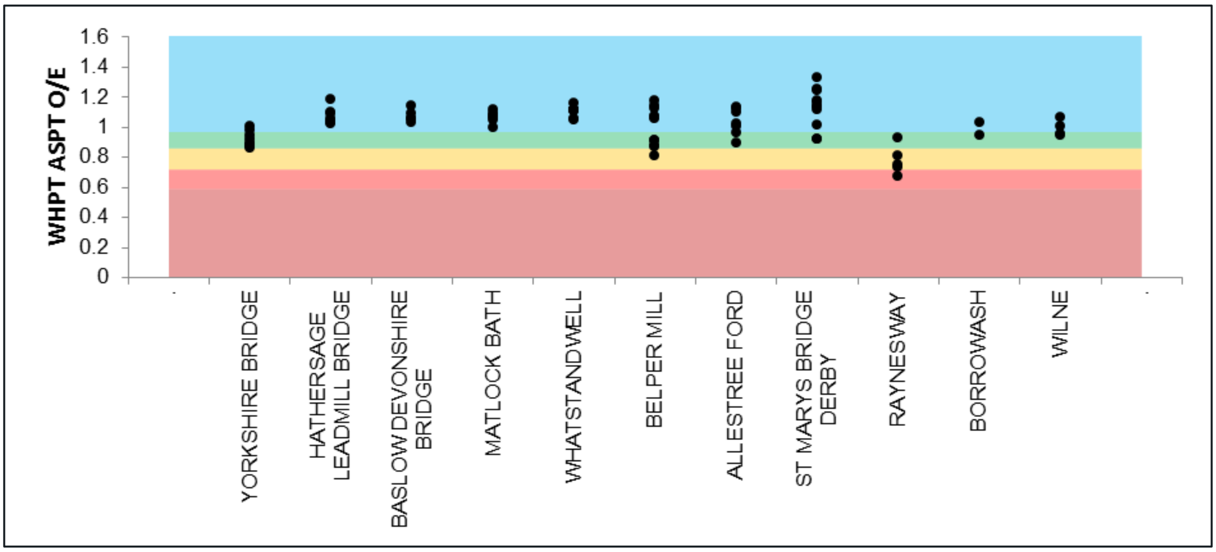


**Figure 4.9 WHPT ASPT O/E ratios (2014-2017)**
**Sites are presented in upstream [left] to downstream [right] order and WFD classification thresholds shown as standard Environment Agency colours.**

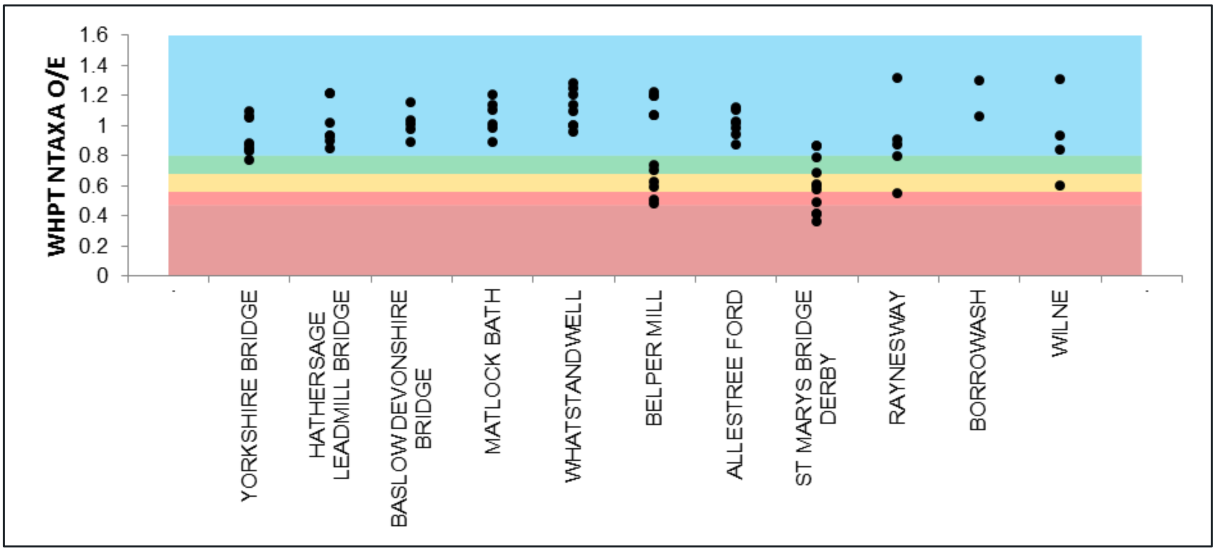


**Figure 4.10 WHPT NTAXA O/E ratios (2014-2017)**
**Sites are presented in upstream [left] to downstream [right] order and WFD classification thresholds shown as standard Environment Agency colours.**

### 4.5.1 Rare species

There were two records of endangered or notable macroinvertebrate species present on the River Derwent. The caddisfly *Glossosoma intermedium* (Klapalek, 1892) - Small Grey Sedge is found on the River Derwent near Grindleford (NGR SK 24 77). The small grey sedge (*Glossosoma intermedium*) is one of Britain's rarest caddis flies and known to inhabit calcium rich streams. The mayfly *Nigrobaetis niger* (Linnaeus, 1761) - Southern Iron Blue is found at the same location on the River Derwent at Grindleford and also Whatstandwell and Baslow. The two species are currently UK Biodiversity Action Plan priority species and Natural Environment and Rural Communities Act 2006 - Species of Principal Importance in England. The *Glossosoma intermedium* record is included as a precautionary measure as the latest review of caddis flies of the UK describes this species as only present in the Lake District with no additional records found since 2001 (Wallace, 2016). The southern iron blue was listed as a priority species under the UK Biodiversity Action Plan in 2007.

Recent analysis of the distribution of this species has recommended that this species be downgraded as it is likely more widespread than previously thought (likely this species occurs in more than 100 hectares) and is also included in this report as a precautionary measure (MacAdam, 2016).

## 4.6 Fish

More recent fish survey data do not show substantial differences from those presented in the previous DP EAR (ESI & APEM, 2012). As then, these are affected by stocking of both salmonid and coarse fish species throughout the river but are sufficient to show distinct differences in community composition in the upper and lower reaches of the River Derwent.

Brown trout and grayling dominate the species composition in the River Derwent from Westend to Wye, with a range of associated complimentary 'minor' fish species, e.g. bullhead, stone loach, minnow. Salmonids, including brown trout and grayling, remain present in fish surveys in the River Derwent from Wye to Amber and River Derwent from Amber to Bottle Brook, and Atlantic salmon have been recorded in the three lower waterbodies in recent years, but there is a trend towards a coarse fish dominated community through the middle courses of the river. A number of rheophilic species, including barbell, chub and dace are present, in addition to eurytopic species such as perch, pike and roach. In the River Derwent from Bottle Brook to Trent there is a shift towards a species composition dominated by a greater number of limnophilic species – i.e. those preferring still or slow-moving water (e.g. tench, rudd *Scardinius erythrophthalmus*, bream).

These changes reflect differences in physical habitat and, potentially, cooler water in the upstream reaches. As reported in the previous DP EAR (ESI & APEM, 2012), walkover surveys show a relatively large proportion of juvenile/rearing habitat for salmonids in the River Derwent from Westend to Wye, suggesting its greater suitability for spawning and nursery habitat. In contrast, downstream of the River Wye confluence, the prevalence of glide and increasingly lowland nature make the River Derwent more suited for adult fish and for passage during migration.

### 4.6.1 Effect of barriers

Access to the sea and utilisation of habitats along the length of the river is prevented by some of the mills and weirs along the river (Table 5.10)[14]. Many of these restrict habitat connectivity and fish passage under baseline conditions. The River Derwent supports a number of diadromous species (those that migrate between the sea and freshwater at particular stages of life), including eel and salmon. Where free passage for diadromous species is impeded (e.g. due to the impact of weir structures or low-flow induced reductions in water depth), species may be exposed to migration delay (leading to inopportune seasonal timings for spawning or habitat utilisation), or prevention of migration, each of which can impact on productivity and recruitment of populations. As in the previous DP EAR (ESI & APEM, 2012), Atlantic salmon are thought to reach as far upstream as Belper, but barriers there and at Ambergate prevent access upstream. It is highly likely that the distribution of Atlantic salmon would extend to the River Derwent from Westend to Wye WFD waterbody in the absence of these barriers.

In addition, there are a number of rheophilic coarse fish species which are known to demonstrate upstream migrations (in some cases over quite considerable distances) for the purpose of depositing their eggs within the upper catchment. These species require unimpeded connectivity through river systems to access habitat types which fulfil distinct ecological requirements specific to certain life stages. From the walkover data available (1 km reaches centred upon the APs) and given fish population data gathered under baseline conditions, it appears that, at least in the River Derwent from Westend to Wye and Wye to Amber, habitat

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[14] Note that since the previous DP EAR (ESI & APEM, 2012), a fish pass was constructed at Calver Weir in the upper reaches of the River Derwent (upstream of Matlock) in 2015 to facilitate upstream passage of brown trout, grayling and brook lamprey. Impenetrable barriers remain, however, 10 km downstream at Baslow and Chatsworth.

diversity within reaches bounded by barriers to these species are sufficient to support all lifestages of resident fish under baseline conditions.

## 4.7 River Users

### 4.7.1 Amenity and leisure

The River Derwent supports a mixed fishery with trout important within the upper and middle reaches. Slower velocities and increased depths provide suitable conditions for coarse fishery downstream of Matlock. There are a large number of angling clubs (Appendix G) that control waters throughout the Derwent, providing good angling access to large stretches of the river. A number of specialist fly fishing clubs also operate upstream of the Ambergate abstraction. Both the trout and coarse fisheries are considered to be of good quality. However, due to a decline in productivity since the 1990s and remaining barriers to fish migration, both brown trout and coarse fish species are regularly stocked.

Canoeing, kayaking and rowing take place all year round and whilst much of the river is glide habitat most suited to flatwater canoeing, deep run at Matlock supports a slalom course. There are two active canoe clubs that use the River Derwent: Matlock Canoe Club based in Matlock and Midland Canoe Club based at Darley Park. Derwent Rowing Club is also based at Darley Park (Appendix G). Water levels are not reported to restrict in-stream recreation within the currently accessible reaches. There is open access to the River Derwent at Darley Abbey, and there are navigational rights from Darley Abbey Weir downstream as far as the confluence with the River Trent (about 37 km). However, access to the river is limited between Yorkshire Bridge and Darley Abbey. Private access agreements by local users may exist upstream of Darley Abbey but are quite rare and are kept very private. There are no official access agreements on the upper or middle reaches of the River Derwent except for a half mile reach between Matlock and Matlock Bath.

There is public access via footpaths, bridleways, cycle paths and car parks along the whole length of the River Derwent all year round. In particular, the Derwent Valley Heritage Way is an 88 km long-distance path along the Derwent valley from Ladybower Reservoir through to the Derwent Valley Mills World Heritage Site (Derwent Valley Mills Website and Derwent Valley Trust Website, accessed August 2018). This enables access along the length of the River Derwent between Ladybower Reservoir and the confluence with the River Trent near Great Wilne. The Derwent Valley Heritage Way is popular with walkers, dog walkers, photographers and bird watchers. There are also other public footpaths and car parks along the whole length of the river and the river is crossed by a cable car at Matlock Bath, which adds to the visual amenity of the attraction. The Cromford canal represents a considerable amenity and leisure resource within the study area.

The River Derwent passes through the City of Derby and various towns and villages including Ambergate, Belper, Milford and Duffield. There are a multitude of visitor centres, car parks and other facilities along the whole length of the river (Derbyshire County Council Website and maps, accessed August 2018).

The river also passes through a number of nationally and internationally designated sites. The Derwent Mills World Heritage Site, Peak District National Park and Chatsworth House in particular attract large numbers of visitors from a wide catchment area (>30 km) and can be considered important at international level (Derwent Valley Trust and Derwent Valley Mills Websites, accessed August 2018).

The Peak District National Park (upper Derwent Valley and Derwent Valley Reservoirs) is a popular visitor attraction for walkers, wildlife enthusiasts and other recreational users, with Ladybower and Derwent Reservoirs being foci for formal and informal recreation within the area and the 'lost' (i.e. submerged) villages' of Ashopton and Derwent of local interest when revealed by low reservoir levels.

Derwent Valley Mills (between SK2957 and SK3536) is designated due to the outstanding importance of the area as the birthplace of the factory system where in the 18th Century waterpower was successfully harnessed for textile production. Stretching 24 kilometres down the river valley from Matlock Bath to Derby, the World Heritage Site contains a series of historical mill complexes, including some of the world's first 'modern' factories. The site attracts large numbers of visitors every year and is a valuable educational resource. Due to its focus on harnessing waterpower for textile production, the River Derwent is a key feature of the world heritage site.

The River Derwent runs through the Chatsworth Estate which also attracts large numbers of visitors. The river passes the front of the stately home and is an important feature in views of the house. There are various walks and picnic spots alongside the river and during the summer months in-stream recreation including paddling and swimming in the River Derwent is popular.

The Little Chester Roman Site (SK3537) near Derby is also designated as a scheduled monument, although it is not considered to be a visitor attraction and the aesthetic and hydraulic properties of the river are of low importance to its designated status. There are nine bridges within the Derwent Valley that are Scheduled Monuments (Appendix G, MAGIC website accessed August 2018). The individual heritage features include a number of historical mills and their associated industrial communities; features are linked together by the Derwent Valley Heritage Trail.

### 4.7.2 Protected rights

In the River Derwent from Westend to Wye water body, STWL generate HEP at the Howden and Ladybower impoundments. There are also a number of third-party abstractors along the River Derwent, whose licences are controlled by HOF provisions that may be affected by DP operation (Figure 4.11). In the Derwent from Wye to Amber, there is a large abstraction via a mill leat at Masson Mill, near the AP at Matlock Bath. In the Derwent from Amber to Bottle Brook and Bottle Brook to Trent waterbodies there are a further five abstractions controlled at Derby and six abstractions with local controls. None of the six remaining abstractions on this reach are subject to a HoF and will not be impacted by either DP.

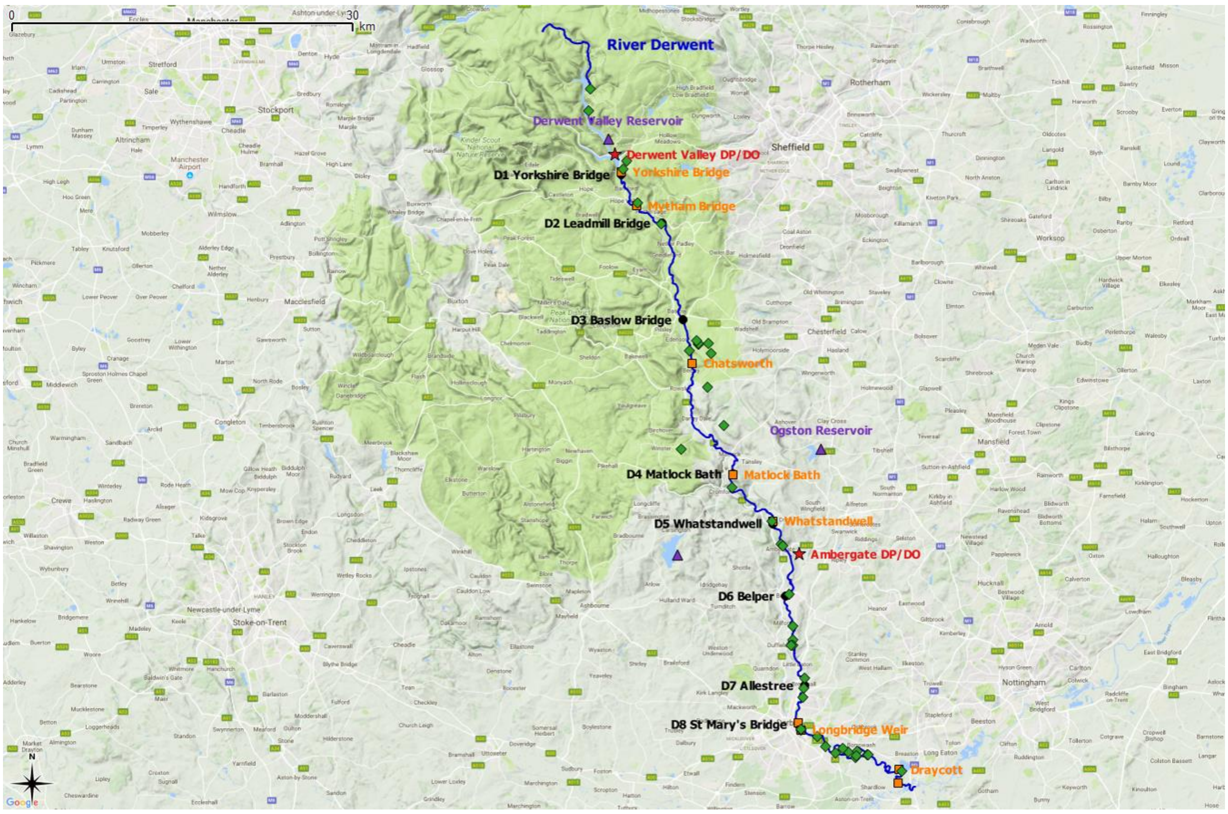


**Figure 4.11 Protected Rights along the River Derwent**
**Abstractions (green diamonds), gauging stations (orange squares), assessment points (black), reservoirs (purple triangles) and DP locations (red stars).**

## 4.8 Water Framework Directive Classification

The status of the four relevant WFD surface waterbodies on the River Derwent is summarised in Table 4.1. The waterbodies are all designated Heavily Modified Water Bodies (HMWB).

The River Derwent is almost entirely underlain by the 'Derwent-Secondary Combined' WFD groundwater body. A short section (approx. 4 km) of the river at Matlock is underlain by the 'Derwent - Carboniferous Limestone' WFD groundwater body. The 'Derwent - PT Sandstone Derby' WFD groundwater body also outcrops at a single location along the river (at Darley Abbey, Derby). All associated groundwater classification elements for these GW waterbodies are currently (2016 Cycle 2)[15] found to be at good status with the exception of the 'Chemical Dependent Surface Water Body Status' for the 'Derwent - Secondary Combined' and 'Derwent - Carboniferous Limestone' waterbodies, which are currently at Poor status. These failings relate to pollution from abandoned mines (non-coal mines); there are no current measures in place to address this as it is currently determined to be either technically infeasible or disproportionately expensive to achieve good status for this GW Chemical Status element.

**Table 4.1 Summary of recent River Derwent WFD classification status and objectives**

| Classification (Cycle) | Water Body ID | Water Body Name | Ecological Status / Potential | Fish | Invertebrates | Macrophytes & Phytobenthos | Ammonia | BOD | Dissolved Oxygen | pH | Phosphate | Temperature | Copper | Zinc | Cadmium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2016 (2) | GB 104028 057880 | Derwent from Westend to Wye | GEP | G | H | G | H | H | H | H | G | H | H | H | G |
| 2015 (2) | | | MEP | H | H | G | H | H | H | H | G | H | H | H | F |
| 2016 (2) | GB 104028 052390 | Derwent from Wye to Amber | MEP *27 | H | H | - | H | H | H | H | G | H | H | M *27 | F *27 |
| 2015 (2) | | | MEP | H | H | - | H | H | H | H | G | H | H | M | F |
| 2016 (2) | GB 104028 052310 | Derwent from Amber to Bottle Brook | MEP | M *27 | H | - | H | H | H | H | M | H | H | M *27 | F |
| 2015 (2) | | | MEP | M | H | - | H | H | H | H | M | H | H | M | F |
| 2016 (2) | GB 104028 053240 | Derwent from Bottle Brook to Trent | MEP | G | H | M | H | H | H | H | M | G | H | M *27 | G |
| 2015 (2) | | | MEP | G | H | M | H | H | H | H | M | G | H | M | G |

NB H=High, G=Good, M=Moderate, F=Fail, GEP=Good Ecological Potential, MEP=Moderate Ecological Potential; *27=Objective is to achieve at least Good by 2027. From http://environment.data.gov.uk/catchment-planning/

[15] No change between Cycle 2, 2016 and Cycle 2, 2019 with exception improvement in Fish classification to Good in GB104028052310 and to High in GB104028053240, and improvement in Zinc classification to High in GB104028053240.

## 4.9 Designated sites

There are a number of designated sites on or adjacent to the River Derwent, as presented in Table 4.2 to Table 4.5 (arranged by WFD water body).

**Table 4.2 Designated sites on or adjacent to the River Derwent (Ashop to Wye)**

| Site Name | Designation | Grid reference | Reason for designation |
|---|---|---|---|
| Derwent at Hathersage | SSSI | SK2082 to SK2280 | Typical example of downstream channel adjustment to headwater impoundment, discharge regulation and sediment load reduction |
| Chatsworth Old Park | SSSI | SK2668 | Ancient pollarded oaks with rich and diverse deadwood invertebrate fauna and rich assemblage of lichens |

**Table 4.3 Designated sites on or adjacent to the River Derwent (Wye to Amber)**

| Site Name | Designation | Grid reference | Reason for designation |
|---|---|---|---|
| Matlock Parks | Local Nature Reserve | SK2082 to SK2280 | 5 historical parks that run along the Derwent valley between Matlock and Matlock Bath |
| Masson Hill SSSI | SSSI | SK2959 | Series of caverns and solution caves. Areas of species rich grassland and areas of ancient and semi-natural broadleaved woodland. |
| Matlock Woods | SSSI | SK2959 to SK2958 | One of the best examples in Derbyshire and the Peak District of ash-elm woodland |
| Peak District Dales | SAC | SK2959 to SK2957 | Primary habitat designations: Semi-natural dry grasslands and scrubland facies on calcareous substrates; Tilio-Acerion forests of slopes, screes and ravines. Primary species designations: White-clawed crayfish; note citation lists the River Dove specifically. Further qualification species: Brook lamprey and bullhead. |
| Shining Cliff Woods | SSSI | SK3353 to SK3352 | Ancient semi-natural oak woodland adjacent to River Derwent. |
| Cromford Canal | SSSI and Local Nature Reserve | SK2956 to SK3552 | Eutrophic freshwater habitat with rich submerged and emergent aquatic flora and a diverse marsh/wet grassland margin. (The canal is fed by water from the aquifer) |
| Derwent Valley Mills | World Heritage Site | SK2957 to SK3536 | Birthplace of the factory system, historical mills |

**Table 4.4 Designated sites on or adjacent to the River Derwent (Amber to Bottle Brook)**

| Site Name | Designation | Grid reference | Reason for designation |
|---|---|---|---|
| Duffield Millennium Meadow | Local Nature Reserve | SK3543 to SK3543 | Part of the Lowland Derbyshire Biodiversity Action Plan and includes floodplain grazing marsh and standing open water with associated vegetation. |
| Derwent Valley Mills | World Heritage Site | SK2957 to SK3536 | Birthplace of the factory system, historical mills |
| Ogston Reservoir* | SSSI | SK3759 | Wintering site for many wildfowl and a feeding site for wading birds on passage in late summer. Grazed and ungrazed grassland, scrub, woodland and tall herb communities provide peripheral mosaic of semi-natural habitat for a range of breeding birds. |

NB: *Ogston Reservoir is itself a WFD lake water body (ID GB30433781) within the Amber catchment; see Section 2 for connectivity discussion.

**Table 4.5 Designated sites on or adjacent to the River Derwent (Bottle Brook to Trent)**

| Site Name | Designation | Grid reference | Reason for designation |
|---|---|---|---|
| Darley and Nutwood | Local Nature Reserve | SK3539 | Former municipal refuse tip. Habitats include grassland being invaded by scrub and woodland. |
| The Sanctuary | Local Nature Reserve | SK3735 | Formerly a gas works tip; ‘bird and wildlife reserve’ |
| Derwent Valley Mills | World Heritage Site | SK2957 | Birthplace of the factory system, historical mills |

### 4.9.1 International designated sites

The Peak District Dales SAC lies within the River Derwent corridor. The River Derwent also flows, via the Trent, into the Humber Estuary, which is designated as an SAC and SPA.

The EU Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) provides a framework for the conservation and management of natural habitats, wild fauna (except birds) and flora in Europe. Its aim is to maintain or restore natural habitats and wild species at a favourable conservation status.

The relevant provisions of the Directive are the identification and classification of Special Areas of Conservation (SACs) (Article 4) and procedures for the protection of SACs and SPAs (Article 6). SACs are identified based on the presence of natural habitat types listed in Annex I and populations of the species listed in Annex II. The Directive requires national Governments to establish SACs and to have in place mechanisms to protect and manage them.

Developments that may affect the integrity of SACs must be screened for Habitats Regulations Assessment (HRA) considerations, specifically the potential for Likely Significant Effects (LSE).

The Derwent Valley Mills World Heritage Site is also present. World Heritage Sites are designated to meet the UK's commitments under the World Heritage Convention, 1972. These sites are designated for their globally important cultural or natural interest and require appropriate management and protection measures, intended for practical conservation for posterity.

### 4.9.2 Nationally designated sites

Several Sites of Special Scientific Interest (SSSIs) have been identified within the River Derwent corridor. SSSI's are designated under national legislation (notified under the Wildlife and Countryside Act, 1981[16] (WCA)) by Natural England for features of special interest, that may relate to its:

- Wildlife;
- Geology; or
- Landform.

Natural England's objective is to achieve 'favourable condition' status for all SSSIs. Favourable condition means that the SSSI's habitats and features are in a healthy state and are being conserved by appropriate management.

Duties under the WCA require water companies to take reasonable steps, consistent with the proper exercise of their functions, to further the conservation and enhancement of SSSI features. The potential effect of drought actions on SSSIs (and their designating features) are assessed within this EAR. Several Local Nature Reserves (LNRs) have also been identified. LNRs are generally created by local authorities (under the National Parks and Access to the Countryside Act, 1949). Town and parish councils can create LNRs if the district council has given them the power to do this. LNRs may be locally important for:

- Wildlife;
- Geology;
- Education; or
- Enjoyment (without disturbing wildlife).

EAR drought guidance (Environment Agency, 2017) suggest that LNRs may be considered lower risk (relative to SSSIs for example), but specific consideration may need to be given to particular features. The potential effect of drought actions on LNRs (and their designating features) are assessed within this EAR.

## 4.10 Invasive Non-Native Species

Environment Agency INNS records were downloaded from the online data repository (Environment Agency, 2018); no additional INNS data were available via direct Environment Agency data request. A number of INNS are present in the study area (Table 4.6). Defra (2015) lists 'High' impact INNS species, of which one high impact macroinvertebrate species is present in the River Derwent (Signal crayfish), two high impact riparian plant INNS (Japanese knotweed and Himalayan balsam) and three high impact aquatic plant INNS (water fern, Canadian pondweed and western waterweed) are present in the River Derwent.

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[16] Improved provisions for the protection and management of SSSIs were introduced by the Countryside and Rights of Way Act 2000

**Table 4.6 Invasive non-native species recorded in the River Derwent**

| Species | Impact (High impact species defined by Defra 2015) |
|---|---|
| *Potamopyrgus antipodarum* (New Zealand mud snail) | Moderate |
| *Physella acuta* group (Bladder snail) | Unknown |
| *Crangonyx pseudogracilis* (Freshwater shrimp) | Low |
| *Gammarus tigrinus* (Freshwater shrimp) | Unknown |
| *Pacifastacus leniusculus* (American signal crayfish) | High |
| *Fallopia japonica* (Japanese knotweed) | High |
| *Impatiens glandulifera* (Himalayan balsam) | High |
| *Lemna minuta (Duckweed)* | Low |
| *Azolla filiculoides (Water Fern)* | High |
| *Elodea Canadensis (Canadian pondweed* | High |
| *Elodea nuttallii (Nuttalls pondweed)* | High |

# 5 The Derwent Valley Reservoirs DP

## 5.1 Pathways Assessment - Reservoir levels

The annual pattern of reservoir drawdown during DP operation is illustrated in Figure 5.1[17]. Predicted changes in reservoir levels inevitably vary between droughts, but from that simulated, appear small, particularly in the context of much greater differences between years under baseline operation. For much of the year the drawdown under this simulation of DP operation also follows the same pattern as for No DP operation. The most notable changes are that a Derwent Valley Reservoirs DP is predicted to cause reservoir levels in the upper Derwent Reservoirs to remain at or above baseline levels at all percentiles throughout the 1959/60 period, but the difference is not great, and it is only at Howden Reservoir that the period of maximum storage is noticeably increased. Carsington and Ogston tend to be a little more drawdown than under the No DP scenario, but this reduction is again typically small – the greatest increase in drawdown being a short period when Ogston Reservoir was drawn down by a maximum of 1.5 m in the late autumn of 1960.

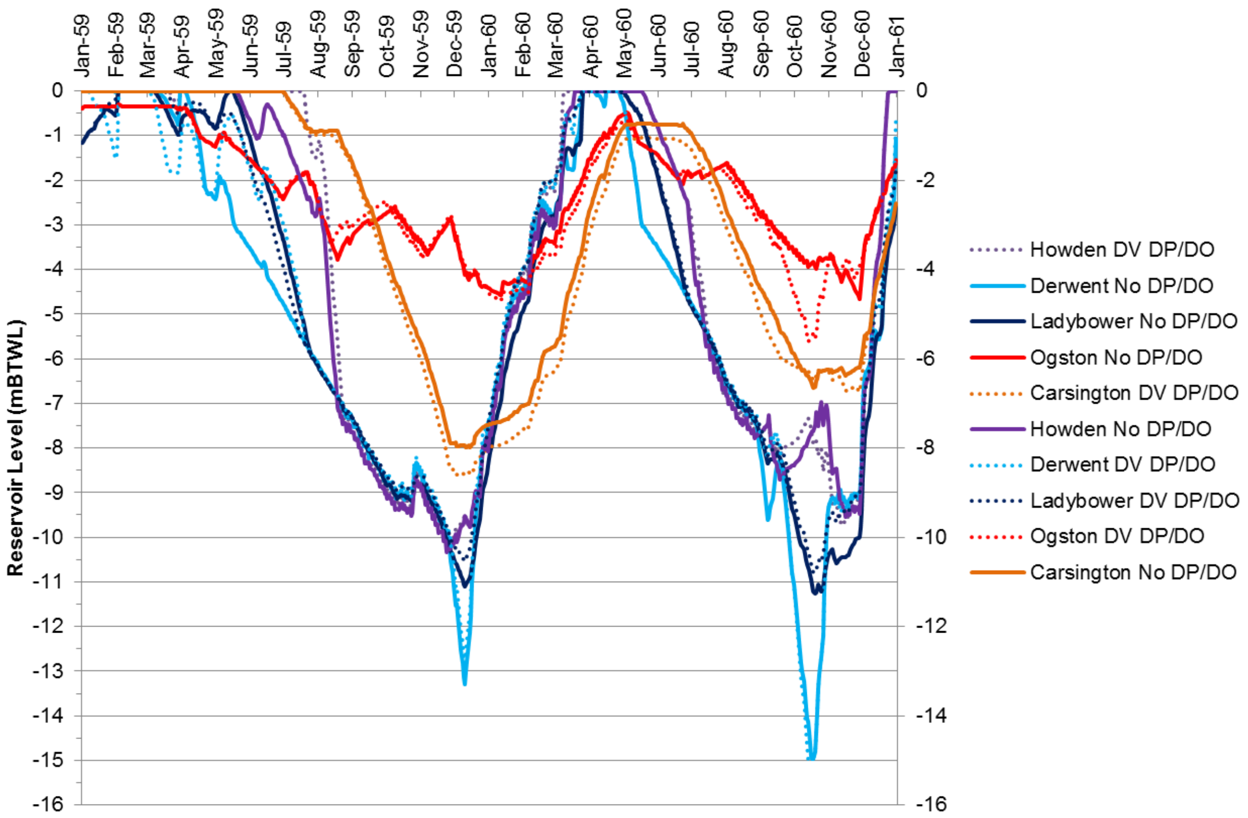



**Figure 5.1** **Reservoir level duration curves for the 1959-60 Modelled Stochastic drought**

[17] Consistent with the illustration of the baseline scenario, this is based upon modelled flows output from STWL's 2018 Aquator™ model (i.e. representing STWL's Strategic Grid in 2018) with a synthetic rainfall sequence intended to represent worse than historic drought (termed the 1959-60 Modelled Stochastic drought scenario). This is used here to illustrate the effect on reservoir levels in the Derwent Valley Reservoirs during the 1959/60 stochastic drought (i.e. a drought statistically perturbed to allow for climate change) and although STWL's supply system, Aquator™ model and therefore flow outputs have all been upgraded since, the broad patterns illustrated here are likely to be the same.

## 5.2 Pathways Assessment - Downstream flows

The effect of Derwent Valley Reservoirs DP operation on flows during the two periods of drought operation during 1959/60 using Modelled Stochastic scenario are shown in Figure 5.2. These have been assessed against baseline operation over the same period (Figure 4.1; and reproduced within Figure 5.2). Both periods of DP operation were introduced in the mid-late autumn, following a sustained period of inflow recession and unvarying summer compensation flows.

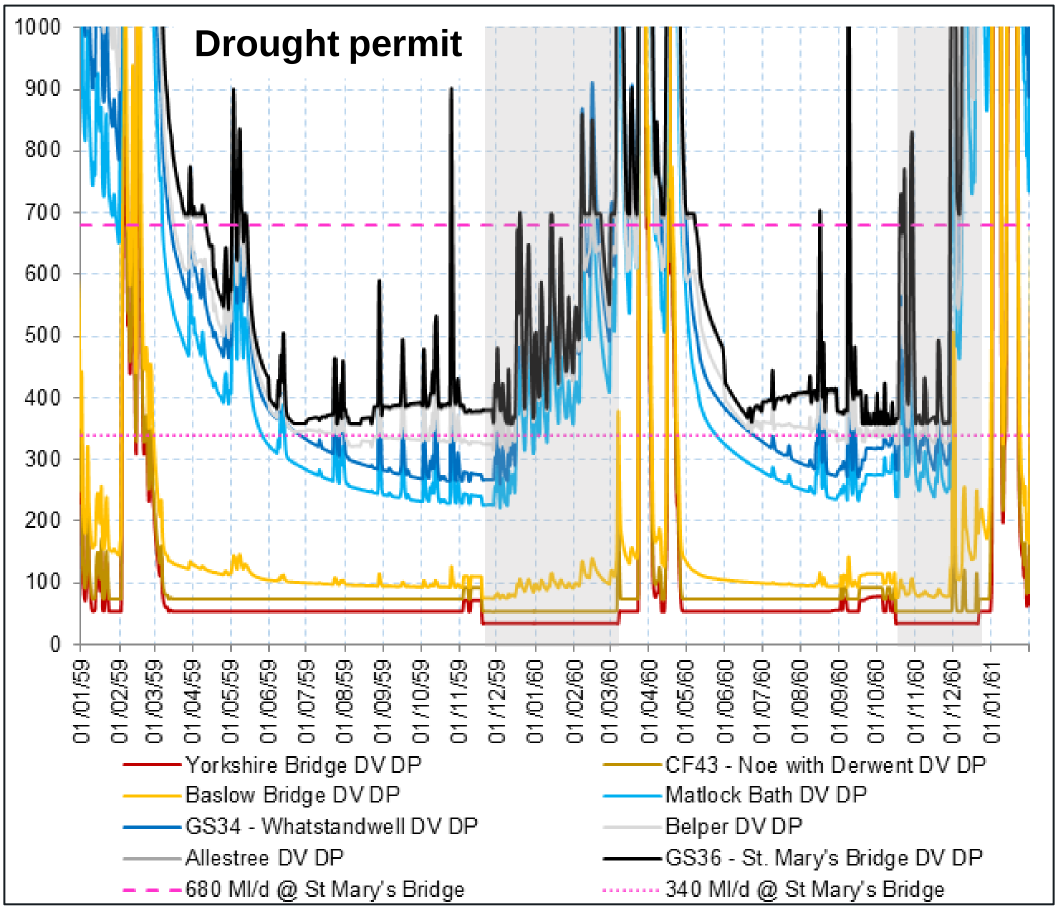
Prior to DP operation a short-lived increase in compensation flows (from 54 Ml/d to 74 Ml/d) was simulated. This was a feature of the baseline, not DP operation, and may have been triggered by downstream requirements, although the licence requirement to release higher compensation flows of 72 Ml/d when flows at Derby St Mary's Bridge are at or below 340 Ml/d appears to have been satisfied. If STWL were in the process of applying for a DP it is likely this increase in compensation would not be required, but the potential effects of a reduction from 72 Ml/d have been considered nonetheless.

With the onset of DP/ DO operation, there was an immediate and substantial drop in flows to 34 Ml/d (as per DP conditions) at Yorkshire Bridge. There are similar reductions in flow at APs downstream, except that flows in the River Derwent Amber to Bottle Brook and Bottle Brook to Trent are maintained above 340 Ml/d by releases from Carsington.

The reduction in flow is most evident at Yorkshire Bridge (AP1), Hathersage Leadmill Bridge (AP2) and Baslow Bridge (AP3), the reduction being a much higher proportion of river flow in the River Derwent from Westend to River Wye than it is further downstream. As expected, spate flows were not evident in the Yorkshire Bridge (AP1) and Hathersage Leadmill Bridge (AP2) flow series throughout DP operation. The removal of spate flows was no different to that of the baseline condition. Spate flow would not usually be intentionally released into the Derwent or Noe in drought conditions.

Aside from at Yorkshire Bridge (AP1) and Hathersage Leadmill Bridge (AP2), flows start to recover well before the period of DP operation comes to an end. In the winter of 1959/60, rising tributary inflows are evident from the 18th December onwards (DP operation continuing until 07/03/1960) and in the winter of 1960/61, from the 30th November (DP operation continuing until 21/12/1960). Spate flows, albeit damped are also evident from these dates downstream of Hathersage Leadmill Bridge (AP2). Therefore, although compensation flows were reduced for 2-3 months longer, the very low flows caused by DP operation and naturally low flow accretion are only evident for periods of about a month to six weeks (19/11/1959 – 15/12/1959 and 18/10/1960 – 30/11/1960) downstream of Hathersage Leadmill Bridge (AP2).

The cessation of DP operation caused an immediate increase in compensation flow and in early 1960 was coincident with a spate flow in all flow series except that at Yorkshire Bridge (AP1). The upper Derwent reservoirs were simulated to fill in late March 1960 and in December 1960. These are the first times since DP operation over the preceding weeks that a spate is predicted at Yorkshire Bridge (AP1). With the upper Derwent Reservoirs full, spate flows at other APs are also markedly higher than those during DP operation. The capture of spate flows by the Derwent Valley Reservoirs is a feature of baseline operation and is not exacerbated by DP operation.



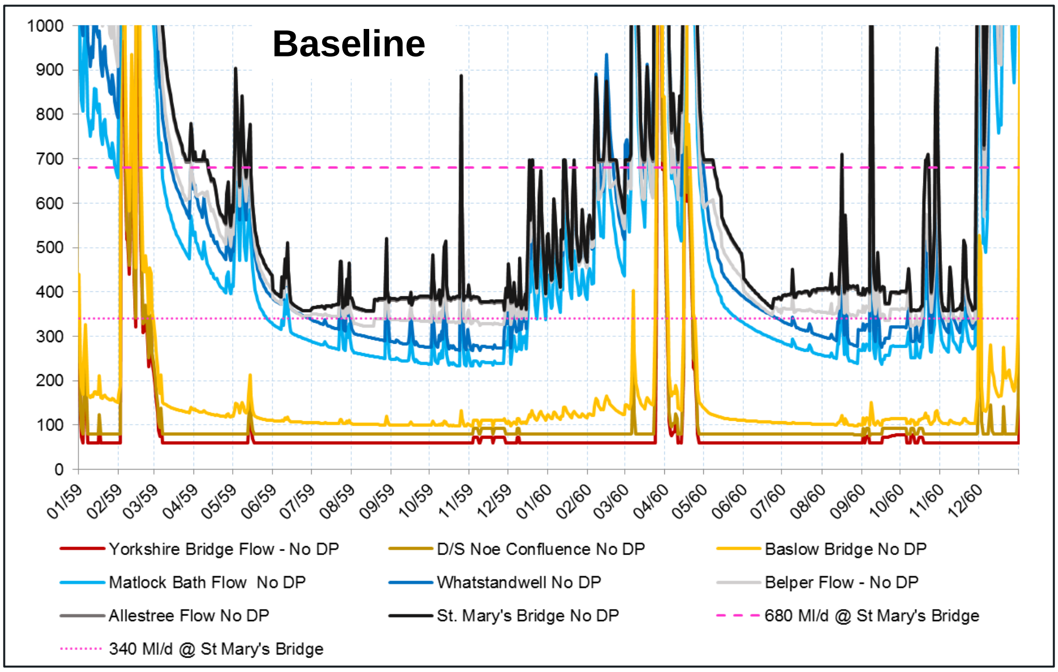




**Figure 5.2 River discharge, Derwent Valley Reservoirs DP for the 1959/60 Modelled Stochastic drought.**
**Y axis = discharge in Ml/d. DP operation shaded (upper).**

**Equivalent baseline operation (replicate of Figure 4.1) shown as lower graph, for ease of visual comparison.**

Estimated flow accretion from the 18th December 1959, prior to rising tributary inflows are shown in Table 5.1. Accretion on the 4th November 1960 represents the lowest flows and lowest accretion between APs in the River Derwent Westend to Wye waterbody during the 1959-60 modelled stochastic drought and low accretion (between Q85 and Q90 over the 19th November 1959 – 21 December 1960 period of DP operation) at APs downstream. However, the lowest flows during this modelled stochastic drought do not occur on the same day throughout the River Derwent and minimum simulated flows can be lower than those used for the accretion profile downstream of the River Wye confluence[18]. The accretion used is, however, within c. 10% of these minima and sensitivity analysis shows differences in hydraulic parameters between the 4th November 1960 and these minimum simulated flows during the most severe worst than historic drought are small.

**Table 5.1 Flow accretion for Derwent Valley Reservoirs No DP and DP scenarios**

| Location | No DP/DO (Ml/d) Derby St Mary's < 340 Ml/d | No DP/DO (Ml/d) Derby St Mary's > 340 Ml/d | DP/DO (Ml/d) | % Change from No DP/DO Derby St Mary's < 340 Ml/d | % Change from No DP/DO Derby St Mary's > 340 Ml/d |
|---|---|---|---|---|---|
| AP1 Yorkshire Bridge | 72 | 54 | 34 | -53% | -37% |
| AP2 Leadmill Bridge | 92 | 74 | 51 | -45% | -31% |
| AP3 Baslow Bridge | 116 | 93.6 | 75 | -35% | -20% |
| AP4 Matlock Bath | 288 | 265 | 247 | -14% | -7% |
| AP5 Whatstandwell | 333 | 311 | 292 | -12% | -6% |
| AP6 Belper | | 333 | 331 | | -1% |
| AP7 Allestree | | 354 | 366 | | 3% |
| AP8 Derby St Marys Bridge | | 355 | 369 | | 4% |

## 5.3 Pathways Assessment - Hydromorphology

### 5.3.1 Transects at Assessment Points

Predicted changes in hydraulic parameters at selected AP transects are illustrated in Table 5.2 to Table 5.5. Data for all APs, including photographs of cross section locations and habitat walkover maps (with cross section locations marked) are given in Appendix C.

Predicted changes at APs are greatest in the River Derwent from Westend to Wye. This is partly because flow changes arising from the Derwent Reservoirs DP are greatest here, but cross-sections are also in some cases less regular. Thus, reductions in flow may cause a greater loss of wetted perimeter per unit discharge.

In contrast, in the River Derwent from Wye to Amber , River Derwent from Amber to Bottle Brook and River Derwent from Bottle Brook to Trent , the very small degree of flow change [19]means that changes to the character of flow is unlikely; predicted changes in individual hydraulic parameters are less than <5%. The long

[18] In the simulations used, 221 Ml/d on the 3rd December 1959 at Matlock Bath (AP4); 260 Ml/d on 3rd December 1959 at Whatstandwell (AP5); 314 on 9th December 1959 at Belper (AP6); 356 on 11th December 1959 at Allestree (AP7) and 358 on 11th December 1959 at Derby St Mary's Bridge.

[19] Hydraulic effects may also be suppressed by the effect of the numerous in-channel structures, although this has not been demonstrated for these waterbodies.

stretches of wide, deep glide under baseline flows will therefore be maintained under a Derwent Valley Reservoirs DP.

Although greater than further downstream, hydraulic changes in the River Derwent from Westend to Wye are not predicted to be large under the Derwent Valley Reservoirs DP scenario, despite the larger reductions in discharge.

Moderate changes to the velocity of flow, driven in part by the moderate surface bed slope, also mean that effects on shear stress at the channel bed are also generally modest, so that in turn, changes to rates of sedimentation and erosion are likely to be small. Typically, rates of geomorphic processes will be low during baseline (dry) conditions in any case and impacts on coarse and fine sediment dynamics are likely to be minimal). The interaction of velocity with depth, captured by the flow intensity and measured by the Froude Number (Fr), is also not greatly affected. This suggests that the character of surface flow type (riffle, run, glide, pool etc.) will generally be maintained.

Reductions in the cross-section area cause a reduction in river depth, and potentially also, river width. These two variables further determine the wetted perimeter (which equates to the total available benthic habitat). For all the APs in the River Derwent, substantial depths are predicted to be maintained across the wetted channel. This maintains longitudinal connectivity even for larger fish, although this may still be impeded at in-channel structures (or possibly even at shallows not captured by the cross sections. Because substantial depths are maintained, losses of width and wetted perimeter are also modest, being restricted to the margins and to irregularities in the channel. Given the low sinuosity of planform in the River Derwent from Westend to Wye, this is also likely to be broadly representative of the reach more generally, although loss of wetted perimeter may be greater in the at depositional features such as vegetated bars or in the compound channel in the River Derwent at Hathersage SSSI.

That these hydraulic effects are not commensurate with the moderate change in river discharge at the APs is not atypical; hydraulic response tends to moderate reductions in river discharge because the change in flow is translated into concurrent reductions in both velocity and wetted area, each of which are individually smaller than the change in discharge. In fairly steep, broad channels such as the River Derwent downstream of Ladybower Reservoir, the channel slope also tends to maintain velocity and flow changes are often accommodated by a loss of wetted area without significant losses to wetted width or wetted perimeter.

**Table 5.2 Hydraulic parameters under baseline and DP scenarios at AP1 (Yorkshire Bridge). Orange shading denotes a moderate change, yellow shading a low change. Light yellow denotes a negligible change.**

| | Derwent Valley Reservoirs DP | | |
|---|---|---|---|
| | No DP/DO (Ml/d) Derby St Mary's < 340 Ml/d | No DP/DO (Ml/d) Derby St Mary's > 340 Ml/d | DP/DO Derwent Valley |
| Flow (Ml/d) | 72.00 | 54.00 | 34.00 |
| Depth (m) | 0.84 | 0.80 | 0.75 |
| Wetted Perimeter (m) | 15.42 | 15.02 | 14.53 |
| Wetted Width (m) | 15.17 | 14.79 | 14.31 |
| Velocity (m/s) | 0.11 | 0.09 | 0.06 |
| Froude Number (-) | 0.04 | 0.03 | 0.02 |
| Shear Stress ($N/m^2$) | 67.73 | 63.88 | 58.98 |

**Table 5.3 Hydraulic parameters under baseline and DP scenarios at AP2 (Leadmill Bridge).** Yellow shading denotes a low change. Light yellow denotes a negligible change.

| | Derwent Valley Reservoirs DP | | |
|---|---|---|---|
| | No DP/DO (Ml/d) Derby St Mary's < 340 Ml/d | No DP/DO (Ml/d) Derby St Mary's > 340 Ml/d | DP/DO Derwent Valley |
| Flow (Ml/d) | 92.00 | 74.00 | 51.00 |
| Depth (m) | 0.38 | 0.36 | 0.33 |
| Wetted Width (m) | 16.21 | 16.28 | 15.84 |
| Wetted Perimeter (m) | 16.77 | 16.51 | 16.03 |
| Velocity (m/s) | 0.34 | 0.30 | 0.26 |
| Froude Number (Fr) | 0.18 | 0.16 | 0.14 |
| Shear Stress ($N/m^2$) | 3.90 | 3.52 | 2.95 |

**Table 5.4 Hydraulic parameters under baseline and DP scenarios at AP3 (Baslow Bridge).** Yellow shading denotes a low change. Light yellow denotes a negligible change.

| | Derwent Valley Reservoirs DP | | |
|---|---|---|---|
| | No DP/DO (Ml/d) Derby St Mary's < 340 Ml/d | No DP/DO (Ml/d) Derby St Mary's > 340 Ml/d | DP/DO Derwent Valley Reservoirs |
| Flow (Ml/d) | 116.00 | 93.60 | 75.00 |
| Depth (m) | 0.84 | 0.82 | 0.79 |
| Wetted Width (m) | 22.45 | 22.32 | 22.14 |
| Wetted Perimeter (m) | 22.73 | 22.60 | 22.40 |
| Velocity (m/s) | 0.11 | 0.10 | 0.09 |
| Froude Number (Fr) | 0.04 | 0.04 | 0.03 |
| Shear Stress ($N/m^2$) | 11.47 | 11.07 | 10.45 |

**Table 5.5 Hydraulic parameters under baseline and DP scenarios at AP4 (Matlock Bath). Yellow shading denotes a low change. Light yellow denotes a negligible change.**

| | Derwent Valley Reservoirs DP | | |
|---|---|---|---|
| | No DP/DO (Ml/d) Derby St Mary's < 340 Ml/d | No DP/DO (Ml/d) Derby St Mary's > 340 Ml/d | DP/DO Derwent Valley Reservoirs |
| Flow (Ml/d) | 288.00 | 265.00 | 247.00 |
| Depth (m) | 0.72 | 0.70 | 0.68 |
| Wetted Width (m) | 13.10 | 12.79 | 12.48 |
| Wetted Perimeter (m) | 13.42 | 13.11 | 12.79 |
| Velocity (m/s) | 0.60 | 0.59 | 0.58 |
| Froude Number (Fr) | 0.22 | 0.22 | 0.22 |
| Shear Stress ($N/m^2$) | 7.58 | 7.39 | 7.21 |

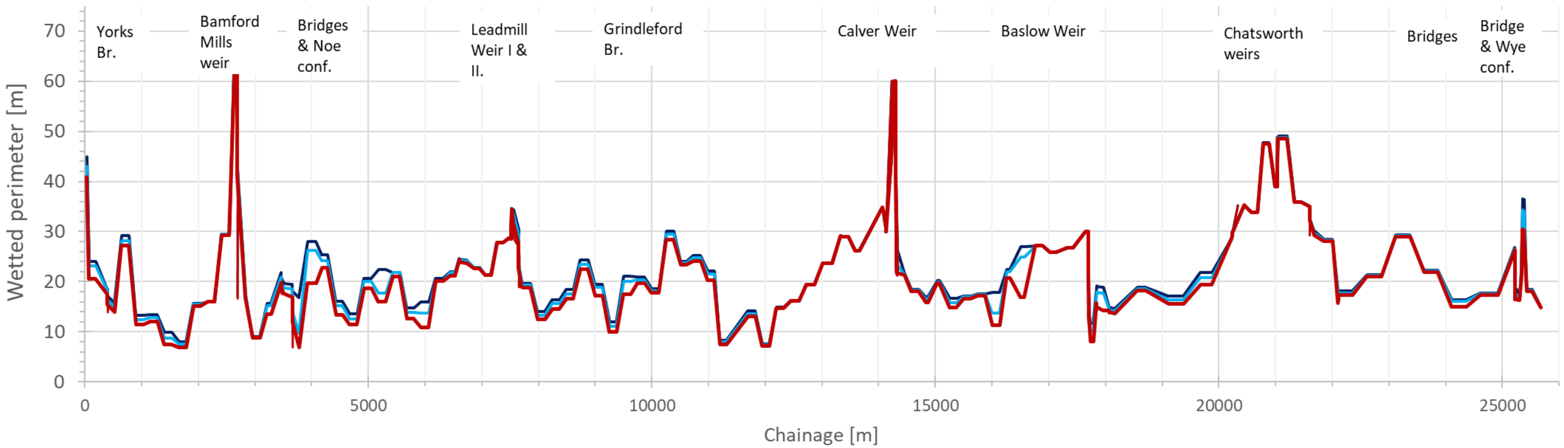
### 5.3.2 Hydraulic modelling in the Derwent: Westend to Wye

Outputs of the integrated hydraulic model in the Derwent: Westend to Wye indicate only modest hydraulic effects arising from the DP scenario. This is illustrated below (Figure 5.3 to Figure 5.5), with mean, minimum and maxima data provided in Table 5.6, Table 5.7 and Table 5.8 respectively.

Changes in mean hydraulic characteristics are less than 20% for all hydraulic parameters. Minima data suggest larger changes at some locations and for some parameters, but even these appear unlikely to cause substantial effects: Depth would not become limiting to fish movement, wetted perimeter changes do not indicate a substantial loss of marginal habitat, or that the bed would become exposed at any location. Likewise, velocity and flow intensity changes do not indicate substantial changes in habitat character.

Notably, changes in flow arising from the DP scenario are much smaller than the extensive effects at weirs in particular, and the effects of a DP scenario are also suppressed in reaches affected by weirs (in essence, the structure, rather than the inflow, remains the dominant hydraulic control in such reaches). Because of this, reaches affected by weirs and bridges have been treated separately in the presentation of results, with mean changes shown in Table 5.9.


**Figure 5.3a and b** **Modelled DP effects on max. cross section depth (upper) and mean transect velocity (lower), Ladybower to Wye confluence.**



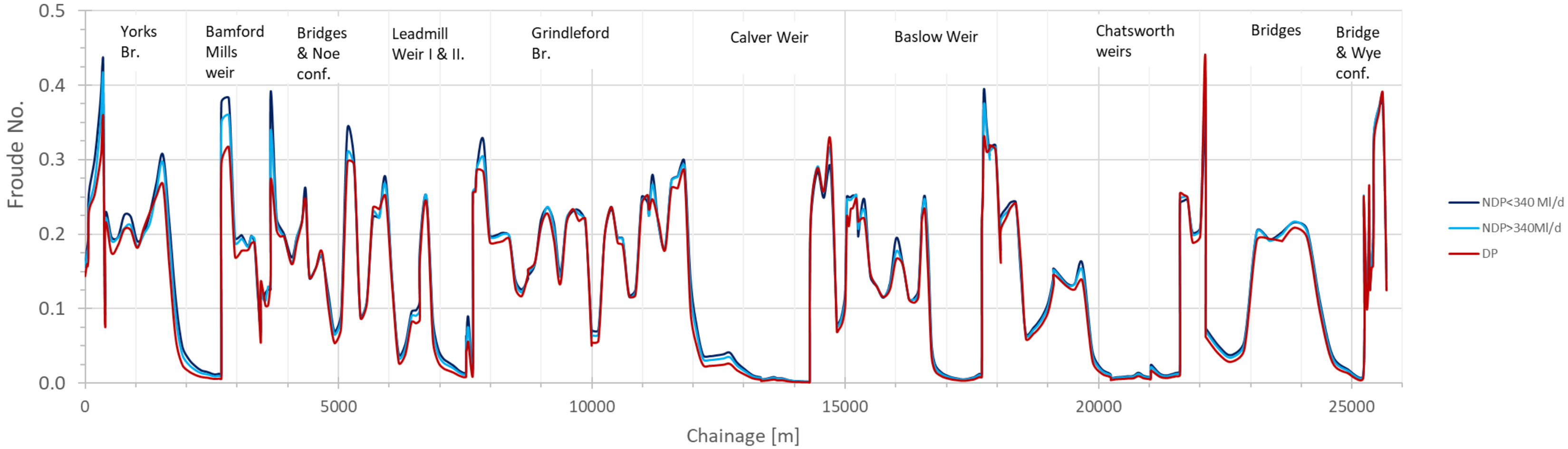
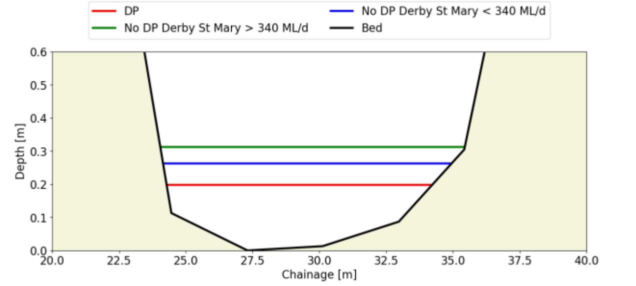
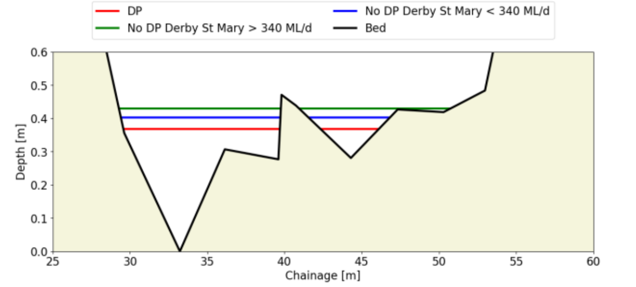




**Figure 5.4a and b** **Modelled DP effects on wetted perimeter (upper) and Froude No. (lower), Ladybower to Wye confluence.**

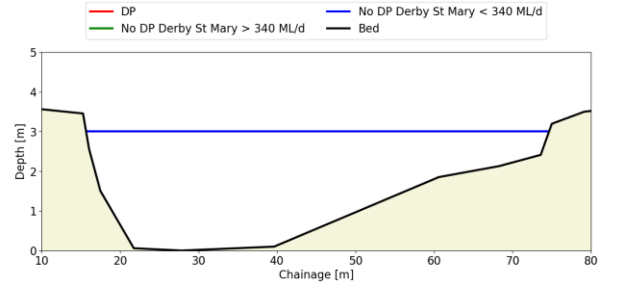
Example of depth change in the Yorkshire Bridge to Bamford reach, unaffected by structures




Example of depth change at a depositional feature (complex cross section) in the Bamford Weir to Hathersage Leadmill Bridge reach, unaffected by structures




Example of depth change at a structure (Calver Weir) in the Leadmill Bridge to Calver reach.




Example of depth change in a simple cross section in the Chatsworth to Rowsley (Wye confluence) reach.

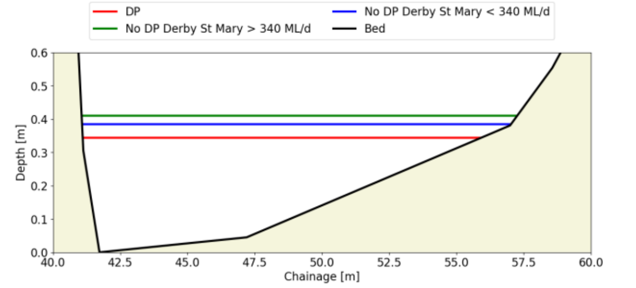



**Figure 5.5 Predicted depth changes at example cross sections, Derwent from Westend to Wye.**

**Table 5.6 Modelled mean hydraulic parameters for baseline and DP scenarios – River Derwent between Ladybower Reservoir and the Wye confluence (reaches affected by structures excluded)**

| Mean hydraulic parameters | No DP DSM<340 | No DP DSM>340 | DP | Change DP vs No DP DSM<340 Ml/d | Change DP vs No DP DSM >340 Ml/d | Change DP vs No DP DSM<340 Ml/d (%) | Change DP vs No DP DSM >340 Ml/d (%) |
|---|---|---|---|---|---|---|---|
| **Depth (m)** | 0.54 | 0.51 | 0.47 | 0.07 | 0.04 | 13% | 8% |
| **Wetted Perimeter (m)** | 19.91 | 19.10 | 17.95 | 1.96 | 1.15 | 10% | 6% |
| **Velocity (m/s)** | 0.27 | 0.25 | 0.23 | 0.04 | 0.02 | 16% | 10% |
| **Froude No.** | 0.18 | 0.17 | 0.17 | 0.01 | 0.01 | 6% | 4% |

**Table 5.7 Modelled minima for hydraulic parameters under baseline and DP scenarios – River Derwent Ladybower Reservoir to the Wye confluence (reaches affected by structures excluded)**

| Hydraulic parameters_minima | No DP DSM<340 | No DP DSM>340 | DP | Change DP vs No DP DSM<340 Ml/d | Change DP vs No DP DSM >340 Ml/d | Change DP vs No DP DSM<340 Ml/d (%) | Change DP vs No DP DSM >340 Ml/d (%) |
|---|---|---|---|---|---|---|---|
| Depth (m) | 0.20 | 0.18 | 0.14 | 0.06 | 0.04 | 28% | 20% |
| Wetted Perimeter (m) | 7.60 | 7.40 | 6.95 | 0.65 | 0.45 | 9% | 6% |
| Velocity (m/s) | 0.02 | 0.02 | 0.01 | 0.01 | 0.00 | 38% | 26% |
| Froude No. | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 38% | 25% |

**Table 5.8 Modelled maxima for hydraulic parameters under baseline and DP scenarios – River Derwent Ladybower Reservoir to the Wye confluence (reaches affected by structures excluded)**

| Hydraulic parameters_maxima | No DP DSM<340 | No DP DSM>340 | DP | Change DP vs No DP DSM<340 Ml/d | Change DP vs No DP DSM >340 Ml/d | Change DP vs No DP DSM<340 Ml/d (%) | Change DP vs No DP DSM >340 Ml/d (%) |
|---|---|---|---|---|---|---|---|
| Depth (m) | 2.56 | 2.55 | 2.55 | 0.01 | 0.01 | 0% | 0% |
| Wetted Perimeter (m) | 36.53 | 34.29 | 30.47 | 6.05 | 3.82 | 17% | 11% |
| Velocity (m/s) | 0.55 | 0.53 | 0.48 | 0.06 | 0.04 | 12% | 8% |
| Froude No. | 0.39 | 0.37 | 0.33 | 0.06 | 0.04 | 16% | 12% |

**Table 5.9 Modelled mean hydraulic parameters at reaches affected by weirs and bridges under baseline and DP scenarios – River Derwent Ladybower Reservoir to the Wye confluence**

| Mean hydraulic parameters | No DP DSM<340 | No DP DSM>340 | DP | Change DP vs No DP DSM<340 Ml/d | Change DP vs No DP DSM >340 Ml/d | Change DP vs No DP DSM<340 Ml/d (%) | Change DP vs No DP DSM >340 Ml/d (%) |
|---|---|---|---|---|---|---|---|
| Depth (m) | 1.68 | 1.67 | 1.66 | 0.01 | 0.01 | 0% | 0% |
| Wetted Perimeter (m) | 32.92 | 32.69 | 32.36 | 2.21 | 1.23 | 3% | 2% |
| Velocity (m/s) | 0.08 | 0.07 | 0.06 | 0.07 | 0.01 | 12% | 6% |
| Froude No. | 0.08 | 0.07 | 0.06 | 0.07 | 0.03 | 12% | 6% |

## 5.4 Pathways Assessment - Water Quality

In the upper catchment point source contributions of parameters such as ammonia and phosphate are low in comparison to diffuse inputs. Point source contributions at AP2 constitute an estimated 21% of the total ammonia load for example (Section 4.4.2). The DP related reduction in low flows is predicted to have a small scale of negative change to ammonia and phosphate concentrations in the Derwent from Westend to Wye water body. BOD and nitrate in the upper catchment are dominated by diffuse contributions and there is potential for a small positive change associated with the DP given a reduced loading from the reservoir compensation.

The reservoir release moderates summer maximum temperatures in the River Derwent from Westend to Wye and although this effect may be particularly noticeable during dry periods under baseline operation, a reduction in the Ladybower compensation would reduce this effect. Likewise, warming of autumn and early winter water temperatures in the River Derwent from Westend to Wye would be reduced by DP operation. The main driver for the effects of flow releases on temperature is likely to be the thermal mass[20] of the water released. Reductions in the baseline effect on temperature would therefore be in proportion to the change in compensation flow as a proportion of river discharge.

The strong seasonal dissolved oxygen concentration trend is likely to be linked primarily to temperature and dominates other influences in these data. The potential for adverse dissolved oxygen and temperature change is therefore assessed to be **Negligible** under this DP.

Further downstream (within subsequent downstream water bodies) the flow change is small and there is **Negligible** potential for the DP to influence water quality relative to the baseline. Thus, in the River Derwent from Westend to Wye predicted water quality changes are small despite substantial flow changes because of low pollutant inputs. In the waterbodies downstream, predicted water quality changes are small despite substantial pollutant inputs, because of the small changes to river flow.

All water quality pathway assessment results are presented as Appendix I and discussed in Appendix D.

## 5.5 Ecology - Macroinvertebrates

LIFE O:E ratios derived from these data are shown in Figure 5.6.

Index scores for the sample taken in 1996 at Yorkshire Bridge (following DP implementation) is not notably lower than in other years. Despite the fact that the Ladybower compensation and spills dominate the flow regime at this location, trends in time series data (Figure 4.8 with all data presented in Appendix E) suggest that factors other than low flows drive variability in macroinvertebrate community composition. There is a wide range of effects that might be expected in the vicinity of a reservoir, including the proximity of a large body of open water, changes to both low flows and spates, changes to the sediment regime and to water quality, changes to channel structure and episodic reservoir operations such as scour valve tests.

Index scores for all 1996 samples taken from the remaining sites in the River Derwent from Westend to Wye waterbody remain above the threshold used by the EA to indicate possible flow stress in the absence of other pressures, but low flow response relative to site history is arguably a more relevant measure. Aside from the autumn 1996 sample at Hathersage Leadmill Bridge (AP2), all 1996 samples are close to the low end of the sampled range. Recovery in 1997 samples also appears incomplete at these locations. However, LIFE O:E ratios in 1996 (when DP powers were operated to) were not always lower than those in 1995 (a similarly dry summer when DP powers were not in force), and any differences[21] may relate to the effect of sequential dry years, rather than to the DP. Thus, whilst 1996 LIFE O:E ratios undoubtedly appear depressed relative to average in much of the River Derwent from Westend to Wye waterbody, it is less clear that this is due to DP operation.

Departures from mean LIFE O:E ratios subsequent to DP operation in 1995/96 are less notable in the River Derwent (Wye to Amber), River Derwent (Amber to Bottle Brook) and River Derwent (Bottle Brook to Trent) waterbodies, with most samples post DP implementation being no worse than modestly below average. Notably low scores were only evident at Derby St Mary's Bridge and at Wilne, which might relate to water quality changes, but such instances amongst a wider sample set do not constitute clear evidence of a DP effect (as opposed to a response to natural low flows) and, given the virtual absence of nett flow changes or hydraulic effects arising from a Derwent Reservoirs DP this far downstream, effects on macroinvertebrate communities can be discounted.

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[20] Air temperature and insolation (sunshine) can also be important, even though the river is partially shaded for much of its length in the River Derwent from Westend to Wye. These effects are independent of DP operation.

[21] The previous DP EAR (ESI & APEM, 2012) considered (on the basis of ANOVA), that the reductions in 1996 from 1995 were not significant in the upper Derwent. However, the comparison was acknowledged to have weak statistical power due to the small sample set, and (to increase the dataset) also included data from Matlock Bath and Whatstandwell.)

Aside from the samples at Yorkshire Bridge, which appear driven by baseline factors, the response of LIFE O:E ratios to the 1995/96 drought were, if not unambiguous, at least consistent with expectations:

- That reductions in LIFE O:E ratios are more pronounced in the River Derwent from Westend to Wye is consistent with the greater changes in flow and hydraulic parameters predicted for this waterbody.
- That LIFE O:E ratios were not greatly reduced relative to site history, and not sufficiently reduced to indicate possible flow stress using the EA's guideline metric, suggests that flow stress was modest. This is consistent with the modest degree of habitat change predicted for the reach – and is probably a greater degree of change than expected from hydraulic predictions.
- That macroinvertebrate communities recover quite promptly – over one or at most two years (1997 LIFE O/E does not appear to be substantially impacted relative to long-term means and results are generally higher than 1995/96 results), is also consistent with experience elsewhere in the UK: In all riverine situations, macroinvertebrate communities are typically resilient to single-season low flow periods, recovering rapidly from any negative impacts of low flows. Reductions in LIFE O:E ratios experienced elsewhere in the UK also suggest that relatively deep mature lowland rivers are less sensitive to low flows than shallow groundwater-fed and upland watercourses.

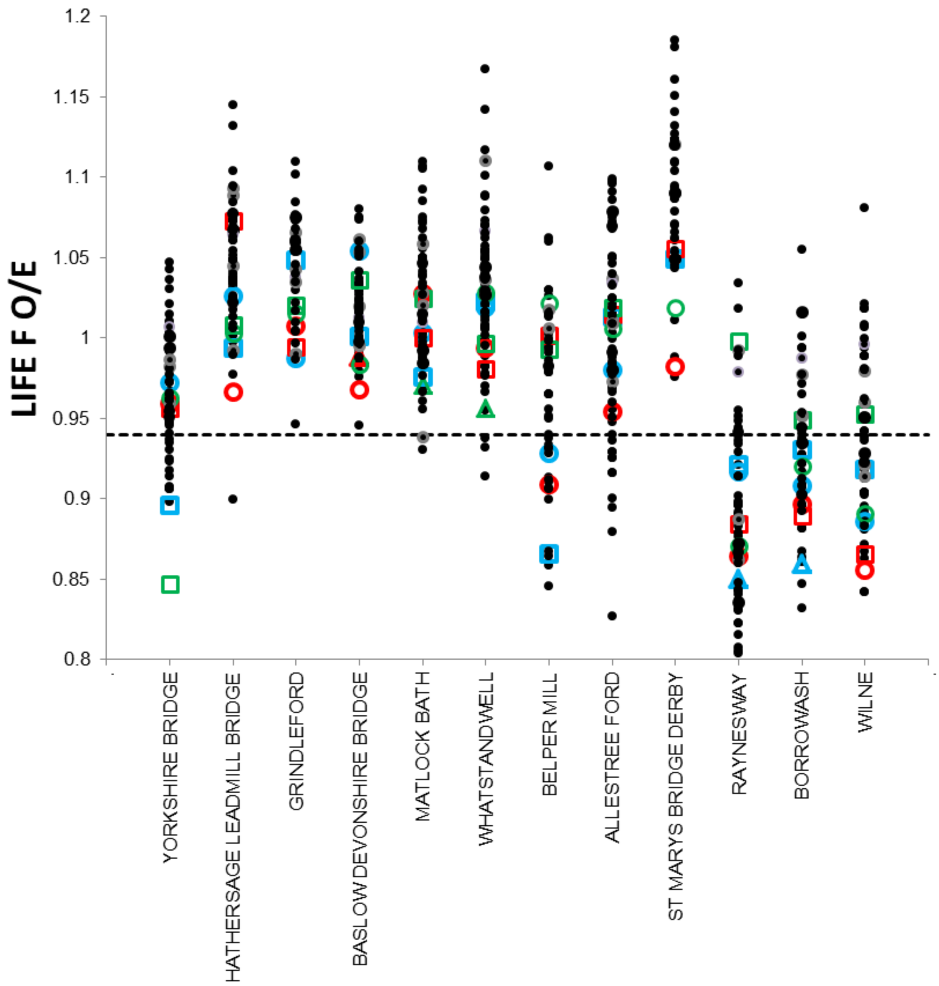


**Figure 5.6 Macroinvertebrate response to reduction in Ladybower compensation flow, 1996. Red denotes 1996 samples. Blue = 1995. Green = 1997. Circle = spring; triangle = summer; square = autumn. Other sample points (black dots) cover 1983-2017. Black dashed line = guidance threshold.**

### 5.5.1 Ecology - Rare species

In Britain small grey sedge (*Glossosoma intermedium*) larvae are often found in areas of medium to low flow and rarely in fast flowing sections (Wallace, 2011). In the UK the larvae of the small grey sedge grow rapidly during late spring and seal themselves into a pupal case by July. Being immobile, at this stage they are most vulnerable to changes in water levels and may become exposed if water levels drop.

The southern iron blue (*Nigrobaetis niger*) is commonly found under in-stream vegetation in riffle areas and can be affected by low flows (MacAdam, 2011). There are two generations a year with one generation growing through the winter and a second generation that grows quickly through the summer, resulting in the emergence of this species from April to October.

## 5.6 Ecology - Fish

### 5.6.1 Changes to passability at structures

Reductions in flow during implementation of a Derwent Valley Reservoirs DP would not affect access for diadromous species, which do not have access to the River Derwent under baseline conditions. Reference to Table 5.10 suggests that it is only at Cromford that in-river passage may be theoretically affected by DP operation, and possibly also at Calver if flows under the DP scenario are below the operational threshold of the fish pass.

Given the small predicted scale of change at these locations, the difference in passability during DP operation is likely to be very small, particularly given consideration of the preferred migration conditions (below), which target elevated flows.

Elsewhere, in the River Derwent from Westend to Wye barriers are either considered likely to be passable or impassable under all flows. However, it should be noted that the categorisation used by Bottomly and Jarrams (1985) is based upon salmon passage. If a structure is impassable to salmon migrating upstream it has been considered impassable to the majority of other species, but the reverse does not follow; structures that are passable for salmon may be impassable for other fish species, particularly weaker swimming coarse fish species such as perch and bream. There may also be additional barriers that were not considered for upstream migrating salmon yet would act as barriers to other species. For the majority of salmonid and coarse fish species which undertake spawning migrations, however, these are timed to coincide with periods of elevated flow, targeting spate flows (including receding spate limbs) in particular. The reductions in flow during implementation of the Derwent Valley Reservoirs DP would comprise a relatively small proportion of total river flow at these preferred times, and spate flow character would not be different to those under baseline operation. It is therefore considered that implementation of the DP would have a **Negligible** magnitude of effect and a **Negligible** impact significance on migration, including at Cromford and Calver.

**Table 5.10 Passability of in stream structures to Atlantic salmon**

| Site | Grid reference | Category | Comments |
|---|---|---|---|
| **Derwent from Westend to Wye (GB104028057880)** | | | |
| Bamford | SK 2083 | B | |
| Hathersage | SK 2380 | D | |
| Grindleford | SK 2479 | D | Fishing weir |
| Calver | SK 2475 | D | Larinier fish pass constructed in 2015 |
| Baslow | SK 2572 | A | |
| Chatsworth | SK 2568 | A | |
| Chatsworth | SK 2569 | A | |
| **Derwent from Wye to Amber (GB104028052390)** | | | |
| Cromford | SK 2957 | C | |
| Whatstandwell | SK 3354 | D | Structure not listed in Bottomly and Jarrams (1985) – information on weir and Larinier fish pass provided by EA as part of data request. |
| Ambergate Wire Works | SK 3452 | A | Currently the subject of fish passage investigation works by Derwent Valley Mills |
| **Derwent from Amber to Bottle Brook (GB104028052310)** | | | |
| Belper | SK 3448 | A | Currently the subject of fish passage investigation works by Derwent Valley Mills |
| Milford (Glow-worm) | SK 3445 | B | HEP offtake upstream of weir which creates a depleted reach, including the weir. Weir likely to be passable to high flows (revised from category A to B) |
| Milford (Rec Ground) | SK 3544 | D | Fish pass |
| Peckwash Mill, Duffield | SK 3542 | D | Weir partly collapsed |
| **Derwent from Bottle Brook to Trent (GB104028053240)** | | | |
| Darley Abbey | SK 3538 | D | Larinier fish pass constructed in 2014 |
| Longbridge Weir, Derby | SK 3536 | D | Larinier fish pass constructed alongside HEP scheme in 2013 |
| Incinerator plant | SK 3834 | A | Flood relief weirs only – upstream passage possible via other routes |
| Power station sluices | SK 3934 | A | |
| Derby power station | SK 4032 | A | |
| Borrowash | SK 4134 | D | Larinier fish pass constructed in 2012 |
| Wilne gauging weir | SK 4431 | D | STWL owned |
| Church Wilne | SK 4431 | C | Old derelict fish pass |

Updated from Bottomly and Jarrams, 1985. Listed upstream to downstream. A = Impassable at all flows, B = Passable at high flows, C = Passable at all flows with difficulty, D = Passable at all flows with no difficulty. Note that, where applicable, the original classifications have been revised at structures where fish passes have been constructed.

### 5.6.1 Changes to physical habitat

*Derwent from Westend to Wye*

Predicted changes in habitat suitability for specific fish species and lifestages are presented for different reaches in the Derwent from Westend to Wye in Figure 5.7 (brown trout) and Figure 5.8 (for bullhead and brown trout). As discussed in Section 3.3.1, the predictions are made assuming accretion during very low flows (at the lower extreme of summer and autumn flows and below even these at other times of year). The predictions are based upon maximum depths and transect averaged velocities arrived at via hydraulic modelling with a high density of cross sections with extrapolation to flows lower than those for which model calibration data were available.

The separation of results into reaches, each of roughly equal length, is intended to allow for the disconnection of habitat along the Derwent from Westend to Wye by the many weirs present, although not all of these may be a total barrier to movement for all species. Note that results are not separated into those at weirs and free flowing reaches (given that these are in connection), however, aside from the furthest downstream reach (Chatsworth to Rowsley Wye confluence) the reach typically comprises an extensive free flowing upstream reach and a section ponded behind the weir that delineates the downstream extent of the reach. In addition to the habitat presented, tributary streams flowing into each reach will extend the availability of habitat, particularly for species or life stages with a preference for smaller streams, and these are not affected by the proposed DP. Likewise, the furthest downstream reach - Chatsworth to Rowsley Wye confluence - is in connection with the River Wye and with the River Derwent downstream.

Brown trout parr and adult flow preferences are flexible and much of the reaches (often a large majority) are within acceptable depth and velocity ranges. All reaches afford suitable flow conditions for all life stages of brown trout under baseline conditions, which is supported by fish survey data (where available).

DP-induced habitat changes for all brown trout life stages are small in all reaches. DP induced flow changes are predicted to increase habitat suitability for some brown trout life stages, most notably (but not exclusively) for fry, in which suitability is predicted to increase in all reaches under the DP scenario. DP induced impacts on brown trout therefore appear unlikely, based upon the hydraulic analysis (and acknowledging uncertainties in the modelling approach).

DP-induced impacts on bullhead also appear unlikely, based upon the hydraulic analysis.

From modelled results, flow conditions are broadly above those which would be suitable for brook lamprey ammocoetes throughout the majority of all reaches, even under baseline conditions, though flow modelling indicates that there would be some areas of marginal slack water which may constitute suitable lamprey ammocoete habitat. This does tally with walkover data, which suggests that the silty slow flowing waters preferred by this species life stage are scarce in the main stem of the river in the Derwent from Westend to Wye. However, data does suggest some utilisation by the species, and it should be remembered that the suitability of flow conditions is inferred from maximum depths and transect averaged velocities. Therefore, the hydraulic model data do not preclude suitable flow conditions to occur in the slower flower margins. Such conditions are most likely to persist in marginal shallows in areas ponded by weirs. Hydraulic conditions have been shown to change least where flow is ponded by weirs and therefore DP induced impacts on larval habitat appear unlikely.

Modest DP-induced impacts cannot, however, be discounted from flow suitability assessment for brook lamprey spawning, which does appear to decline in all reaches between Ladybower Reservoir and Baslow, particularly between Yorkshire Bridge and Bamford Mill Weir and between Baslow and Chatsworth. In both of these reaches, flow conditions inferred from maximum depth and transect average velocity are suitable at only a minority (a third or less) of cross sections under baseline conditions, but the reductions in the suitability of flow conditions under DP operation may render such habitat scarce (present at fewer than 10% of cross sections). However, impacts on brook lamprey spawning are likely to be correlated to a degree with the passability of within-river structures to this species, with only three out of the seven barriers identified within this waterbody considered passable at all flows with no difficulty.

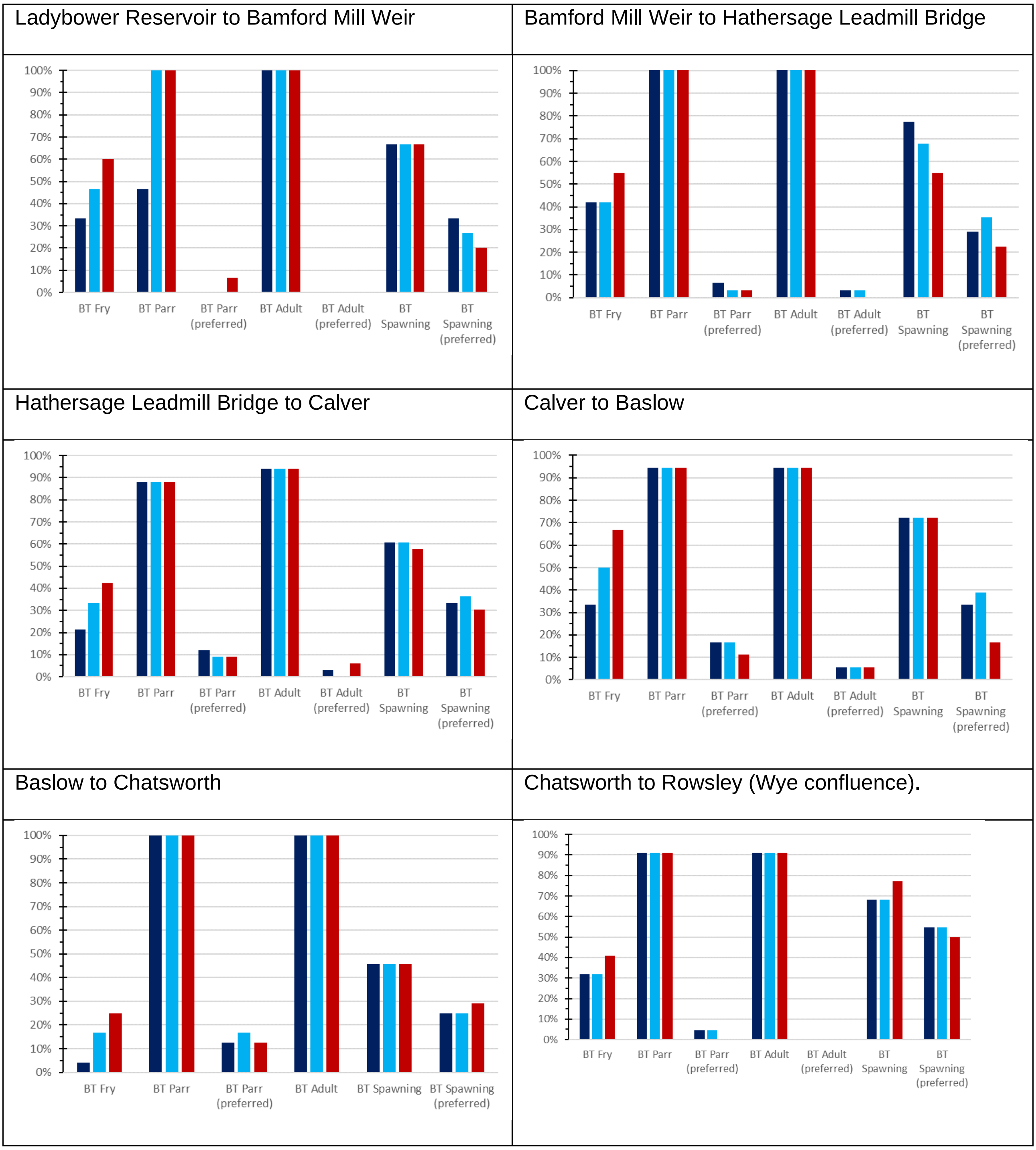


**Figure 5.7 Percentage change in habitat suitability for different lifestages of brown trout in different reaches of the Derwent from Westend to Wye.**
**Dark blue = No DP with DSM < 340 Ml/d. Light blue = No DP with DSM > 340 Ml/d. Red = DP.**

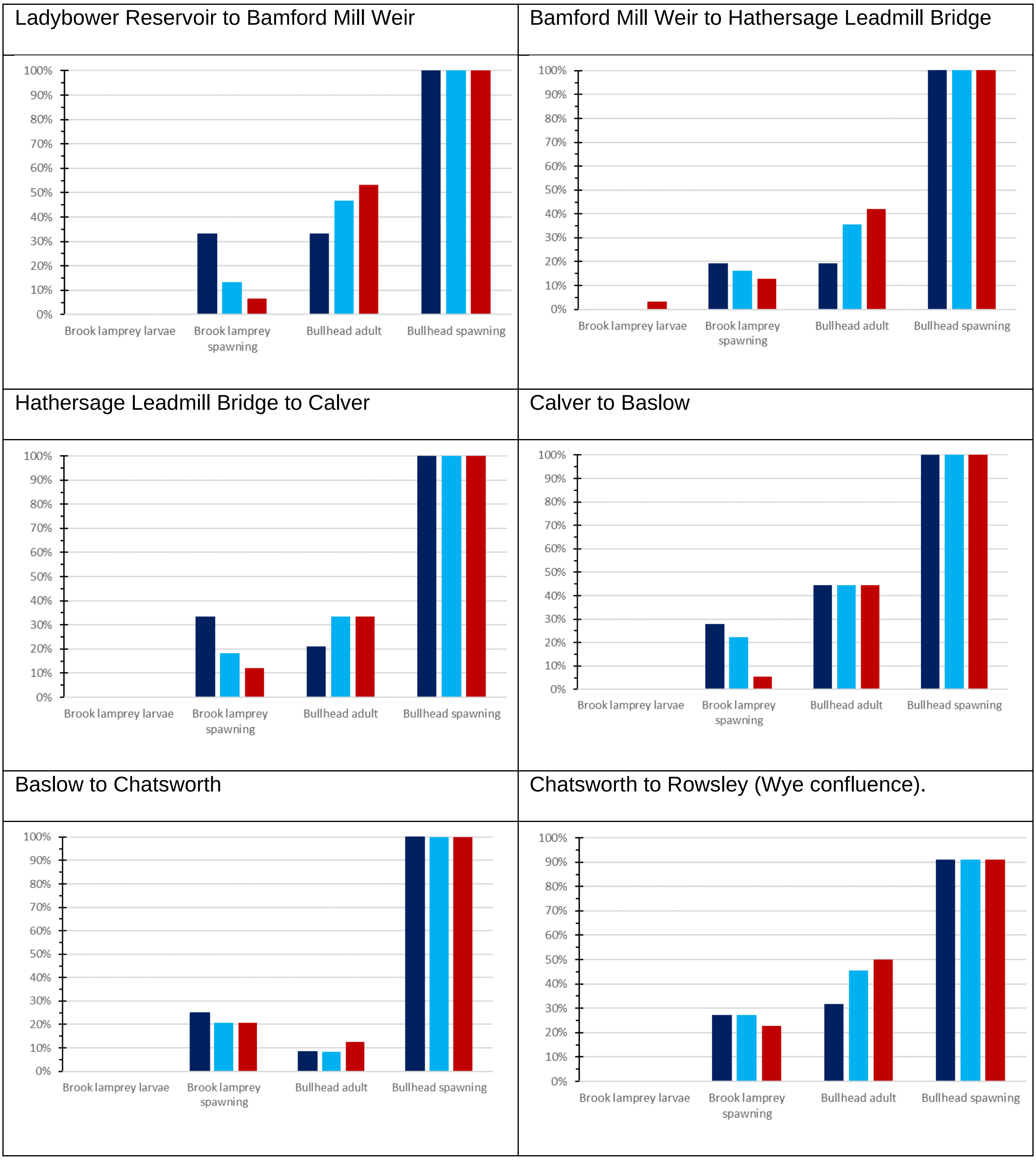


**Figure 5.8 Percentage change in habitat suitability for brook lamprey and bullhead lifestages in different reaches of the Derwent from Westend to Wye.**
**Dark blue = No DP with DSM < 340 Ml/d. Light blue = No DP with DSM > 340 Ml/d. Red = DP.**

<u>Ladybower Reservoir to Bamford Mill Weir</u>

Flow modelling within the Ladybower Reservoir to Bamford Mill Weir reach indicates that there are likely to be small reductions in water depth, flow velocity and wetted perimeter, but marginal habitat would be displaced, not necessarily lost. Loss in wetted habitat is caused primarily by dewatering of shallow, marginal channel areas which serve as important nursery habitats for juvenile fish, particularly young of year life stages of brown trout, and loss of wetted marginal areas associated with lamprey ammocoete habitat. However, new such habitat would be created slightly closer to the mid-channel. With regards to spawning and egg incubation, trout typically spawn in habitat at the tail end of pools at a water depth of 20 – 40 cm, with eggs buried to a depth of 10 – 20 cm beneath the gravel surface (Crisp and Carling, 1989). The predicted changes in depth would maintain a sufficient depth of water above cut trout redds and, whilst a small reduction in available trout spawning habitat is anticipated, this is considered to pose little risk to dewatering of eggs, leading to a **Negligible** impact significance. Flow modelling indicates that habitat availability for all other brown trout life stages will either remain unchanged or will increase under the DP, leading to a **Negligible** or **Minor** positive impact significance.

Similarly, a modest increase in bullhead habitat is anticipated under the DP, whilst bullhead spawning habitat is predicted to remain unchanged. Bullhead spawn over areas of coarse substrate in areas of medium depth. Predicted small reductions in water depth and velocity are not considered to be of a sufficient magnitude to cause dewatering of bullhead spawning sites nor cause a marked change in the overall availability or suitability of spawning habitat. It should also be noted that, although the DP EAR considers likely effects should the DP operation be implemented at any time of year, in practice, the effects on accretion are unlikely to be as severe as modelled outside the late summer to early winter. A **Negligible** impact magnitude is anticipated for this species life stage, equating to a **Negligible** impact significance overall on bullhead spawning and egg incubation

There is little literature relating to the population response of lamprey species to reduced habitat. Whilst juvenile lamprey ammocoetes are often viewed as a sedentary life stage, they do exhibit lateral movement when exposed to poorer quality habitat. Recent surveys (not published) completed by APEM on the River Rivelin, in a neighbouring catchment to the River Derwent, identified ammocoetes relocating from dewatered marginal silts back into the wetted fraction of the channel upon reduction of a compensation flow. However, it is possible that ammocoetes may be exposed to elevated levels of predation and/or become condensed into smaller areas of habitat at increased densities. A key determining factor in this response is whether lamprey ammocoetes exhibit a density dependant response, whereby, below a critical density (lamprey per $m^2$ of suitable habitat) lamprey can co-exist without adversely affecting population levels as a whole. Likely mechanisms for any impacts would be via increased competition and reduced prey availability whereby individuals experience reduced growth and / or survival. Ammocoete densities recorded during lamprey quadrat surveys as part of previous APEM baseline monitoring on the Derwent have recorded low ammocoete densities, below ‘optimal’ densities supported on other rivers and suggests that density dependent mortality of ammocoetes during implementation of the DP is unlikely to occur. It should also be noted that limited areas of lamprey habitat were observed during the previous habitat walkover surveys and thus any impacts would be expected to manifest over a small spatial scale. A **Minor** negative impact significance overall is therefore anticipated for brook lamprey.

Implementation of the DP is likely to result in impacts which occur over a medium scale and short duration. It is therefore concluded that implementation of a DP would lead to **Minor** negative impacts on lamprey spawning, and **Negligible** or **Minor** positive impacts on all brown trout life stages, bullhead (all life stages) and lamprey ammocoetes, for a DP that is operational between approximately March to August.

Bamford Mill Weir to Hathersage Leadmill Bridge

Flow modelling within the Bamford Mill Weir to Hathersage Leadmill Bridge reach indicates that there are likely to be small reductions in water depth, flow velocity and wetted perimeter. A small reduction in habitat availability for spawning brown trout is anticipated, leading to a **Minor** negative impact significance for this life stage, but impacts on habitat availability for all other brown trout life stages are anticipated to be of negligible magnitude, leading to a **Negligible** impact significance overall.

A minimal impact on bullhead spawning is anticipated under the DP, whilst an overall increase in adult bullhead habitat is also anticipated. A **Negligible** to **Minor** positive impact significance is therefore predicted for bullhead.

A **Minor** negative impact significance is anticipated for lamprey ammocoetes, whilst impacts on lamprey spawning are predicted to range from **Negligible** to **Minor** positive significance.

Implementation of the DP is likely to result in impacts which occur over a medium scale and short duration. It is therefore concluded that implementation of a DP would lead to **Minor** negative impacts for lamprey ammocoetes and brown trout spawning, and **Negligible** to **Minor** positive impacts for all bullhead life stages, and all other lamprey and brown trout life stages**,** for a DP that is operational between approximately March to August.

<u>Hathersage Leadmill Bridge to Calver</u>

Flow modelling within the Hathersage Leadmill Bridge to Calver reach indicates that reductions in water depth and flow velocity are likely to be small. Reductions in wetted perimeter are predicted for the upper half of the reach but increases in wetted perimeter are predicted for the lower half of the reach towards Calver Weir, suggesting an increase in habitat availability.

Modelled changes in habitat availability for brown trout parr and adults are barely discernible, whilst an increase in habitat availability is predicted for brown trout fry. An impact significance ranging from **Negligible** to **Minor** positive is therefore anticipated for brown trout in this reach.

Similarly, modelled changes in habitat availability for bullhead spawning are barely discernible, whilst an increase in habitat availability is predicted for bullhead adults. An impact significance ranging from **Negligible** to **Minor** positive is therefore anticipated for bullhead in this reach.

Reductions in habitat availability for lamprey ammocoetes are predicted to be relatively small and are likely to be confined to the upper end of this reach, where reductions in wetted perimeter are anticipated. A **Negligible** impact significance is therefore anticipated for lamprey ammocoetes within this reach. Small reductions in lamprey spawning habitat availability are predicted, which coupled with small reductions in water depth and flow velocity equates to a **Negligible** to **Minor** negative impact significance overall.

Implementation of the DP is likely to result in impacts which occur over a medium scale and short duration. It is therefore concluded that implementation of a DP would lead to **Negligible** to **Minor** positive impacts for brown trout and bullhead, and **Negligible** to **Minor** negative impacts for lamprey, for a DP that is operational between approximately March to August.

<u>Calver to Baslow</u>

Flow modelling within the Calver to Baslow reach indicates that small reductions in water depth and flow velocity are anticipated, with minimal changes in wetted perimeter.

Modelled changes in habitat availability for brown trout parr and adults are barely discernible, whilst an increase in habitat availability is predicted for brown trout fry. An impact significance ranging from **Negligible** to **Minor** positive is therefore anticipated for brown trout in this reach.

Similarly, modelled changes in habitat availability for bullhead spawning and adults are barely discernible, and a **Negligible** impact significance is therefore anticipated for bullhead in this reach.

Flow modelling also indicates small reductions in lamprey ammocoete and spawning habitat within this reach but any reductions in habitat availability are likely to be short-term in duration and temporary in nature. A **Negligible** impact significance is therefore anticipated for lamprey ammocoetes and spawning in this reach.

Implementation of the DP is likely to result in impacts which occur over a medium scale and short duration. It is therefore concluded that implementation of a DP would lead to **Negligible** impacts for all species and life stages in this reach, for a DP that is operational between approximately March to August.

Baslow to Chatsworth

Flow modelling within the Baslow to Chatsworth reach indicates that minimal changes in water depth are anticipated, accompanied by small reductions in flow velocity and small increases in wetted perimeter.

Modelled changes in habitat availability for brown trout parr and adults are barely discernible, whilst an increase in habitat availability is predicted for brown trout fry. An impact significance ranging from **Negligible** to **Minor** positive is therefore anticipated for brown trout in this reach.

Similarly, modelled changes in habitat availability for bullhead spawning and adults are barely discernible, and a **Negligible** impact significance is therefore anticipated for bullhead in this reach.

Whilst flow modelling indicates small reductions in lamprey ammocoete habitat within this reach, modelled changes in wetted perimeter are minimal, and any reductions in habitat availability are likely to be short-term in duration and temporary in nature. Flow modelling indicates a minimal change in lamprey ammocoete habitat, and a **Negligible** impact significance is therefore anticipated for lamprey spawning and ammocoetes in this reach.

Implementation of the DP is likely to result in impacts which occur over a medium scale and short duration. It is therefore concluded that implementation of a DP would lead to **Negligible** impacts for all species and life stages in this reach, for a DP that is operational between approximately March to August.

Chatsworth to Rowsley (Wye confluence)

Flow modelling within the Chatsworth to Rowsley (Wye confluence) reach indicates that minimal changes in water depth are anticipated, accompanied by small reductions in flow velocity and small increases in wetted perimeter.

Modelled changes in habitat availability for brown trout parr and adults are barely discernible, whilst an increase in habitat availability is predicted for brown trout fry. An impact significance ranging from **Negligible** to **Minor** positive is therefore anticipated for brown trout in this reach.

Similarly, modelled changes in habitat availability for bullhead spawning are barely discernible, and a **Negligible** impact significance is therefore anticipated for bullhead spawning in this reach. Modelled changes in habitat availability for bullhead adults suggest a positive impact on this life stage, and a **Minor** positive impact significance is therefore anticipated for bullhead adults in this reach.

Flow modelling indicates that changes in lamprey spawning and ammocoete habitat availability are barely discernible, and a **Negligible** impact significance is therefore anticipated for lamprey in this reach.

Implementation of the DP is likely to result in impacts which occur over a medium scale and short duration. It is therefore concluded that implementation of a DP would lead to **Negligible** impacts for all species and life stages in this reach, except for a **Minor** positive impact for bullhead adults, for a DP that is operational between approximately March to August.

*Derwent from Wye to Amber, Amber to Bottle Brook and Bottle Brook to Trent*

As described in Section 3.3.1, habitat changes downstream of the River Wye confluence is inferred from predicted hydraulic changes at APs during DP implementation rather than from combinations of hydraulic variables to assess specific habitat preferences. This is because of the relatively low degree of change downstream of the River Wye confluence.

Predicted changes in the Derwent from Wye to Amber waterbody were small and the glide habitat primarily suited to less flow sensitive species and lifestages. Consequently, impacts on all species and life stages are considered to be minimal in magnitude for all months, leading to a **Negligible** impact significance. Impacts associated with small changes in depths at structures and water quality were also considered to be minimal.

Predicted hydraulic changes in the two downstream waterbodies (Derwent from Amber to Bottle Brook and Derwent from Bottle Brook to Trent) were equally minimal, whilst walkover survey data indicated a smaller proportion of low-flow sensitive habitat in each waterbody. Impacts on all species and life stages are therefore also considered to be **Negligible** in magnitude for all months, leading to a **Negligible** impact significance. Impacts associated with small changes in depths at structures and water quality were also considered to be **Negligible**.

## 5.7 River Users - Amenity and Leisure

Based on the magnitude of hydraulic change, particularly predicted water level changes, DP impacts on informal recreation, aesthetics, landscape and amenity are considered unlikely at any site with the possible exception of some visual changes at Yorkshire Bridge, where the largest hydrological changes are predicted to occur as a consequence of the proposed Derwent Valley Reservoirs DP. The river is visible from footpaths above the river at Yorkshire Bridge.

Angling clubs and fishery interests have previously expressed concern regarding the current flow regime on the Derwent and 'lack of flow' (previous DP EAR (ESI & APEM, 2012)). That report further noted that damage to fishing quality or habitat could potentially result in claims for loss of amenity or similar (EA Fisheries Officer, pers. comm. June 2011). However, this concern has been primarily expressed with regard to baseline operation and not DP operation. Predicted impacts of the DP on fish, even those species considered to be most sensitive to changes in flow, are modest, as are effects on habitat which support longer term population performance. These include, but have not been limited to, riffles which are seasonally important as they perform spawning and nursery functions for a range of species, including brown trout. Based on predictions that all adult lifestages of species considered to be of angling interest are unlikely to be subject to any more than **Minor** negative impacts, detectable impacts on angling performance are considered unlikely.

The character of river at the Chatsworth estate is strongly influenced by weirs. Conceivably, lower flows may be noticeable on the downward faces of the weirs, but changes are predicted to be imperceptible on the ponded flow upstream. The same is true at historical mills at Bamford and Calver. Effects are even less likely at the remainder of historical mills in the Derwent Valley Mills, as proportional flow reductions are much smaller downstream of the River Wye confluence. Whilst the river is an integral part of the Derwent Valley Mills World Heritage Site and contributes to views of the Chatsworth Estate, it is not central to the amenity use of either. Effects on visitor's enjoyment of the sites during DP operation are likely to be slight – low flows might even amount to a curiosity. Effects would not last longer than DP induced reductions in flows.

## 5.8 River Users - Protected Rights

The protected rights assessment has focussed upon third party water users.

The Fallinge Edge abstraction at Rowsley has a HOF on the River Trent at North Muskham and the slight differences in the flow time series between DP scenarios are generally below the HOF. The impact of the Derwent Valley Reservoirs DP on this abstraction is considered **Negligible**.

The abstraction at Masson Mill is a large abstraction that may be affected by water availability. Although the reduction may be small relative to the large flow contribution of the River Wye, the Derwent Valley Reservoirs DP does reduce the water available for abstraction at the lowest flows. However, it is not known how the abstraction infrastructure is affected. The loss of water during low flows may also be compensated for by an increase in water available subsequently, in the form of larger spills. Taking a precautionary approach, it is considered that a Derwent Valley Reservoirs DP would have a small negative effect, but the degree of impact on the water use is uncertain without confirmation of how the abstraction is operated.

Flows in the Derwent for Amber to Bottle Brook and Bottle Brook to Trent waterbodies are likely to be sustained by releases from Carsington or Ogston, such that the flow at Derby St Mary's Bridge remains at or above 340 Ml/d. Thus, impacts of a Derwent Valley Reservoirs DP are expected to be **Negligible** in these waterbodies.

Flow changes from the Derwent Reservoirs DP are very small downstream of the River Wye confluence. At the lowest flows, when flows at Derby St Mary's Bridge might otherwise fall below 340 Ml/d, the changes would also be compensated in part by increased releases from Carsington or Ogston in the lower reaches. Therefore, implementation of a Derwent Valley Reservoirs DP is considered to have a **Negligible** effect on any decision to implement this constraint.

## 5.9 Designated Sites Assessment

Reference to site characterisations (e.g. citations) for all relevant designated sites (Section 4.9) suggests that most designated sites are not (to a large extent) water dependent i.e. there is no pathway via which changes in river flow/character may affect the designated features. In these instances, the designated sites were discounted from further consideration.

The Masson Hill SSSI is water dependent, designated on account of a series of caverns and solution caves. The scale of predicted DP related hydraulic change (e.g. Section 5.3) is not deemed sufficient to affect groundwater in any respect and potential effects on the Masson Hill SSSI are discounted as a result.

The Cromford Canal is a surface water dependent site. However, the designated features are not dependent on the River Derwent for water supply. Under normal operation it is not hydraulically connected to the River Derwent. The Leawood Pumphouse, which is maintained for heritage purposes, can still lift water from the Derwent into Cromford Canal, however, is only run periodically for heritage steam purposes. The Cromford Canal was scoped out of further consideration.

Review of the following designated sites found them to be (at least in part) water dependent and therefore further consideration is made below:

- River Derwent at Hathersage SSSI;
- Peak District Dales SAC;
- Derwent Valley Mills World Heritage Site;
- Ogston Reservoir SSSI.

### 5.9.1 River Derwent at Hathersage SSSI

The River Derwent at Hathersage (SK 2082 to SK 2280) is designated a geological Site of Special Scientific Interest (SSSI), designated as a typical example of downstream channel adjustment to headwater impoundment, discharge regulation and sediment load reduction. As a typical example, the site is not unique in terms of its response to impoundment. However, the number of other SSSI's designated for this reason is unknown. It may be few, if any, meaning this site may be unique with respect to its designation.

The description of the notification cites the formation of a compound channel cross section of largely depositional origin bounded by marked breaks in slope, which has developed within the main channel downstream of the River Noe. At the time of notification (1992), the minimum age of the feature is estimated to be 51 years. The Geological SSSI "River Derwent at Hathersage" most recent classification (magic.gov.uk, accessed 2018) describes the feature as being in Favourable Condition.

Aggradation is a common response to impoundment in UK rivers and results from a change in the balance of flows capable of transporting sediment, and sediment supply (Gilvear, 2004). Both are affected by reservoir construction; the flow regime generally becomes less variable. The presence of the depositional bench feature downstream of the confluence with the Noe implies that the introduction of sediment by the tributary into the regulated main River Derwent may be the significant factor controlling the formation of this channel feature. A reduction in flow volume is predicted at this location under a Derwent Valley Reservoirs DP scenario, however this is unlikely to affect sediment transport processes associated with the SSSI, which will be dominated by higher flows with sufficient energy to support bed transport for example. The character of higher flows will be maintained e.g. the character of spate flows is unchanged under DP conditions relative to baseline conditions. Given the compound channel nature, there is also some potential for loss of water depth at this location. However, this would be temporary and is not predicted to affect SSSI site characteristics. It is therefore considered that implementation of the DP would have a **Negligible** magnitude of effect and a **Negligible** impact significance on the River Derwent at Hathersage SSSI.

### 5.9.2 Peak District Dales SAC

A critical review of the relevant habitats and species associated with the Peak District Dales SAC in the context of the predicted hydrological, hydraulic and water quality pathways represents a screening against Habitats Regulations Assessment (HRA) considerations, specifically the potential for Likely Significant Effects (LSE). A review of the SAC characteristics combined with consideration of the pathways assessment results and professional judgement have allowed the requirement for a specific Habitats Regulation Assessment (HRA) to be determined.

The Peak District Dales SAC is a collective designation covering several composite geographical areas. The habitat features of European importance that are a primary reason for designation of this site (JNCC, 2018) are two Annex I habitats:

- Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*); and
- Tilio-Acerion forests of slopes, screes and ravines.

The Peak District Dales represents one of the most extensive surviving areas in England of *Festuca ovina – Avenula pratensis* grassland (JNCC, 2018). Grasslands at this site range from hard-grazed short turf through to tall herb-rich vegetation, with transitions through to calcareous scrub and Tilio-Acerion forests – a diversity of structural types unparalleled in the UK. There is also a great deal of physical diversity due to rock outcrops, cliffs, screes and a variety of slope gradients and aspects.

The Peak District Dales SAC contains a large area of *Tilio-Acerion*, dominated by ash *Fraxinus excelsior*. This represents the north-central part of its UK range. Locally, sycamore *Acer pseudoplatanus* is abundant. The Dales provide good examples of woodland-scrub-grassland transitions, with associated rich invertebrate populations and plant communities.

Further Annex I habitats are present (as qualifying features) but are not primary reasons for designation:

- European dry heaths;
- Calaminarian grasslands of the *Violetalia calaminariae*;
- Alkaline fens;
- Calcareous and calcshist screes of the montane to alpine levels (*Thlaspietea rotundifolii*); and
- Calcareous rocky slopes with chasmophytic vegetation.

Review of the general site characteristics shows that there is a very small proportion of the total site area (2336.91 ha) associated with water or strongly water dependent habitats of any description:

- Dry grassland, Steppes (43.7%)
- Broad-leaved deciduous woodland (37.1%)
- Humid grassland, Mesophile grassland (13%)
- Heath, Scrub, Maquis and Garrigue, Phygrana (4%)
- Inland rocks, Screes, Sands, Permanent Snow and ice (1.8%)
- Inland water bodies (Standing water, Running water) (0.3%)
- Bogs, Marshes, Water fringed vegetation, Fens (0.1%)

Of these, groundwater is more important than surface water. Review of DEFRA's magic.gov.uk (magic.gov, 2018) website confirms that none of the Peak District Dales SAC primary designating or qualifying habitat features are directly related to or dependent on the main channel of the River Derwent. A small portion of the overall site area relates to riparian woodland on the left bank near Matlock Bath.

JNCC (2016) documents the likely 'pressures' on the Peak District Dales SAC, i.e.:

- Biocenotic evolution, succession (K02),
- Grazing (A04),
- Pollution to groundwater (point sources and diffuse sources) (H02),
- Fertilisation (A08), and
- Human induced changes in hydraulic conditions (J02).

Of these likely pressures only 'J02' is of relevance to the DP, although given the habitat characteristics and locations, it is considered likely that changes in local groundwater conditions are of primary concern, rather than hydraulic conditions within river channels (including the River Derwent). In the riparian zone, head (depth) changes in the channel of the River Derwent may affect local groundwater levels in floodplain gravels. However, at Matlock Bath (and other Assessment Points) the magnitude of depth changes in the main channel is small under the Derwent Valley Reservoirs DP scenario.

Further to the habitats of European importance, the White-clawed (or Atlantic stream) crayfish (*Austropotamobius pallipes)* is listed as a primary reason for selection of this site. JNCC (2018) confirm that this population occurs within the River Dove specifically. The River Dove discharges to the River Trent and therefore flow and hydraulic parameters in the River Dove would not be influenced by the proposed Derwent Valley Reservoirs DP.

Further Annex II species are present (as qualifying features) but are not primary reasons for SAC designation:

- Brook lamprey *Lampetra planeri*
- Bullhead *Cottus gobio*

These fish species are considered specifically within the Fish assessment. Given that the detailed fish assessment concludes no significant adverse impact upon the qualifying Annex II fish species, it is concluded that there will be no LSE associated with the Derwent Valley Reservoirs DP on the Peak District Dales SAC.

Adopting this assumption therefore, no adverse effect on integrity (AEoI) of the Peak District Dales SAC is concluded and an HRA report is not required.

The changes in flow proposed by DP operation at the Derwent Valley Reservoirs are insignificant relative to flows into the Humber estuary, which is also designated as a SAC.

### 5.9.3 Derwent Valley Mills World Heritage Site

An assessment of potential effects on the Derwent Valley Mills World Heritage Site has been undertaken as part of the Amenity and Leisure assessment. Whilst the river is an integral part of the Derwent Valley Mills World Heritage Site, it is not central to the amenity use of the site (Section 5.7). Any hydraulic change associated with the Derwent Valley Reservoirs DP relative to a baseline drought scenario would therefore have no effect on the integrity or practical conservation of the World Heritage Site.

### 5.9.4 Ogston Reservoir SSSI

Ogston Reservoir is located in the River Amber catchment but is augmented by abstractions from the River Derwent at Ambergate and Carsington Reservoir. Under the Derwent Valley Reservoirs DP scenario, there tends to be a little more drawdown in Ogston reservoir relative to the baseline no DP scenario. The reservoir margins support a mosaic of semi-natural habitats e.g. scrub and herb communities that are utilised by breeding birds, and therefore reservoir level change has the potential to adversely affect designated features.

However, consideration of the scale of this predicted change (Section 5.1) finds that reservoir level change during DP operation relative to baseline is typically small, particularly in relation to inter-annual and inter-seasonal changes under baseline operation. As such, it is considered that the baseline vegetation communities will be resilient to routine and extensive water level fluctuation, in a way that may not necessarily be the norm for marginal communities associated with a more 'natural' standing open water. The variation in reservoir level associated with Ogston reservoir under a baseline scenario, has been found to be greater than 4.5 m for the 1959-60 modelled stochastic drought (Figure 5.1). It is therefore considered that implementation of the DP would have a **Negligible** magnitude of effect and a **Negligible** impact significance on the Ogston Reservoir SSSI.

## 5.10 Invasive Non-Native Species

As the proposed Derwent Valley Reservoirs DP will not transfer new water into the catchment, it will not result in new species being introduced. The Ambergate abstraction transfers water to the River Dove catchment at Carsington, which may be released back into the Derwent. However, this transmission route is already present, and the Dove and Derwent are both tributaries of the River Trent and consequently INNS will be present throughout the Trent catchment.

The six documented 'High impact' INNS species in the River Derwent waterbodies are known to be invasive and have caused documented harm in habitats where they have become established. These are considered in relation to potential impact mechanisms below.

### 5.10.1 Reduction in wetted perimeter

Signal crayfish are already present throughout much of the Derwent catchment and it is considered unlikely that implementation of the Derwent valley Reservoirs DP/DO would enhance the spread of this species. A reduction in wetted perimeter would be a (albeit small) negative pressure on signal crayfish as burrows would potentially become exposed and predation on this species (from predators such as otter and mink) may increase.

Himalayan balsam and Japanese knotweed benefit from disturbance to the bankside habitat. Himalayan balsam, for example, forms thick stands that shade other plant species, and thus suppress understory growth, leading to potential riverbank erosion once Himalayan balsam dies back. Erosion can have subsequent impacts to water quality and in-stream ecology. A reduction in the wetted perimeter would expose potential riparian areas for colonisation from these invasive riparian plants.

Die back of large Himalayan balsam stands in winter may also lead to deoxygenation if large volumes of vegetation enter pools or slow-flowing sections. The predicted scale of change to wetted perimeter throughout the majority of the Derwent (see Section 5.3) is very slight, with the exception of in the uppermost reach (Yorkshire Bridge to Bamford Mills Weir) immediately downstream of the compensation release. The predicted changes associated with the potential Derwent Valley Reservoirs DP (on all water bodies other than the Derwent from Westend to Wye) are also expected to be minimal. Adopting a precautionary approach, given some predicted change in the wetted perimeter in the river immediately downstream of the reservoir release, the proposed Derwent Valley Reservoirs DP may have a low negative magnitude of effect within the Derwent from Westend to Wye, facilitating the temporary spread or establishment of these species. However, this impact is likely to only persist until water levels rise again and reverse their expansion, as neither of these riparian macrophyte species is aquatic (i.e. moderate negative strength of effect; short term; localised; high sensitivity across the year). An associated impact significance of **Mino**r adverse is predicted.

### 5.10.2 Velocity reduction

The distribution of signal crayfish is unlikely to be affected by a reduction of flow as this species is likely spread throughout the Derwent catchment. High impact aquatic plant species present on the Derwent (Water Fern, Canadian pondweed and Nuttalls pondweed) could be positively affected by a reduction in flow as all three species are more commonly found in ponds, lakes, canals, ditches and slow flowing rivers. A reduction in flow during the macrophyte growing season (May to September) would likely increase the proportion of slow flowing habitats available for colonisation. The greatest change in flows (Section 5.3) have been predicted to be associated with the most upstream waterbody under the Derwent Valley Reservoirs DP (strength of potential effects on INNS in this reach are already classified as **Minor** negative on account of wetted perimeter change). Although, once normal flows resume the proportion of cover of these invasive plants will reduce as expansion is reversed.

Some INNS may be negatively affected by a loss of high discharge events however, which may be marginally increased as the DP is intended to aid reservoir refill. However, this is expected to be a minimal effect. Conversely, a reduction in flow attributable to the proposed DP during a naturally occurring drought could facilitate establishment along the river edges and increased density of INNS that may be present locally. Decreased velocity can aid in the expansion of Canadian and Nuttalls pondweed as both species prefer static or slow flowing habitats. The hydraulic model does not indicate a substantial change to the shear stress and therefore velocity that the river will endure therefore, the impact should be minimal. The high impact riparian plant species considered here have already been recorded in the River Derwent, and any potential decrease in the wetted area under the proposed DP (Estimated at 5% within the mean hydraulic model within Section 5.3) may encourage the additional establishment of Japanese knotweed and particularly Himalayan Balsam if there are source propagules from upstream. This is more likely with Himalayan balsam particularly during peak seed production, as seeds can be released by the plant and float downstream. The reduction in wetted width may allow increased growth of Japanese knotweed from the rhizomes as the water recedes. Both species however prefer riparian rather than fully aquatic habitat and once flow returns to normal the expansion of these species can be reversed. To note here that any establishment of INNS during these scenarios be it plants, or seeds will then have the potential to be washed further downstream once normal flows return, resulting in higher propagule pressure downstream this does depend on DP implementation timing and INNS biology. Resumption of normal flows will then return the risk to back to normal conditions.

### 5.10.3 INNS Summary

Established populations of high impact INNS are already found within the catchments and therefore, it is unlikely that the DP will represent a high risk of spread beyond what would be natural for the river both in and out of drought. This would be despite the high sensitivity of the receptors and downstream habitats.

The predicted impact significance associated with the potential Derwent Valley Reservoirs DP implementation is summarised in Section 7. Adopting a precautionary assessment approach throughout, the only predicted significance of greater than **Negligible** is associated with the Derwent from Westend to Wye water body under the potential Derwent Valley Reservoirs DP, where a **Minor** adverse impact is predicted.

From the perspective of WFD classification, the presence of high impact species would only influence those waterbodies currently classed as High under WFD (Defra 2015). The baseline presence of high impact species and current WFD potential at less than High means that there will be no predicted effects on WFD status associated with INNS considerations.

# 6 Assessment changes compared to previous EAR

The previous DP EAR (ESI & APEM, 2012) identified the following potential significant impacts (greater than **Minor**) that differ from this version.

The 2012 DP EAR considered there would be the following potential impacts in the River Derwent (Westend to River Wye), should DP operation be implemented at the Derwent Valley Reservoirs:

- **Major** impacts upon bullhead spawning (March and April only) and egg incubation (March to May only); **Moderate** impacts on brown trout parr (all year) and egg incubation (February to May only); **Moderate** impacts on brook lamprey spawning (March and April only) and egg incubation (March to May) and **Moderate** impacts on amenity and leisure use (June to August).

The previous DP EAR (ESI & APEM, 2012) also considered there would be the following potential impacts in the River Derwent (Wye to Amber), should DP operation be implemented at the Derwent Valley Reservoirs at any time of year:

- **Moderate** impacts on brook lamprey spawning (March and April only) and egg incubation (March to May) and **Moderate** impacts on amenity and leisure use (June to August).

Finally, the previous DP EAR (ESI & APEM, 2012) also considered there would be the following potential impacts in the River Derwent (Amber to Bottle Brook) and River Derwent (Bottle Brook to Trent), should DP operation be implemented at the Derwent Valley Reservoirs at any time of year:

- **Moderate** impacts on amenity and leisure use (June to August).

The assessment of the magnitude of change to pathway variables such as physical habitat and wetted perimeter remain broadly the same and this report generally supports the conclusions of the 2012 DP EAR in suggesting only small changes. A different view of the likely impact of pathway changes on fish and amenity has been formed in this report, following additional consideration of the likely magnitude of these effects on ecological receptors in the intervening period. This has changed the classification of the likely effects from **Major/ Moderate** to **Minor** for some fish species and for amenity. The current assessment, which has been improved and updated using data and learnings from recent years, supersedes our 2012 assessment.

# 7 Summary

A summary of predicted pathway changes and potential effects on ecological receptors associated with proposed DP operation are provided in this section.

Impacts of DP operation are assessed against a baseline of current operation, which has existing effects on the flow regime of the River Derwent. Any predicted DP impacts also take place in the context of a catchment otherwise affected by water quality and hydromorphological changes from point source and diffuse pollution, and a number of channel modifications, including structures within the river channel.

## 7.1 The Derwent Valley Reservoirs DP

A Derwent Valley Reservoirs DP is predicted to have a **small beneficial** effect on reservoir levels in the upper Derwent Reservoirs (principally at Howden Reservoir) and a **small negative** effect on levels in Ogston and Carsington Reservoirs. This is because the reduced compensation release from Ladybower Reservoir causes a slight reduction in flows at Derby St Mary's Bridge, which is maintained (within Aquator™) by a slightly higher release from Carsington.

Because the operation of the reservoirs tends to maintain water at Howden, the uppermost reservoir in the Derwent Valley Reservoirs cascade, rather than in Ladybower (Section 5.1), effects on spills (and consequently to spates and to flow variability) in the River Derwent downstream are predicted to be **Negligible**. Howden storage is most noticeably improved because water is purposely kept in the higher reservoirs so that spills are retained within the reservoir system and not lost to the river. Effects on spills at Ogston Reservoir are also predicted to be **Negligible** because Ogston is not run full so will only spill if intended, and not during low flow periods.

River discharge within the River Derwent from Westend to Wye waterbody is predicted to be reduced under the Derwent Valley Reservoirs DP relative to baseline, which is assessed as a **Moderate Negative** change. However, flows would remain above those that would naturally occur during a severe drought.

The reduction in river discharge in the River Derwent from Westend to Wye waterbody will reduce the river's capacity to dilute pollutant inputs but this effect is predicted to result in only **Small Negative** changes to ammonia and phosphate concentrations. Other changes to water quality parameters are considered likely to be **Negligible** or of **Small Benefit** (due to reduced loads from the reservoir compensation).

Reductions in depth and velocity in the River Derwent from Westend to Wye waterbody are predicted to cause **Small Negative** changes to the size of wetted habitat (wetted width and perimeter) and to the character of flow.

Downstream of the confluence with the River Wye, tributary inflows – principally from the River Wye itself, are predicted to be sufficient to render flow changes in the River Derwent Wye to Amber, River Derwent Amber to Bottle Brook and River Derwent Bottle Brook to Trent waterbodies **Negligible**. Consequent predicted effects on water quality and physical habitat are likewise predicted to be **Negligible**.

As a consequence of the generally modest predicted changes to impact pathways, there are no significant (i.e., moderate significance or greater) impacts predicted to affect ecological receptors or other water user receptors (summary tables provided below). On account of predicted flow and habitat change being greatest within the upper catchment (largely associated with the River Derwent from Westend to Wye catchment) the most extensive predicted impacts are expected there. Predicted reductions in wetted perimeter and consequent effects on marginal channel areas are predicted to result in potential small adverse effects on the juvenile young of year fish (salmonid and coarse fish species). Table 7.2 summarises **Minor** adverse effects for these species which utilise this habitat generally between March and August. Fish migration is not predicted to be affected by the proposed Derwent Valley Reservoirs DP, with all associated effects of **Negligible** significance.

During previous DP operation in 1996, only modest and quite short-lived effects on macroinvertebrate communities were observed and these may be attributable to the effects of a multi-year (1995-96) drought rather than DP operation *per se*. The diverse nature of available macroinvertebrate mesohabitat is not expected to change and therefore resistance of the macroinvertebrate community is expected to be high. Across river types, macroinvertebrate communities are also typically resilient to single-season low flow periods, recovering rapidly from any negative impacts of low flows. The predicted effect of the Derwent Valley Reservoirs DP on macroinvertebrates within the Derwent from Westend to Wye water body is determined to be **Minor** adverse across the calendar year, with any effects further downstream of **Negligible** significance.

INNS may be affected by the predicted changes in river flows and associated low water levels. While 'high impact' INNS species are categorised as high sensitivity receptors, the presence of established populations in the River Derwent impacts means that this sensitivity rating is precautionary. The only predicted significance of greater than negligible with regards INNS is associated with the Derwent from Westend to Wye water body, where a **Minor** adverse impact is predicted.

The Derwent Valley Reservoirs DP is predicted to have very little effect on Protected Rights throughout the catchment. A seasonal distinction has been identified with the winter and spring period determined as least sensitive to potential effects, resulting in a **Negligible** potential impact significance at all locations. During the summer, and also adopting a precautionary approach during the autumn, a **Minor** potential effect is predicted on the Masson Mill abstraction (Derwent from Wye to Amber water body).

Predicted effects associated with the Derwent Valley Reservoirs DP on amenity and leisure receptors and on designated sites have been predicted to be **Negligible** at all locations (at all times).

Downstream of the confluence with the River Amber the small scale of predicted pathways changes have resulted in potential effects, on all receptor types, being determined as of **Negligible** significance (Table 7.4 and Table 7.5).

**Table 7.1 Pathways assessment results at greater than negligible scale of change**

| | | Derwent Valley Reservoirs DP | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Month** | **J** | **F** | **M** | **A** | **M** | **J** | **J** | **A** | **S** | **O** | **N** | **D** |
| **Derwent from Westend to Wye water body** | Hydrology pathway – Low flows | M | M | M | M | M | M | M | M | M | M | M | M |
| | Hydraulic pathway – Size of wetted habitat | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- |
| | Hydraulic pathway – Character | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- |
| | Water quality pathway – Ammonia | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- |
| | Water quality pathway – Phosphate | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- | S- |
| | Water quality pathway – BOD | S+ | S+ | S+ | S+ | S+ | S+ | S+ | S+ | S+ | S+ | S+ | S+ |
| | Water quality pathway – Nitrate | S+ | S+ | S+ | S+ | S+ | S+ | S+ | S+ | S+ | S+ | S+ | S+ |
| | NB: all other locations and pathways assessments: | N | N | N | N | N | N | N | N | N | N | N | N |

**Key to Pathways scale of change:**

| | |
|---|---|
| M | Medium negative scale of change |
| S- | Small negative scale of change |
| S+ | Small positive scale of change |
| N | Negligible scale of change |

Note, full table provided as Appendix I.

### Table 7.2 Pre-mitigation impacts, Derwent Valley Reservoirs DP (Westend to Wye)

| | Derwent Valley Reservoirs DP | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **J** | **F** | **M** | **A** | **M** | **J** | **J** | **A** | **S** | **O** | **N** | **D** |
| **Brown Trout populations** | N | N | Min- | Min- | Min- | Min- | Min- | Min- | N | N | N | N |
| **Bullhead populations** | N | N | N | Min- | Min- | Min- | Min- | N | N | N | N | N |
| **Rheophilic coarse fish populations** | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| **Eurytopic coarse fish populations** | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| **Minor coarse fish populations** | N | N | N | Min- | Min- | Min- | Min- | Min- | Min- | N | N | N |
| **Brook lamprey populations** | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- |
| **Fish migration** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Macroinvertebrates** | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- |
| **Amenity and Leisure** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Protected Rights** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Designated sites** | N | N | N | N | N | N | N | N | N | N | N | N |
| **INNS** | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- | Min- |

**Key to Environmental Effects:**

| | |
|---|---|
| N | Negligible impacts |
| Min- | Minor negative impacts |
| Mod- | Moderate negative impacts |
| Maj- | Major negative impacts |
| Pot | Potential beneficial impacts |
| N/A | Not applicable |

### Table 7.3 Pre-mitigation impacts of Derwent Valley Reservoirs DP (Wye to Amber)

| | Derwent Valley Reservoirs DP | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **J** | **F** | **M** | **A** | **M** | **J** | **J** | **A** | **S** | **O** | **N** | **D** |
| **Brown Trout populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Bullhead populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Rheophilic coarse fish populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Eurytopic coarse fish populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Minor coarse fish populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Brook lamprey populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Fish migration** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Macroinvertebrates** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Amenity and Leisure** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Protected Rights** | N | N | N | N | N | Min- | Min- | Min- | Min- | Min- | Min- | N |
| **Designated sites** | N | N | N | N | N | N | N | N | N | N | N | N |
| **INNS** | N | N | N | N | N | N | N | N | N | N | N | N |

**Key to Environmental Effects: (see Table 7.2 key above)**

### Table 7.4 Pre-mitigation impacts of Derwent Valley Reservoirs DP (Amber to Bottle Brook)

| | Derwent Valley Reservoirs DP | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **J** | **F** | **M** | **A** | **M** | **J** | **J** | **A** | **S** | **O** | **N** | **D** |
| **Atlantic salmon populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Brown Trout populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Bullhead populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Rheophilic coarse fish populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Eurytopic coarse fish populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Minor coarse fish populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Fish migration** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Macroinvertebrates** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Amenity and Leisure** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Protected Rights** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Designated sites** | N | N | N | N | N | N | N | N | N | N | N | N |
| **INNS** | N | N | N | N | N | N | N | N | N | N | N | N |

**Key to Environmental Effects: (see Table 7.2 key above)**

**Table 7.5 Pre-mitigation impacts of Derwent Valley Reservoirs DP (Bottle Brook to Trent)**

| | Derwent Valley Reservoirs DP | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **J** | **F** | **M** | **A** | **M** | **J** | **J** | **A** | **S** | **O** | **N** | **D** |
| **Atlantic salmon populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Brown Trout populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Bullhead populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Rheophilic coarse fish populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Eurytopic coarse fish populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Minor coarse fish populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **European eel populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Brook lamprey populations** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Fish migration** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Macroinvertebrates** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Amenity and Leisure** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Protected Rights – local receptors** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Protected Rights – regional receptors** | N | N | N | N | N | N | N | N | N | N | N | N |
| **Designated sites** | N | N | N | N | N | N | N | N | N | N | N | N |
| **INNS** | N | N | N | N | N | N | N | N | N | N | N | N |

**Key to Environmental Effects: (see Table 7.2 key above)**

# 8 Mitigation measures

## 8.1 Introduction

Mitigation measures are proposed to avoid, reduce or remedy those impacts which are considered likely to occur and sufficiently significant to warrant them, or where there is particular uncertainty about an impact. Mitigation measures are proposed to cover eventualities that may occur during DP operation and may not be required in every period of DP operation. Note also that mitigation measures are proposed to reduce the impact of DP operation and not the impacts of the drought itself.

There are no impacts associated with the Derwent Valley Reservoirs DP that are predicted to be of Moderate significance or greater, even prior to mitigation. If present, these would necessitate compulsory mitigation. However, implementation of monitoring or mitigation measures may also be appropriate where there are elements of the assessment that are uncertain. In particular, although integrated modelling has increased confidence in predictions of hydraulic change, effects of reduced flows on physical habitat in the River Derwent (Westend to River Wye) have (necessarily) been estimated by extrapolation. Mitigation options have therefore been considered below to cater for the possibility that within drought monitoring shows habitat loss to be greater than anticipated.

## 8.2 Mitigation using the compensation flow release

Should monitoring during a DP indicate significant impacts to ecological receptors or other river users, potential mitigation measures that use the Ladybower compensation flow release include:

- Implementing reductions to the compensation flow in phases. The phasing of flow changes would be determined by infrastructure constraints and reservoir levels but might aim, for example, for reductions of approximately of 5 Ml/d per phase over six hours;
- Discharge of a freshet release from the reservoir to assist fish movement or in the event of a pollution incident downstream of Ladybower, if the EA deemed such action appropriate;
- Return to statutory compensation flow, or temporary elevation of discharge in the event of a pollution incident, evidence of ecological distress, or evidence of serious detrimental environmental consequences on downstream watercourses;
- Use of best endeavours where possible to manage storage within the Derwent Valley Reservoirs to ensure that compensation flows from Ladybower do not rely upon water drawn from the bottom levels of the reservoir, should water quality data suggest a problem;
- Discharge of a freshet release from the reservoir should particular events be considered to be potentially impacting internationally important sites.

## 8.3 Additional measures to mitigate environmental impacts during DP Implementation

A number of additional mitigation measures could be implemented should monitoring during a DP indicate that significant impacts to ecological receptors, or other river users, are occurring. It may not be necessary to implement all these mitigation measures in order to reduce the observed impacts. Any such implementation of mitigation measures would be undertaken in consultation with the EA:

- If fish are observed to be trapped, or in distress, during the proposed DP a number of measures could be taken. The decision on which method to deploy should be taken in discussion with the Environment Agency, and according to the specific nature of the problem. Options may include:
  - Temporary or partial reinstatement of compensation flows, if not deemed too high a risk to drinking water supply;
  - Deployment of localised aeration;

  - Installation of fish refugia in spatially limited areas;
  - Fish rescue and relocation may also be used, as a spatially limited option, but is considered least preferable by the Environment Agency, to be deployed if no other suitable alternative is available.
- Funding of appropriate reasonable measures (e.g. habitat restoration) could be made in mitigation of ecological damage occurring in reaches affected by reduced compensation flows in the longer term.

# 9 Environmental monitoring plan

Monitoring before, during or after DP implementation is proposed to ensure an absence of significant impacts where the predicted impacts of DP EAR assessment are not sufficiently certain to discount them. It should be acknowledged, however, that monitoring cannot remove all uncertainties. This is because many of the constraints of environmental datasets are inherent in the limitations of sampling or survey protocols; for example inherent variability of fish survey data, or the need to use representative reaches or sampling locations to inform a more general prediction of likely response over the River Derwent as a whole.

The following outline proposal for DP monitoring has been prepared in support of STWL's Drought Plan (STWL, 2022) and meets the requirements of the Environment Agency's Water Company Drought Plan Guidelines (EA, 2017) and in most respects is consistent with draft guidance (2019), at consultation stage at the time this text was written[22]. The monitoring plan presented here is informed by the level of risk to individual receptors as predicted in this report and by existing monitoring programmes as recommended by drought guidance (EA, 2017).

## 9.1 Proposed Baseline Monitoring Plan

Baseline monitoring provides an understanding of the pathways and receptors in the Derwent Valley under normal operation of STWL's water resource system. From this baseline, any impacts of DP operations over and above the effects of other pressures, including natural drought, can be identified. A baseline drought monitoring programme for the River Derwent commenced in 2011 in support of the previous DP EAR (ESI & APEM, 2012). This programme has been reviewed on an annual basis and targeted catchment data have been collected each year to complement ongoing Environment Agency surveillance monitoring. The Derwent catchment therefore benefits from long running and extensive historical datasets for most parameters of relevance to this EAR.

Future baseline monitoring will be targeted at improving understanding where uncertainties remain and given the previous investment in baseline data collection, there is therefore little routine baseline monitoring proposed. Rather, further baseline monitoring is proposed either to capture the response of key pathways and receptors to natural low flow events that are not often repeated, or to capture any significant changes in the catchment (such as improved passability at structures). Significant changes are those that may render the current baseline characterisation of the catchment out of date and mean that significant pre- or post-mitigation risks of drought permit operation may no longer be discounted on the basis of existing data.

Currently it is proposed that the existing Environmental Monitoring Plan (EMP) sites will continue to focus on the 13 riverine locations currently utilised (and as originally selected by the EA and STWL). Monitoring will thus continue to capitalise upon historic/existing EA monitoring sites. The current sites include the existing EA sites at Yorkshire Bridge (AP1), Hathersage, Leadmill Bridge (AP2), Baslow Devonshire Bridge (AP3), Matlock Bath (for invertebrates, Cromford for fish) (AP4), Whatstandwell (AP5), Belper (AP6), Duffield (fish only), Allestree Ford (AP7), St Mary's Bridge (invertebrates only) (AP8) and Raynesway (fish only).

Ongoing monitoring will continue to adapt in the light of new demands and as the EA continues to evolve its survey network. Any such evolutions will be agreed with the EA through preparation of an annual Site Investigation Plan (SIP), with subsequent annual reporting of data collected. The SIP and annual report will set out the rationale for any monitoring changes and the detail of site locations, parameters measured and analyses to be undertaken on the data once collected.

[22] An exception to this is the recommendation for control sites. A suitable control to the River Derwent could not be identified.

The earlier sections of this report concluded that a Derwent Valley Reservoirs DP could not entirely discount adverse impacts on fish populations in the River Derwent from Westend to River Wye. Impacts of a Derwent Valley Reservoirs DP on those water bodies further downstream can be largely discounted given the relatively small effect (which is in all cases insignificant) on these water bodies.

Proposed baseline monitoring, and associated rationale, is given in the following sections.

### 9.1.1 Hydrology and hydromorphology

Flow accretion is considered sufficiently well understood not to require further gauging, with the exception that:

- Flows in potentially impacted reaches of the River Derwent should be gauged if flows fall substantially below those that have been gauged to date. However, note that flows substantially lower than those already captured in the River Derwent from Westend to Wye are unlikely under baseline conditions, because of the Ladybower compensation release.
- Inflows simulated by Hysim (WRA, 2018) should be checked against recent low flows to ensure they are representative of accretion under drought conditions. This might include inputs from the limestone catchment to the River Noe, which are not represented separately by current scaling methods. Note, however, that this is not a concern for the current analysis and by assigning this accretion to the reach between Hathersage Leadmill Bridge and Baslow, the current method is conservative.

Any future gauging should be referenced to Ordnance Datum, with a surveyed cross section.

### 9.1.2 Water quality

The Environment Agency routine monitoring network for water quality continues to provide an extensive data set for the Derwent. Whilst this does not provide continuous data or allow insight into diurnal variations in temperature or dissolved oxygen, the data that are available do not indicate that there is a significant risk from a Derwent Valley Reservoirs DP. As such, only limited further baseline monitoring is proposed:

- In hot, dry periods, monthly monitoring (of routine *in-situ* water quality parameters i.e. water temperature, DO, pH and conductivity) should be undertaken on the same day (across the catchment) during periods of stable flow with monitoring upstream of the Derwent Valley Reservoirs (control), Yorkshire Bridge (AP1), Hathersage Leadmill Bridge (AP2), Grindleford, Baslow Bridge (AP3) and Rowsley. STWL (and potentially the Environment Agency) will trigger this additional baseline monitoring during routine catchment management reviews or as part of drought preparedness (noting that DP implementation would generally take place after a prolonged period of planning).
- Water temperature, DO, pH and conductivity should continue to be measured using a multi-parameter probe during seasonal survey visits for macroinvertebrates (throughout the catchment).

### 9.1.3 Macroinvertebrates

Macroinvertebrates are key indicators of low flow impacts. Continued macroinvertebrate data collection will provide warning of changes to catchment behaviour and an ongoing baseline against which to compare within DP monitoring. It may also allow modelling of flow-macroinvertebrate response as datasets extend. Ongoing macroinvertebrate monitoring can, however (in relation to the Derwent Valley Reservoirs DP), be limited to the three APs in the River Derwent from Westend to Wye water body and, for any given season, should be carried out at whichever locations EA samples are not being collected.

Summer sampling is not considered necessary, except during dry periods, during which they will improve characterisation of response during these relatively infrequent episodes. The appropriateness of summer sampling will be reviewed in consultation with the Environment Agency each year (as part of the development of the Site Investigation Plan (Section 9.4)), noting that proposed EAR Environment Agency guidance, currently at consultation (Environment Agency, 2019), suggests three season sampling.

### 9.1.4 Fish

Fish surveys were completed annually between 2010 and 2013 to achieve a continuous three-year baseline dataset, which is complemented by EA monitoring at a number of locations since. These data are described further in Appendix F. The continuous three-year baseline dataset comprised wet and dry years and given that inherent variability of these data mean that only broad comparisons can be drawn between baseline and DP operation, the data are considered sufficient for baseline purposes. As such, extension of the fish survey dataset is only considered:

- During (if appropriate) and for two years after dry years, to characterise baseline response to infrequent drought events (fish survey would not be undertaken during DP implementation, or if DP implementation is deemed likely, to avoid any unnecessary stress);
- If EA surveillance data for the River Derwent from Westend to Wye suggest baseline conditions are sufficiently changed to require renewal of the baseline (for example following establishment of access for diadromous fish).

Fish population surveys should comprise electric fishing surveys at sites in the River Derwent from Westend to Wye water body including surveys for lamprey (triple shock at sites within optimal habitat and single shock at sites within sub-optimal habitat). Lamprey surveys are intended to confirm the absence of river and brook lamprey where they have not previously been recorded. It is recommended that these surveys include the Ladybower Reservoir to Bamford Mill Weir reach within the Derwent from Westend to Wye waterbody, at which reductions in wetted perimeter are predicted. Fish surveys would be undertaken annually in September. Survey methods would be the same as EA survey methods at the same sites.

Reconnaissance surveys should also be undertaken to identify barriers to coarse fish migration. This should be undertaken prior to DP operation to ensure against unforeseen/ unacceptable reductions in connectivity for migratory coarse fish.

### 9.1.5 Protected rights

The abstraction at Masson Mill is a large abstraction that may be affected by water availability. It is unlikely that a Derwent Valley Reservoirs DP would have significant effect given very small predicted changes to water depth and the modest predicted changes to mid-range flows only. However, there remains uncertainty, without confirmation regarding how the abstraction is operated.

Further (baseline) investigation is recommended into the effects on the Masson Mill abstraction under natural drought conditions. This is best achieved through consultation with the licence holder. In particular, the effect of reduced abstraction on site operation at different flows needs to be understood, and the effect of reduced flows at the abstraction structure.

### 9.1.6 Physical habitat

Baseline in-river habitat mapping would benefit from update to capture changes in recent years. The geographic scope of future mapping could be extended (beyond AP locations in the upper river) to cover potentially sensitive locations that are identified via the proposed walkovers. Baseline monitoring would target a low flow period as appropriate.

## 9.2 During Drought Permit Monitoring

During DP monitoring provides a confirmation (or contradiction) of predicted responses to DP operation that are based on baseline data. It also allows early response should any unpredicted problems or impacts occurring as a result of the DP. Monitoring should seek to differentiate between the effects of DP implementation and those arising from drought conditions more generally.

Close contact will be maintained with local stakeholders including in-stream recreational users, particularly if it is necessary to implement a DP in the summer months at the height of the tourist season. Any unexpected or concerning results arising from the monitoring will be reported by STWL to the EA immediately, and all data collected by STWL during DP implementation will be reported to the EA after DP implementation has ended.

### 9.2.1 Monitoring for unforeseen effects

A reconnaissance will be undertaken along the River Derwent from Westend to Wye under stable flows and baseline operation 1) as a one-off baseline low-flow visit (e.g. when summer low flow conditions allow) and 2) immediately prior to implementation of the Derwent Valley Reservoirs DP. Reconnaissance surveys would then be undertaken at regular intervals during the Derwent Valley Reservoirs DP operation along the same reaches, unless impacts can be discounted. As a minimum, coverage should include AP's and the Derwent at Hathersage SSSI (and other specific locations identified during the reconnaissance e.g. high interest angling sites). Liaison with stakeholders such as the Chatsworth Estate may reduce the need for surveillance in other reaches. Flow changes downstream of the River Wye confluence are sufficiently small not to require clarification that effects can be discounted.

Should reconnaissance surveys identify signs of stress on biota or impacts upon water users, or indications of habitat deterioration or loss, weekly visits would be carried out to monitor for further signs of ecological stress and if necessary, to trigger/ determine appropriate mitigation measures.

### 9.2.2 Hydromorphology

Flow accretion during reduced compensation releases from Ladybower Reservoir has not been captured by the gaugings undertaken to date. Confirmatory gauging is recommended to improve confidence in flow and hydraulic scenarios.

A single confirmatory gauging is recommended during DP operation at all assessment points and also at the Noe confluence (to confirm accretion assumptions). It is recognised that implementation of the DP is not predicted to affect the entire reach, but a single gauging at all APs allows accretion assumptions to be verified and an opportunity to extend the baseline understanding of low flows.

Translation of predicted flow changes to changes in physical habitat suitability is based upon extrapolation to lower flows than used for model calibration, because under baseline conditions flows are maintained by the compensation flow. Even within the integrated model, predictions at cross sections are used to characterise river reaches.

Monitoring will include a spatial record (to reduce reliance upon 'representative' transects) and gauging to provide additional quantitative information.  The spatial record will include as a minimum the reaches centred upon APs 1-3 (in response to the Derwent Valley Reservoirs DP) mapped under baseline conditions and will additionally include any sensitive reaches identified during the planned reconnaissance surveys. Precision should be sufficient to confirm (or otherwise) that flow changes do not cause widespread loss of wetted perimeter or changes in physical habitat type relative to baseline conditions and will include characterisation of surface flow type and fish habitat and additionally, fixed point photography (at locations identified during reconnaissance surveys) for comparison with images taken during baseline conditions. Gaugings will be referenced to Ordnance Datum, with a surveyed cross section and will be undertaken at current APs and any further transects identified for focussed monitoring during the initial reconnaissance (if necessary).These will allow confirmation (or otherwise) of transect estimates and model calibration..

### 9.2.3 Water quality

An increased frequency of *in situ* water quality monitoring should be undertaken on implementation of DP operation. This is recommended not in direct response to predicted water quality change, but rather to provide an early indication of potential ecological stress. For the Derwent Valley Reservoirs DP, this increased frequency of *in situ* monitoring should take place at APs on the River Derwent from Westend to Wye.

The frequency of visits will be determined in consultation with the Environment Agency, as this would be influenced by the time of year (e.g., higher frequency of visits, or potentially remote logger monitoring, may be appropriate during a summer implementation). *In-situ* water quality monitoring will ideally be carried out at a similar time of day, during each visit to minimise any changes due to normal diurnal effects.

### 9.2.4 Fish migration

A fish passage assessment recorded by fixed point photography should be carried out at structures in the River Derwent from Westend to River Wye considered likely to pose an additional risk to fish migration during a Derwent Valley Reservoirs DP implementation. As a minimum, this should include Calver, to ensure operation of the fish pass during Derwent Valley Reservoirs DP operation (as predicted) but should also include any further structures identified by reconnaissance survey. In particular, assessment of passage for migratory coarse fish and confirmation of passability for salmonids during very low flows should also be undertaken at structures in Grindleford and Hathersage considered to be passable for Atlantic salmon under all flows. Initial passage assessments should be carried out during baseline low-flow periods (e.g. when summer low flow conditions allow), allowing opportunity to repeat surveys during DP implementation.

If flows associated with the Derwent Valley Reservoirs DP are sufficiently low and gaugings taken at Matlock Bath (AP4) suggest that Derwent Valley Reservoirs DP effects cannot be discounted, fish passage assessment may also be extended to Cromford, downstream of the River Wye confluence, because fish passage at this structure is considered to be flow dependent.

Assessment and fixed-point photography should be undertaken during either DP operation and low flow accretion and, if considered necessary during that assessment, also during DP operation with moderate accretion. This will help define the likely duration of any impediment to habitat connectivity. Fixed point photography should include reference points from which water levels can be accurately assessed. These may include clearly observable points on fish passage structures etc., or if necessary, require installation of gaugeboards.

### 9.2.5 Protected rights

Monitoring of water levels is recommended at abstraction structures at Rowsley, to ensure that Derwent Valley Reservoirs DP flow reductions do not affect the operation of the abstraction infrastructure. If flows are sufficiently low and gaugings taken at Matlock Bath (AP4) suggest that effects cannot be discounted, water levels may also be monitored at Masson Mill.

Where required, fixed point photography should include reference points from which water levels can be accurately assessed. These may include clearly observable points on riparian structures etc., or if necessary, require installation of a gaugeboard.

### 9.2.6 Physical habitat

Physical habitat mapping is recommended at those sites undertaken during baseline monitoring for comparison purposes. Should monitoring for unforeseen events identify noticeable hydraulic change beyond that predicted in this EAR, additional during DP habitat mapping is recommended.

## 9.3 Post Drought Permit (Recovery) Monitoring

Monitoring after the DP period will be necessary in order to assess whether the implementation of the DP has any long-term effects on any environmental features.

Following the cessation of DP operation, monitoring of receptors will continue in each of the monitoring locations/ reaches at the same frequency as employed during the baseline period. The duration of post DP monitoring of receptors will depend on the severity of the natural drought but will cover the period of recovery and will be carried out in consultation with the regulators. STWL will report the details of post-drought monitoring to the EA on a yearly basis (as per baseline drought monitoring).

Pathway variables will be monitored only to confirm the reinstatement of physical and chemical habitat to pre-drought conditions. Re-survey of physical habitat and water quality at sensitive reaches is recommended during a period of stable, low natural accretion shortly after cessation of DP implementation, to ensure comparability with surveys undertaken during DP operation.

Post DP surveys of both receptors and pathway variables should use the same methods as those used during DP operation.

## 9.4 Reporting and review of monitoring programme

At the end of each year during which monitoring has been undertaken, the data will be presented and reviewed in an annual report (as per current practice). This approach will help determine monitoring proposals for the following year (if required).

At the start of each year during which monitoring is to be undertaken, the monitoring recommendations made within this EMP and the results of the annual report from the previous year will be used to create a Site Investigation Plan (SIP) specific to the upcoming year, and the new SIP will also be issued as an additional appendix to this EAR report. The SIP for each year should be updated as required in consultation with the Environment Agency to allow complimentary data collection and ensure against duplication of survey effort.

**Table 9.1 Environmental Monitoring Plan for Derwent Valley Reservoirs DP**

| Parameter | Site/Location | By Whom | Brief Scope | Baseline Timing/ Frequency | During DP Timing/ Frequency | Post Drought Permit Timing/ Frequency |
|---|---|---|---|---|---|---|
| Additional targeted gaugings | At locations to improve characterisation of inputs from the River Noe | STWL | Surveyed cross sections (referenced to Ordnance Datum) to characterise inputs from River Noe. Locations at bottom of River Noe and on the River Derwent at the confluence. | Single campaign (initially, then review) to be undertaken during targeted low flow period | Single gauging to confirm / improve current characterisation | n/a |
| Additional targeted gaugings | All existing APs | STWL | During DP gauged transects (referenced to Ordnance Datum) to confirm EAR predictions. | Ad-hoc additional baseline gauging at all APs if extended low flow period experienced (below flows already characterised) | Single gauging at stable DP flows, at AP1-8 to confirm / improved current characterisation | n/a |

| Parameter | Site/Location | By Whom | Brief Scope | Baseline Timing/ Frequency | During DP Timing/ Frequency | Post Drought Permit Timing/ Frequency |
|---|---|---|---|---|---|---|
| Water quality *in situ* monitoring | Sites to include upstream of the Derwent Valley Reservoirs and Yorkshire Bridge (AP1), Hathersage Leadmill Bridge (AP2), Grindleford, Baslow Bridge (AP3) and Rowsley | STWL | *In situ* parameters (DO, temp, pH & conductivity) | Monthly during low flow periods. Plus, in combination with invertebrate sampling.<br><br>Annual review for catchment wide WQ monitoring requirement. | Increased frequency tbc with EA. Ideally in parallel with monitoring walkovers. | n/a |
| Macroinvertebrates | Yorkshire Bridge (AP1), Hathersage Leadmill Bridge (AP2), Grindleford, Baslow Bridge (AP3) | STWL | Ongoing seasonal monitoring i.e. Spring & Autumn, with additional summer sampling (in response to particular dry periods). To include *in situ* WQ monitoring. | Ongoing seasonal monitoring in conjunct with EA monitoring | As per baseline | As per baseline |

| Parameter | Site/Location | By Whom | Brief Scope | Baseline Timing/ Frequency | During DP Timing/ Frequency | Post Drought Permit Timing/ Frequency |
|---|---|---|---|---|---|---|
| Fish - electrofishing | Limited to sites in River Derwent from Westend to Wye water body | STWL | Electric fishing surveys including lamprey surveys (triple shock at sites within optimal habitat and single shock at sites within sub-optimal habitat). | During (if appropriate) and for two years after dry years – excluding potential DP years to avoid fish stress. Ideally 3 years consecutive data (September). Or following change in EA surveillance data. | None to avoid fish stress | To include at least 2 years following DP |

| Parameter | Site/Location | By Whom | Brief Scope | Baseline Timing/ Frequency | During DP Timing/ Frequency | Post Drought Permit Timing/ Frequency |
|---|---|---|---|---|---|---|
| Fish – barrier recon | Recon. Surveys along the length of the upper catchment – upstream of Wye confluence | STWL | Recon. surveys to identify barriers to coarse fish migration, but also to identify sensitive locations for habitat mapping | Ideally undertaken under low flow conditions | n/a | n/a |
| Fish – walkover surveys | Stretches of upper river to be agreed with EA (taking into consideration access). Suggest 4 stretches of river above Wye confluence. | STWL | During DP: Weekly walkover surveys (initially), looking for signs of fish in distress (e.g. gasping, trapped, dead fish). Weekly visits may not be required throughout DP implementation – dependent on ecological effects. 4 sites to cover x3 upper APs & Derwent at Hathersage SSSI | n/a | Initially weekly, reviewed dependent on ecological effects | n/a |

| Parameter | Site/Location | By Whom | Brief Scope | Baseline Timing/ Frequency | During DP Timing/ Frequency | Post Drought Permit Timing/ Frequency |
|---|---|---|---|---|---|---|
| Fish passage | Minimum at Calver, Grindleford & Hathersage, plus any identified via reconnaissance surveys | STWL | Fixed point photography at Calver, plus any identified via reconnaissance surveys. Also passage assessments at structures in Grindleford and Hathersage for Atlantic Salmon (and other species). | Passage assessments at structures in Calver, Grindleford and Hathersage for Atlantic Salmon. | Repeat fixed point photography (and spot measurements where appropriate) | X1 repeat fixed point photography (and spot measurements where appropriate) |
| Protected Rights | Masson Mill | STWL | If following additional consultations to understand abstraction infrastructure etc DP effects cannot be discounted, fixed point photography may be useful. | n/a | Repeat fixed point photography (and spot measurements where appropriate) | n/a |

| Parameter | Site/Location | By Whom | Brief Scope | Baseline Timing/ Frequency | During DP Timing/ Frequency | Post Drought Permit Timing/ Frequency |
|---|---|---|---|---|---|---|
| Physical habitat | Mapping at sensitive reaches and improvement in assumed habitat relationships. | STWL | Mapping centred on APs 1-3, plus sensitive cross section locations. Velocity profiles collected in parallel. | Target low flows – 1 visit | Update survey | 1 visit |
| Monitoring for unforeseen effects | APs 1-3, plus Derwent at Hathersage SSSI and any locations identified during recon. | STWL | Targeted walkovers to allow identification of any unforeseen effects e.g. fish in distress | Target low flows – 1 visit;<br><br>Immediately prior to DP implementation | TBC with regulators at DP application stage e.g. initially weekly, then dropping in frequency. | Likely not required unless specific impacts require post DP monitoring |

# 10 Conclusions and recommendations

The Derwent Valley Reservoirs is listed as potential DP sites within STWL's Drought Plan (STWL, 2022).

The proposed Derwent Valley Reservoirs DP scenario would allow a reduction in the compensation flow that is released from Ladybower Reservoir to the River Derwent, from 54 Ml/d under baseline operation to 34 Ml/d at Yorkshire Bridge during a DP (maintaining 51 Ml/d below the Noe confluence).

During those times within the stochastic record when the Derwent Valley Reservoirs DP is triggered, operation is predicted to only be necessary during the late autumn to early spring period; i.e. to improve reservoir refill. Even so, potential impacts of DP operations within this EAR have been considered for any time of year, to provide flexibility to STWL in the face of unforeseen events.

Should DP operation be triggered at the Derwent Valley Reservoirs, it appears likely that it would have (a maximum of) only **Minor** impacts on the ecology and water users of the River Derwent, even prior to mitigation measures. It is also concluded that impacts are only likely to be short-term and temporary in nature. This is despite **Moderate** changes in flow in the River Derwent (Westend to River Wye) waterbody. Flow effects are considered **Negligible** downstream of the River Wye confluence.

Mitigation measures and an Environmental Monitoring Plan (EMP) have been proposed to acknowledge remaining uncertainties in the impact assessments. The proposed mitigation measures are similar to those proposed in the previous DP EAR (ESI & APEM, 2012). The baseline requirements of the EMP represents a nett reduction in scope compared to the previous EAR. This is in part because data collection has been focussed predominantly on those reaches of the river where DP effects might be predicted and in part an acknowledgement that a baseline dataset has already been collected through previous EMPs.

It is recommended that the proposed baseline, during-DP and post-DP monitoring be undertaken to extend the baseline dataset for future updates of this report, and to allow the conclusions of this report to be tested.

It is further recommended that implementation of mitigation measures and details of the during-DP and post-DP monitoring should be discussed with the EA prior to DP implementation. It is recommended that STWL is prepared to implement all of the proposed mitigation measures described in Section 8, where appropriate. It should be noted that situations may arise where not all of the mitigation measures described are required or appropriate during every DP. Should this situation arise, those measures deemed not necessary or not appropriate should be discussed and agreed with the EA during the DP application process.

It is also recommended that the proposed monitoring programme be re-evaluated (via an annual report, SIP and consultations with the EA) after each year of data collection to establish whether the sampling locations, type and frequencies remain valid.

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# APPENDICES