Bristol Avon Rivers Trust

By Brook Catchment Fluvial Audit:

Source to confluence River Avon to include tributaries

March 2015

Document Control

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Executive Summary

In 2014 the Bristol Avon Rivers Trust (BART) was commissioned by the Environment Agency (EA) to undertake a fluvial audit of the By Brook catchment. The purpose of the audit was to utilise a catchment-scale methodology to simultaneously identify the key geomorphological and ecological parameters of the catchment, in addition to identifying and classifying diffuse and point source inputs of phosphates, ammonia, other pollutants and barriers to fish migration within the waterbody. The 11-day fluvial audit encompassed approximately 45km of the By Brook catchment, assessing all active and potential issues within six Water Framework Directive (WFD) sub-waterbodies (GB109053027500, GB109053027490, GB109053027480, GB109053027460, GB109053027400 and GB109053027380) and a further waterbody not classified under WFD (Lid Brook).

The main driver for this project is the EU Water Framework Directive (2000/60/EC) for all EU countries to aim to achieve at least Good Ecological Status (GES) for all water bodies by 2015, or where this is not possible and subject to the criteria set out in the Directive, aim to achieve good status by 2021 or 2027. Not all waterbodies within the By Brook catchment are failing GES, the By Brook (source to confl Broadmead Brook (GB109053027500)) and the By Brook (confl Broadmead Brook to confl unnamed trib (GB109053027480)) are currently achieving GES; however it is important to identify any potential impacts that may also cause deterioration in status. The Broadmead Brook (GB109053027490) and the unnamed trib (GB109053027460) are both at moderate ecological status now, which is due to biological elements-fish- which currently achieve moderate. The two downstream waterbodies are also failing GES, and both are currently classified as poor ecological status, again due to biological elements-fish-which currently achieve poor.

A total of 486 sources were recorded on the 45 km walked in the By Brook catchment. Of these, 140 were diffuse and 38 were point sources. A further 640 features were recorded during the audit, such as barriers to fish passage, large woody debris, and depositional features, however these are not included in the point source and diffuse source pollution scores. The majority of sources were classified as Grade 3, with a total of 300 inputs. There were 28 Grade 2 sources (6%) and 158 Grade 4 sources (32%) were recorded in the catchment.

This document is intended to provide supplementary information for the Fish Pass Feasibility Study being undertaken concurrently to this work by Royal Haskoning DHV and to ascertain the geomorphology of the catchment and any issues that may impact on achieving GES.

1.0 Introduction

In 2014, BART was commissioned by the Environment Agency to undertake a fluvial audit of the By Brook catchment. The purpose of the survey was threefold:

- to support the catchment work undertaken by BART through the first phase of Environment Agency funding into the By Brook;
- to provide supplementary information for the Fish pass Feasibility Study being undertaken by Royal Haskoning DHV on the By Brook, and;
- to ascertain the geomorphology of the catchment and the issues impacting upon its function and ability to achieve Water Framework Directive GES.

The fluvial audit was undertaken on the whole By-Brook catchment from source to confluence with the River Avon (Bristol) and included all major WFD tributaries. A catchment-scale methodology was used to simultaneously identify and classify diffuse and point inputs of phosphates, ammonia and other pollutants within the catchment waterbodies and any barriers to fish migration were assessed and classified accordingly. In addition, further field data was collected on sediment transport characteristics, sediment sinks, physical habitat features and channel geometry.

1.1 Background

During 2012 BART worked with Area EA staff to identify and agree a sub-catchment within the Bristol Avon area, in which to carry out a collaborative river restoration project. The sub-catchment identified was the By Brook. During the summer of 2013 and winter 2014 BART delivered a project in which it started to address the main causes of WFD failure in the catchment with a primary focus on the area between Ford and Slaughterford on the By Brook. An initial fish pass feasibility study was undertaken by Mike and Matt Beach on nine of the fourteen in-channel structures identified in this study reach with suggested options for providing fish passage and outline drawings provided for each. BART also undertook a substantial amount of riparian protection works along one of the main tributaries, the Lid brook in order to prevent excess sedimentation and nutrients reaching important spawning gravels in the main By Brook. Further wet weather sediment monitoring was undertaken using a series of autosamplers and specialist water quality monitoring equipment on the Lid brook to ascertain the contribution of sediment and phosphate entering the By Brook is from this tributary. Engagement with local angling clubs along the river, landowners and local communities also started what is hoped to be a joint long-term relationship with these groups with a shared commitment to delivering improvements in the catchment.

This second-stage of the project builds upon all the aforementioned work already undertaken by BART and will provide costed site-specific designs for overcoming in-channel obstructions for fish in the intermediate reaches (Reaches 4a, 4b and upstream of Reach 5) of the By Brook. The information contained within this fluvial audit will help to inform the design process and identify any important geomorphological or ecological features within the areas concerned or those immediately upstream or downstream of the structures.

1.2 Water Framework Directive (2000/60/EC)

The Water Framework Directive (2000/60/EC) came into force in December 2000 and subsequently became part of UK law in December 2003. The legislation is designed to improve and integrate the manner in which waterbodies are managed. Furthermore, it aims to enhance the status and prevent further deterioration of aquatic ecosystems, promote the sustainable use of water, reduce pollution of water by 'priority' and 'priority hazardous' substances and ensure progressive reduction of groundwater pollution. All member states must aim to reach good chemical and ecological status in both inland and coastal waters by 2015. Despite this, in England and Wales only 26% of waterbodies achieved 'good status' in 2009 (EA, 2009). The WFD waterbody condition assessments are currently undertaken by the Environment Agency using methodologies agreed with the UK Technical Advisory Group (UK TAG). For surface waters, such as rivers and lakes, the 'overall status' of a waterbody is comprised of an ecological and a chemical component. Ecological status is recorded on the scale high, good, moderate, poor and bad (with moderate or worse being regarded as a failure), while chemical status is measured simply as 'good' or 'fail'. Recommendations for remedial catchment management interventions are made through River Basin Managements Plans (RBMPs) and Catchment Management Plans (CMPs).

1.3 By Brook Catchment Overview

The By Brook flows for approximately 19 km from its source near Burton to its confluence with the River Avon (Bristol) at Bathford on the south east outskirts of Bath. Flowing initially in an easterly direction then south towards Castle Combe where the tributary of the Broadmead Brook flows into the By Brook before flowing southwards towards the village of Ford where the Doncombe Brook and an unnamed tributary join the By Brook on its right-hand bank before flowing through the village. The river continues to flow southwards where a further tributary, the Lid Brook joins the By Brook on its right-hand bank before flowing through Box and south-westerly where it flows in the River Avon (Bristol) at Bathford.

The hydrogeology of the By Brook catchment is comprised of a significant limestone aquifer (Great Oolite Group) capable of producing large yields and a flashy response to precipitation. Midford Sands of the Upper Lias are present in some areas but to a far lesser extent (CEH, 2015).

Several Sites of Special Scientific Interest (SSSI) are located within the By Brook catchment. These include Rack Hill SSSI (a 10.35 hectare lowland calcareous grassland) located south of Castle Combe, Dank's Down and Truckle Hill SSSI located adjacent to an unnamed tributary of the By Brook. Honeybrook Farm SSSI is a 42.28 hectare site situated south of Slaughterford and approximately 300m east of the By Brook. It features three types of lowland calcareous grassland, Centaurea nigra grassland and *Fraxinus excelsior* - *Acer campestre* - *Mercurialis perennis* woodland. In addition to this, the By Brook also flows through Colerne Park and Monk's Wood SSSI just south of Slaughterford (Magic, 2015).

1.4 River Typology

The typology of the river is based on the Vegetation Communities of Great Britain (JNCC, 1999), which categories river systems on an environmental gradient with three hierarchical levels:

1. River Groups. This highest level consists of four distinct broad groups (A-D) representing an environmental gradient from lowland eutrophic rivers, to those that are essentially upland, torrential and oligotrophic.

2. River Community Types. This second tier of division comprises ten River Community Types (RCTs) (I-X).

3. Sub-types. This final sub-division includes 38 river sub-types (AIa-DXe).

The By Brook catchment is a mixture of Type II, lowland clay-dominated rivers and Type V, sandstone, mudstone and hard limestone rivers. These distinct geomorphological types give rise to specific vegetation community types and in-channel habitat characteristics. Type II rivers are located between 10m and 200m AOD with a mean slope of 19km-1 and dominated by clay, gravel and silt substrates. Type II rivers are dominated by runs and slacks and support approximately 38 different taxa, including *Carex riparia* and *Potamogeton pectinasus* communities. Sandstone dominated Type V rivers are located between 5 and 244m AOD with a slope of 6.6km-1 and are dominated by pebble, cobble and gravel substrates. Type V rivers are also dominated by slacks and runs whilst also containing a moderate number of riffle habitats, which combined support an average number of 35 different taxa (JNCC,1999).

The identification of river type and geomorphological characteristics is important when considering a baseline for restoration. Consideration of the change in river type down the By Brook corridor is important when choosing options for riparian improvement and alterations to channel morphology.

1.5 Summary of Current EA WFD Data

For the purposes of the fluvial audit and report, the audit reach has been split into seven sections following the WFD waterbody classification and identification scheme.

Table 1 Summary of waterbodies surveyed during the audit and the reach within which they were surveyed. Waterbodies are in order of upstream to downstream presence.

Reach ID	WFD Waterbody ID	Waterbody Name	Location
Reach 1	GB109053027500	By Bk - source to conf Broadmead Bk	Burton to Castle Combe
Reach 2	GB109053027490	Broadmead Bk - source to conf By Bk	Pennysylvania to Castle Combe
Reach 3	GB109053027480	By Bk - conf Broadmead Bk to conf unnamed trib	Castle Combe to Ford
Reach 3a	GB109053027460	Unnamed trib - source to conf By Bk	North Wraxhall to Ford
Reach 3b	GB109053027400	Doncombe Bk - source to conf By Bk	Marshfield to Ford
Reach 4a	GB109053027380	By Bk - conf Doncombe Bk to conf R Avon (Brist)	Ford to Slaughterford
Reach 4b	GB109053027380	By Bk - conf Doncombe Bk to conf R Avon (Brist)	Slaughterford to Drewett's Mill
Reach 4c	N/A	Lid Brook- source to conf By Bk	Westwood Farm to Saltbox Farm, Box
Reach 5	GB109053027380	By Bk - conf Doncombe Bk to conf R Avon (Brist)	Drewett's Mill to Bathford

The current ecological and physico-chemical WFD classifications for each of the WFD waterbodies audited are summarised below (Table 2). The uppermost reach (Reach 1) is one of only two reaches in the By Brook catchment classified as Good Ecological Status (GES), the other is Reach 3. The Broadmead Brook is currently classed at Moderate Ecological Status due to its failure for fish. The 'Moderate' classification is led by the fish biological element, which is predicted to rise to 'Good' status by 2027. It has been determined that it would be 'disproportionately expensive' and 'technically infeasible' to try and achieve GES by 2015 (EA 2009b). Similarly Reach 3a is also classified as Moderate due to fish and again with the objective of reaching 'Good' by 2027; however the ability to achieve 'Good' before this date has been deemed 'disproportionately expensive'.

There is an evident deterioration in ecological status in the intermediary and downstream reaches of the By Brook catchment. All the hydromorphology elements meet GES and overall the physico-chemical elements are 'High' for both Reach 4b and Reach 5; however, Reach 4b is only achieving 'Moderate' for phosphate. It is however, the 'Poor' status of fish which is the biological failing element and therefore reducing the ecological status to 'Poor' for both reaches. The absence of connectivity in the reach is the overriding factor causing declines in fish populations and subsequent diversity. The connectivity of the By Brook throughout the intermediary and downstream reaches, and with the River Avon is currently being affected by a series of man-made barriers, which impede the natural passage of fish. Large barriers can have a major impact on fish population numbers and diversity, as feeding or spawning movements upstream or downstream of the obstruction are prevented. Phosphate levels in Reach 4b do not meet GES, and after discussions with the water company regarding discharges from the sewage treatment works into the Doncombe Brook, it is possible that point source pollution is an additional pressure on both water and biological quality in this reach.

Table 2 Summary of EA WFD Waterbody classification data for the surveyed reaches of the By Brook Catchment.

Waterbody Name	By Bk - source to conf Broadmead Bk	Broadmead Bk - source to conf By Bk	By Bk - conf Broadmead Bk to conf unnamed trib	Unnamed trib - source to conf By Bk	Doncombe Bk - source to conf By Bk	By Bk - conf Doncombe Bk to conf R Avon (Brist)
Waterbody ID	**GB109053027500**	**GB109053027490**	**GB109053027480**	**GB109053027460**	**GB109053027400**	**GB109053027380**
Typology	**Low, Small, Calcareous**	**Low, Small, Calcareous**	**Low, Small, Calcareous**	**Low, Small, Calcareous**	**Low, Medium, Calcareous**	**Low, Medium, Calcareous**
Overall Status	**Good**	**Moderate**	**Good**	**Moderate**	**Poor**	**Poor**
Ecological Status	**Good**	**Moderate**	**Good**	**Moderate**	**Poor**	**Poor**
Chemical Status	Does not require assessment	Does not require assessment	Does not require assessment	Does not require assessment	Does not require assessment	Does not require assessment
	Biological					
Fish	-	Moderate	-	Moderate	Poor	Poor
Macroinvertebrates	High	High	High	-	Good	-
	Physico-chemical					
Ammonia	High	High	High	High	High	High
Dissolved Oxygen	High	High	High	High	High	High
pH	High	High	High	High	High	High
Phosphate	Good	High	Good	High	Moderate	Good
	Hydromorphology					
Hydrology	Supports Good	Supports Good	Supports Good	Supports Good	Supports Good	Supports Good
Morphology	Supports Good	Supports Good	Supports Good	Supports Good	Supports Good	Supports Good

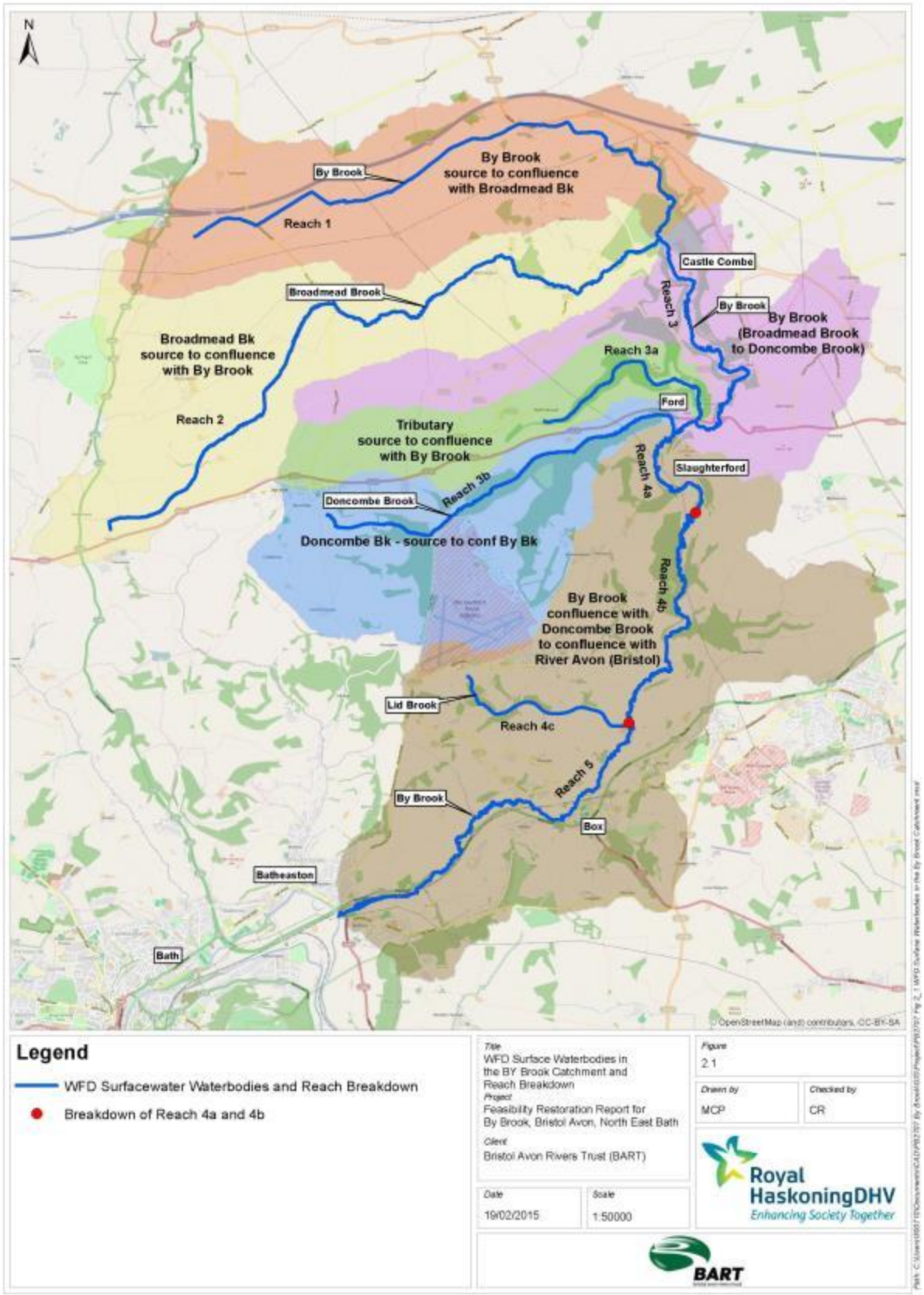


Figure 1 WFD Surface Waterbodies in the By Brook Catchment and Reach Breakdown.

2.0 Methodology

A standardised baseline walkover survey of the By Brook catchment was undertaken by BART and covered approximately 45Km over a period of 11 days. The reaches surveyed are provided in Table 3 below. Walking in an upstream to downstream direction, each reach was walked by a trained catchment officer during December 2014 and January 2015.

Table 3 Surveyed reaches of the By Brook catchment. *Based on approximate measured distance on maps.

Reach	NGR Start Point	NGR End Point	Date Surveyed	Approximate Reach Length (km) *
1	379370,178477	383642,177747	29/12/2014	6.09
2	376539,174439 378126,176691	377069,174791 383638,177751	02/01/2015 03/01/2015	7.27
3	383638,177751	384208,174786	08/01/2015	4.07
3a	381045,174376	384205,174816	09/01/2015	4.52
3b	378510,173173	383900,174673	15/01/2015	6.00
4a	384225,174795	384130,173852	20/01/2015	1.84
4b	384130,173852	383232,169949	20/01/2015	5.32
4c	380539,170311	383179,169941	27/01/2015	2.95
5	383232,169949	378576,166991	28/01/2015 02/02/2015	6.48

2.1 Geomorphological and Ecological Survey

The field survey of the catchment (undertaken in December and January 2014/15) included a walkover survey of the By Brook catchment between Burton and the confluence with the River Avon (Bristol) (approximately 19km in length) and four further tributaries of the By Brook. During the survey, visual observations of key geomorphological and ecological parameters were recorded from the top of the banks. The survey did not involve intrusive investigations or in-channel surveys.

Key geomorphological and ecological parameters were recorded at a series of “checkpoints”. At every change of hydromorphological character in the river, flow type, bed and bank material, channel geometry, sediment dynamics and vegetation character were recorded. Assessment of differences in these parameters was used to highlight spatial trends throughout the catchment. Changes to the

predominant geomorphological, ecological and land use characteristics of the river were then used to determine the limits of the reaches.

A previous walkover survey of the By Brook catchment undertaken by BART in August 2013 contains data on bed sediments, summer flows, and land management issues during the summer period. As such, this report is based on analysis of the data from the previous field survey undertaken in August 2013 as well as the data from the new survey undertaken in December and January 2014/15 to inform this report. The inclusion of both summer low flow condition data and winter high flow condition data provides a comprehensive representation of the channel geomorphology during two dominant flow scenarios. In addition to this, the inclusion of both sets of data allows the predominant geomorphological characteristics of the river channel to be captured and to adequately allow a robust assessment of the form and function of the river and the issues affecting it to be made.

2.2 Recording of field data

Sediment sources, sediment sinks and flow types were continuously tallied for each reach, and overall morphological parameters relating to valley form, channel geometry, and boundary conditions of the reach were recorded. Grid references for key features were recorded using a hand held GPS.

The ecological characteristics of each reach were recorded and the presence of riparian vegetation and invasive species were also noted. Key habitat requirements for interest species of Type II and Type V rivers were also assessed along with observations as to where the channel appeared to be recovering from previous modifications. The field data collected were based on visual observation and therefore to some extent dependant on the conditions found on the day of survey.

2.3 Point and Diffuse Pollution Source Survey

Diffuse and point sources of pollution entering the waterbodies, including sediment and organic inputs, were identified and recorded on the survey form (**Appendix 3**). Each source was categorised based on the EA standard walkover survey methodology OI 356_12 (**Appendix 1: Table 1**) and the location recorded as a 10 figure National Grid Reference (NGR) using a hand-held GPS, to allow subsequent spatial distribution analysis through ArcGIS. The origin of each input was recorded to facilitate analysis into the types of land-use practices causing significant levels of pollution into the catchment as a whole. The impact or potential severity of each source was classified on a scale of Grade 1 to Grade 4 (**Appendix 2**). Photographs were taken of each source and relevant comments

recorded as appropriate. Information was also recorded regarding the type of land-use present on both banks and whether stock fencing was present. An additional second survey form was used on each reach to capture information on sediment sources and sediment transport, physical habitat features and channel geometry. The second survey form was provided by Royal Haskoning DHV and is used for all fluvial audit surveys.

2.4 Barriers to Fish Migration

Any natural and manmade barriers to fish migration, such as LWD, weirs, dams and fords, were also recorded and assessed using EA standard walkover methodology. The type, length, width and degree of influence of the barrier were recorded, with the degree to which the barrier could be passed by fish assessed from Grade 1 to Grade 4 (**Appendix 2**).

3.0 Results

3.1 Geomorphological and Ecological Condition

3.1.1 Summary of Management Reach-characteristics

Table 4 to Table 21 provide details of the geomorphology and ecology of each of the Reaches in the catchment, including a photographic overview of typical characteristics of each reach. The locations of each reach are shown in **Figure 1**.

3.1.1 Reach Summary Tables

Table 4 Reach Summary Table: Reach 1.

Reach 1 (By Bk - source to conf Broadmead Bk)		
Upstream survey limit NGR 379370,178477	**Downstream survey limit** NGR 383642,177747	**Approximate length of river surveyed** 6.09Km
Reach characterisation		
Hydromorphology: In Reach 1, the upstream section of the reach between Phyldornick (NGR 379377,178482) and Goulter's Mill Farm (NGR 382875,179170) was dry at the time of survey (**Plate A).** The river displays a limited degree of flow and morphological diversity. The channel planform is characterised by large sections of straightened channel, some of which have been heavily modified (**Plate C**) as a result of road transport networks, residential housing, or historic milling. The banks are typically steep-sided where they have been over-deepened and support predominantly glide flows (**Plate B**). There is a lack of substrate between Phyldornick and Westfield Farm (NGR 379987,178907) where the river runs through a grass channel (**Plate A**). After Westfield Farm the substrate becomes predominantly comprised of pebbles, cobbles and small boulders (**Plate D**). Floodplain land use consists predominantly of grazing land with evidence of severe bank erosion due to poaching in some upstream sections (**Plate E**). **Ecology**: Trees are almost absent in the upstream section of the reach, whilst intermediate and downstream sections benefit from the shading created on the areas of open water. Bank vegetation is generally restricted due to grazing by livestock in the upstream section; however downstream sections of bank support a variety of riparian species including . Deciduous woodland is present along the banks of the downstream section of the reach providing a complex habitat for wildlife and		

beneficial microclimate for freshwater species.	
Geomorphological assessment	
Attribute	**Survey assessment**
Flow dynamics and diversity	In Reach 1, the upstream section of the reach between Phyldornick (NGR 379377,178482) and Goulter's Mill Farm (NGR 382875,179170) was dry at the time of survey (**Plate A).** The river displays a limited degree of flow and morphological diversity. The channel planform is characterised by large sections of straightened channel, some of which have been heavily modified (**Plate C**) as a result of road transport networks, residential housing, or historic milling. The banks are typically steep-sided where they have been over-deepened and support predominantly glide flows (**Plate B**).
Substrate	There is a lack of substrate between Phyldornick and Westfield Farm (NGR 379987,178907) where the river runs through a grass channel (**Plate A**). After Westfield Farm the substrate becomes predominantly comprised of pebbles, cobbles and small boulders (**Plate D**). In addition to this, the reach contains substantial evidence of siltation, which in areas of low flow velocity have settled out and gradually built up on the river bed, thus further slowing the flow and allowing more sediment to fall out of suspension. There was no evidence of clean stable gravels in this reach. In shallow downstream sections of the river where the sediment was visible, there was a substantial proportion of sediment coated in algae (**Plate F**).
Channel and banks	The channel planform is characterised by large sections of straightened channel, some of which have been heavily modified (**Plate C**) as a result of road transport networks, residential housing, or historic milling. A combination of limited geomorphological diversity and sedimentation in the channel has led to areas of the channel becoming choked by vegetation, thus further slowing the flow (**Plate G**).
Plant community species: Composition and abundance	Species observed during the audit included hard rush (*Juncus inflexus*), compact rush (*Juncus conglomeratus*), meadowsweet (*Filipendula ulmaria*), floating sweet grass (*Glyceria fluitans*),

	fennel pondweed (*Potamogeton pectinatus*), stinging nettle (*Urtica dioca*), thistle spp., dock species, and greater willow herb (*Epilobium hirsutum*).
Reach Issues	
Native species	Algae identified within the reach of a coverage of <25%.
Invasive non-native species	No alien/introduced species were identified in this reach.
In-stream barriers	1 in-stream barrier was identified in this reach (**Plate H**).

Issues for restoration and management	**Potential restoration options**
• Algal formation on substrate. • Livestock poaching. • Dominating glide flows. • Heavy siltation of substrate.	• BART could work with local farmers to increase buffer strips on arable land, employ good practise soil management and possibly introduce sediment traps in areas most at risk of sedimentation. • BART/EA to work with local residents to identify misconnections from private residences. • BART could work with farmers to encourage fencing the river and providing a riparian strip to both benefit bank profile and the quality of gravel substrate. • BART could introduce some small flow deflectors and channel narrowing to increase flow diversity.

Constraints
• The necessary permissions and permits would be required to install livestock fencing and possible alternative water supplies. • The necessary permits would be required to undertake in-stream works.

Table 5 Overview of Reach 1.

Overview of Reach 1 (By Bk - source to conf Broadmead Bk)	
Reach character photographs	
 A: Dry grass channel upstream Reach 1.	 B: Dominant glide flows.
 C: Substantial sections of heavily modified channel in the upstream section of the reach.	 D: Pebble, cobble substrate.

E: Poaching by livestock.

F: Algae covered sediment.

G: Channel chocked by dense vegetation growth.

H: In-channel structures.

Table 6 Reach Summary Table: Reach 2.

Reach 2 (Broadmead Bk - source to conf By Bk)		
Upstream survey limit NGR 376539,174439	**Downstream survey limit** NGR 383638,177751	**Approximate length of river surveyed** 7.27Km
Reach characterisation		
Hydromorphology: In this reach, the Broadmead Brook flows through a narrow, shallow valley, with a floodplain dominated by pastoral agriculture. The channel planform is characterised by regular meandering within pastoral agricultural areas, whilst in the villages the river has been realigned as a result of historical milling and potential flood defence for properties. There is some evidence of historical channel widening in areas such as West Kington, which has resulted in an over-wide and uniform channel with a shallow gradient. Fine sedimentation dominates the substrate within the middle sections of this reach, notably between Castle Farm, Marshfield and downstream to West Kington (**Plate A**). **Ecology:** Emergent vegetation is present throughout the reach with a dominance of reed species, particularly within areas of glide habitat. Sedges, rushes, and water mint were also noted, whilst water-starwort was recorded in areas with clean gravels and good light penetration. A variety of deciduous tree species are present in a semi-continuous habit throughout the reach which provides shading and areas of open water. Bank vegetation is varied due to the diversity of land management along the river. There is little bank vegetation in areas of pastoral agriculture where livestock graze vegetation down to the water's edge. There are occasional patches of nettle, thistle and greater willowherb in these areas. At the downstream section of this reach there is an area under woodland management whereby the banks are dominated by nettles, harts tongue fern and scrub with mature trees.		
Geomorphological assessment		
Attribute	**Survey assessment**	
Flow dynamics and diversity	This reach has a good diversity of flow with riffle-run-glide flows present along the majority of the reach. The presence of large woody debris and a number of in-stream structures also contribute to the diversity of flow introducing both chute and rapid flow to some areas. Glide habitat tends to dominate in areas where the channel has been over-widened or over-deepened which has led	

	to areas dominated by reeds.
Substrate	The downstream sections of the reach contain clean stable gravels alongside silt deposits at the channel margins. However the middle reaches exhibit excessive siltation possibly due to the presence of large populations of American signal crayfish burrowing into the soft banks (**Plate D**).
Channel and banks	The planform within this reach displays relatively large-scale sinuosity and little evidence of active bank erosion, associated with lower energy flows and a shallow channel gradient. There are no embankments along the length of the reach, and the banks are generally shallow (**Plate G**). Evidence of historic channel realignment and hard bank reinforcement was observed during the fluvial audit, notably within the village of West Kington (**Plate H**).
Plant community species: **Composition and abundance**	Species observed during the audit included hard rush (*Juncus inflexus*), compact rush (*Juncus conglomeratus*), pendulous sedge (*Carex pendula*), lesser water-parsnip (*Berula erecta*), water-crowfoot (*Ranunclus* spp.), water-milfoil (*Myriophyllum aquaticum*), floating sweet grass (*Glyceria fluitans*), fennel pondweed (*Potamogeton pectinatus*), water mint (*Mentha aquatica*), water starwort (*Callitriche stagnalis*). Vegetation along the banks was noted to includes stinging nettle (*Urtica dioca*), thistle spp., dock species, greater willow herb (*Epilobium hirsutum*) and hartstongue (*Phyllitis scolopendrium*) on woodland river banks.
Reach Issues	
Native species	Algae identified within the reach of coverage of 25%.
Invasive non-native species	There have been a number of visual sightings of American signal crayfish on the upper sections of this reach. In addition to this, crayfish traps and banks peppered with crayfish-sized holes were recorded upstream of West Kington.
In-stream barriers	61 in-stream barriers were identified in this reach of which 3 were Grade 2 weirs and 8 were Grade 3 weirs. Substantial amounts of large woody debris were present in the channel with 29 observations of where it was causing blockages.

Issues for restoration and management	Potential restoration options
• Siltation of substrate. • Algae covered substrate. • Domestic outputs of phosphate. • Invasive American signal crayfish. • Poaching by cattle.	• Joint BART/ EA project to look at misconnections and public awareness of phosphate in the river. • Strategic trapping of American signal crayfish • Potential BART project to look at cattle fencing and water provision.
Constraints	
• Trapping of American signal crayfish will need to be undertaken by licensed individuals over a period of time. • The necessary permissions and permits would be required before undertaking livestock fencing.	

Table 7 Overview of Reach 2.

Overview of Reach 2 (Broadmead Bk - source to conf By Bk)	
Reach character photographs	
	
A: Heavy siltation of substrate	B: Eutrophication and dense algal growth during summer

C: Domestic outputs of phosphate

D: Possible presence of American signal crayfish causing bank erosion

E: Heavily poached banks

F: Good amounts of large wood debris

G: Good flow diversity

H: Over-widened channel

Table 8 Reach Summary Table: Reach 3.

Reach 3 (By Bk – conf Broadmead Bk to conf unnamed trib)		
Upstream survey limit NGR 383638,177751	**Downstream survey limit** NGR 384208,174786	**Approximate length of river surveyed** 4.07Km
Reach characterisation		
Hydromorphology: In this reach, the By brook exhibits a substantial proportion of hydromorphological alteration due to historic milling and flood defence. Downstream of the confluence with the Broadmead Brook, the river is situated within a straight heavily modified channel and exhibits predominant glide flows. As the river flows past Brook House it enters a steep sided valley where the gradient of the river increases and thus the river starts to exhibit more varied flows. **Ecology:** Emergent vegetation is present sporadically through the reach and is comprised predominantly of reeds in areas of glide habitat. *Ranunculus* spp. was noted on two occasions in this reach in areas of fast flow and good light penetration. In areas of woodland the bankside vegetation was predominantly comprised of nettles, dog's mercury and scrub; whilst open water areas support water-mint, meadowsweet, sweet vernal grass and *Ranunculus* spp. Deciduous woodland is present along a good proportion of this reach, however the river is not over shaded as woodland areas are interspersed with areas of pasture and floodplain meadow.		
Geomorphological assessment		
Attribute	**Survey assessment**	
Flow dynamics and diversity	In the upstream section of the reach, the river is situated within a straight heavily modified channel and exhibits predominant glide flows. As the river flows past Brook House it enters a steep sided valley where the gradient of the river increases and thus the river starts to exhibit more varied flows.	
Substrate	The substrate in the reach is comprised predominantly of pebble cobble substrate with the presence of some small boulders (**Plate G**). The presence of macrophytes such as *Ranunculus* spp. in fast flowing sections of the reach results in the in-channel accumulation of isolated patches of fine sediment (**Plate A**). There is considerable evidence of sedimentation occurring within the river, with a number of sites identified having a 'milky' appearance (**Plate**	

	D). There is also evidence of algal growth on a substantial proportion of substrate, which is evident in the shallow sections of the reach (**Plate H**).
Channel and banks	The channel has been enlarged and realigned and banks heavily modified, most noticeably in Castle Combe and near the weirs which are present throughout the majority of the reach (**Plate C**). Although there has been considerable realignment and widening of the channel in areas, there still remains a good connection of the river with the floodplain in the middle sections of the reach and as such a number of wetland habitats are present (**Plate B**). The banks in the reach are relatively unstable due to a combination of high energy flows from channel gradient, in-channel structures and livestock poaching (**Plate E**). The floodplain becomes quite narrow south of Long Dean and is used for pastoral agriculture, and grazing is allowed right up to the river's edge. This is likely to contribute towards sediment loading and siltation in the downstream reaches of the By Brook.
Plant community species: **Composition and abundance**	Species observed during the audit included meadowsweet (*Filipendula ulmaria*), water mint (*Mentha aquatica*), water-crowfoot (*Ranunclus* spp.), branched bur-reed (*Spargantium erectum*), and some blanket weed. On the banks stinging nettle (*Urtica dioca*), thistle spp., sweet vernal grass (*Anthoxanthum odoratum*), dock species and greater willow herb (*Epilobium hirsutum*) were noted.
Reach Issues	
Native species	Algae identified within the reach of coverage of 25%.
Invasive non-native species	No alien/introduced species were identified in this reach.
In-stream barriers	47 in-stream barriers were identified in this reach of which 5 were Grade 1 weirs and 1 Grade 2 weir, and 5 Grade 3 weirs. Substantial amounts of large woody debris were present in the channel with 9 observations of where it was causing blockages.

Issues for restoration and management	**Potential restoration options**
• Barriers to fish and eel passage. • Poaching by livestock.	• Potential for BART/ EA project to look at fish passage options throughout this reach.

• Algae covered sediment. • Heavy siltation in areas. • Highly eroding banks.	• Potential BART project to install livestock fencing and water provision.
Constraints	
• Fish pass feasibility studies will need to consider flood risk constraints. • Constraints related to current land use.	

Table 9 Overview of Reach 3.

Overview of Reach 3 (By Bk – conf Broadmead Bk to conf unnamed trib)	
Reach character photographs	
	
A: Presence of diverse bank-side and emergent vegetation with in channel *Ranunculus.*	B: The river is well connected to the floodplain.

C: Over-widened channel in residential areas.

D: Considerable silt deposition on substrate.

E: High energy gradient between Brook House and Lower Long Dean.

F: A large number of in-stream structures.

G: Predominant pebble, cobble substrate.

H: Considerable algal growth on substrate.

Table 10 Reach Summary Table: Reach 3a.

Reach 3a (Unnamed trib - source to conf By Bk)		
Upstream survey limit NGR 381045,174376	**Downstream survey limit** NGR 384205,174816	**Approximate length of river surveyed** 4.52Km
Reach characterisation		
Hydromorphology: Reach 3a is dominated by run conditions and swifter flows than the reaches on the main By Brook channel. Sediment transport is the dominant process, with the substrate displaying significant sections of clean gravels and other coarse sediment (**Plate A**). Land use is characterised by deciduous woodland with some low intensity grazing in North Wraxhall and on the right-hand bank at the downstream section of the reach (**Plate B**). **Ecology:** The majority of the riparian strip throughout the reach is enclosed by deciduous woodland which supports a complex structure of vegetation adapted to shade conditions. The complex vegetation structure is likely to support a range of wildlife, including habitats for invertebrates.		
Geomorphological assessment		
Attribute	**Survey assessment**	
Flow dynamics and diversity	This reach is dominated by run flows, which has resulted in more varied channel geomorphology and created conditions suitable for aquatic macrophytes and macroinvertebrates (**Plate C**).	
Substrate	The reach contains evidence of clean gravels and other coarse sediment. Unlike the previous reaches, there is no evidence of excessive siltation due to the increased flow diversity and associated zones of erosion in areas of swift flow and preferential deposition in low energy zones.	
Channel and banks	The planform within this reach is sinuous and channel banks are generally shallow. Floodplain connectivity is good in the downstream section as a result of the shallow bank height (**Plate D**). There is some isolated evidence of channel realignment and modification in North Wraxhall where the river enters a number of culverts and is heavily modified in short sections (**Plates E and F**). This is likely as a result of flood defence.	

Plant community species: **Composition and abundance**	Species observed during the audit included hard rush (*Juncus inflexus*), compact rush (*Juncus conglomeratus*), and lesser water-parsnip (*Berula erecta*), Vegetation along the banks was noted to include common comfrey (*Symphytum officinalis*), stinging nettle (*Urtica dioca*), and hartstongue (*Phyllitis scolopendrium*) on woodland river banks.
Reach Issues	
Native species	No native species of concern were identified in this reach.
Invasive non-native species	No alien/introduced species were identified in this reach.
In-stream barriers	19 in-stream barriers were identified in this reach of which 1 was a Grade 2 culvert, 1 Grade 3 culvert, and 12 Grade 4 structures including bridges, culverts and weirs (3). Some large woody debris was present in the channel with 5 observations of where it was causing blockages.

Issues for restoration and management	**Potential restoration options**
There are no issues for restoration and management in this reach.	There is no restoration options required for this reach.
Constraints	
N/A.	

Table 11 Overview of Reach 3a.

Overview of Reach 3a (Unnamed trib - source to conf By Bk)
Reach character photographs

A: Clean gravels and other coarse substrate.

B: Low-intensity grazing in adjacent pasture.

C: Good flow diversity and clean substrate provide good habitat for macrophytes and macroinvertebrates.

D: Shallow banks along the reach.

E: Short sections of heavily modified channel.

F: Short sections of culverting.

Table 12 Reach Summary Table: Reach 3b.

Reach 3b (Doncombe Bk - source to conf By Bk)		
Upstream survey limit NGR 378510,173173	**Downstream survey limit** NGR 383900,174673	**Approximate length of river surveyed** 6.00Km
Reach characterisation		
Hydromorphology: In Reach 3b, the river displays a good degree of flow and morphological diversity. The channel planform is characterised by a meandering low flow channel with varied bank and bed profiles. Cattle poaching and large scale tree removal from woodland areas result in the substrate character of lower reaches being dominated by fine sedimentation. Gravels and pebbles are cleaner in the upstream sections of the reach but a large proportion of the substrate is covered by filamentous algae in the middle and downstream reaches. Hard bank reinforcement is observed downstream and the channel is disconnected from its floodplain. Land use is dominated by deciduous woodland along the majority of the reach with some areas used as pastoral agriculture **Ecology:** The reach is dominated by deciduous woodland along the majority of the reach with an understorey of nettles and scrub. Some fields adjacent to the river in the middle section of the reach are mown for hay which has allowed a good variety of riparian vegetation to establish, including meadowsweet, water-mint, thistle, teasel and lesser water-parsnip.		
Geomorphological assessment		
Attribute	**Survey assessment**	
Flow dynamics and diversity	This reach exhibits good flow diversity with the presence of riffle-run-glide flows resulting in varied channel morphology. Only a short section of the downstream reach is dominated by glide habitat where the river is impounded and over abstracted during the summer (**Plate D**).	
Substrate	Pebble-cobble is the dominant substrate along the reach with gravels inter-dispersed. Sediment in the middle section of the reach is covered in large amounts of filamentous algae, possibly due to the sewage treatment works upstream (**Plate B**); whilst the sediment and heavily modified channel in downstream section of the reach is covered in fine silt, possibly due to heavy cattle poaching upstream (**Plate A**).	

Channel and banks	The bank profile displays considerable variation, including sections of shallow and steep active erosion on the left-hand bank (**Plate C**). The absence of livestock or woodland in small section of the middle reaches has led to shallow banks and improved floodplain connectivity. In the downstream sections of the reach livestock grazing has impacted on the riparian vegetation structure and has damaged considerable lengths of bank through poaching. Further downstream the channel has been straightened and impounded, including the presence of a large sluice and the more recent construction of an amenity lake (**Plate D**).
Plant community species: **Composition and abundance**	Species observed during the audit included compact rush (*Juncus conglomeratus*), meadowsweet (*Filipendula ulmaria*), lesser water-parsnip (*Berula erecta*), water mint (*Mentha aquatica*). Vegetation along the banks was noted to include teasel (*Dipsacus fullonum*), common comfrey (*Symphytum officinalis*), sweet vernal grass (*Anthoxanthum odoratum*), stinging nettle (*Urtica dioca*), thistle spp., dock species, greater willow herb (*Epilobium hirsutum*) and hartstongue (*Phyllitis scolopendrium*) on woodland river banks.
Reach Issues	
Native species	Algae identified within the reach of coverage of 25%.
Invasive non-native species	No alien/introduced species were identified in this reach.
In-stream barriers	26 in-stream barriers were identified in this reach of which 2 were Grade 1, including a wall and a weir; 2 Grade 3 structures and 8 Grade 4 structures. There were 13 observations of large woody debris in the channel with 8 observations of where it was causing blockages.

Issues for restoration and management	**Potential restoration options**
• Heavily poached banks due to cattle access. • Filamentous algae on sediment. • Over abstraction & low flows.	• Potential for BART to work with landowners on livestock management / fencing to reduce cattle access to the river and water provision. • EA to work with Wessex Water to introduce 'phosphate stripping' at Marshfield STW.

	• EA to work with Wessex Water and landowners over low flows and abstraction for amenity lake.
Constraints	
• Implementation of 'phosphate stripping' at works may not be cost effective. • All necessary permissions and permits would need to be received before undertaking any livestock fencing.	

Table 13 Overview of Reach 3b.

Overview of Reach 3b (Doncombe Bk - source to conf By Bk)	
Reach character photographs	
	
A: Poached banks and cattle access to the brook	B: Substrate covered in algae
	

C: Eroding left-hand and right-hand banks.

D: Over abstraction, including water use for amenity ponds & lakes.

E: Pebble-cobble substrate.

F: Open un-grazed areas support good riparian vegetation structure and diversity.

Table 14 Reach Summary Table: Reach 4a.

Reach 4a (By Bk – (Conf Doncombe Brk to conf R. Avon) Doncombe Brook to Slaughterford)		
Upstream survey limit NGR 384225,174795	**Downstream survey limit** NGR 384130,173852	**Approximate length of river surveyed** 1.84Km
Reach characterisation		
Hydromorphology: In reach 4a, the river is dominated by glide conditions associated with four in-channel structures throughout the reach resulting in a large proportion of the reach becoming impounded. This section of the river is situated within an asymmetrical valley with the river engineered against the steep-sided valley to provide a sufficient hydraulic gradient suitable for milling. The asymmetrical shape gives rise to a wide floodplain; however the channel is disconnected from its floodplain to the over-deepened channel. Low flow velocities and impoundment result in the substrate character being dominated by fine sedimentation. **Ecology:** Bank vegetation is open grazed grass with occasional mature trees and hawthorns. There are planted willows (cricket bat willows) on a short section of the right-hand bank. The highly impounded sections of the reach give rise to large amounts of reed growth both on the margins and within the centre of the channel.		
Geomorphological assessment		
Attribute	**Survey assessment**	
Flow dynamics and diversity	Flow in this reach is dominated by impounded glide conditions and areas of no perceptible flow (**Plates A** and **B**). One riffle was observed (**Plate E**); however, this reach is predominantly impounded by the four structures along its course.	
Substrate	The sediment regime in this reach is dominated by the in-channel deposition of fine sediments; however substantial sections of eroding bank were observed along the reach, predominantly upstream and downstream of structures as a result of the constriction of flow, particularly during winter periods when flows are higher. There was one section of the reach where a riffle was observed where flow energies were higher. Here the coarse substrate is overlain with silt deposits (**Plate E**) and as a result, no	

	clean gravels were observed.
Channel and banks	The planform within this reach has been modified as a result of the river's milling history, which has left this reach with vast lengths of straightened, over-deepened and over-widened channels. There is one section in the middle of the reach which is slightly sinuous and no evidence of channel straightening and thus exhibits a short section of riffle-run flows. The bank height indicates disconnection of the channel from its floodplain except in periods of flood flows.
Plant community species: **Composition and abundance**	Species observed during the audit included hard rush (*Juncus inflexus*), compact rush (*Juncus conglomeratus*), pendulous sedge (*Carex pendula*), common reed (*Phragmites communis*), branched bur-reed (*Spargantium erectum*), meadowsweet (*Filipendula ulmaria*) and lesser water-parsnip (*Berula erecta*). Within the river, water-crowfoot (*Ranunclus* spp.), floating sweet grass (*Glyceria fluitans*), and fennel pondweed (*Potamogeton pectinatus*). Vegetation along the banks was noted to include stinging nettle (*Urtica dioca*) and dock species.
Reach Issues	
Invasive non-native species	Algae identified within the reach of a coverage of >25%.
In-stream barriers	No alien/introduced species were identified in this reach.
Land management	27 in-stream barriers were identified in this reach of which 8 were Grade 1, including 7 weir structures; 1 Grade 2 bridge, 2 Grade 3 bridges and 2 Grade 4 bridges. There were 15 observations of large woody debris in the channel with 3 observations of where it was causing blockages.

Issues for restoration and management	**Potential restoration options**
• In-stream structures • Algae covered sediment • Silt covered spawning gravels • Bank erosion due to livestock poaching	• BART/ EA to work with landowners, angling club and residents to identify suitable options for fish passage. • BART/EA to work with the water company to reduce phosphate inputs into the river. • BART to work with farmers on livestock

	fencing and land management to reduce sediment and nutrient input into the river.
Constraints	
• White-clawed crayfish are known to inhabit areas of the By Brook and therefore an approved strategy must be in place to ensure the survival of this species before implementing any fish passage options. • Work to move any crayfish will require a special licensed individual. • All necessary permissions and permits should be sought before installing any livestock fencing.	

Table 15 Overview of Reach 4a.

Overview of Reach 4a (By Bk – (Conf Doncombe Bk to conf R. Avon) Doncombe Brook to Slaughterford)	
Reach character photographs	
	
A: In-stream structures are an issue for fish passage.	B: Channel impoundment with no perceptible flow.

C: Bank erosion downstream on in-channel structures.

D: Large algal blooms cover sediment and form on the surface during the summer.

E: Silt covering potential spawning gravels.

F: Bank collapse exasperated by poaching from livestock.

Table 16 Reach Summary Table: Reach 4b.

Reach 4b (By Bk – (Conf Doncombe Brk to conf R. Avon) Slaughterford to Drewett's Mill)		
Upstream survey limit NGR 384130,173852	**Downstream survey limit** NGR 383232,169949	**Approximate length of river surveyed** 5.32Km
Reach characterisation		
Hydromorphology: The upstream section of Reach 4b is situated within a steep-sided valley which results in a dominance of run conditions and swifter flows than the upstream reach. Sediment transport is the dominant process in the upstream section of the reach, with the substrate displaying significant sections of clean gravels and other coarse sediment. However, downstream of Tilley's Wood, Widdenham, the channel is straightened and over-deepened and has led to a dominance of glide habitat. Land use is characterised by a mixture of cattle grazing and woodland (**Plates A** and **B**). **Ecology:** The upstream section of the reach is situated within deciduous woodland where a complex structure of bankside vegetation is present. Downstream, land is grazed by dairy cattle right down to the water's edge which has resulted in limited amounts of riparian vegetation and occasional scattered trees (**Plate B**).		
Geomorphological assessment		
Attribute	**Survey assessment**	
Flow dynamics and diversity	The upstream section of Reach 4b is situated within a steep-sided valley which results in a dominance of run conditions and swifter flows than in Reach 4a. However, downstream of Tilley's Wood, Widdenham, the channel is straightened and over-deepened to accommodate the downstream weir, which has led to a dominance of glide habitat. Downstream of Widdenham Farm, glide habitat is dominant with sporadic riffle-run flows.	
Substrate	The sediment regime in the upstream section of the reach above Widdenham Farm is dominated by transport processes, supporting gravels and other coarse sediments (**Plate A**). The presence of macrophytes such as *Ranunculus* spp. in fast flowing sections of the reach results in channel accumulation of isolated patches of fine sediment.	

Channel and banks	The planform within this reach is varied and consists of a sinuous planform with shallow banks in the upstream valley dominated reach. Moving downstream the channel becomes over-widened and over-deepened to accommodate historic milling practices (**Plates G and H**).
Plant community species: **Composition and abundance**	Species observed during the audit included hard rush (*Juncus inflexus*), compact rush (*Juncus conglomeratus*), pendulous sedge (*Carex pendula*), water-crowfoot (*Ranunclus* spp.), floating pondweed (*Potamogeton natans*), common duckweed (*Lemna minor*), floating sweet grass (*Glyceria fluitans*). Vegetation along the banks was noted to stinging nettle (*Urtica dioca*), dock species and hartstongue (*Phyllitis scolopendrium*) on woodland river banks.
Reach Issues	
Native species	Algae identified within the reach of coverage of 25%.
Invasive non-native species	No alien/introduced species were identified in this reach.
In-stream barriers	43 in-stream barriers were identified in this reach of which 4 were Grade 1 weirs, including 7 weir structures; 1 Grade 2 bridge, 2 Grade 3 weirs and 1 Grade 4 weir. There were 35 observations of large woody debris in the channel with 7 observations of where it was causing blockages.

Issues for restoration and management	**Potential restoration options**
• In-stream structures • Algae covered sediment • Silt covered spawning gravels • Bank erosion due to livestock poaching	• BART/ EA to work with landowners, angling club and residents to identify suitable options for fish passage. • BART/EA to work with the water company to reduce phosphate inputs into the river. • BART to work with farmers on livestock fencing and land management to reduce sediment and nutrient input into the river.
Constraints	

- White-clawed crayfish are known to inhabit areas of the By Brook and therefore an approved strategy must be in place to ensure individuals are relocated to suitable ARK before implementing any fish passage options.
- Work to move any crayfish will require a special licensed individual.
- All necessary permissions and permits should be sought before installing any livestock fencing.

Table 17 Overview of Reach 4b.

Overview of Reach 4b (By Bk – (Conf Doncombe Bk to conf R. Avon) Slaughterford to Drewett's Mill)	
Reach character photographs	
	
A: Gravels and coarse sediment substrate.	B: Cattle grazing down to the river have limited riparian vegetation development.
	
C: Diffuse pollution from nearby cattle yards.	D: Cattle poached banks and nutrient enrichment

E: Siltation of potential spawning gravels.

F: Algae covered sediment and signs of eutrophication.

G: In-channel structures have lead to over-deepened channels and are an obstruction to fish passage.

H: Engineered straight channel.

Table 18 Reach Summary Table: Reach 4c.

Reach 4c (Lid Brook- source to conf By Bk)		
Upstream survey limit NGR 380539,170311	**Downstream survey limit** NGR 383179,169941	**Approximate length of river surveyed** 2.95Km
Reach characterisation		
Hydromorphology: Reach 6 is situated within a high gradient valley and as a result displays a good degree of flow and morphological diversity. The channel planform is characterised by a meandering channel with varied bank and bed profiles. The channel is connected well to the floodplain along the majority of the reach and is present on both banks in the upstream sections of the reach. However, in the middle sections of the reach the river becomes disconnected from the floodplain due to the steep banks and returns to a wide connected floodplain in the downstream sections of the reach. Land use in the floodplain consists of pastoral agriculture and is dominated by dairy cattle on both banks of the river. Excessive poaching in the past has led to accelerated bank erosion and destruction of riparian habitat. **Ecology:** Very little riparian vegetation exists along this reach. This is largely due to livestock access to the river and the excessive poaching which has caused damage to bankside structure and vegetation. However, with livestock fencing that has been erected in the past year it is hoped that a good diversity of riparian vegetation begins to establish.		
Geomorphological assessment		
Attribute	**Survey assessment**	
Flow dynamics and diversity	The high gradient of the river supports a dominance of riffle-run flows along the reach. The presence of natural in-stream structures such as large tree roots and large woody debris also provides additional areas of flow diversity, including chute flow (**Plate A**). The downstream lower gradient sections of the reach exhibit glide habitat and this is particularly evident adjacent to Saltbox Farm where the river has been straightened and the banks heavily modified to accommodate the farm (**Plate B**).	
Substrate	Upstream sections of the reach are dominated by sand and gravel substrate (**Plate C**) with coarser pebbles and cobbles deposited in the middle sections of the reach. Clean gravels are present in the	

	downstream sections of the reach with short section of heavy silt deposition in the low energy straightened sections of the river.
Channel and banks	The planform within this reach is slightly sinuous and channel banks are varied with upstream and downstream sections exhibiting low banks, whilst the high energy middle section is generally steep. Similarly floodplain connectivity is good in the upstream and downstream sections of the reach, whilst connectivity is limited in the middle reaches due to bank height. Isolated evidence of channel adjustment was observed in the downstream section at Saltbox Farm. The installation of livestock fencing through funding of the 1st phase of this project will help to provide valuable riparian habitat and reduce sediment and nutrient inputs into the river (**Plate D**).
Plant community species: **Composition and abundance**	Species observed during the audit included stinging nettle (*Urtica dioca*), thistle spp., dock species, and hartstongue (*Phyllitis scolopendrium*).
Reach Issues	
Native species	No native species were identified in this reach.
Invasive non-native species	No alien/introduced species were identified in this reach.
In-stream barriers	24 in-stream barriers were identified in this reach of which 1 was a Grade 2 culvert and 8 Grade 4 structures, including 3 fenced drinking bays, 1 fence, 2 bridges and 2 further culverts. There were 15 observations of large woody debris in the channel with 8 observations of where it was causing blockages.

Issues for restoration and management	**Potential restoration options**
• Sedimentation of downstream river gravels. • Nutrient influx from nearby farms.	• BART could work with farmers to improve land management practices, such as bringing cattle in over the winter, reducing compaction and introducing land drainage where required. • BART could work with farmers to introduce measures to reduce diffuse

	pollution on farms, such as the installation of guttering where required and installation of concrete sleeping policeman to reduce the likelihood of dirty water reaching nearby watercourses.
Constraints	
• There are no constraints identified.	

Table 19 Overview of Reach 4c.

Overview of Reach 4c (Lid Brook- source to conf By Bk)	
Reach character photographs	
 A: Tree roots provide good habitat and flow diversity.	 B: Heavily modified channel through Saltbox Farm.

	
C: Sand and gravel substrate is dominant in the upstream section of the reach.	D: The installation of livestock fencing provides a good riparian buffer strip.

Table 20 Reach Summary Table: Reach 5.

Reach 5 (By Bk – (Conf Doncombe Bk to conf R. Avon) Drewett's Mill to Bathford)		
Upstream survey limit NGR 383232,169949	**Downstream survey limit** NGR 378576,166991	**Approximate length of river surveyed** 6.48Km
Reach characterisation		
Hydromorphology: The upstream section of Reach 5 is dominated by over-widened and over-deepened channels with a number of large in-stream structures. Downstream of Box Mill studios the river returns to a more natural planform with good sinuosity interspersed with further in-stream structures, yet their effect on the river dynamics appears to be less dramatic than upstream. Downstream of Middlehill gauging weir a large section of riffle-run and pool habitat exists. **Ecology:** The predominant land management along this reach is grazing with very little of the river fenced off from livestock. As such there is limited riparian vegetation present; however in areas of glide and no perceptible flow there is a dominance of marginal reed species. Despite this, in-channel vegetation is present sporadically through the reach and *Ranunculus* spp. was noted on a number of occasions in areas of fast flow and good light penetration (**Plate E**).		
Geomorphological assessment		
Attribute	**Survey assessment**	
Flow dynamics and diversity	Flows in the upstream reaches between Drewett's Mill and Box Mill studios are less varied than would be typical for a type II river of this kind due to the impoundment of the river by a series of weirs (**Plate B**). Flows in the upstream reaches are dominated by low energy glides with sections of no perceptible flow (**Plate A**). The middle section of the reach from Box Mill studios to Box Bridge however, exhibits good flow diversity with the presence of pools, riffles, glides and chute flow. Downstream again from Box Bridge the channel is straightened in sections with the presence of a number of weirs which have led to further glide flows or no perceptible flow (**Plate C**).	
Substrate	Sediment deposition as a result of impoundment is the dominant process in the upstream and downstream sections of Reach 5. As a result there are few areas of shallow flow with clean gravels suitable	

	for salmonid spawning in these areas. However, the middle section of Reach 5 supports good quality clean stable gravels suitable for spawning (**Plate D**).
Channel and banks	The upstream section of Reach 5 is dominated by over-widened and over-deepened channels with a number of large in-stream structures. Between Box Mill studios and the Box Road Bridge the river returns to a more natural planform with good sinuosity interspersed with one further in-stream structure, yet its effect on the river dynamics appears to be less dramatic than upstream. Downstream of Box Road Bridge the river again returns to a straightened, over-deepened channel and there is visible evidence of impoundment along large sections of the river. The banks along the majority of the reach are quite steep as a result of historic deepening of the channel (**Plate E**) and show substantial signs of erosion (**Plate F**), whilst areas of shallow river bank exist sporadically along the reach.
Plant community species: **Composition and abundance**	Species observed during the audit included included hard rush (*Juncus inflexus*), compact rush (*Juncus conglomeratus*), common reed (*Phragmites communis*), branched bur-reed (*Spargantium erectum*), meadowsweet (*Filipendula ulmaria*) and lesser water-parsnip (*Berula erecta*). Within the river, water-crowfoot (*Ranunclus* spp.), floating pondweed (*Potamogeton natans*), water-milfoil (*Myriophyllum aquaticum*), floating sweet grass (*Glyceria fluitans*), fennel pondweed (*Potamogeton pectinatus*), and water mint (*Mentha aquatica*). Vegetation along the banks was noted to include teasel (*Dipsacus fullonum*), common comfrey (*Symphytum officinalis*), sweet vernal grass (*Anthoxanthum odoratum*), stinging nettle (*Urtica dioca*), thistle spp., dock species, and greater willow herb (*Epilobium hirsutum*)
Reach Issues	
Native species	No native species of concern were identified in this reach.
Invasive non-native species	No alien/introduced species were identified in this reach.
In-stream barriers	88 in-stream barriers were identified in this reach of which 7 were Grade 1 weirs, 8 were Grade 2 bridges and culverts and 1 Grade 2

	weir. In addition to this, there were a total of 11 Grade 3 bridges, culverts and groynes. There were 56 observations of large woody debris in the channel with 8 observations of where it was causing blockages.
Issues for restoration and management	**Potential restoration options**
• In-stream structures. • Agricultural run-off. • Steeply eroding banks.	• BART/ EA to work with landowners, angling club and residents to identify suitable options for fish passage. • BART to work with farmers on implementing good land management practices to reduce agricultural run-off.
Constraints	
• White-clawed crayfish are known to inhabit areas of the By Brook and therefore an approved strategy must be in place to ensure the successful relocation of individuals to suitable ARK sites before implementing any fish passage options. • Work to move any crayfish will require a special licensed individual.	

Table 21 Overview of Reach 5.

Overview of Reach 8 (By Bk – (Conf Doncombe Bk to conf R. Avon) Drewett's Mill to Bathford)	
Reach character photographs	
	
A: Dominant glide flow and no perceptible flow in upstream sections of the reach.	B: In-stream structures.

C: Impoundment downstream of Box Bridge due to in-channel structures.

D: Clean spawning gravels in the middle section of Reach 5.

E: Over-deepened steep banks.

D: Agricultural run-off.

E: *Ranunculus* thrives in areas of open shallow water.

F: Steeply eroding banks.

3.2 Point and Diffuse Pollution

A total of 486 sources were recorded on the 45 km walked in the By Brook catchment. Of these, 140 were diffuse and 38 were point sources. A further 640 features were recorded during the audit, such as barriers to fish passage, large woody debris, and depositional features, however these are not included in the point source and diffuse source pollution scores. The source grade analysis is shown in Figure 2. The majority of sources were classified as Grade 3, with a total of 300 inputs. There were 28 Grade 2 sources (6%) and 158 Grade 4 sources (32%) were recorded in the catchment.

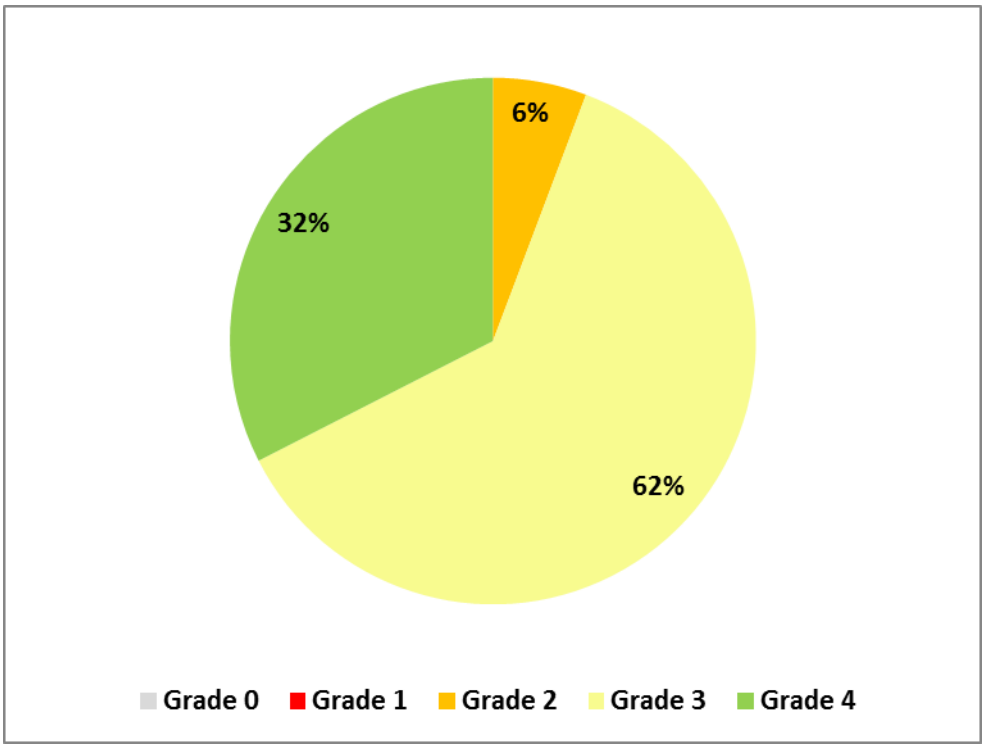


Figure 2 Percentage of sources analysed by Grade.

The location of each source has been mapped in ArcGIS (**Appendix 2**). An analysis of graded sources by category (**Figure 3**) highlights the groups of activities and issues causing notable inputs of sediment, point source pollution and diffuse pollution. Livestock (Category B) and other sources (Category E) were the sole contributors to Grade 2 sources in the By Brook catchment, with 18 and 10 sources respectively. Other sources (Category E) were the largest cause of Grade 3 inputs/issues, with a total number of 231 recorded. Livestock sources (Category B) accounted for 19% of Grade 3 pollution, whilst point source conduits (Category C), accounted for 2.3% of Grade 3 pollution inputs. Similarly, other sources accounted for 51% of Grade 4 source inputs, whilst livestock accounted for 34% of Grade 4 inputs.

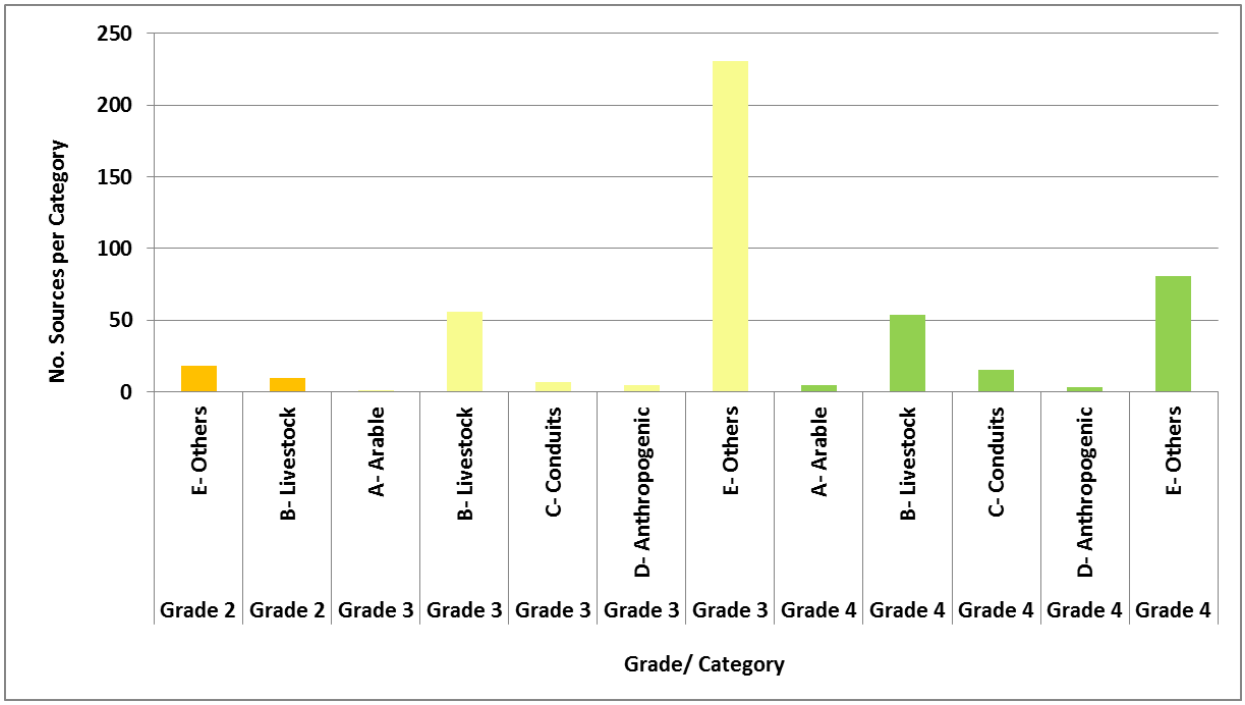


Figure 3 Number of sources per Grade and analysed by Category.

A total of 21 different types of pollution sources or potential issues were documented during the fluvial audit. These are mapped separately in Appendix 2. The most common type of issue recorded was eroding cliffs, which accounted for 52% of sources; whilst exposed tree roots were also recorded quite frequently, and accounted for 14% of sources (**Figure 4**). Poaching by livestock was the next most common source of pollution accounting for 20% of point and diffuse sources of pollution combined. Drainage pipes from transport links and the occurrence of algae on sediment accounted for 4% and 3% of sources respectively.

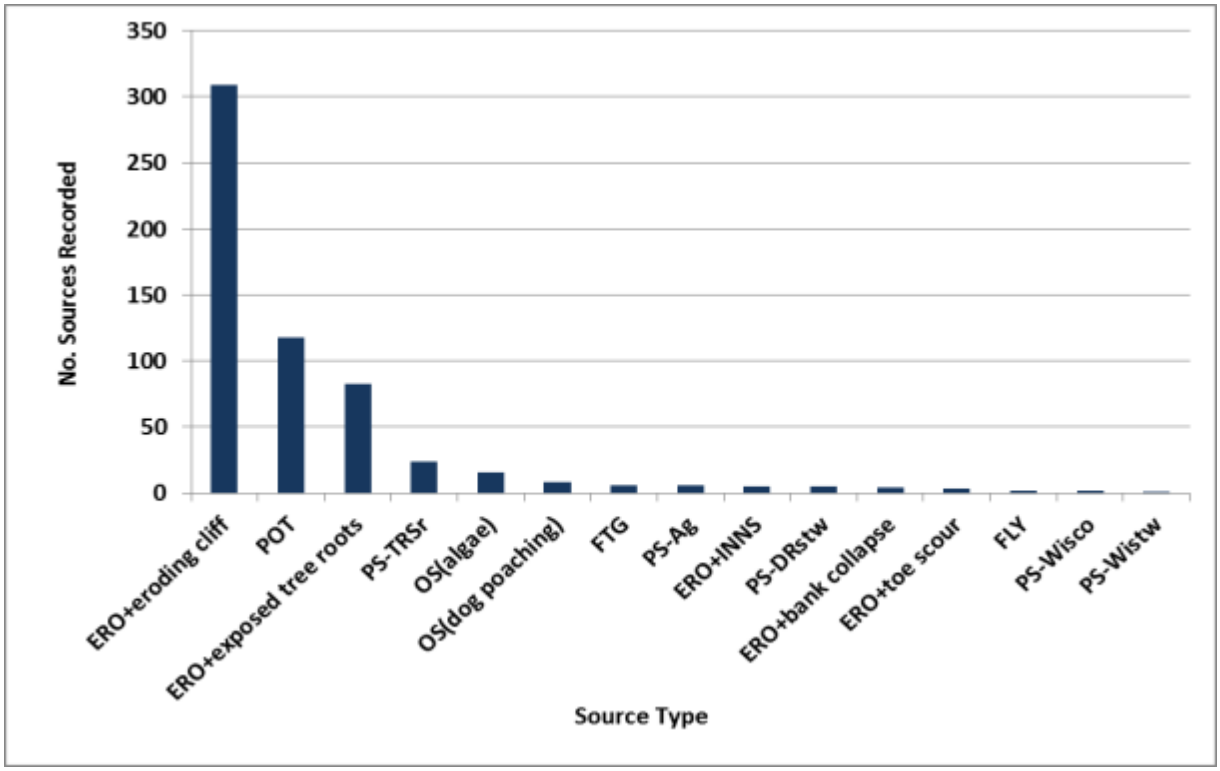


Figure 4 Number of sources by type.

3.3 Barriers to fish passage

A total of 249 barriers to fish passage were recorded in the By Brook catchment during the fluvial audit. A breakdown of the different types of barrier is given in **Figure 5** below. Large woody debris was the most common type of barrier to fish passage in the catchment with 89 separate records, this accounting for 36% of barrier types. Bridges and weirs were the second most common type of barrier to fish passage with records of 53 (21%) and 51 (20%) respectively. The fluvial audit also highlighted a large number of other types of barrier not commonly observed in rivers, including telegraph poles, walls and iron sheeting, although these only accounted for a small proportion of records.

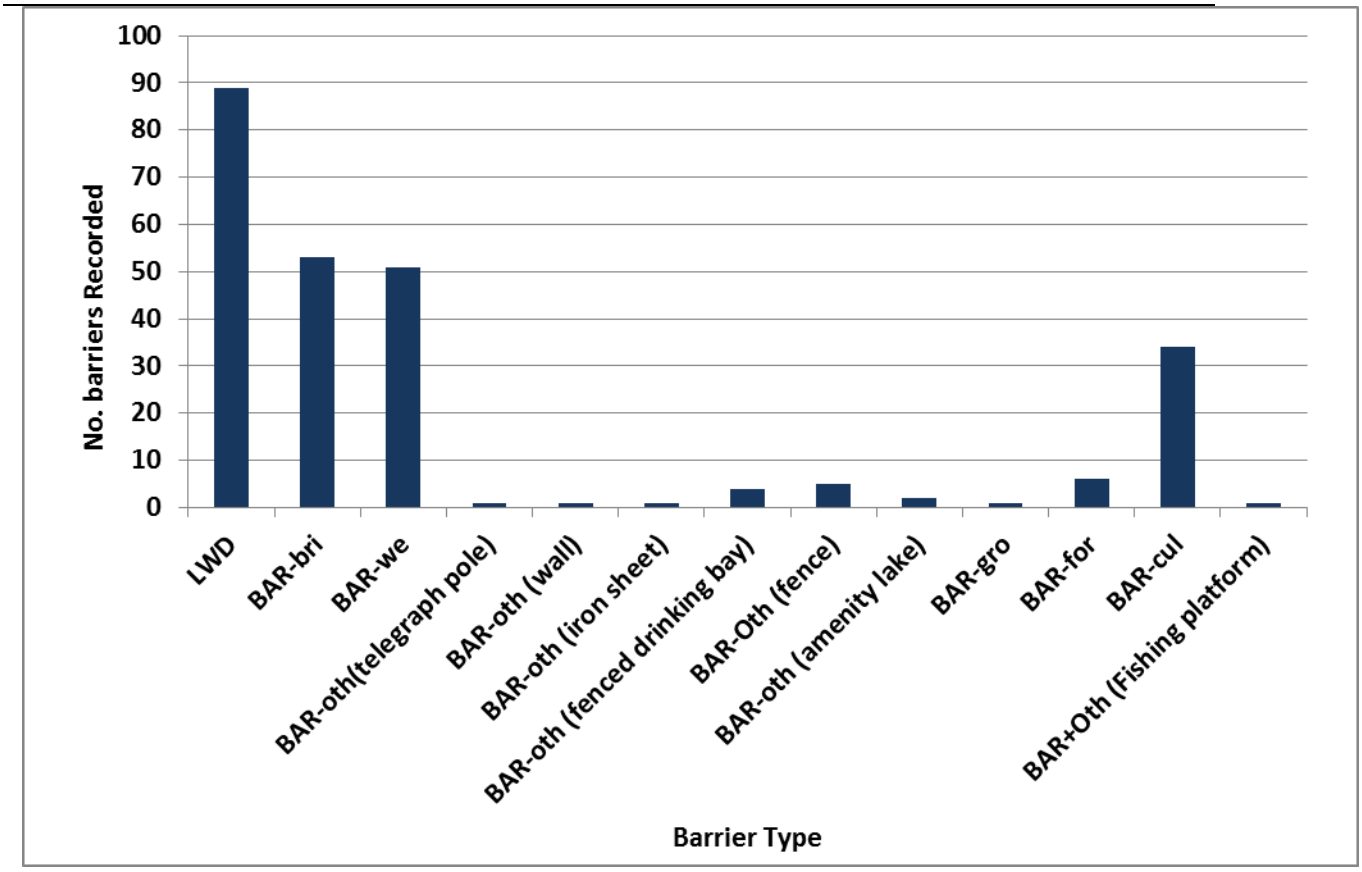


Figure 5 Number of barriers to fish passage by type.

There was 1 Grade 2 barrier recorded on the Broadmead Brook (Reach 2) and 4 Grade 2 barriers recorded on the By Brook. In addition to this, a Grade 3 barrier was recorded on the By Brook on Reach 1 and a further 5 Grade 3 barriers were also recorded on the By Brook all located on Reach 3 between Castle Combe and Ford. The sources identified are all in-stream barriers to fish migration that have not been recorded by BART previously and are new to the project. Individual Grade assessments were completed for each of the Grade 1 to 3 barriers identified (see **Table 22 to Table 32** below).

Table 22 Potential barriers to fish migration: Reach 1, 383599,178866.

Project	By Brook catchment	River	By Brook
Reach Number	1	Recorder	MH
Date	29/12/2014	NGR	383599,178866
Category	E	Type	BAR-we
Description	Straight drop weir approximately 0.8m high and 0.8m wide.		
Land Use	LHB: lay-by/ trees.	RHB: improved/ semi-improved grassland.	
Comments	A straight drop weir of approximately 0.8m in height and 0.8m in width, situated upstream of Gatcombe Mill. The weir is only likely to be passable to migratory fish in medium and high flows. 		

Table 23 Potential barriers to fish migration: Reach 2, NGR 383456,177586.

Project	By Brook catchment	River	Broadmead Brook
Reach Number	2	Recorder	MH
Date	03/01/2015	NGR	383456,177586
Category	E	Type	BAR-we
Description	Broad crested weir approximately 2.3m high and 5m wide.		
Land Use	LHB: Residential	RHB: Public track/ woodland	
Comments	A broad crested weir of approximately 2.3m in height and 5m in width, situated downstream of Nettleton Mill, near Castle Combe. The weir is only likely to be passable to migratory fish at high flows. 		

Table 24 Potential barriers to fish migration: Reach 3, NGR 384 056,176 723.

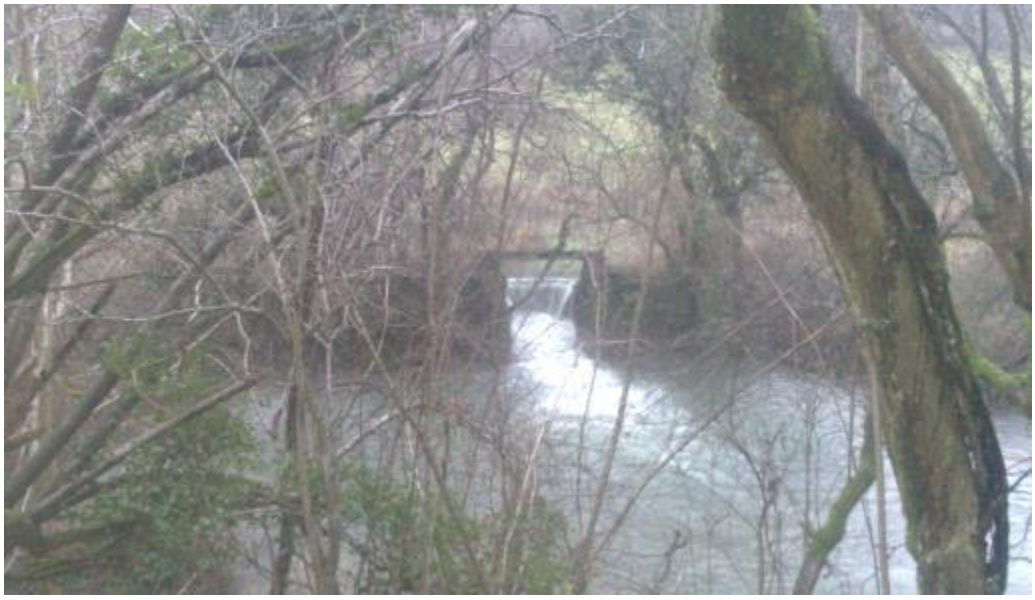
Project	By Brook catchment	River	By Brook
Reach Number	3	Recorder	MH
Date	08/01/2015	NGR	384 056,176 723
Category	E	Type	BAR-we
Description	Straight drop weir approximately 3.5m high and 3m wide.		
Land Use	LHB: Improved/ semi-improved grassland	RHB: Improved/ semi-improved grassland	
Comments	A straight drop weir of approximately 3.5m in height and 3m in width, situated downstream of Brook House, Castle Combe. The weir is unlikely to be passable to any migratory fish, even in high flows. 		

Table 25 Potential barriers to fish migration: Reach 3, NGR 384104,176585.

Project	By Brook catchment	River	By Brook
Reach Number	3	Recorder	MH
Date	08/01/2015	NGR	384104,176585
Category	E	Type	BAR-we
Description	Stepped weir approximately 3.5m high and 13m wide.		
Land Use	LHB: Improved/ semi-improved grassland	RHB: Improved/ semi-improved grassland	
Comments	A straight stepped weir of approximately 3.5m in height and 13m in width, situated downstream of Brook House, Castle Combe. The weir is unlikely to be passable to any migratory fish, even in high flows. 		

Table 26 Potential barriers to fish migration: Reach 3, NGR 384165,176151.

Project	By Brook catchment	River	By Brook
Reach Number	3	Recorder	MH
Date	08/01/2015	NGR	384165,176151
Category	E	Type	BAR-we
Description	Stepped weir approximately 3m high and 8m wide. Also sluice gates.		
Land Use	LHB: Improved/ semi-improved grassland	RHB: Residential garden.	
Comments	A straight stepped weir of approximately 3m in height and 8m in width, situated at Colham Mill, near Castle Combe. The weir is only likely to be passable to migratory fish at high flows. 		

Table 27 Potential barriers to fish migration: Reach 3, NGR 384169,176159.

Project	By Brook catchment	River	By Brook
Reach Number	3	Recorder	MH
Date	08/01/2015	NGR	384169,176159
Category	E	Type	BAR-we
Description	Stepped weir approximately 2m high and 10m wide.		
Land Use	LHB: Residential garden	RHB: Residential garden	
Comments	A straight stepped weir of approximately 2m in height and 10m in width, situated at Colham Mill, Castle Combe. The weir is only likely to be passable to migratory fish at high flows. 		

Table 28 Potential barriers to fish migration: Reach 3, NGR 384577,175985.

Project	By Brook catchment	River	By Brook
Reach Number	3	Recorder	MH
Date	08/01/2015	NGR	384577,175985
Category	E	Type	BAR-we
Description	Broad crested weir approximately 1m high and 4m wide.		
Land Use	LHB: Deciduous woodland	RHB: Improved/ semi-improved grassland	
Comments	A broad crested weir of approximately 1m in height and 4m in width, situated downstream of Colham Mill, near Castle Combe. The weir is likely to be passable to migratory fish in moderate and high flows. 		

Table 29 Potential barriers to fish migration: Reach 3, NGR 384700,175651.

Project	By Brook catchment	River	By Brook
Reach Number	3	Recorder	MH
Date	08/01/2015	NGR	384700,175651
Category	E	Type	BAR-we
Description	Broad crested weir approximately 1.7m high and 2m wide.		
Land Use	LHB: Deciduous woodland	RHB: Improved/ semi-improved grassland	
Comments	A broad crested weir of approximately 1.7m in height and 2m in width, situated upstream of Long Dean. The weir is only likely to be passable to migratory fish in high flows. 		

Table 30 Potential barriers to fish migration: Reach 3, NGR 384964,175683.

Project	By Brook catchment	River	By Brook catchment
Reach Number	3	Recorder	MH
Date	08/01/2015	NGR	384964,175683
Category	E	Type	BAR-we
Description	Straight drop weir approximately 4m high and 5m wide.		
Land Use	LHB: Improved/ semi-improved grassland	RHB: Improved/ semi-improved grassland	
Comments	A straight drop weir of approximately 4m in height and 5m in width, situated at Long Dean Mill. The weir is unlikely to be passable to any migratory fish, even in high flows. 		

Table 31 Potential barriers to fish migration: Reach 3, NGR 385007,175532.

Project	By Brook catchment	River	By Brook
Reach Number	3	Recorder	MH
Date	08/01/2015	NGR	385007,175532
Category	E	Type	BAR-we
Description	Straight drop weir approximately 2m high and 2.5m wide.		
Land Use	LHB: Improved/ semi-improved grassland	RHB: Residential garden	
Comments	A straight drop weir of approximately 2m in height and 2.5m in width, situated at Lower Long Dean Mill. The weir is only likely to be passable to migratory fish at moderate and high flows. 		

Table 32 Potential barriers to fish migration: Reach 5, NGR 379,833,167,429.

Project	By Brook catchment	River	By Brook
Reach Number	5	Recorder	MH
Date	02/02/2015	NGR	379833,167429
Category	E	Type	BAR-we
Description	Straight drop weir approximately 2m high and 4m wide.		
Land Use	LHB: Scrub/ Railway embankment	RHB: Scrub/ rank grassland	
Comments	A straight drop weir of approximately 2m in height and 4m in width, situated downstream of Box Bridge. The weir is unlikely to be passable to any migratory fish. 		

3.4 Overview of catchment conditions

This section describes a summary of the data gathered during the winter 2015 fluvial audit and supporting evidence from the BART walkover survey gathered in the summer of 2013.

3.4.1 Substrate conditions

The fluvial audit has demonstrated that the sediment regime in the By Brook is comprised of a good mixture of erosional and depositional processes, with substantial evidence of both eroding cliffs and fine siltation throughout the catchment. As a result of the combination of erosional and depositional processes acting within the channel, the substrate composition of the main By Brook channel is comprised of a good mixture of gravels with coarser sediments deposited in areas of slower flow.

The substrate in Reaches 4a and the upstream section of Reach 5 are dominated by fine sediments and uniform bed conditions (**Figure 6**). The gravel supply in these areas is good since there is still a substantial amount of bank erosion processes occurring, particularly in periods of high flows and where the channel obstructions cause a restriction in flow and therefore increase erosional processes around the obstruction. It appears that there is sufficient material in the system (including in-situ material and sediment that is transported over these obstructions during high flows); however due to the size of the obstructions (four Grade 1 sources) the impact of these structures on the river is major and thus fine sedimentation is still occurring even during periods of high flows. This means that it is not possible to encourage further substrate recovery in these reaches through physical modifications to bed and bank form unless the obstructions were removed or altered in such a way as to substantially reduce the impounding effect they currently have on the river.

Figure 6 Large amounts of fine sediment are common throughout impounded reaches of the By Brook.

The proportion of gravel substrate increases through Reach 4b and within the middle section of Reach 5 (between Middlehill gauging weir and Box Road Bridge). The increase in the proportion of coarse sediment at these sites is connected to a combination of bank erosion within the reach and from localised increases in geomorphological diversity associated with channel narrowing due to the development of vegetated berms, increased channel gradient and increased flow velocities. However, as a result of a combination of land management activities in the catchment, particularly poaching by livestock and agricultural run-off; with the addition of sewage treatment works and private septic tanks, the quality of the sediments are generally in a 'moderate' condition. Observations throughout the winter fluvial audit and the walkover survey undertaken in 2013 indicate a number of sites which potentially could support good spawning gravels are covered in silt or algae.

The presence of algae coated sediments was particularly notable in Reaches 2, 3 and 3b where algae coverage on sediment was approximated at around 25%. Algae covered sediment was also noted in Reach 1, 4a and 4b; however this was to a lesser extent. During the fluvial audit and the walkover survey in 2013, a number of sites were identified where a sweet smell of washing powder, foam and algal were recorded together. Situations like this are suggestive of misconnections and therefore further investigation by the EA is recommended.

Silt covered sediments were noted throughout the catchment except for the Lid Brook, where a good supply of clean sand and gravels were present. The fact that clean sediments were only recorded in the Lid Brook is particularly poignant since BART and the EA delivered a scheme of land management advice and livestock fencing along the majority of the river during 2013/2014. It is therefore suggested that more land management and infrastructure work is implemented throughout the catchment in order to reduce the sediment influx into the catchment.

The historical dredging activities on the By Brook are likely to be responsible for observed increases in channel capacity throughout. It is likely that these channel modifications have, in conjunction with the shallow channel gradient characteristic of this river type, exacerbated the observed sedimentation issues, since low energy flows in the enlarged channel sections are less able to transport sediments than swifter flows in more natural channels. As a result, the range of aquatic habitats supported by these flow conditions and abundant fine sediment supply is limited. Suitable habitat for aquatic vegetation such as water crowfoot and water milfoil is generally limited on the main By Brook channel, with the exception of some areas within Reaches 4b and 5 where flows are sufficiently fast to prevent siltation and the river bed displays a mosaic of substrate materials characteristic of this river type.

3.4.2 Planform and profile characteristics

The planform of the By Brook demonstrates that it has been altered quite significantly over time as a result of historical milling activities which took place on the river on a grand scale. Reaches 1, 2, 3 and 3a display the most sinuous planform within the study area, with few signs of recent channel straightening. These reaches exhibit characteristics of natural channel carrying capacity and cross section shows the banks are generally low sided and of a low gradient. Some sections within these reaches have been affected by localised geotechnical failure and livestock trampling, which is particularly evident between West Kington and Nettleton Shrub in Reach 2. The planform of the river within Reach 3 between Brook House and Lower Colham exhibits a varied geotechnical form with the presence of river braiding, varied flows, good habitat structure and the presence of a diverse range of aquatic macrophytes (**Figure 7**).

Figure 7 Braided river and wetland features at Colham Mill.

A short section of the By Brook in Reach 4b (between Honeybrook Farm and Weavern Farm) presents a good example of Type II river morphology, despite that a redundant mill leat runs alongside this section of the river. This higher gradient section of the river gives rise to good flow diversity with a number of riffle-run and pool flows present throughout and consequently a number of point bars, side bars and vegetated mid-channel bars have formed.

With the exception of the reaches discussed above, the majority of the By Brook channel displays a bank geometry characterised by a uniform, trapezoidal cross section with high banks and limited floodplain connectivity. There is however an example of excellent floodplain habitat exhibited in Reach 5 between Drewett's Mill and Box Mill Sudio's. Part of a paleochannel runs from upstream of Inghalls Cottages and along the field boundary for approximately 450m before flowing into the mill pool below Box Mill Studio's (**Figure 8**). The presence of the spring fed paleochannel has allowed a vast area of floodplain wetland habitat to develop within which grey heron (*Ardea cinerea*) and little egret (*Egretta garzetta*) have been seen amongst a variety of invertebrates, including dragonflies and butterflies (**Figure 9**).

Figure 8 Spring-fed paleochannel flows along the field boundary near Box Mill Studio's.

Figure 9 Floodplain wetland habitat upstream of Box Mill Studio's.

3.4.3 Flow dynamics and diversity

The flow regime along a large proportion of the By Brook catchment is characterised by glide flows, broadly complying with the requirements for Type II lowland, clay dominated rivers. However, widespread channel enlargement has resulted in a reduction in the occurrence of faster flow velocities, as well as riffle features. These are of crucial importance to the maintenance of the mosaic of in-channel habitats that support the characteristic flora and fauna of this river type.

Upstream reaches and tributaries, for example Reach 2, Reach 3, Reach 3a and Reach 3b exhibit a wide range of flow diversity as a result of a more natural geomorphological structure of the channel and increased bed gradient.

Impoundment by in-channel structures is a major issue in through Reaches 4a and Reach 5, which is concurrent with enlarged sections of the river and subsequent reduction in flow velocity resulting in notable sections of the river with no perceptible flow. Evidence of channel recovery is present at a number of locations within Reaches 4a and 5 where wide vegetated berms have established (**Figure 10**). There is also a dominance of large woody debris throughout the catchment; however, there are only a few occurrences where these cause natural impoundment of the waterbody and are therefore likely to be providing a wealth of valuable habitat for fish and macroinvertebrates as well as aiding variation in flow velocity.

Figure 10 Vegetated berm formation as the river tries to recover into a more natural channel.

Notable exceptions to the uniform flows occur in Reaches 2, 3 and 3a with a short upstream section in Reach 4b. These reaches include a good range of in-channel geomorphological features including low banks and small point bars associated with light grazing and localised bank collapse, resulting in variable flow types with faster flows coexisting with areas of refugia. These reaches are therefore a good example of ideal flow characteristics for this type of a shallow gradient river.

3.4.4 Habitat structure and species abundance

Vegetation species observed during the summer 2013 walkover survey included hard rush (*Juncus inflexus*), compact rush (*Juncus conglomeratus*), pendulous sedge (*Carex pendula*), common reed (*Phragmites communis*), branched bur-reed (*Spargantium erectum*), meadowsweet (*Filipendula ulmaria*) and lesser water-parsnip (*Berula erecta*). Within the river, water-crowfoot (*Ranunclus* spp.), floating pondweed (*Potamogeton natans*), water-milfoil (*Myriophyllum aquaticum*), common duckweed (*Lemna minor*), floating sweet grass (*Glyceria fluitans*), fennel pondweed (*Potamogeton pectinatus*), water mint (*Mentha aquatica*), water starwort (*Callitriche stagnalis*), and some blanket weed were recorded. Vegetation along the banks was noted to include teasel (*Dipsacus fullonum*), common comfrey (*Symphytum officinalis*), sweet vernal grass (*Anthoxanthum odoratum*), stinging nettle (*Urtica dioca*), thistle spp., dock species, greater willow herb (*Epilobium hirsutum*) and hartstongue (*Phyllitis scolopendrium*) on woodland river banks.

Dense stands of trees and woodland were also present along the tributary rivers and the vast majority of the main By Brook channel providing shading to the river and a contribution of large woody debris for in-stream habitat for fish and a food resource for macroinvertebrates. Furthermore the presence of tree-lined banks also helps to support the bank structure particularly in areas of active erosion which were recorded in a large number of reaches.

The trapezoidal cross-sectional profile with an over-wide and over-deep channel which dominates the majority of the By Brook main channel is strongly associated with the small, abrupt zone of hydrological transition observed during the fluvial audit. The lack of a more natural, gradual transitional zone limits the range of habitat niches that are supported in the margins of the channel. This limits the potential for colonisation of emergent species such as branched bur-reed, brook-lime, water forget-me-not, water-mint and water-cress, and invertebrates which depend upon them.

There was no evidence of any native protected species recorded during either of the surveys, although specific white-clawed crayfish (*Austropotamobius pallipes*) surveys undertaken by Ahern Ecology and OHES confirmed the presence of white-clawed crayfish within the By Brook.

3.4.5 Invasive non-native species

No invasive non-native species were observed during the walkover survey; however evidence of crayfish burrows were present on the Broadmead Brook. The presence of crayfish traps (**Figure 11**) at the side of the river and discussions with local residents are likely to suggest that the signal

crayfish (*Pacificastacus leniusculus*) is prevalent in the Broadmead Brook, particularly upstream of West Kington.

Figure 11 Crayfish trap observed on the bank of the Broadmead Brook u/s of West Kington.

3.5 Point Source Pollution

The fluvial audit recorded 40 locations where point source pollution could be causing an issue. Observations throughout the winter fluvial audit and the walkover survey undertaken in 2013 indicate a number of sites which potentially could support good spawning gravels are covered in algae. The presence of algal coated sediments was particularly notable in Reaches 2, 3 and 3b where algal coverage on sediment was approximated at around 25%. Algae covered sediment was also noted in Reach 1, 4a and 4b; however this was to a lesser extent. During the fluvial audit and the walkover survey in 2013, a number of sites were identified where a sweet smell of washing powder, foam and algal were recorded together. Situations like this are suggestive of misconnections and therefore further investigation by the EA is recommended.

3.6 Diffuse Source Pollution

Diffuse pollution inputs into the By Brook catchment were far more numerous than point sources, which is not surprising considering the rural nature of the catchment. Poaching and erosion were the

most significant pressures identified during the survey and these sources are commonly connected. The flashy nature of the watercourse has resulted in a number of eroding banks and recent bank slips. The input of excess sediment and fine material has the potential to smother fish spawning habitat. To reduce bank erosion and riparian vegetation degradation by livestock, it is suggested a combination of livestock fencing and water provision is installed, particularly in those sites connected with good spawning gravels. Water provision for livestock could include the provision of solar powered pumps, pasture pumps, drinking bays and mains water to troughs where suitable. Drinking bays and mains water troughs are less favourable options as the former still encourages livestock to drink and therefore defecate in the river, whilst dependence on mains water is unfavourable with a number of farmers. However, solar powered pumps and pasture pumps keep cattle away from the river completely and would be the recommended options for these sites. Restricting livestock from the watercourse will also reduce the ammonia and phosphate loading potential.

There is very little arable land managed within the By Brook catchment, however in the few areas where land is managed under arable rotation it is suggested that BART could work with landowners to increase the size of buffer strips or look at changes in land management practices, such as the growing of cover crops over winter, and harvesting high risk land earlier by growing early season varieties of crops.

3.7 Barriers to Fish Migration and Connectivity

The number and scale of barriers present in the By Brook catchment present a significant issue to the successful catchment management and delivery of WFD objectives. An additional nine barriers were newly identified during the fluvial audit and are concentrated in Reach 3 with a further barrier in Reach 2. Barriers to migratory fish movement have been created in all cases due to changes in hydraulic conditions at the structures, which exceed the swimming capabilities or do not suit the behavioural characteristics of fish attempting to pass upstream. The major changes to natural waterway conditions at these sites include, higher velocities, reduced flow depth, lack of resting places or shelter, excess turbulence and water surface drop. The additional weirs require investigation on a case-by-case base basis. There may be scope for retrofitting fish migratory aids, such as fish ladders and passes, on a number of structures on the By Brook. A substantial amount of LWD was recorded during the fluvial audit, and only a small proportion resulted in the formation of debris dams. Woody debris can provide refugia from high velocity flows, shade, feeding, spawning and nursery habitat for a number of fish, macroinvertebrate and mammalian species.

In-channel structures alter the natural processes which operate within the river channel, creating slow flowing impounded conditions upstream and preventing the free movement of fish and other aquatic organisms. These changes in condition can encourage fine sedimentation, reduce the movement of coarse sediments, and create uniform bed habitats. In addition, impounded conditions can also result in increased water temperature and a change in biological communities from those that prefer active flows to those that prefer still water.

3.8 Key issues affecting the By Brook catchment

The previous sections demonstrate that the condition of the By Brook catchment is adversely affected by physical modifications and land management, which impact upon the habitats that can be supported. The fluvial audit demonstrates that there are four primary issues which are likely to be impacting on the catchment and overall ecological status of the waterbodies and these are in-channel structures; fine sediment supply and deposition; nutrient enrichment; and bank erosion.

3.8.1 In-channel structures

The By Brook is affected by a large number of in-channel structures, including those already identified by BART and the Environment Agency and the nine newly identified structures identified as a result of the fluvial audit. These structures alter the natural functionality of the geomorphological and hydrological processes that operate within the river channel, creating slow flowing impounded conditions upstream and potentially limiting coarse sediment supply downstream. These low energy conditions combine with high fine sediment supply to encourage sedimentation in the channel. Structures also act as significant barriers to the free movement of fish and other aquatic organisms, and may also increase temperature and promote still water species.

3.8.2 Fine sediment supply and deposition

Fine sedimentation is a common feature throughout the catchment and although good quality gravels were observed on the Lid Brook, previous wet weather surveys undertaken by BART and Wavelength with EA funding discovered 6 tonnes of sediment entering the main By Brook channel from this small tributary, whilst a staggering 46 tonnes were recorded in the main By Brook channel on the same wet weather event (BART, 2014). Sedimentation in the By Brook is largely as a result of agricultural practices in the catchment, such as arable farming in the headwaters, agricultural run-off from yards and fields, and livestock grazing up to the river bed. Erosive processes are present throughout the catchment and it likely that livestock grazing up to the edge of river banks is

causing excessive pressure and resulting in a number of banks collapsing. In addition to this, an increase in channel capacity as a result of historical modifications and natural processes, and a change in river flow regime due to the influence of the in-channel structures combine with the increased sediment supply to promote in-channel sedimentation. Excessive fine sedimentation has a detrimental effect on river habitat by reducing the diversity of the channel bed and creating uniform, silted conditions. Furthermore, important habitats for spawning fish, macroinvertebrates, and macrophytes become smothered and unsuitable for supporting healthy populations of aquatic species.

3.8.3 Nutrient enrichment

Evidence of nutrient enrichment was observed both during the 2013 walkover survey and the recent fluvial audit. The main affected areas in the catchment were Reaches 2, 3 and 3b where algal coverage on sediment was approximated at around 25%. Algae covered sediment was also noted in Reach 1, 4a and 4b; however this was to a lesser extent. In Reach 2 it is likely that a number of misconnections are present within local residences causing an influx of phosphate into the watercourse. During the survey a sweet smell of washing powder was noted along with foam on the water surface, which could suggest a misconnected washing machine. Other possible misconnections could include septic tanks and cess pits. The algal growth noted in Reach 3b is likely to be due to the sewage treatment works at Marshfield which discharges into the Doncombe Brook. Substantial areas of algal covered sediment were observed during the walkover, reducing their suitability for fish and macroinvertebrates. In addition to this, cattle have access to the river for drinking and it is likely that a further combination of defecation and urination from cattle is increasing the nutrient input, alongside the degradation of the banks and influx of phosphate-bound sediment.

Reach 4a and 4b are downstream of the two aforementioned tributaries and are therefore likely to be receiving excessive nutrient loading from these upstream areas. In addition to this, a septic tank misconnection was noted just downstream from Ford and the active erosion of the bank in these areas is also likely to be contributing phosphate-bound sediment into the system.

3.8.4 Bank erosion

There are 410 records of bank erosion which were noted during the fluvial audit across the By Brook catchment. The catchment is ‘flashy’ in nature and supports both erosive and depositional processes throughout; however a combination of in-channel structures causing constriction in flow

and livestock grazing are accelerating the rate of erosion in some areas leading to bank collapse and the destruction of riparian habitat. For example over a 1Km section of Reach 2 has been damaged by excessive poaching by cattle overwintering in the adjacent fields. Poaching by cattle accessing the river to drink was also frequently recorded in Reaches 4a and 4b and in these areas it was also noted that a number of point bars and riffles were present which could be suitable spawning sites for fish if they didn't have a fine coating of silt likely to be from the adjacent poaching activity.

The presence of in-channel structures again places a further pressure on the river in terms of constriction of flow, particularly in periods of high flow when both supporting banks and the structures themselves come under pressure. Erosional activity both upstream and downstream of the structures in Reach 4a and 4b was noted and particularly around the structures themselves. A combination of bank lowering upstream of the structures to form a more natural bank gradient and soft revetment downstream may help reduce the erosional impact in these areas. This work would only be recommended where removal of the weir itself wasn't proposed.

4.0 RESTORATION MEASURES

In order to improve the ecological status of the six waterbodies of the By Brook catchment, the potential restoration measures have focused on ameliorating the effect of the aforementioned impacts, removal of any historical modifications where possible and to reinstate natural river processes to allow more natural forms to develop through time. The process of devising a set of prioritised measures has involved the analysis of a large amount of information taken from the 2013 walkover survey, 2014 fluvial audit and GIS; and previous phase I work undertaken in the catchment. It must be taken into consideration that these suggested restoration measures are those which BART feel could be achievable in the catchment. Whilst many local people have been involved in the By Brook project over the past 2 years, a full stakeholder exercise has not yet been undertaken to discuss priorities and options and this would be BART'S recommended next step.

The measures required to reduce the impacts on the By Brook catchment can be categorised into two forms; short-term measures which could be undertaken in the next 1-3 years, and long-term measures for delivery over a 5-10 year period.

The measures identified to remove or alleviate the impacts currently acting on the By Brook catchment are as follows:

- Livestock fencing;
- Soft bank revetment;
- Bank re-profiling;
- Removal of in-channel structures or provision of fish passage;
- Engagement with local residents regarding misconnections;
- Engagement with the local water company regarding sewage treatment works discharges.

4.1 Short-term Measures

4.1.1 Livestock fencing

The accessibility of the river to the grazing and poaching action of cattle has encouraged bank erosion along substantial sections of Reach 2, 4a, and 4b and is likely to be contributing to poor water quality, increasing sediment influx into the river and impacting on valuable spawning habitat. Given that limited grazing and poaching actually promote biodiversity, the ideal solution to excessive grazing and poaching is to reduce stock density. However, in reality this may not be viable economically. Therefore the simplest means of restricting cattle access to the river channel

and riparian margins is the use of livestock fencing. Fencing should be located parallel to the waterbody, and situated a minimum of 2m from the banktop so not as to cause an obstruction during flooding.

Fencing will require that a drinking water supply is provided for stock, this could be in the form of solar powered pumps, pasture pumps (for non-dairy cattle), mains water troughs or livestock drinking bays (if required and where suitable). Additionally, a gate will need to be incorporated into each field parcel to allow management of the strip and to retain payment under the new basic payment scheme.

4.1.2 Soft bank revetment

A programme of soft bank revetment is suggested for areas of high bank erosion that have been identified by the audit. In some areas soft bank revetment could be combined with livestock fencing to help restore the structure of the bank and provide good riparian habitat in areas that have been heavily poached. In areas prone to high erosive processes, bank revetment could provide additional structural support to aid stabilisation and reduce excessive sediment loads entering the channel and covering valuable spawning habitat.

Reach 2, 4a and 4b were recorded as having the largest amount of bank erosion and therefore a combination of spilling with local willow, faggot bundles, and the log and Christmas tree technique could be used to help stabilise banks and provide excellent in-stream habitat for fish and macroinvertebrates.

4.1.3 Bank re-profiling

Reducing the gradient of the banks in Reach 4a through re-profiling will provide an opportunity for natural bank-side vegetation to establish, in association with the new gradual transition between the channel and floodplain. It is suggested that bank re-profiling upstream of the four major structures on Reach 4a will relieve the pressure on the structures, thus reducing the amount of erosion around the structure during periods of high flow. Re-profiling will allow a secondary flood flow channel to develop which will take part of the flow away from the structure and be diverted into and area downstream of the structure. A small amount of channel formation may be required to allow this feature to work as effectively as possible. Excess spoil produced by the re-profiling of river banks could be taken away by local farmers and used as topsoil on arable land.

4.1.4 Engagement with local residents regarding misconnections

During the summer 2013 walkover survey and 2014 fluvial audit, a number of misconnections were noted in the catchment. It is therefore recommended that further work is undertaken by the EA to establish the number, type and specific location of misconnections in these areas. The main areas of impact for misconnections appear to be in Reaches 1, 2, and 4a. In Reach 1, the main area of impact was between Fosse Bridge and Castle Combe, whilst in Reach 2, the observed foam in the river and sweet smell of washing powder was upstream of West Kington. In addition to this, high levels of algae were recorded on the sediment on the By Brook between Ford and the confluence with the Doncombe Brook. There have also been reports from local residents and local anglers regarding a continual foul smell in this area.

Advice on misconnections could be provided by an initiative similar to operation 'Streamclean', which was a partnership project between Wessex Water, EA, and Bristol City Council, which identified and corrected sewerage misconnections at residential properties (EA, 2009b). This Wessex Water initiative could be easily tailored to the By Brook and would provide a cost-effective measure to help deliver improvements.

4.2 Long-term Measures

4.2.1 Engagement with the local water company regarding sewage treatment works discharges

Engagement with the local water company, Wessex Water, regarding sewage treatment works discharges could potentially be a long-term project as any improvements to their works will have to be factored into their AMP funding rounds which are developed every 6 years. As a result of the level of algae recorded in Reach 3b it is suggested that discussions with Wessex Water are undertaken with a view to encouraging them to place phosphate stripping treatment on their works or a similar or additional feature which will reduce the amount of phosphate in the Doncombe Brook. This issue is particularly poignant during the summer when low flows are common in the waterbody and therefore the dilution factor for the phosphate becomes a lot less.

4.2.2 Removal of in-channel structures or provision of fish passage

The large number of in-channel structures in the By Brook catchment creates a substantial impact on fish passage and subsequently on the achievement of the WFD. As this report has been

designed to support the fish pass feasibility work being undertaken by Royal Haskoning DHV, this section will not go into detail regarding the removal or provision of fish passage on particular structures in the catchment. However, it is important to note that the ten newly identified in-channel structures identified by the audit will require further investigations. In particular, it is suggested that the five Grade 2 structures on the Broadmead Brook and By Brook should be investigated first with subsequent Grade 3 structures investigated afterwards. There were no Grade 1 in-channel structures identified during the audit.

The current fish pass feasibility study is considering fish passage options between Ford and Shockerwick inclusive. It is important to note that assessment of the most downstream in-channel structures, situated at the Paper Mill at Bathford in Reach 5 should be considered a priority for the EA since the structures currently pose a severe barrier to fish migration. The provision of fish passage on these downstream structures will allow migratory fish upstream into the By Brook to access further feeding and spawning habitat and thus will fully compliment the work being undertaken by BART (in conjunction with the EA) to allow fish passage through the majority of the By Brook channel. The installation of fish passage on the Paper Mill in conjunction with the weirs situated between Shockerwick and upstream to Ford would open up approximately 14Km of extra habitat for fish, thus allowing a more robust and genetically diverse populations of Salmon, trout, sea trout and coarse fish to exist.

5.0 CONCLUSIONS AND FURTHER ACTION

5.1 Purpose of this section

This section provides a brief summary of the key geomorphological issues which adversely affect the By Brook catchment, suggests the development of a restoration strategy to address these issues and provides options for delivery in order to restore the catchment to GES.

5.2 Summary of key issues

The previous sections have demonstrated that the geomorphology of the By Brook catchment is controlled by the interaction of a complex range of physical and hydrological parameters. Four main factors have been identified as key issues which adversely affect the catchment:

- In-channel structures.
- Fine sediment supply and deposition.
- Nutrient enrichment.
- Bank erosion.

It is therefore important that these issues are addressed effectively in any future restoration actions undertaken within the catchment.

5.3 Restoring the By Brook Catchment

5.3.1 Development of a restoration strategy

The previous sections have demonstrated that there are a number of key geomorphological issues within the By Brook catchment that are adversely affecting the lowland river habitat. These habitats are to some extent dependent on the physical habitat conditions which support them, which are themselves controlled by the interaction of geomorphological and hydrological parameters. There is therefore a clear need to develop a restoration strategy to ensure that the catchment reaches GES.

5.3.2 Delivery mechanisms

This fluvial audit report provides an overall catchment-wide assessment of the By Brook taking into account key issues affecting the catchment and a means of restoration. The findings of this report

will support the fish pass feasibility study from Royal Haskoning DHV and be combined to produce a 5 year By Brook catchment plan.

It is BART's intention during 2015 -16 to discuss all information that has been collated about the catchment, including the fish pass feasibility study, and fluvial audit with the EA and all stakeholders across the catchment. This will enable BART to refine their restoration plan into a set of key deliverable actions with clear ownership of each of those actions, thus enabling them to seek funding where appropriate.

The key to accessing a wide range of funding opportunities is to emphasise the objectives of the project that match the criteria for each funding stream. This opens up access to the numerous funding streams that support sustainable development and urban regeneration and is critical to illustrate clearly the social, environmental and economic benefits of river restoration. The three main sources of funding are National Lottery, UK Government, and European Government. The restoration of the By Brook catchment appears to meet the requirements set by the National Lottery's Heritage Lottery Fund (HLF) and Big Lottery Fund, whilst European Government funding may be available through the LIFE programme or European Maritime and Fisheries Fund (EMFF).

5.3.2.1 Countryside Stewardship

Countryside Stewardship could be a key mechanism for the delivery of some of the By Brook catchment restoration measures and it will be crucial to maintain a strong partnership with Natural England due to their role as Countryside Stewardship administrators and their relationship with landowners.

It is possible to deliver one of the proposed measures (livestock fencing) through the Countryside Stewardship scheme. However, achieving land owner support for options such as fencing may prove difficult due to the slight negative aesthetic impact that some landowners feel that livestock fencing creates, in addition to possible extra maintenance costs. However, it is considered that the benefits of livestock fencing to landowners still remains high as it provides a means of stopping livestock from straying onto other land, reduces lameness, and reduces the likelihood and frequency of health issues such as liver fluke and mastitis.

5.3.2.2 Wessex Water

Wessex Water is the single water and sewerage service company operating within the By Brook catchment. The company has implemented a number of measures to improve WFD waterbodies in

the catchment as a part of their AMP4 and AMP5 investment programme, including those laid out in Annex C of the Severn River Basin District River Basin Management Plan. Delivery under these previous AMP rounds has included compliance with Urban Waste Water Treatment Directive Sensitive Area designation's to remove phosphates from Strongford Sewage treatments works and the delivery of operation Streamclean.

Using the funding from the AMP investment programme, the proposed measures for Reach 3b may be achieved. Suggested measures that could be delivered through future AMP funding include those which will address both point and diffuse pollution impacts (phosphate stripping, misconnections, agricultural land management advice, and fencing) to reduce the nutrient and sediment input into the river and thus helps to achieve statutory actions under the Water Framework Directive.

5.3.2.3 DEFRA (Catchment Based Approach)

The Bristol Avon is one of over 100 WFD catchments in England where local partnerships are actively supporting the Catchment Based Approach (CABA). CABA has sought to work in partnership to deliver improvements to waterbodies at the catchment scale. The Bristol Avon catchment is hosted by the Avon Wildlife Trust (on behalf of the Bristol Avon Catchment Group) (CABA, 2015). The current River Basin Management Plan, encompassing the Bristol Avon and By Brook, identifies urban intermittent discharges and improvements to sewage treatment works, invasive non-native species (INNS), abstraction and agricultural diffuse pollution as the main challenges facing these catchments (EA 2009a). The plan promotes adaptive and collaborative approaches, which include 'Operation Streamclean', a partnership project with Wessex Water to highlight and correct sewerage misconnections, Catchment Sensitive Farming (CSF) delivery initiatives, and the Avon Frome Partnership working with the Bristol Invasive Weeds Forum to tackle INNS issues in the catchment.

5.3.2.4 Environment Agency (Fisheries)

Despite public sector spending constraints, EA fisheries funding, due to it largely deriving from rod licence revenue, in theory should be relatively secure, as well as being particularly applicable for spending towards the measures outlined in this report. However, it is unlikely to be able to fund all the work required to achieve measures such as the removal of in-channel structures, and as such should be used where it can generate maximum leverage, e.g. in providing part funding with other parties contributing on the basis of EA"s contribution, for example the EMFF or HLF.

5.3.2.5 Local Angling Clubs

It is possible that local angling clubs alongside volunteers from BART and possibly the EA via their Environmental leave days could help deliver measures to address bank erosion through the implementation of soft revetment. The local angling clubs have a small pot of money from their subscription fees which they may want to use towards restoring the banks along their individual syndicate reaches. This work could be undertaken very cheaply using local resources and members of the angling club, BART and the EA in order to achieve the maximum amount of benefit for the lowest cost.

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