Warleigh Weir Bathing Water investigation

Desk Study

Wessex Water

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Contents

1. Introduction

1.1 Purpose of this document

This document contains the findings of the desk study task of the Warleigh Weir Bathing Water investigation. This is an AMP7 Water Industry National Environment Programme (WINEP) output being undertaken by Wessex Water to be delivered by September 2023.

The purpose of this document is to:

- Provide the context and background to the investigation;
- Collate and analyse all relevant existing data;
- Identify any gaps in existing data and define a monitoring plan to obtain the additional data;
- Set out how the investigation will be delivered and any changes to the scope and programme of work resulting from the above tasks.

1.2 Summary of scope

This is the second output from this investigation following the production of a scope, agreed with the Environment Agency in February 2021, which is summarised here for information:

This collaborative investigation will build on the work undertaken to date and investigate the factors affecting bacterial water quality at Warleigh Weir and lead to the development of a programme of improvements at Wessex Water assets and in the wider catchment to improve water quality at the weir.

For further detail the reader should refer to the scope document.

1.3 Investigation background and aim

Warleigh Weir is located on the Bristol Avon approximately 8km upstream of Bath city centre. The weir is a popular location for bathing and other in-river recreational activities such as paddling, canoeing and paddle boarding.

Under the Bathing Water Directive (2006/7/EC) Member States must identify bathing waters in their territory and establish a monitoring programme to classify each bathing water against standards set out in Annex II of the directive. Currently, a section of the River Wharfe at Ilkley in Yorkshire is the only designated river Bathing Water in England (designated December 2020). The owner of Warleigh Weir is considering applying to Defra for bathing water status at this location, potentially as early as the 2021 bathing season.

The potential designation of Warleigh Weir as an inland Bathing Water poses a high-profile and poorly understood water quality issue to Wessex Water, the Environment Agency and for the recreational users of the weir. Upstream are numerous continuous and intermittent discharges operated by Wessex Water and third parties and a range of land management practices that will all influence bacterial water quality at Warleigh Weir.

The absence of designation as a Bathing Water has meant that until now there has been no statutory or regulatory drivers to monitor bacterial water quality at the weir and in the catchment upstream. A limited monitoring programme was undertaken by Wessex Water, Environment Agency, Bristol Avon Rivers Trust (BART) and the owner of Warleigh Weir in September 2020 to characterise the issue and help to inform future studies. This investigation will build on this previous work and has the following aims:

- To characterise bacterial water quality at Warleigh Weir under a range of flow conditions in respect of the standards set for inland bathing waters set under the Bathing Water Directive.
- To identify the main sources of bacterial contamination upstream of Warleigh weir through a targeted water quality monitoring programme.
- To define a programme of measures to be implemented by Wessex Water and other parties to address the main sources of bacterial contamination to improve bacterial water quality at Warleigh Weir.

The WINEP investigation will meet the requirements above and is the focus of this desk study. A separate application has been made to the Ofwat Innovation Fund in partnership with Northumbrian Water, technology providers and stakeholders including the Rivers Trust and Bristol Avon Rivers Trust with the following aims.

- To trial innovative approaches to water quality monitoring such as in-situ spot monitoring equipment and real-time monitoring systems and compare the findings to 'traditional' lab based techniques.
- To develop predictive alert systems similar to Wessex Water's Coastwatch system and to make this information available to recreational users of Warleigh Weir.

The tasks delivered through the Ofwat innovation fund bid (assuming successful) are outside the scope of the WINEP investigation and not considered further in this desk study. However, depending on the success of the trial, data from it may be used alongside information from this WINEP investigation to inform future investment decisions.

1.4 Structure of this document

This document is structured as follows:

- **Section 1** **Introduction**, setting out the purpose and structure of this document
- **Section 2** **Context**, providing further background to the investigation and summarising previous work.
- **Section 3** **Environmental monitoring data review,** reviewing all relevant data and information available.
- **Section 4** **Preliminary data analysis,** analysis of the available data and setting out what additional data are required.
- **Section 5** **Monitoring plan and changes to scope**, setting out any significant changes to the scope of work and programme set out in the scoping report resulting from the desk review.

2. Context

This section describes Warleigh Weir, providing an overview of its location, recreational use and its management and ownership. The water quality standards, set out in the Bathing Waters Directive are presented here. Water quality would be assessed against these standards by the Environment Agency if the application for bathing water status were successful. A brief overview of the factors that can influence water quality is presented, with details about discharges owned and operated by Wessex Water and those outside the company's control. Available monitoring information is presented in Section 3, which in turn is used to inform the monitoring plan presented in Section 4.

2.1 Warleigh Weir and the Bristol Avon catchment

Warleigh Weir is a river structure on the Bristol Avon, located approximately 8km upstream of Bath city centre (see Figure 2-1). Its original purpose was to provide a head of water to a grist mill (cereal grinding) at Claverton, however the weir was raised in the early 1800s and to supply water to the Kennet and Avon canal via Claverton pumping station. The pumping station operated from 1813 to 1952 at which point canal traffic had declined at the pumping station was no longer required, but was subsequently restored in the 1970s by volunteers[1].

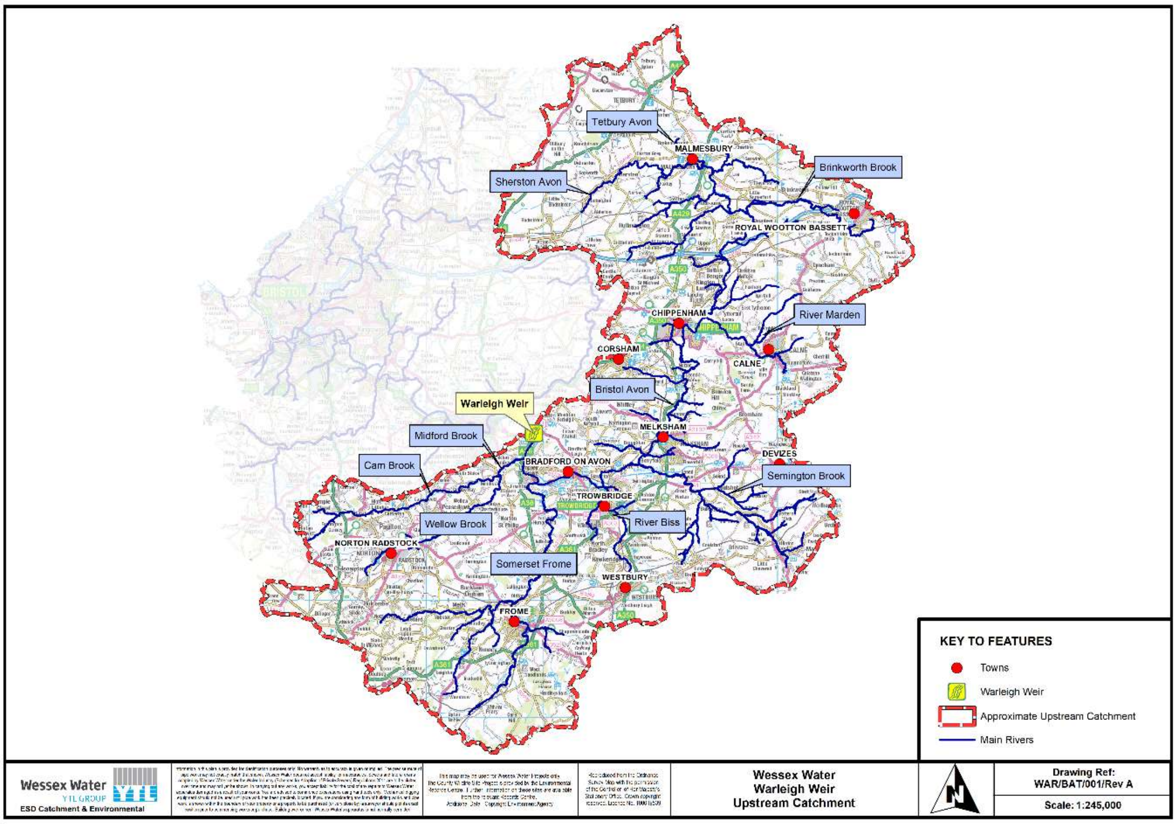
The river island, weir and adjacent land are privately owned and managed by the Warleigh Weir Project[2], a non-profit social enterprise comprising volunteers and contributors from the area. Management of the weir is the responsibility of the Canal and Rivers Trust[3]. The weir is a popular location for bathing and other in-river recreational activities and is promoted as a site for wild swimming[4].

Figure 2-1 Warleigh Weir

[1] https://www.claverton.org/
[2] https://warleighweir.co.uk/
[3] https://warleighweir.co.uk/faqs/
[4] https://www.wildswimming.co.uk/map/claverton-weir-avon/

The catchment area upstream is extensive (with an approximate catchment size of 1,452km^2), comprising settlements such as Bradford on Avon, Trowbridge, Frome, Melksham, Chippenham and Malmesbury and surrounding villages. The main tributaries upstream of the weir include the Cam and Wellow brooks, the Rivers Frome and Biss, the Semington Brook, River Marden and Brinkworth Brook. Upstream of Malmesbury the Avon splits into the Tetbury and Sherston arms.

Figure 2-2 The Bristol Avon and its tributaries upstream of Warleigh Weir



2.2 Bathing Waters and the Bathing Water's Directive

Since the 1970s, the EU has had rules in place to protect bathing water quality and safeguard public health; the Bathing Water Directive (76/160//EEC). Prior to 2011 the UK Environment Agency monitored all designated bathing waters in the UK in line with the requirements of the 1976 directive, which included microbiological parameters (total and faecal coliforms and faecal streptococci) and physico-chemical parameters (e.g. pH and temperature).

After 2011, following recommendations made by the World Health Organisation, the revised Bathing Water Directive of 2006 (Directive 2006/7/EC)[5] changed the bacterial parameters monitored; in place of coliform and faecal streptococci standards, the revised directive sets standards for *Escherichia coli* (E. Coli) and intestinal Enterococci measure in colony forming units per 100ml (cfu/100ml). The physico-chemical parameters were no longer measured.

The presence of these bacteria in a bathing water indicate that there is a risk to bathers' health; the greater the concentration the greater the risk to health. The standards were

[5] Transposed under the Bathing Water Regulations,2008 and updated in the Bathing Water Regulations, 2013.

developed from World Health Organisation research into the incidence of gastrointestinal disease (stomach upsets) in people bathing in waters of differing bacterial concentrations.

Under the new regulations coastal and inland bathing waters are classified as 'excellent', 'good', 'sufficient' and 'poor' quality. The assessment is based on a percentile evaluation for *E. coli* and intestinal Enterococci and defines three different standards separately for inland and coastal bathing waters (shown in Table 2-1). Bathing waters not meeting the standards for sufficient quality are classified as poor.

Table 2-1 Bathing Water Standards - inland bathing waters

Parameter	*E. coli* (cfu/100ml)	Intestinal Enterococci (cfu/100ml)	Required sample percentile
Excellent	<500	<200	95
Good	<1,000	<400	95
Sufficient	<900	<330	90
Poor	Worse than sufficient		

It is these standards that water quality at Warleigh Weir would be assessed against if an application for bathing water status were successful.

In England, it is the Environment Agency that undertake monitoring for compliance with Directive and classify bathing waters against the standards listed above. Up to twenty samples are collected each bathing season, which runs from 15th May to 30th September at a designated sampling point (DSP)[6]. Classification for each bathing water is calculated annually based on samples from the previous four years. As Warleigh Weir is not currently designated as a Bathing Water, no routine sampling for compliance has been undertaken and the water is not classified.

The monitoring regime has recognised limitations including that the spot samples collected by the Environment Agency provide water quality information at that specific time, but water quality can change rapidly withing the course of one day. These factors are explored further below.

2.2.1 Factors influencing bacterial water quality

E. coli and intestinal Enterococci are present in the gut and faeces of animals and can enter the water environment from sources including public (Wessex Water) and private sewerage systems, non-sewered properties (septic tanks), domestic animals (dogs and cats), agricultural sources (livestock) and from wildlife. They can enter a watercourse directly via treated effluent from a WRC or from livestock defecating into a stream, or indirectly, through overland flow washing faecal material into a watercourse after rainfall. Intermittent discharges from the public sewerage system through the operation of storm flows are also a direct method (see section 2.2.3).

River water quality changes over time and over the course of a day due the following factors:

- Diurnal variations in load to WRCs. Discharges from WRCs peak in the morning and in the evening reflecting people's lifestyles;
- Rainfall conditions; rainfall leads to surface runoff (and pollutants) entering water courses and the operation of storm overflows. Higher flows can also lead to the mobilisation of settled sediments and pollutants from river beds and banks.

[6] https://environment.data.gov.uk/bwq/profiles/help-understanding-data.html

- Antecedent conditions; a dry period followed by intense rainfall can lead to a 'flush' of more concentrated pollutants entering a watercourse through overflows and runoff.
- Physico-chemical factors such as temperature, pH, geology, the presence of suspended sediment etc.

These factors will influence the load and the persistence of *E.coli* and intestinal Enterococci in a watercourse. Typically Enterococci are more persistent in the environment than *E.coli*. The parameter required to model the decay of coliforms is their decay rate expressed in terms of a T90 value. T90 (in hours) is the time taken for a population to reduce to 10% of its original density.

The T90 value in a freshwater system will be influenced by the following variables of note:

- Ultra-violet (UV) radiation levels (a major driver of bacterial inactivation);
- Level of predation;
- Turbidity/suspended solids (affecting the level of UV exposure and may provide protection from grazing); and
- Temperature, pH and conductivity.

The physico-chemical factors listed above vary depending on the time of year for example, in the winter shorter daylight hours will lead to much reduced UV radiation level and lower temperatures compared to summer conditions. T90s can therefore vary widely and this is illustrated by the values presented in Table 2-2, which were provided by the Environment Agency for use in modelling work on a previous Wessex Water bathing water investigation (Wessex Water, 2017)[7].

Table 2-2: Enterococci T90 range for the Burnham Jetty Bathing Water Investigation (2017)

Water conditions	Time of day	Lower	Typical	Upper
Tidal	Day-time T90 (hours)	6.6	39.5	48
	Night-time T90 (hours)	24.8	65.1	72
	Average	15.7	52.3	60
Freshwater	Day-time T90 (hours)	36	54	72
	Night-time T90 (hours)	72	96	120
	Average	54	75	96

Note the average has been calculated here for use later in this report and is simply calculated as the daytime value plus the night time value divided by two.

2.2.2 Wessex Water continuous discharges

Wessex Water operate 66 WRCs upstream of Warleigh Weir shown in Figure 2-3. Details of those within 20km upstream of Warleigh Weir are listed in Table 2-3, with a full list provided in Appendix A. The closest WRC is Freshford, approximately 4.5km upstream, whilst WRCs at Winsley, Bradford on Avon and Westwood all lie within 10km upstream. The most distant is Great Badminton, 82km upstream.

Appendix A also lists the WRCs in order of population equivalent (PE), the largest of which is Trowbridge with a PE of almost 68,500. Other significant WRCs are located at Chippenham (PE ~37,700), Frome (PE ~30,333) and Westbury (PE ~26,400). There are 7 WRCs with a PE less than 100; these typically serve a handful of domestic properties. The smallest is Rudge with a PE of 4. All of the WRCs except the smallest have secondary treatment

[7] Intestinal enterococci are more conservative than *E. Coli. Hence dat*

processes and all are compliant with their discharge permits. None of the WRCs have permit conditions for bacteria due to the absence of a sensitive receptor downstream (i.e. no bathing water or shellfish water considered to be affected by the discharge).

Figure 2-3 Wessex Water continuous discharges

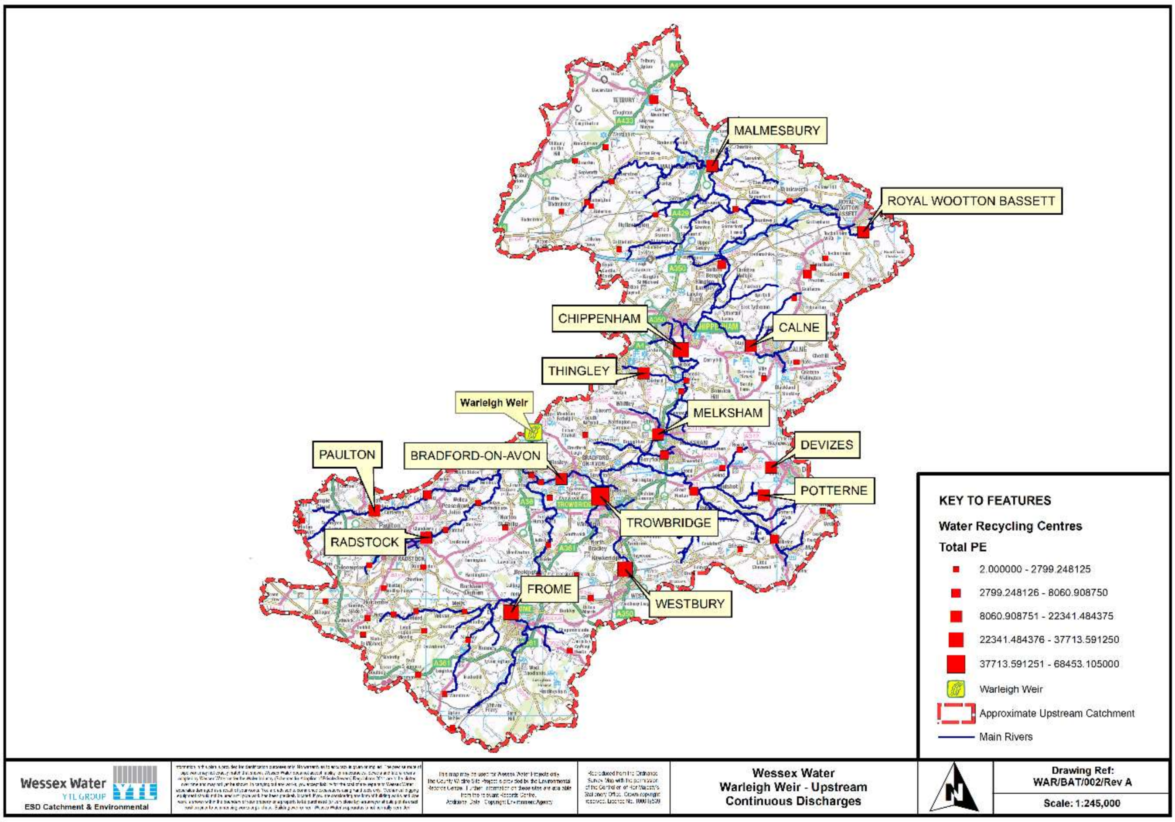
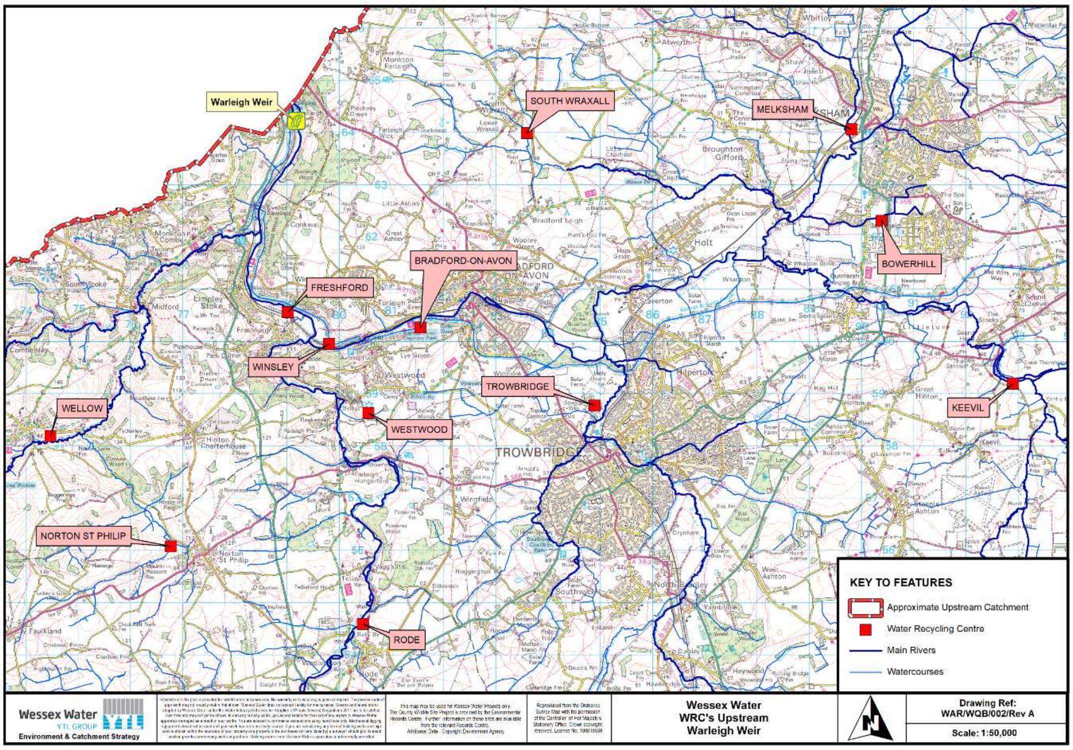


Table 2-3 Wessex Water WRCs within 20km upstream of Warleigh Weir

Site ID	WRC	Treatment processes	PE	DWF (m^3/d)	Receiving watercourse	Distance upstream Warleigh Weir
13130	Freshford	SBI	1528	460	River Avon	4.48
13352	Winsley	SBI	1974	430	River Avon	5.36
13031	Bradford-On-Avon	TB2	10925	3013	River Avon	7.66
13341	Westwood	TB1	1008	325	Haygrove Stream	9.43
13331	Wellow	SBI	411	136	Midford Brook	10.96
13318	Trowbridge	TB2	68453	14000	River Avon	12.19
13226	Norton St Philip	TB2	1125	315	Norton Brook	13.51
13045	Cam Valley	SAE	7479	1750	Cam Brook	14.47
13256	Rode	SBI	1009	230	River Frome (Somerset)	15.16
13274	Shoscombe	SBI	1786	505	Midford Brook	16.13
13252	Radstock	TB2	22341	5984	Wellow Brook	18.64
13017	Beckington	TB1	1117	344	River Frome (Somerset)	18.79
13356	Woodborough Hill	SBI	24	No flow limit	Midford Brook	18.88

Key for treatment types: PRI Primary = septic tank only. SAE Secondary / aeration. SBI Secondary / traditional biological. TA2 Advanced Tertiary / plus aeration. TB1 Simple Tertiary / plus traditional biological, TB2 Advanced Tertiary / plus traditional biological.

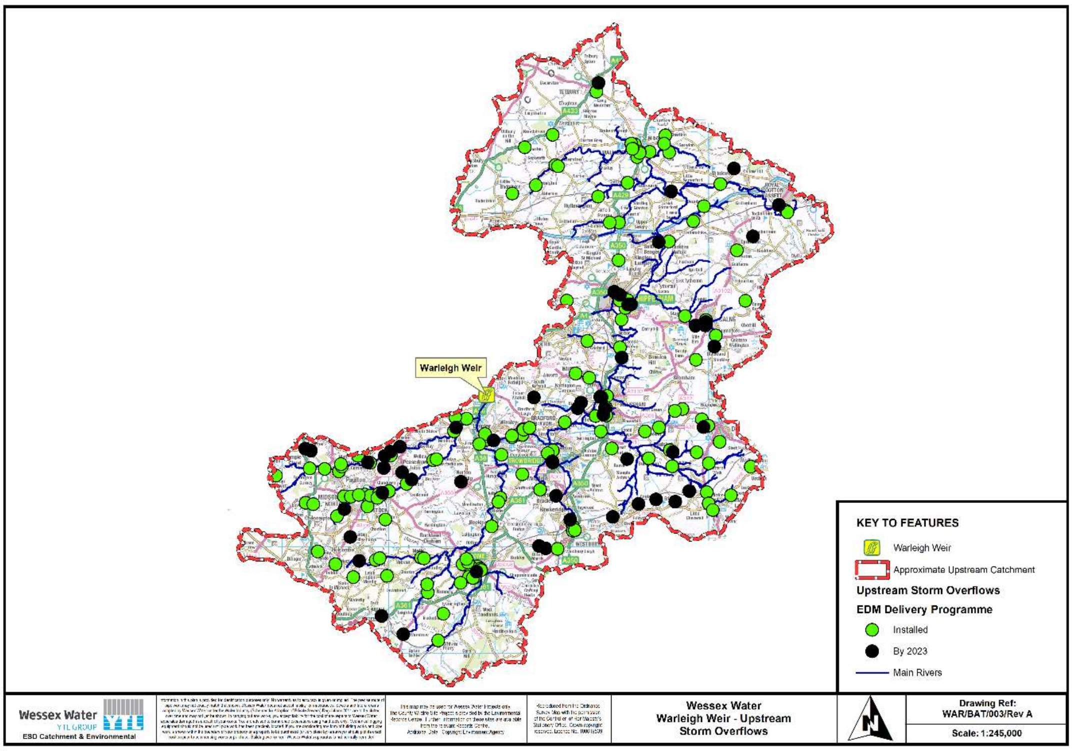
Figure 2-4 Water recycling centres immediately upstream of Warleigh Weir



2.2.3 *Wessex Water storm overflows*

There are 222 Wessex Water storm overflows upstream of Warleigh Weir, shown in Figure 2-5 and listed in Appendix B.

Figure 2-5 Wessex Water intermittent discharges upstream of Warleigh Weir



Storm overflows play an important and essential role in the sewerage system. Combined sewers transport sewage from homes and industry as well as carrying surface water run-off from gutters, drains and some highways. Heavy or prolonged rainfall can rapidly increase the flow in a combined sewer until the amount of water exceeds sewer capacity. Storm overflows act as relief valves, allowing excess stormwater to be released to rivers or the sea, protecting properties from flooding and sewage backing up into streets and homes.

As storm overflows should only operate during periods of intense rainfall, any foul water released from them will be very dilute because of the large volumes of rainwater within the system. Rarely is a pollution incident attributed to a storm overflows operating correctly as there is no significant environmental impact in terms of ammonia, suspended solids and biochemical oxygen demand. Flows are further diluted by the receiving watercourses that will also be swollen by the same heavy rain. Many storm overflows are fitted with screens or scumboards that prevent debris entering the watercourse or have attenuation tanks which also improve water quality.

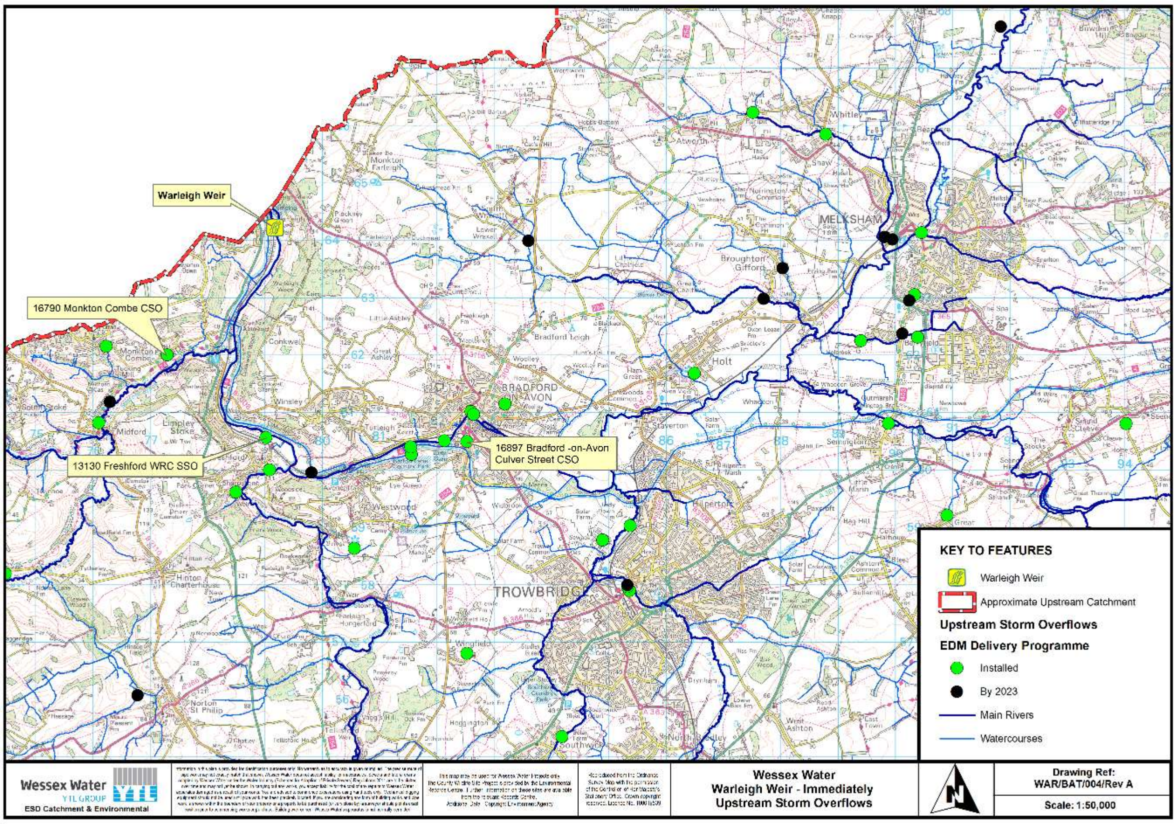
Four types of overflows are listed in Appendix B but for the purpose of this report they are all referred to as ‘storm overflows’:

- Combined Sewer Overflows – CSOs. Designed to operate as described above.
- Settled Storm Overflows – SSO. Usually located at a WRC, these overflows operate when the capacity of storm tanks at the WRC are exceeded and settled but dilute sewage
- Emergency Overflows – Operate differently to a CSO, when there is a failure in the system such as sewage pumping station. These should not operate as a CSO does following periods of heavy rainfall.
- Sewage Pumping Station (SPS) storm overflow – Located at SPS, permit usually requires a Pass Forward Flow from the pumps before discharge is allowed.

Wessex Water has been progressively installing Event Duration Monitoring (EDM) at the company’s 1,292 storm overflows. At the time of writing EDM is installed at 1,021 storm overflows (79%) and an ongoing programme of installations will provide 100% coverage (on all 1,292 overflows) by March 2023. The location and programming of installation upstream of Warleigh Weir is shown in Figure 2-6. EDM allows information on duration and frequency of storm overflow spills. It does not however, provide information on volume or quality of water spilled. The spill frequency of the upstream sites is shown in Appendix B[8].

[8] This information is available from Wessex Water’s Drainage and Wastewater Management Plan (DWMP Portal) https://wessexwater.maps.arcgis.com/apps/MapSeries/index.html?appid=e371301c24ca4228b36db3a3a6ba8560

Figure 2-6 Wessex Water storm overflows immediately upstream of Warleigh Weir



Three of the storm overflows located upstream of Warleigh Weir have recently been added to Wessex Water's Coastwatch[9] website; these shown in Figure 2-6 and listed in Table 2-4 with details about their distance upstream of the weir and average spill frequency over the last three years. Dry Weather Flow (DWF) shown in the table is an estimate of the flow that passes through the network at this location under dry conditions (i.e. when not spilling). It is not the volume that is discharged during a spill however it provides an indication of the likely size of spill relative to other overflow. For example, a spill from site 16897 Bradford on Avon – Culver Street (DWF 968m^3/d) is likely to be larger than a spill from site 13130 Freshford WRC overflow (DWF 460m^3/d).

Table 2-4 Storm overflows listed on Coastwatch

SiteID	SiteName	Type	Distance upstream of WW	DWF estimate m3/d	Annual average spill count, 2017-19
16790	Monkton Combe - Mill Lane CSO	CSO Network	3.96	540	25
13130	Freshford O/F	Storm Tank at STW	4.48	460	-
16897	B O Avon - Culver Street Recreation Park Off Pound Lane	CSO Network	8.51	968	64

Average spill data based on 2017-19 inclusive. 2020 not available at the time of writing. No data available for 13130 Freshford O/F.

[9] Coastwatch is Wessex Water's online overflow notification system which provides near real-time information of when combined sewer overflows (CSOs) have operated at designated bathing waters and at amenity waters used regularly for recreation. https://www.wessexwater.co.uk/coastwatch.

Figure 2-7 shows the average spill frequency data for the last three years (2017-2019) for all overflows upstream of Warleigh Weir. The underlying data are shown in Appendix B. Due to the rolling programme of EDM installation, some sites only have data for part of this three year period (or not at all). The average spill count 2017-19 accounts for this by determining the average number of spills per year for which data are available. For example, a site with data available from 2018 and 2019 will be a two year average and sites with data only from 2019 will be a one year average. Further detail for the overflows closest to the weir is shown in Figure 2-8.

Figure 2-7 Annual average spill count, storm overflows upstream of Warleigh Weir

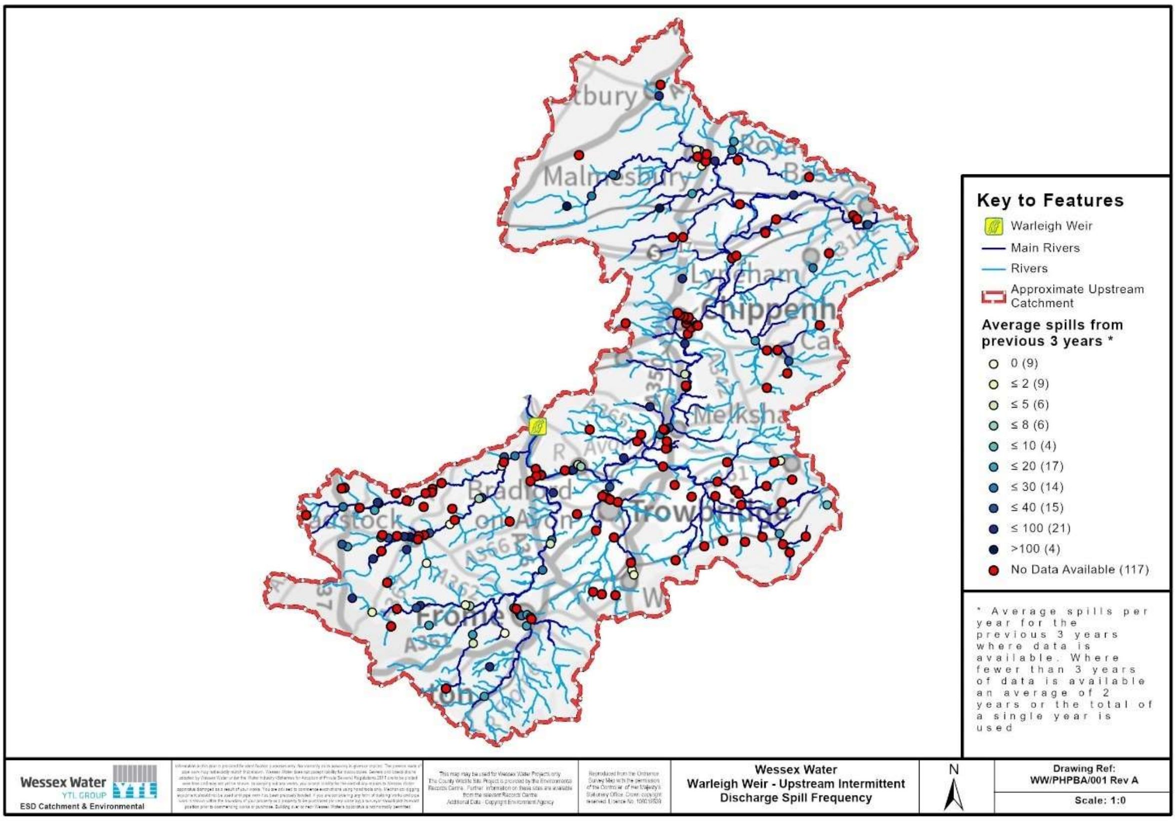
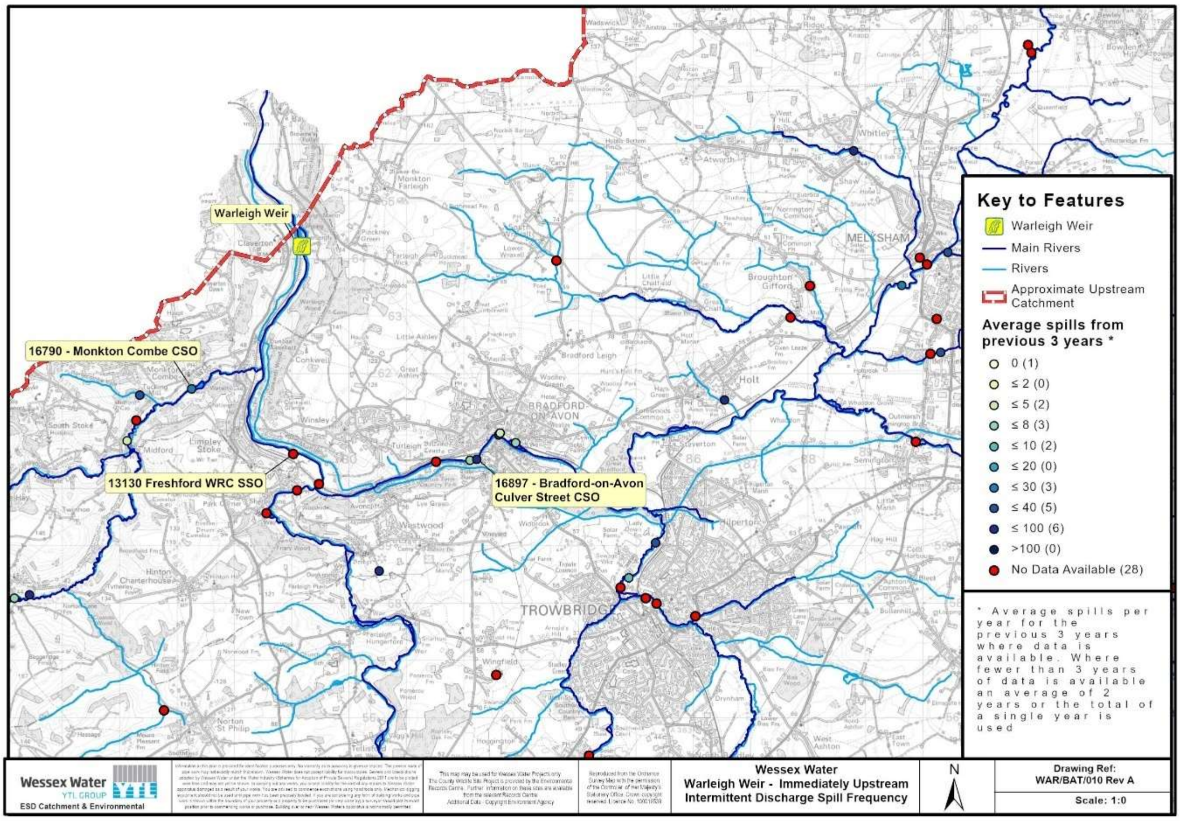


Figure 2-8 Annual average spill count, storm overflows immediately upstream of Warleigh Weir



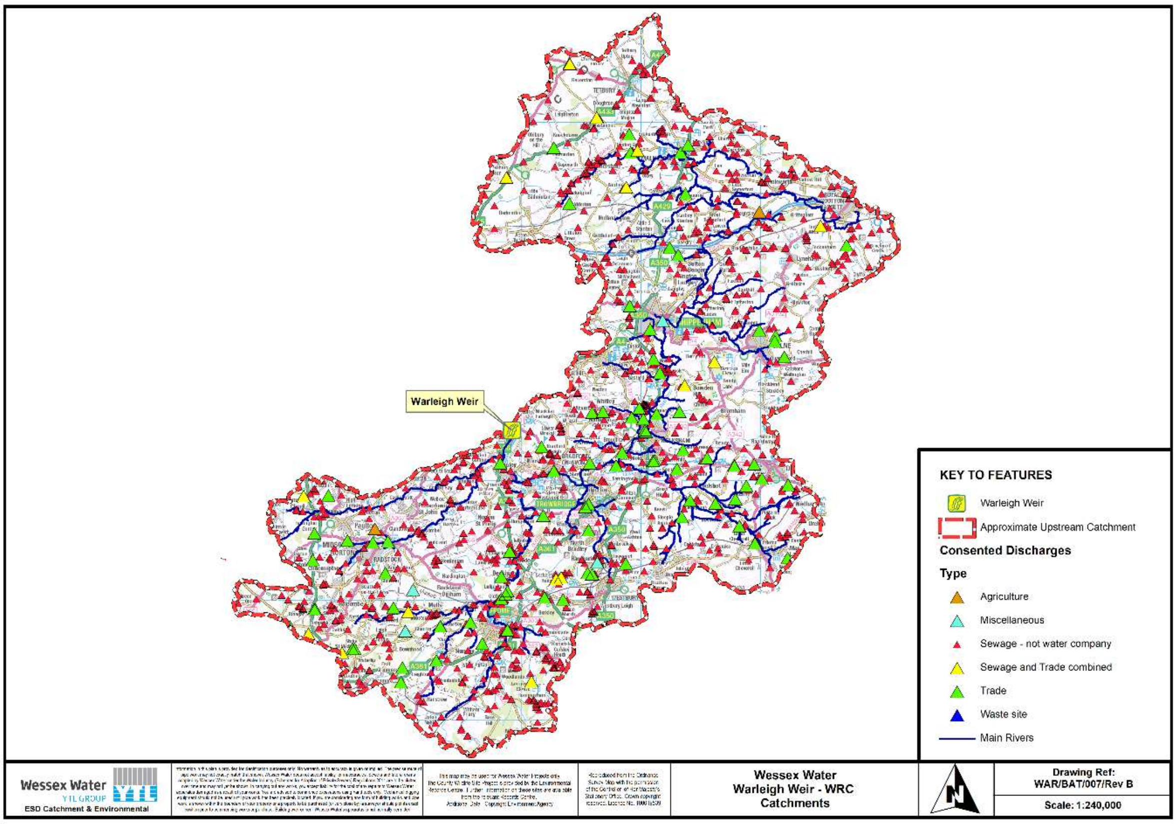
2.2.4 Non Wessex Water and catchment influences

There are non-Wessex Water influences in the catchment upstream of Warleigh Weir that have the potential to contribute to bacti loads in the Bristol Avon. These include:

- Private sewage and trade discharges
- Septic tanks from properties not connected to mains discharges
- Surface run-off from land adjacent to the watercourses

Figure 2-9 shows that there are a significant number of non-Wessex Water consented discharges in the catchment upstream of Warleigh Weir, the majority of which are from private sewage plants, traders and a combination of sewage and trade effluent.

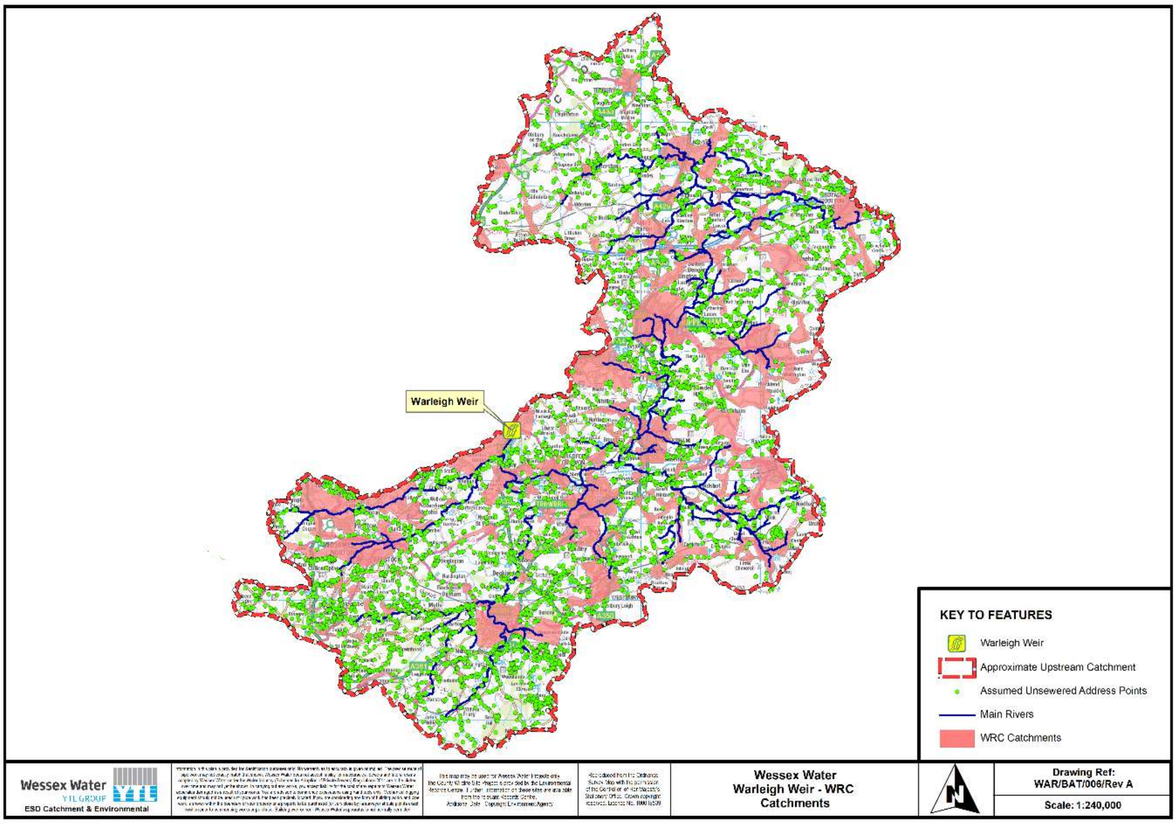
Figure 2-9 Non Wessex Water effluent discharges upstream of Warleigh Weir



The address points displayed on Figure 2-10 are those that appear on GIS records but are not connected to mains sewerage. It is not possible to determine the nature of sewerage at these properties through this desk study however it is likely that many of these addresses will have septic tank installations. Septic tanks in close proximity to watercourses pose a risk of faecal coliform bacteria contamination, particularly those that are poorly maintained.

Other sources of bacterial contamination from sewerage include illegal discharge points, misconnections and groundwater intrusion/surface run-off. The impact of these discharges on bacterial water quality will generally be greater in the headwaters of the catchment where watercourse flows are typically smaller and offer less dilution. Further down the Bristol Avon catchment at Warleigh Weir, inputs of coliform bacteria from these sources are likely to be less significant compared to the other sources due to greater flow and dilution. That said, poorly maintained septic tanks, misconnections or illegal discharges located close to Warleigh Weir could influence water quality at the weir.

Figure 2-10: Assumed unsewered address points upstream of Warleigh Weir



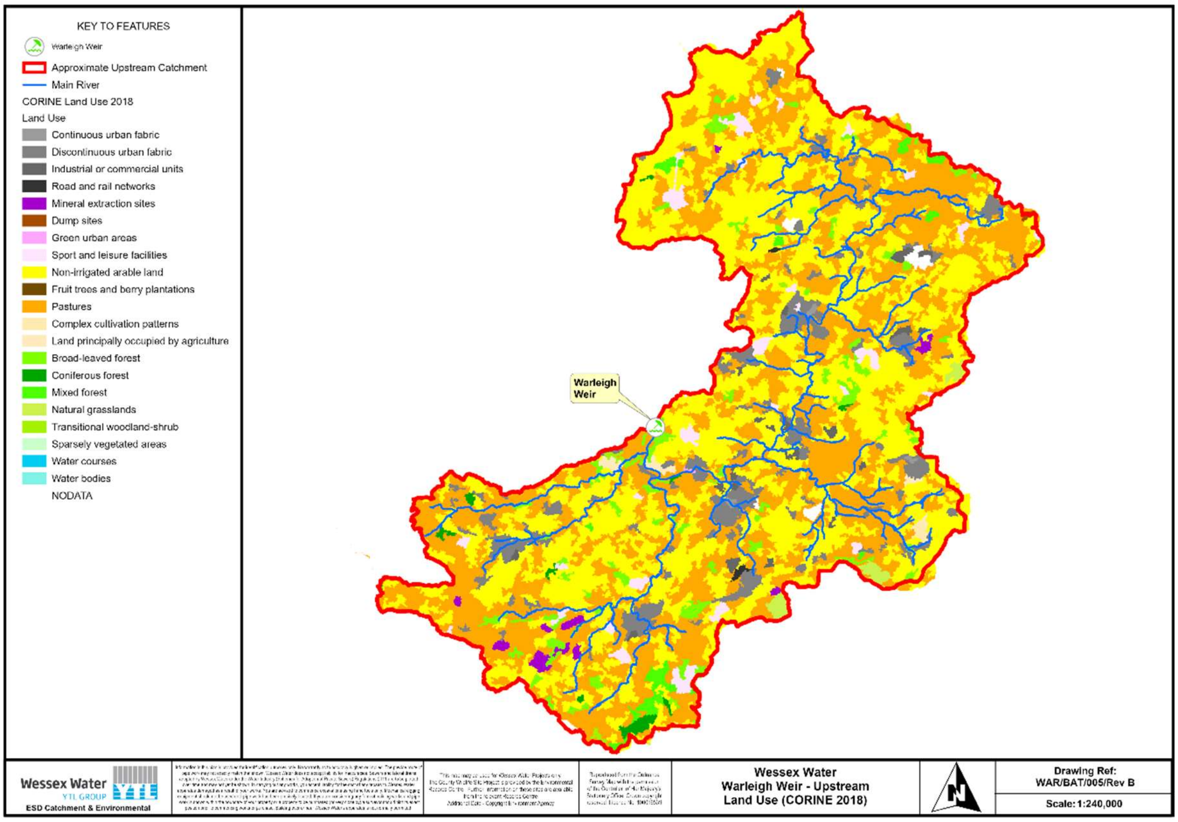
Coliform bacteria will be present on particular land-use types , depending on the presence/absence of the following potential diffuse sources:

- Livestock and wildlife
- Fertiliser derived from faecal sources (manure, biosolids to land).

The abundance of bacteria, and level of risk of entering nearby watercourses, is more complicated and will affected by:

- The number and type of livestock and wildlife
- Illness and infection rates in livestock
- Management practices such as fencing of livestock away from watercourses or the application of farmyard manures to land; and
- Environmental factors including rainfall, resulting in soil and contaminants being washed into watercourses

Figure 2-11: Land-use upstream of Warleigh Weir



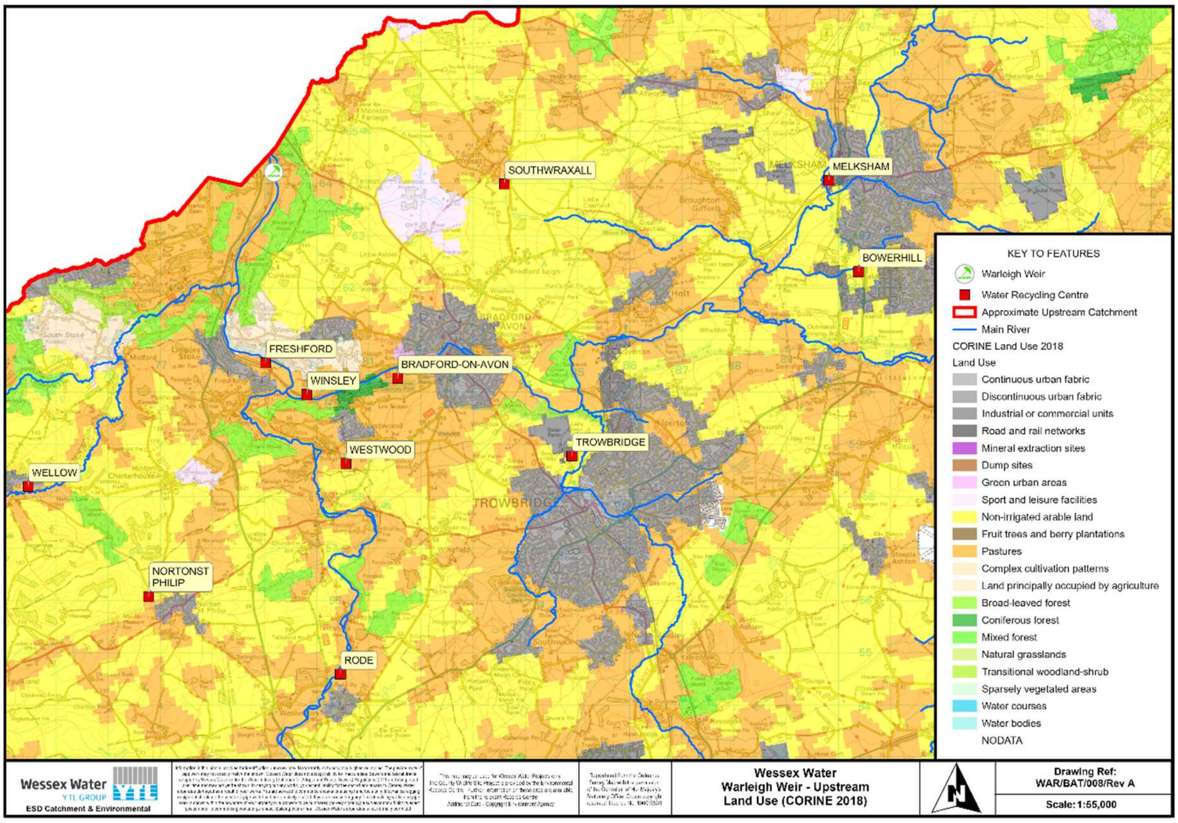


Figure 2-11 displays land use types upstream of Warleigh Weir at a catchment level. The overall catchment is dominated by 'pastures' and 'non-irrigated arable land', with pockets of urban and industrial areas close to the Bristol Avon and its tributaries. The area more immediately upstream of Warleigh Weir is dominated by pasture land and urban areas.

Pasture land may contain grazing livestock and be subject to manure-spreading, both of which are potential sources of coliform bacteria to the land. Surface run-off from pasture land may provide a pathway for coliform bacteria into waterways. Pasture land can also provide a habitat for wild animals, another noted source of coliform bacteria in the environment. Pasture land is the dominant land use type in the area upstream of Warleigh Weir.

Non-irrigated arable land may contain applied biosolids, which are used to provide nutrients and stable organic matter for growing crops. Biosolids are processed using a range of legislative and good practice measures under the Biosolids Assurance Scheme (BAS). A 2-log removal of E.Coli is required for the final biosolids product. Biosolids will still contain some coliform bacteria and are a potential source to watercourses via surface run-off. Biosolids are typically used for 'combinable crops'. There is little arable crop land in the catchment area immediately upstream of Warleigh Weir due the urban and sloped gradient characteristics of the area.

Urban areas may be a potential source of coliform bacteria to watercourses, particularly during wet weather events, from domestic pet waste, rodents and sewer misconnections to surface water drains.

2.3 Summary

There is an extensive (1,452km^2) and largely rural catchment upstream of Warleigh weir that includes the towns and villages of West Wiltshire and North East Somerset. There are 66 Wessex Water WRCs and 222 storm overflows located upstream of Warleigh Weir.

The weir is not currently designated as a Bathing Water and for this reason, water quality at the weir and from Wessex Water's WRC discharges upstream has not been routinely monitored for the bacterial parameters used to assess compliance with Bathing Water standards.

Information on the performance of storm overflows is starting to become available through the roll out of the EDM installation programme however this is incomplete; some overflows will not be monitored until after 2023. Available EDM data shows that 40 overflows upstream of Warleigh Weir have spill frequencies exceeding 40 spills per season, and are therefore considered frequent spillers under the SOAF. Water quality from overflows is not monitored.

Wessex Water's wastewater assets are not the only influences on water quality in the catchment. Private sewage and trade discharges, septic tanks from properties not connected to mains discharges and foul to surface water misconnections will all influence bacterial water quality at the weir. Surface run-off from land adjacent to watercourses will include bacteria from the faeces of livestock and wildlife.

Understanding the relative influence of Wessex Water's discharges in the context of these other factors will be required to meet the aims of this WINEP investigation. The following section reviews available relevant information to help meet these aims.

3. Environmental monitoring data review

This section reviews the relevant available environmental data to identify gaps in data and used to develop the monitoring plan presented in Section 4. The absence of designations for bathing and shellfish waters mean that there has not been a routine programme of bacterial water quality monitoring in the catchment, as happens at designated bathing and shellfish waters. Consequently, there is little bacterial water quality data to inform this investigation.

On 15th September 2020 monitoring was undertaken by Wessex Water, volunteers with the Warleigh Weir project and the Rivers Trusts to provide an initial 'snap shot' of bacterial water quality at Warleigh Weir and selected WRCs and river locations upstream. This sampling was also intended to inform any future monitoring. The report from that day is presented in Appendix C with the key outcomes summarised below.

Wessex Water has no further bacterial water quality data for continuous and intermittent discharges upstream of Warleigh Weir but has monitoring data from the Tucking Mill water treatment centre located near Limpley Stoke on the River Avon, upstream of the weir. This data is presented and compared to available flow data.

3.1 Warleigh Weir monitoring, September 2020

The monitoring and conditions and approach to monitoring are described in Box 1. Further detail is provided in Appendix C.

Box 1: September 2020 Monitoring Day
Conditions at the time of sampling were warm and sunny; there had been no rainfall for a week. The six most frequently spilling storm overflows located upstream had not discharged over the preceding days. • Samples were collected at 25 locations • Samples were taken every two hours at Warleigh Weir and Tucking Mill offtake (approx. 2.5 km upstream) • All other samples were single spot samples. • Samples were analysed at Wessex Water laboratory for e-coli (EC) and intestinal enterococci (IE) by membrane filtration method or at Bristol University vetinary laboratory[10].

Comparing results for single samples with the percentile standards specified in the Bathing Water Directive can give an over-optimistic picture of water quality. Statistical approaches such as those used on the comparable iWharfe citizen science study[11] will be investigated for use on this project to help interpret bacterial data collected.

3.1.1 Water quality at Warleigh Weir

Data from the monitoring at Warleigh Weir are summarised in Figure 3-1. On the day of sampling and noting the antecedent conditions, the following can be observed:

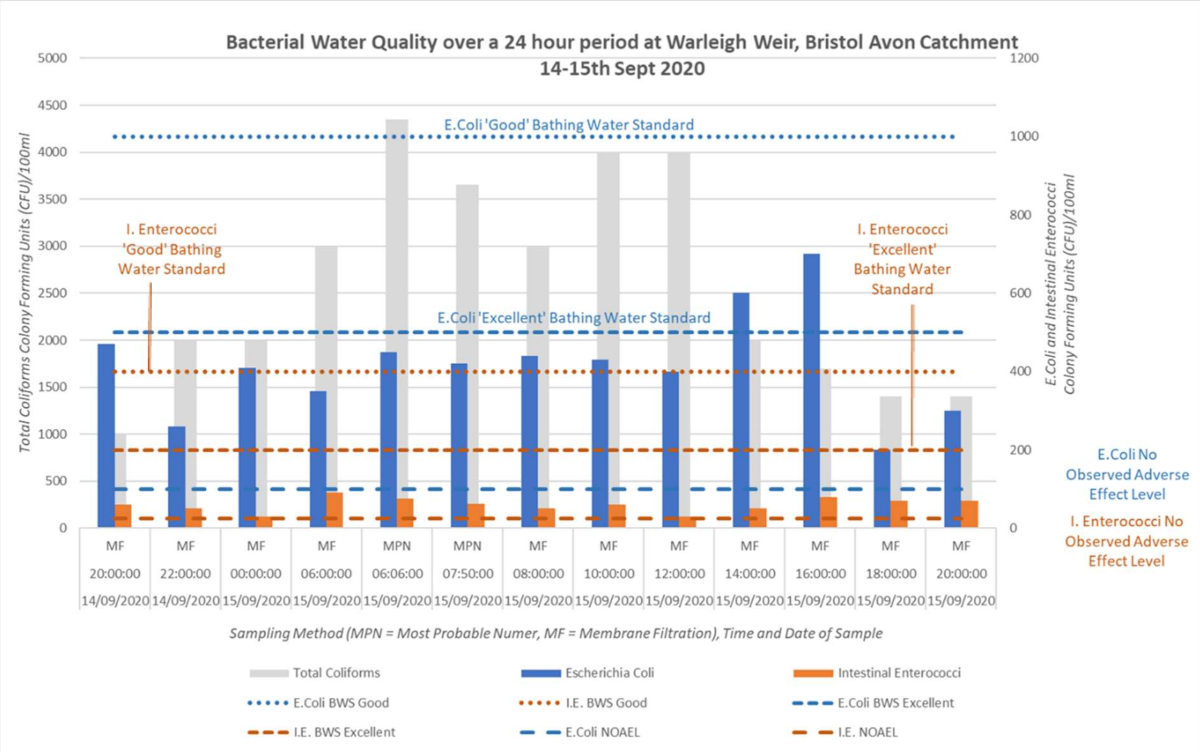
[10] Samples were analysed at different laboratories to help manage analysis capacity. Bristol University uses the Most Probable Number method which is more indicative, whereas Wessex Water's scientific centre uses Membrane Filtration to culture the bacteria for a more accurate result. The methods are different but both comply with the Bathing Water Directive requirements.
[11] https://www.otleytowncouncil.gov.uk/wp-content/uploads/2021/03/iWharfe-Project.pdf

- All intestinal Enterococci samples achieved Excellent standard (and were significantly below this)
- All *E. coli* data achieved Good standard. 11 of the 13 *E.coli* samples achieved Excellent, with the remaining two afternoon samples (2 and 4pm) classified as Good.

The Bathing Water Directive requires both *E. coli* and Intestinal Enterococci results and the classification is based on the lowest score, e.g. if *E. coli* is excellent but Intestinal Enterococci is good the classification is good. Acknowledging that this is just a 'snapshot', water quality would have been classed as good on the day of sampling. Other points to note in these data are:

- *E. coli* and Intestinal Enterococci concentrations are above the No Observed Adverse Effect level.
- *E. coli* data show greater variation over the course of the day compared to intestinal enterococci. Peak *E. coli* concentration occurred in the early to mid-afternoon, lowest concentrations occurred in evening (6pm)
- Intestinal Enterococci concentrations were significantly below (around half) the excellent bathing water standard concentration.

Figure 3-1 Bacterial Water Quality at Warleigh Weir, 14-15th September 2020



Graph provided by The Rivers Trust. The No Observed Adverse Effect Level (NOAEL) is taken from Weidenmann (2006).

3.1.2 Water quality upstream of Warleigh Weir

Data from the 24 upstream sampling locations are displayed in Appendix C, alongside the data from Warleigh Weir. Two maps are presented showing sample location and concentration data for *E. coli* and Intestinal Enterococci, colour coded according to bathing water classification. Again noting that this is a 'snap shot' from one day of monitoring, key findings are:

- There were no samples from the main River Avon in which the concentration of *E. coli* and Intestinal Enterococci were of poor standard:
  - Concentrations of Intestinal Enterococci in all samples would have achieved the excellent bathing water standard.
  - Concentrations of *E. coli* in most samples would have achieved the excellent bathing water standard; one sample achieved good and two samples (Avoncliff and Staverton) achieved sufficient.
- Samples for both parameters at three locations in the upper reaches of the River Frome also achieved the excellent standard.
- Samples from further downstream on the River Frome and the other tributaries of the River Avon showed poorer water quality:
  - Concentrations of intestinal enterococci in the Cam and Wellow Brooks, Rivers Frome and Biss and in the Semington Brook were of poor standard.
  - Concentrations of *E. coli* in the Cam and Wellow Brooks, River Frome and the Biss were of poor standard.
- Nunney, Wanstrow and Frome WRC on the River Frome may be factors in poorer quality observed upstream and downstream of the town of Frome.
- Elevated concentrations of bacteria were found upstream of Trowbridge WRC outfall, including a deterioration between two sample points where there are no Wessex Water continuous discharges. The cause for this deterioration is likely urban runoff, unsewered properties, misconnections and private WRC.
- The Midford Brook (including the Cam and Wellow Brooks) influences water quality at Warleigh Weir. A statistically significant (deterioration) in E.Coli concentrations between Tucking Mill intake (upstream of the Midford Brook on the River Avon) and at Warleigh Weir.

3.2 Other bacterial water quality data

3.2.1 Wessex Water

Wessex Water has an intake on the River Avon at Limpley Stoke on the River Avon, just upstream of the confluence with the Midford Brook. Water abstracted here is transferred to the Tucking Mill water treatment centre (WTC) to be distributed for drinking water supply. Although the abstraction is currently out of use, bacterial water quality samples have been collected on a routine basis here in the past.

Data available are from 4th August 2006 to 3rd October 2018 and include 228 *E. coli* and 194 intestinal enterococci values. Analysis presented in Appendix D shows that the available data are not evenly distributed, with variation in the number of samples analysed by year and by month. Most data are available from 2012 and it is understood that this results from periods of operation or testing of site infrastructure after the dry period in 2011. Acknowledging this variability, these are the largest available set of bacterial water quality data relevant to this investigation.

E. coli data are shown in Figure 3-2 and intestinal enterococci data in Figure 3-3, compared to the respective bathing water standards. As shown in Table 2-1, bathing water compliance is assessed on a percentile basis, therefore the comparison with the bathing water standards presented here should be considered as indicative, not absolute.

The figures show the variability of *E.coli* and intestinal enterococci data throughout the period of record; concentrations vary between excellent and poor. Of the available data,

Figure 3-2 Tucking Mill intake from River Avon; *E. coli* data[12]

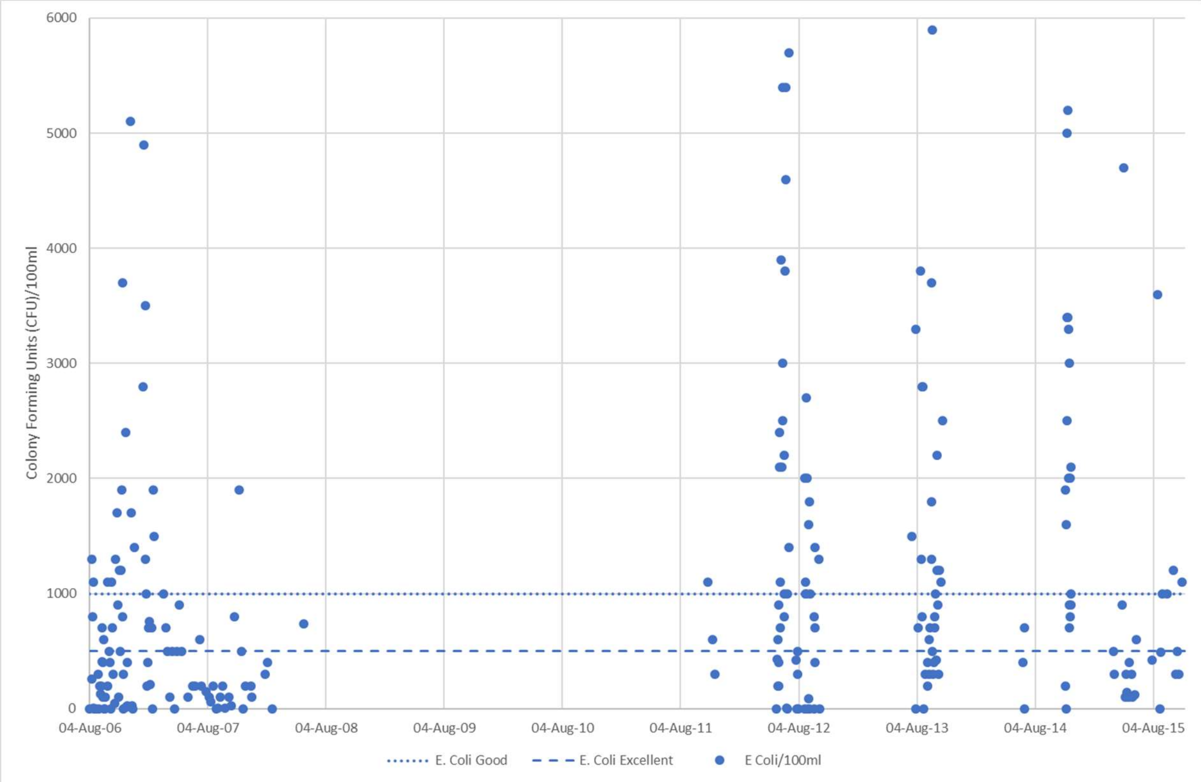
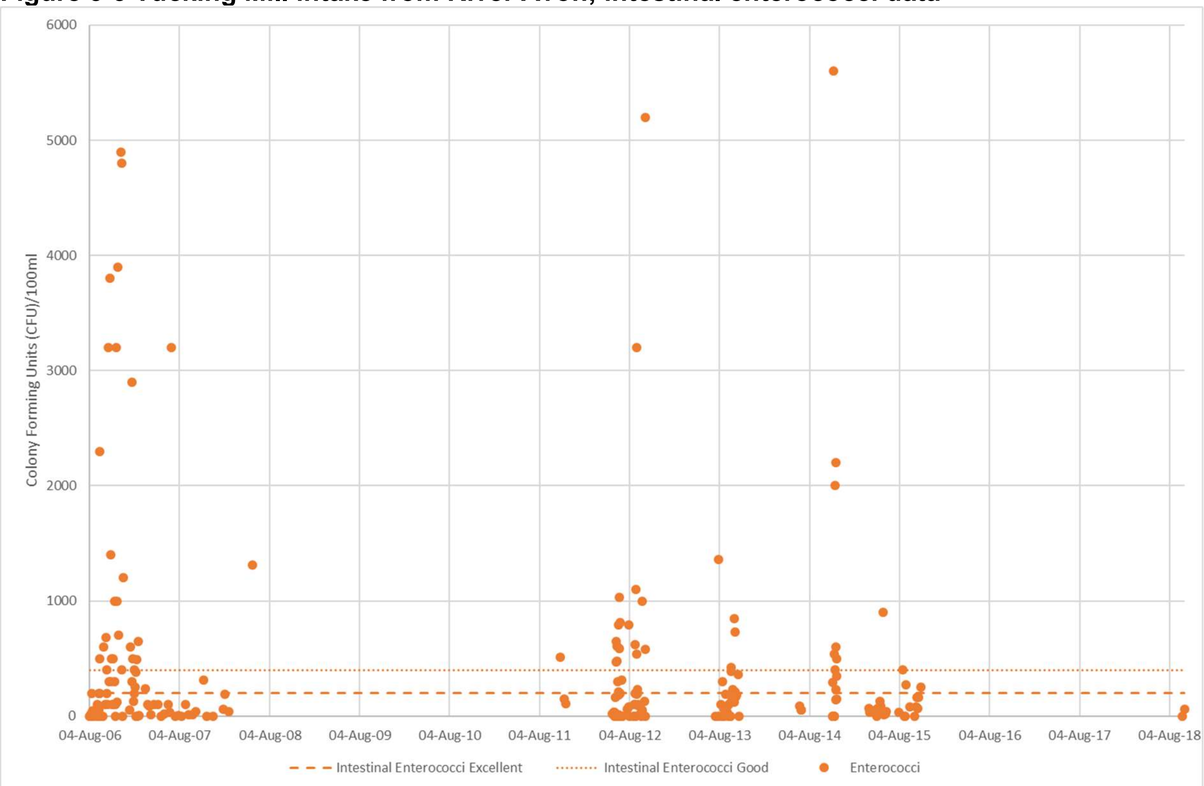


Figure 3-3 Tucking Mill intake from River Avon; intestinal enterococci data



12 'Sufficient' threshold not included on Figures 3-2 and 3-3 as it uses a different percentile evaluation to 'good' and 'excellent'

This microbiological dataset from the Bristol Avon at Tucking Mill was analysed by the Environment Agency (see Appendix E). It was concluded that Warleigh Weir would not meet the conditions to be classed as ‘sufficient’ under the Bathing Water Directive and that a source load reduction in *E. coli* over 70% would be required. With the available data, there is a reasonable level of confidence that the site would not meet the required status, however the dataset from this single location is limited and the level of load reduction is an indicator only. The monitoring plan outlined in Section 4 is designed to provide the level of data required to better understand the classification of Warleigh Weir and the percentage load reduction required for the site to achieve ‘sufficient’ status.

3.2.2 Environment Agency

It is understood that the Environment Agency have no bacterial river water quality data from Warleigh Weir or sites upstream.

3.2.3 Rivers Trust

The Rivers Trust are understood to have collected a single spot sample at Warleigh Weir when early discussions with the Warleigh Weir Project commenced.

3.3 River flow data

River flow data are important to this investigation as they can be used to understand how bacterial water quality at Warleigh Weir changes under different flow conditions and in turn, will help to identify the determining influences on water quality. Under lower flow (dry) conditions ‘background’ concentrations of bacteria might be expected, comprising continuous discharges such as public and private WRCs and septic tanks. Under wetter conditions catchment influences and intermittent discharges such as storm overflows would be expected to have a greater influence on water quality at the weir. Additionally, bacteria may be transported from further upstream in the catchment more quickly during higher flow conditions.

With such as large upstream catchment area the influences on water quality are great (see Section 2). The relative influence of each sub-catchment will vary in response to the differing spatial and temporal variation in rainfall events. River flow data are required to help understand this.

In water quality investigations river flow data help to determine pollutant load (flow multiplied by concentration = load). Pollutant load is a useful concept as it helps to convert instantaneous concentrations to longer term (daily, monthly, annual) load.

The relevant river flow gauging stations are shown in Table 3-1, along with key flow statistics from the National River Flow Archive[13]. The closest gauging station to Warleigh Weir is the River Avon at Bathford, approximately 3.5km downstream. The By Brook joins the River Avon from the east immediately upstream of the gauge at Bathford and can be used to help estimate flows at Warleigh Weir as described below. The remaining gauges are listed in order upstream of Warleigh Weir on the main Avon and then the upstream tributaries as they join the Avon.

The By Brook is gauged at Middlehill, approximately 4km upstream of the confluence with the River Avon. Acknowledging that the upstream catchments will respond differently to rainfall events and that some flow accretion will occur in the Avon between Warleigh and

[13] https://nrfa.ceh.ac.uk/

Bathford and in the By Brook between Middlehill and Bathford, a reasonable approximation of flow at Warleigh Weir can be gained as follows:

Flow at Warleigh Weir = Flow at Bathford – Flow at Middlehill

Estimated flow for key flow statistics for Warleigh Weir derived this way are presented in Table 3-2.

Table 3-1 Relevant river gauging stations[14]

Watercourse	Gauging station	NGR	Period of record start	Q5 (m^3/s)	Mean (m^3/s)	Q95 (m^3/s)
River Avon	River Avon at Bathford	ST785670	Jan 1969	69.5	19.6	2.6
By Brook	By Brook at Middlehill	ST814688	Jan 1971	4.9	1.6	0.2
River Avon	River Avon at Melksham*	ST902641	Jan 1953	21.4	6.7	1.0
River Avon	River Avon at Great Somerford	ST964833	Oct 1963	11.5	3.3	0.3
Midford Brook	Midford Brook at Midford	ST763611	Jan 1961	7.0	2.3	0.4
Wellow Brook	Wellow Brook at Wellow	ST740579	Jan 1966	3.9	1.3	0.2
Somerset Frome	Frome (Somerset) at Tellisford	ST805564	Jan 1961	12.7	3.8	0.6
Somerset Frome	Mells at Vallis	ST757491	Dec 1979	5.3	1.7	0.3
River Biss	Biss at Trowbridge	ST854578	Jan 1984	3.0	0.8	0.2
Semington Brook	Semington Brook at Semington	ST907605	Jan 1953	4.4	1.4	0.3
River Marden	River Marden at Stanley	ST955729	Jan 1969	3.7	1.2	0.3

* Period of record ends Dec 1980

Table 3-2 Estimated flow statistics, Warleigh Weir

	m^3/s	Ml/d
95% Exceedance (Q95):	2.4	205.2
70% Exceedance (Q70):	4.8	414.2
50% Exceedance (Q50):	8.5	730.1
10% Exceedance (Q10):	45.2	3908.0
5% Exceedance (Q5):	64.6	5579.8

3.4 Bacterial water quality and river flow relationship

Daily mean flow data for the Bathford and Middle Hill flow gauges from January 2006 to October 2020 have been obtain from the Environment Agency. The data have been used as described above to provide an estimated flow at Warleigh Weir over this period, shown in Appendix F.

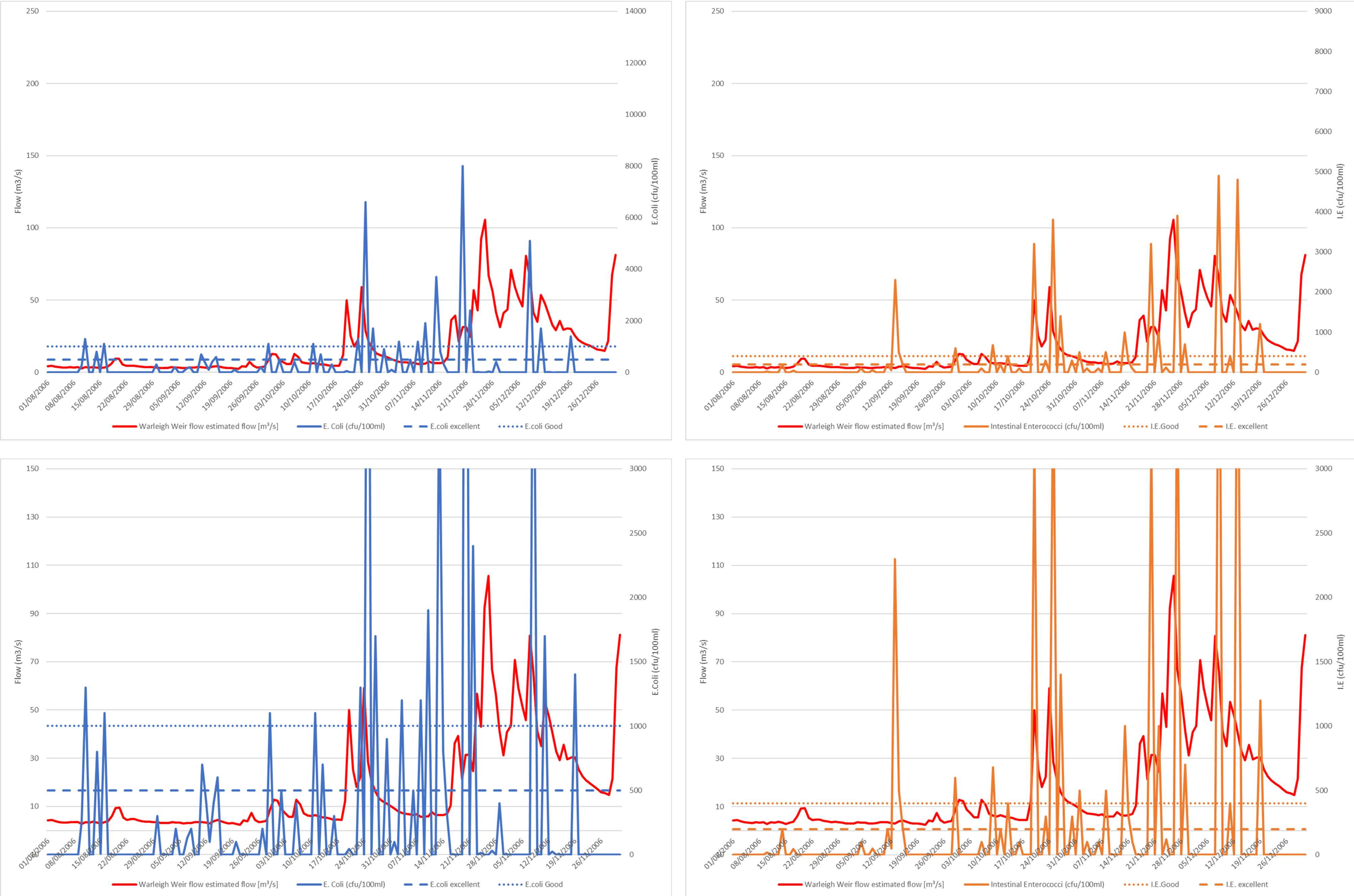
The bacterial data from the Tucking Mill intake have been plotted against this data for the years in which the data sets overlap (Appendix F). Generally, these graphs show increased bacterial concentrations (poorer water quality) during periods of higher flow. This is particularly apparent in late 2006, early 2007 and mid/late 2012 and might be expected, as runoff from catchments and the operation of storm overflows would be expected to be sources of bacteria under these conditions. Figure 3-4 presents further detail from the graphs shown in Appendix F, focusing on the period August to December 2006, when there was good flow and bacteria data available. Both *E.coli* and enterococci concentrations increase in response to flow peaks in mid/late October and mid/late November onwards. However, the data also show anomalies to this trend for example, a peak in enterococci concentration was recorded on 13th September 2006 with no corresponding flow peak.

[14] Information taken from the National River Flow Archive https://nrfa.ceh.ac.uk/

Similarly peaks can be seen in *E.coli* concentration over the period 3^{rd}-13^{th} November 2006, when flow is relatively low. The reasons for this are unknown but could reflect for example, local bacteria sources or responses to a very localised rainfall event that is not reflected in the flow data

A further trend that is apparent from the graphs in Appendix F is that bacterial water quality is generally better than or near the bathing standards when river flows are not elevated, supporting the findings of the September 2020 monitoring day.

Figure 3-4 Flow and bacterial water quality relationship, Warleigh Weir, Aug-Dec 2006 (*E.coli* left, enterococci right). Same data are displayed in more detail on the lower graph.



3.4.1 Travel times

Travel times between Wessex Water assets to Warleigh Weir, and how these may vary under a range of flow conditions, are poorly understood. No empirical survey data from tracer surveys specifically undertaken to calculate travel time are known for this section of the River Avon. However, work undertaken by Wessex Water as part of investigations into the effects of groundwater abstraction in the Malmesbury area in 2005 generated estimates of travel time further upstream in the Bristol Avon catchment. These data are from pumping trials at stream support boreholes on the Tetbury and Sherston branches of the River Avon, recording the duration between discharges starting and when this flow was measured at downstream flow gauges. From these, average velocities of between 0.15 and 0.2 m/s over distances of 6 km to 17 km were determined. The conditions at the time were relatively low flows (approximately Q80-Q93 depending on day of survey[15]), and therefore likely to be relatively conservative.

These measured data give a good indication of velocity over a section of the Bristol Avon approximately 70km upstream of Warleigh Weir under the conditions at the time of the survey. However, in the absence of further data it is not known how representative these data are of velocity further downstream. Velocity is a function of discharge (flow) and area of a river, the discharge of the Bristol Avon increases significantly as it accretes downstream. For example, the difference the Q50 of the Sherston Avon at Fosseway gauging station (0.56 m^3/s) is around 17 times greater than the Q50 at Bathford gauging station (9.41m^3/s). Channel dimensions have not been investigated here however in broad terms, the river is likely to be steeper and will also be shallower and narrower in the Malmesbury area when compared to the section upstream of Warleigh Weir. Furthermore other factors including weirs such as those at Chippenham, Melksham, Bradford on Avon, Avoncliff and at Warleigh impound flow, reducing velocity and increasing travel time.

Recognising these limitations, the data from the Malmesbury investigation have been used as a starting point to estimate travel times from all WRC to Warleigh Weir for incremental changes in velocity between 0.5m^{-s1} and 0.5m^{-s1}. The output of this assessment is shown in Appendix G and summarised in Table 3-3 for WRCs within 25km upstream of Warleigh Weir. The analysis shows that, for example, with an assumed velocity of 0.15 m^{-s1} (from the Malmesbury investigation) the travel time over the 4km from Freshford WRC would be 8.3 hours. The sensitivity analysis presented in the same table shows that with an assumed velocity of 0.05m^{-s1} the travel would increase to 25 hours, whilst at a velocity 10 times faster (0.5m^{-s1}), this would decrease to 2.5 hours.

As noted above, the opportunity for die-off in the river, expressed by the T90, also determines the influence a discharge will exert on bacterial water quality at the weir. To understand the opportunity for die-off the average Lower, Typical and Upper T90s for Enterococci in freshwater (Table 2-2) have also been included in the sensitivity analysis presented in Table 3-3 (shown by the colour coding). Taking again the example of Freshford, the analysis shows that this WRC lies sufficiently close to Warleigh Weir for the travel time for effluent from the WRC to be less than the average Low T90 of 54 hours under all velocity scenarios.

In interpreting the data presented here it is necessary to consider the limitations in the T90s described in Section 2.2.1. Furthermore, it is important to note that the T90 is the time period for 90% die-off of bacteria; it may or may not mean that there is sufficient time for

[15] Flows on the dates of the surveys were between approximately Q91-Q93 at the Sherston Avon at Fosseway gauging station. Flows on the dates of the surveys were between approximately Q80-Q90 at the Tetbury Avon at Brokenborough gauging station.

sufficient bacteria to die off for compliance with Bathing Water standards. That would also require understanding of the bacterial load from each source of contamination.

Acknowledging the limitations described above, this sensitivity analysis provides a useful indication of the travel times between WRCs and the weir and the sensitivity of this to different T90. Key observations include:

- Under the highest assumed velocity of 0.5 m^{-s1}, the travel time to all WRCs in the catchment is less than the average Lower T90 threshold of 54 hours (see Appendix G).
- Under the lowest assumed velocity of 0.05 m^{-s1} the travel time to all WRCs more distant than Radstock (18.6km) is greater than the average Upper T90 threshold of 96 hours (see Appendix G).
- Four WRCs in the catchment (Freshford, Winsley, Bradford on Avon and Westwood) are sufficiently close to Warleigh Weir for the travel time to be less than the average Low T90 of 54 hours under all velocity scenarios (Table 3-3).
- The travel time to all WRCs within 25km of Warleigh Weir is less than the average Low T90 of 54 hours assuming a velocity of 0.15 m^{-s1} (Table 3-3).
- Wellow WRC, at 11 km upstream of Warleigh Weir is located sufficiently far upstream for the travel time to exceed the average Low T90 threshold of 54 hours to be exceeded, under an assumed velocity of 0.05 m^{-s1}. Under the same velocity (0.05 m^{-s1}), the travel time to Norton St Phillip WRC exceeds the average Typical T90 of 75 hours whilst the travel time to Radstock, located 18.6km upstream would be 103.3hours, exceeding the Upper T90 threshold of 96 hours (Table 3-3).

How this assessment may be improved is considered further in Section 4.2.

Table 3-3 Estimated travel time (hours) to WRCs within 15km upstream of Warleigh Weir under a range of flows and T90s

Site ID	WRC	Distance upstream Warleigh Weir (km)	Estimated travel time (hours) under different assumed velocities (m/s)							
			0.05	0.075	0.1	0.15	0.2	0.25	0.3	0.5
13130	FRESHFORD	4.5	25.0	16.7	12.5	8.3	6.3	5.0	4.2	2.5
13352	WINSLEY	5.4	30.0	20.0	15.0	10.0	7.5	6.0	5.0	3.0
13031	BRADFORD-ON-AVON	7.7	42.8	28.5	21.4	14.3	10.7	8.6	7.1	4.3
13341	WESTWOOD	9.4	52.2	34.8	26.1	17.4	13.1	10.4	8.7	5.2
13331	WELLOW	11	61.1	40.7	30.6	20.4	15.3	12.2	10.2	6.1
13318	TROWBRIDGE	12.2	67.8	45.2	33.9	22.6	16.9	13.6	11.3	6.8
13226	NORTON ST PHILIP	13.5	75.0	50.0	37.5	25.0	18.8	15.0	12.5	7.5
13045	CAM VALLEY	14.5	80.6	53.7	40.3	26.9	20.1	16.1	13.4	8.1
13256	RODE	15.2	84.4	56.3	42.2	28.1	21.1	16.9	14.1	8.4
13274	SHOSCOMBE	16.1	89.4	59.6	44.7	29.8	22.4	17.9	14.9	8.9
13252	RADSTOCK	18.6	103.3	68.9	51.7	34.4	25.8	20.7	17.2	10.3
13017	BECKINGTON	18.8	104.4	69.6	52.2	34.8	26.1	20.9	17.4	10.4
13356	WOODBOROUGH HILL	18.9	105.0	70.0	52.5	35.0	26.3	21.0	17.5	10.5
13028	BOWERHILL	20.6	114.4	76.3	57.2	38.1	28.6	22.9	19.1	11.4
13235	PAULTON	20.7	115.0	76.7	57.5	38.3	28.8	23.0	19.2	11.5
13204	MELKSHAM	21.1	117.2	78.1	58.6	39.1	29.3	23.4	19.5	11.7
13131	FROME	23.9	132.8	88.5	66.4	44.3	33.2	26.6	22.1	13.3
13338	WESTBURY	24.3	135.0	90.0	67.5	45.0	33.8	27.0	22.5	13.5
13061	CHILCOMPTON	24.9	138.3	92.2	69.2	46.1	34.6	27.7	23.1	13.8

Key

Travel time is less than the Lower average T90 of 54 hours	Travel time is less than the Upper average T90 of 96
Travel time is less than the Typical average T90 of 75 hours	Travel time exceeds the Upper average T90 of 96 hours

3.5 Summary and data gaps

The information presented shows that there is a paucity of bacterial water quality information at Warleigh Weir; the only data available at the weir are from the single monitoring day in September 2020. A data set exists for the Wessex Water Tucking Mill intake located approximately 3km upstream of the weir however, this dataset excludes the influence of the Midford and Cam and Wellow Brooks, which join the Avon downstream of the intake. These watercourses were shown to be a significant influence on water quality using the data from September 2020.

The relative importance of sources of bacterial contamination affecting Warleigh Weir is not well understood. Three factors critical to understanding this are:

- The bacterial load discharged to the river (available data described above);
- The distance (and time of travel) from the discharge point to Warleigh Weir; and
- The rate of bacterial die-off in the river (the T90).

In the following section a monitoring programme is outlined to required to obtain the following additional data and improve this understanding.

4. Monitoring plan

A monitoring plan to collect the data identified in the preceding section is presented here. The absence of data suggests a two stage approach to monitoring:

- **Phase 1: Baseline monitoring** – building on the monitoring undertaken in September 2020 by implementing a routine monitoring programme at these sites.

- **Phase 2: Targeted monitoring** – to explore particular areas of concern highlighted in Phase 1.

Phase 1 will be implemented in 2021. This will also include work to understand the extent of upstream influence and source apportionment, to enable more targeted monitoring in Phase 2. The Phase 1 monitoring plan is set out below. Data will be reviewed as it becomes available and a decision will be made on how this will be continued in Phase 2 in agreement with the Project Steering Group. Phase 2 monitoring will be undertaken in 2022 and will complete by September 2022.

4.1 Phase 1 Monitoring Plan

4.1.1 River and WRC water quality monitoring

<u>Spot sampling</u>

The monitoring plan for river water quality spot samples is shown in Table 4-1, whilst the location of monitoring points is shown Figure 4-1. Samples will be collected on a weekly basis during the bathing season (15th May to 30th September) from 31 river locations.

The river monitoring locations were selected to give a good representation along the main arm of the River Avon and the tributaries entering between Melksham and Warleigh Weir. Many of these sites were either monitored in September 2020 or are located close to sites that were monitored at that time. Sites that are being monitored by Wessex Water as part of other investigations in the Bristol Avon have also been added as bacterial analysis can be added to the sampling suite. All river sites were subject to site inspection visits by Wessex Water staff in March 2021 to determine suitability for monitoring; this led to some of the sites monitored in September 2020 being dropped due to concerns over access arrangements and health and safety for sampling staff.

Weekly monitoring during the bathing season will allow for 20 samples to be collected at each site and is consistent with the frequency used for bathing water compliance monitoring by the Environment Agency. Monitoring will be extended outside of the bathing season however the frequency of sampling will be reduced to monthly sampling over this period. This monitoring programme will allow for water quality to be characterised under a range of flow conditions. Information about flow conditions at the time of sampling will be gained from existing river flow monitoring and by local rain gauge data (Section 3.3). Phase 1 sampling will commence in April 2021 and continue to the end of March 2022.

All river samples will be analysed at Wessex Water's Saltford Scientific Centre for the following determinands:

Conductivity,
Enterococci,
Total coliforms,
Suspended solids,
Ortho P,
Total P,
Soluble Reactive P,
Alkalinity,
Aluminium,
Iron,
E.coli,
Dissolved oxygen (ATS),
Ammonia,
Nitrate,
Nitrite,
Total N,
pH,
Temperature (ATS)

The five WRCs shaded grey in Table 4-2 were monitored in September 2020. This monitoring will be expanded to include all WRCs with a PE exceeding 250 within 25km of Warleigh Weir in Phase 1 (Woodborough Hill, PE 24 will be excluded). Samples are being collected routinely from a further 13 WRC in the Bristol Avon upstream of Warleigh Weir as part of the Bristol Avon Catchment Permitting trial. These include many of the larger WRC located more than 25km upstream of Warleigh Weir. This gives a total of 31 WRC, which will be monitored either once or twice monthly, depending on how frequently they are visited for compliance monitoring (the frequency is shown in Table 4-2).

All WRC samples will be collected from the final effluent sampling location used for WRC compliance monitoring; no monitoring of crude sewage will be undertaken. The exception to this is the lagoons at Westwood WRC, which will be monitored pre and post lagoon to understand their bacterial removal performance.

All WRC samples will be analysed at Wessex Water's Saltford Scientific Centre for the following determinands (in addition to the existing analysis suites associated with the site permits):

- Total coliforms,
- Enterococci
- E. *coli*

Continuous monitoring

A Xylem sonde was installed at Warleigh Weir in December 2020 and has been recording temperature, conductivity, ammonium, pH, dissolved oxygen and turbidity continuously since. Wessex Water has not identified any technology that can be employed in-river to provide continuous (or near continuous) bacterial water quality data. Consequently, there are no plans to deploy equipment to provide high frequency bacterial water quality data.

The information provided through the Sonde can be used in conjunction with river flow data (Section 3.3) to improve understanding of how water quality varies with changes in flow at Warleigh Weir, and cross referenced against spill events from the three upstream overflows on the Coastwatch system. No further continuous water quality monitoring will be undertaken in Phase 1.

Table 4-1 Phase 1 river water quality monitoring plan

Map ID no.	Sample site code*	Sample point name	X	Y	Frequency (Bathing Season)	Frequency (Non Bathing Season)
1	BA_123	Limpley Stoke bridge	378238	161243	Weekly	Monthly
2	WW24	Tucking mill off take at river	378387	161815	Weekly	Monthly
3	BA_121	Midford under viaduct	376100	160544	Weekly	Monthly
4	BA_119	Midford Mill Cottages	376327	160600	Weekly	Monthly
5	BA_108	Freshford inn bridge	379093	159950	Weekly	Monthly
6	BA_120	Wellow Dunkerton	371075	159353	Weekly	Monthly
7	WW01	Warleigh Weir	379172	164265	Weekly	Monthly
8	WW12	River Frome near Oldford	378587	150559	Weekly	Monthly
9	WW14	River Frome Batchbridge	377810	145925	Weekly	Monthly
10	BA_078	Elm Lane Egford Frome	375700	148535	Weekly	Monthly
11	BA_044	Bulkington	393523	158774	Weekly	Monthly
12	BA_043	Seend bridge	394553	159496	Weekly	Monthly
13	WW15	Fordbury Water Whatley	373251	147885	Weekly	Monthly
14	BA_076	Mells	373015	148983	Weekly	Monthly
15	BA_087	Paulton US	365410	157650	Weekly	Monthly
16	BA_088	Paulton US	365740	158076	Weekly	Monthly
17	BA_089	Paulton DS	366762	157676	Weekly	Monthly
18	BA_070	Radstock US	369560	155010	Weekly	Monthly
19	BA_071	Radstock DS	370577	155372	Weekly	Monthly
20	BA_034	Melksham River Avon US	390464	164186	Weekly	Monthly
21	BA_037	Bowerhill US	390500	162438	Weekly	Monthly
22	BA_054	Cross Guns, Avoncliff	380540	160043	Weekly	Monthly
23	BA_064	Chilcompton US	364781	152540	Weekly	Monthly
24	BA_065	Chilcompton DS	365263	153010	Weekly	Monthly
25	BA_109	R. Frome - Tellisford	380613	155648	Weekly	Monthly
26	BA_063	R. Frome - Farleigh Hungerford	380154	156724	Weekly	Monthly
27	BA_057	R Biss - Trowbridge	384821	158436	Weekly	Monthly
28	WW05	River Avon at Bradford-on-Avon	382747	160840	Weekly	Monthly
29	WW08	River Avon at Semington	389964	161016	Weekly	Monthly
30	WW09	River Biss at Yarnbrook	386593	155089	Weekly	Monthly
31	WW02	Midford Brook at Monkton Combe school	377560	161934	Weekly	Monthly

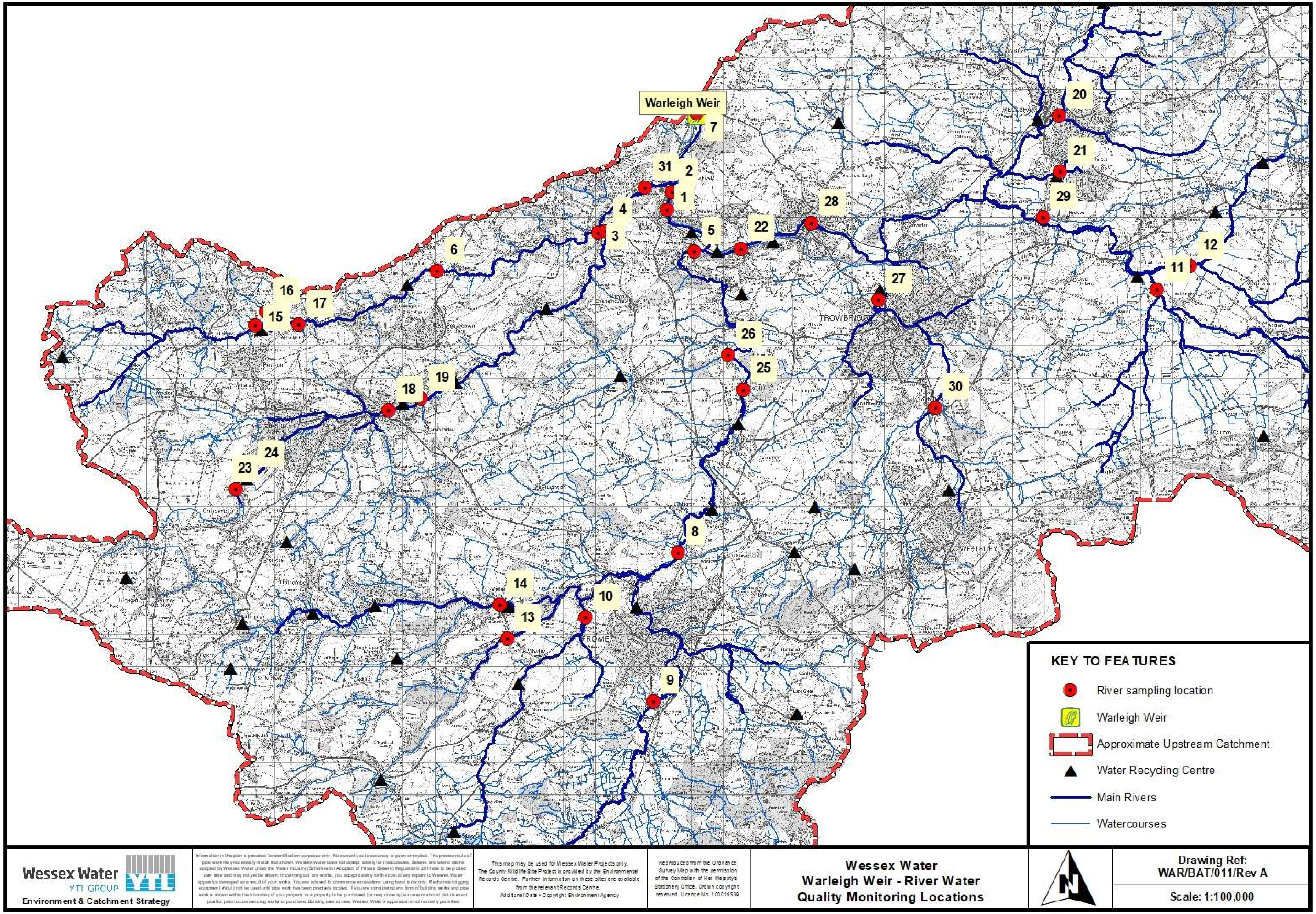
Sample site codes starting “WW” were set up specifically for the September 2020 monitoring day. Site codes starting “BA” were already set up on Wessex Water’s systems under previous investigations

Table 4-2 Phase 1 WRC monitoring plan

Site ID	WRC	Treatment processes	PE	DWF (m^3/d)	Receiving watercourse	Distance upstream Warleigh Weir	Monitored	Frequency/ year	Comment
13130	Freshford	SBI	1,528	460	River Avon	4.48	Y	12	Within 25km
13352	Winsley	SBI	1,974	430	River Avon	5.36	Y	12	Within 25km
13031	Bradford-On-Avon	TB2	10,925	3,013	River Avon	7.66	Y	24	Within 25km
13341	Westwood	TB1	1,008	325	Haygrove Stream	9.43	Y	12	Within 25km
13331	Wellow	SBI	411	136	Midford Brook	10.96	Y	12	Within 25km
13318	Trowbridge	TB2	68,453	14,000	River Avon	12.19	Y	24	Within 25km
13226	Norton St Philip	TB2	1,125	315	Norton Brook	13.51	Y	12	Within 25km
13045	Cam Valley	SAE	7,479	1,750	Cam Brook	14.47	Y	12	Within 25km
13256	Rode	SBI	1,009	230	River Frome (Somerset)	15.16	Y	12	Within 25km
13274	Shoscombe	SBI	1,786	505	Midford Brook	16.13	Y	12	Within 25km
13252	Radstock	TB2	22,341	5,984	Wellow Brook	18.64	Y	24	Within 25km
13017	Beckington	TB1	1,117	344	River Frome (Somerset)	18.79	Y	12	Within 25km
13356	Woodborough Hill	SBI	24	No flow limit	Midford Brook	18.88	N	12	Too small/distant
13028	Bowerhill	TA2	8,061	2,182	Berryfield Brook	20.6	Y	24	Within 25km
13235	Paulton	TB2	10,607	2,252	Cam Brook	20.7	Y	24	Within 25km
13204	Melksham	TB2	17,399	5,000	River Avon	21.1	Y	24	Within 25km
13131	Frome	TB2	30,333	8,250	River Frome	23.9	Y	24	Within 25km
13338	Westbury	TA2	26,445	6,871	Bitham Brook	24.3	Y	12	Within 25km
13061	Chilcompton	TB2	1,668	423	Somer Stream	24.9	Y	24	Within 25km
13164	Keevil	SBI	3,428	795	Semington Brook	25.5	Y	12	Monitored under CP
13262	Seend	TB2	1,961	207	Summerham Brook	30.5	Y	24	Monitored under CP
13244	Potterne	TA2	11,587	3,011	Semington Brook	32.9	Y	24	Monitored under CP
13064	Chippenham	TA2	37,714	10,000	River Avon	34.9	Y	24	Monitored under CP
13116	Erlestoke	TB2	1,166	172	Erlestoke Stream	33.5	Y	24	Monitored under CP
13308	Thingley	TA2	17,507	3,750	Byde Mill Brook	33.6	Y	24	Monitored under CP
13090	Devizes	TB2	15,545	2,200	Waylens Brook	35.3	Y	24	Monitored under CP
13044	Calne	TB2	19,756	4,679	River Marden	46.3	Y	24	Monitored under CP
13298	Sutton Benger	TB2	5,144	1,965	River Avon	47.0	Y	24	Monitored under CP
13522	Lyneham	TB2	3,913	1,200	Springs Watercourse	56.4	Y	24	Monitored under CP
13193	Malmesbury	TB2	11,052	3,168	River Avon (Bristol)	62.4	Y	24	Monitored under CP
13360	Royal Wootton Bassett	TB2	13,739	2,917	Hancocks Water	72.3	Y	24	Monitored under CP
13307	Tetbury	TB2	5,949	1,200	River Avon	74.8	Y	24	Monitored under CP

Key for treatment types: PRI Primary = septic tank only. SAE Secondary / aeration. SBI Secondary / traditional biological. TA2 Advanced Tertiary / plus aeration. TB1 Simple Tertiary / plus traditional biological, TB2 Advanced Tertiary / plus traditional biological.
Grey shading indicates WRCs monitoring as part of September 2020 monitoring day

Figure 4-1 Location of monitoring points



4.1.2 Overflow monitoring

Water quality monitoring of storm overflows for bacteria is challenging to accomplish as samples have to be collected during a spill event. There are two broad approaches that can be implemented: manual sample collection and automated sampling using an autosampler.

Manual sampling can be particularly challenging as it relies on a sampler or team of samplers being ready to mobilise for a storm event and to be in position to collect samples at the moment an overflow starts to spill. Spill events can occur at any time, outside of normal working hours and during periods of darkness. This means that health and safety arrangements need to be carefully managed to ensure safe collection of samples.

Autosamplers can be installed on site at the overflow and triggered remotely to collect samples via telemetry or through on-site water level logging equipment. The advantage of using autosamplers over manual sampling is that they can be triggered to capture the "first flush" discharged from an overflow. However, not all locations are suitable for installation of autosamplers; factors including site health and safety of staff, security of the autosampler and telemetry issues (e.g. mobile phone signal strength) all determine suitability.

Wessex Water installed autosamplers at five storm overflows in the Poole Harbour catchment in December 2020 for a one year period, with the target of collecting water quality samples (including *E.coli* and Enterococci) from five storm events at each location. Wessex Water also have pairs of sondes installed up and downstream of three storm overflows in the Moors River system near Christchurch in Dorset. These were installed in July 2020 for a one year monitoring programme and have been continuously monitoring the parameters listed in Section 4.1.1 (i.e. not bacteria).

Although the nature of the sewerage system in this part of the Bristol Avon will differ from that being monitored in Dorset (the number of properties and types of trade discharges received, extent of surface water separation and groundwater ingress etc) it is considered a reasonable surrogate data set for transfer to characterise the likely relative contribution of bacteria from overflows located upstream of Warleigh Weir.

It is therefore proposed during Phase 1 to analyse the data collected through these other investigations and, in discussion with the Environment Agency, review its suitability for application in the Warleigh Weir investigation. If data from the Bristol Avon are required, this could be collected later in Phase 1 and during Phase 2.

4.2 Improving estimates of travel time

The analysis presented in Section 3.4.1 shows the sensitivity of velocity assumptions in travel time estimates from Wessex Water WRCs to Warleigh Weir. What is unclear is how representative the velocities (used in Section 3.4.1) are of those elsewhere in the Bristol Avon catchment upstream of the weir and how these may vary under a range of flow conditions.

As a first step to improving travel time estimates, early in project delivery available velocity readings will be compiled from gauging stations in the catchment upstream of Warleigh Weir. These are not publicly available through sites such as the National River Flow Archive[16] (only flow is available) and will need to be requested from the Environment Agency. It is important to understand how these recordings are taken; many gauging structures use control structures (weir and flumes) to measure flow and therefore the velocity recorded at the gauging station will not be representative of that in the wider river reach in which the

[16] https://nrfa.ceh.ac.uk/

gauging station is located. Stations such as the one at Bathford, which use a stage discharge relationship and velocity measured by Acoustic Doppler Current Profiler (ADCP) do not have the same structures and therefore velocities measured at these locations may be more representative.

The findings of this review will determine the suitability of this approach for improving estimates of travel time to Warleigh Weir. If further data are required, this could be delivered through a targeted programme of spot velocity measurements using ADCP at locations across the Bristol Avon and its tributaries. This primary limitations of this approach are that the velocity readings would only be representative of the specific location at which the reading was taken and under the conditions at the time of measurement. Thus an extensive programme of monitoring locations sampled frequently under a range of flow conditions may be required.

An alternative approach to using spot velocity readings would be to undertake targeted tracer surveys. In 2020, Wessex Water commissioned an options appraisal of methods for calculating river travel times for watercourses that discharge into Poole Harbour (Ricardo, 2020). The methods reviewed are listed in Table 4-3, with a weighted score based on operational ease, the flow range over which they can be undertaken, their accuracy, cost effectiveness, environmental impact and time taken to complete.

Table 4-3: Evaluation of river travel time methods

Method		Operational ease (6)	Flow Range (5)	Accuracy (4)	Cost effectiveness (3)	Environmental impact (2)	Time efficiency (1)	Total (weight x score)
Direct measurement methods	Dye tracing	18	15	12	9	6	2	62
	Floating GPS trackers	12	15	12	3	4	1	47
Estimation methods	Storm hydrograph peak propagation	18	5	4	9	6	3	45
	Empirical formulas	18	15	4	9	6	3	55
	Modelling - 1D	6	15	8	3	6	1	39
	Modelling - 2D	6	15	8	3	6	1	39
	Modelling - 3D	6	15	12	3	6	1	43
	Direct velocity measurements	18	15	8	3	6	2	52

Taken from Ricardo (2020)

Two methods in particular were highlighted as being effective and feasible: using empirical formulas and dye tracing. A summary of these methods is provided below:

'Empirical formulas that use readily available catchment characteristics are a recommended method of estimating travel time. In particular, Jobson's equations are recommended in conjunction with a method that directly measures travel times, such as dye tracing. Although these equations need to be validated due to their predictive nature, their wide applicability, ease of use, and extremely low cost of collecting input data makes them a highly complementary and useful method. Provided the equations are validated with empirical data, the equations can be used to estimate the travel time at any flow'.

'Dye tracing is a very accurate method of calculating travel time between two points as the method provides a direct measurement of travel time of a package of water between two points. This method also has the benefit of mimicking suspended particulates and should therefore provide the closest approximation of the transport dynamics of E Coli. The only potential limitation with the method is the visual impact in the community, though this can be overcome via effective communication with local stakeholders and dose testing to minimise impact'.

Excluded from the assessment in Table 4-3 is a further tracer method using the bacterial spore *Bacillus atrophaeus*. This method introduces a bacterial spore not commonly found in the environment at an extremely high concentration (typically 3 to $7x10^8$ cfu/100ml). Water quality samples collected at monitoring locations downstream are sent for laboratory analysis to identify the first and peak occurrence of the spore. By recording the time at which the samples are collected, the travel time from the dosing location to the sampling location can be determined. This was used in the AMP6 Burnham Jetty and Sand Bay and Clevedon Bathing Water investigations by Wessex Water but is not suitable for use where it could affect a designated shellfish water (hence not reviewed for use in Poole Harbour in Table 4-3 above). This may be suitable for use in the Bristol Avon catchment.

The key advantage of a tracer survey is that it will provide a measured travel time from the point of dosing to the monitoring points downstream. The main limitations of tracer surveys are that they can be difficult and costly to deliver, usually requiring specialist equipment and significant staff resources. Furthermore, they only provide travel time estimates from the point of dosing to the sampling points under the conditions at the time of the survey. The large catchment and multiple tributaries upstream of Warleigh mean that it would be necessary to select dosing locations carefully and repeat the surveys under different flow conditions. Potential locations for tracer introduction include:

- Radstock WRC on the Midford/Cam Brook system
- Frome WRC on the River Frome
- Chippenham WRC on the main River Avon

To understand how time of travel may vary under different flow conditions tracer surveys would be undertaken during the low flow period, typically in late summer/autumn 2021 and repeated under high flow conditions in winter 2021/22.

In summary, as a first step the available data from existing gauging stations will be reviewed and the findings shared with the Environment Agency, as will the need for additional data collection through ADCP gauging or tracer surveys. If required, the method, location and timing of gauging and tracer surveys will be determined during project delivery in discussion with specialist contractors and the Environment Agency.

4.3 River flow monitoring and rainfall data

Other than the spot velocity readings described in the preceding sections, no further river flow monitoring will be undertaken as part of this investigation. Data collected through existing Environment Agency gauging stations described in Section 3.3 will be used as a surrogate for flows at Warleigh Weir during the investigation.

No rainfall data will be collected specifically for this investigation. The existing network of rainfall gauges used by Wessex Water's water resources team will be used to provide rainfall data across the Bristol Avon catchment during the period of investigation.

4.4 Phase 2 Monitoring Plan

This will be agreed with the Environment Agency and project steering group following completion of Phase 1.

5. Summary and conclusions

There is little information available concerning bacterial water quality at Warleigh Weir. Wessex Water's WRCs and storm overflows, private sewage and trade discharges, septic tanks from properties not connected to mains discharges, foul to surface water misconnections, wildlife and land management practices will all influence bacterial water quality at the weir.

To characterise bacterial water quality at Warleigh Weir under a range of flow conditions and identify the main sources of bacterial contamination upstream a two-phased approach is identified. The first phase comprises targeted river and WRC water quality monitoring and obtaining further existing data concerning velocity in the River Avon and its tributaries. Monitoring data from intermittent discharges elsewhere in the Wessex Water area will also be reviewed to determine its appropriateness for use on this investigation. The emerging findings of Phase 1 will be shared with the Environment Agency and the Project Steering Group to inform further targeted monitoring in Phase 2. This may include further river and WRC water quality monitoring, overflow water quality monitoring and tracer surveys to determine travel time from Wessex Water assets to Warleigh Weir.

6. References

Ricardo (2020) River Travel Time Estimation Methods -Final. Review and options appraisal. Report for Wessex Water Services Limited. October 2020.

Wiedenmann, A. Krüger, P. Dietz, K., Lopez Pila, J., Szewzyk, R,. and Botzenhart, K. (2006) A Randomized Controlled Trial Assessing Infectious Disease Risks from Bathing in Fresh Recreational Waters in Relation to the Concentration of Escherichia coli, Intestinal Enterococci, Clostridium perfringens, and Somatic Coliphages in Environmental Health Perspectives. Volume 114(2) pp228-36.

Wessex Water (2017) Burnham Jetty Bathing Water Investigation. Final Report, Wessex Water, March 2017.

Appendix A. Details of WRC upstream of Warleigh Weir

Table A-1 WRCs upstream of Warleigh Weir, by distance upstream

Site ID	WRC	Treatment processes	PE	DWF (m^3/d)	Receiving watercourse	Distance upstream Warleigh Weir
13130	FRESHFORD	SBI	1,528	460	RIVER AVON	4.5
13352	WINSLEY	SBI	1,974	430	RIVER AVON	5.4
13031	BRADFORD-ON-AVON	TB2	10,925	3,013	RIVER AVON	7.7
13341	WESTWOOD	TB1	1,008	325	HAYGROVE STREAM	9.4
13331	WELLOW	SBI	411	136	MIDFORD BROOK	11.0
13318	TROWBRIDGE	TB2	68,453	14,000	RIVER AVON	12.2
13226	NORTON ST PHILIP	TB2	1,125	315	NORTON BROOK	13.5
13045	CAM VALLEY	SAE	7,479	1,750	CAM BROOK	14.5
13256	RODE	SBI	1,009	230	RIVER FROME (SOMERSET)	15.2
13274	SHOSCOMBE	SBI	1,786	505	MIDFORD BROOK	16.1
13252	RADSTOCK	TB2	22,341	5,984	WELLOW BROOK	18.6
13017	BECKINGTON	TB1	1,117	344	RIVER FROME (SOMERSET)	18.8
13356	WOODBOROUGH HILL	SBI	24	No flow limit	MIDFORD BROOK	18.9
13028	BOWERHILL	TA2	8,061	2,182	BERRYFIELD BROOK	20.6
13235	PAULTON	TB2	10,607	2,252	CAM BROOK	20.7
13204	MELKSHAM	TB2	17,399	5,000	RIVER AVON	21.1
13131	FROME	TB2	30,333	8,250	RIVER FROME	23.9
13338	WESTBURY	TA2	26,445	6,871	BITHAM BROOK	24.3
13061	CHILCOMPTON	TB2	1,668	423	SOMER STREAM	24.9
13164	KEEVIL	SBI	3,428	795	SEMINGTON BROOK	25.5
13293	STRATTON ON THE FOSSE	TB1	1,148	320	MIDFORD BROOK	25.6
19556	SOUTH WRAXALL	TA2	194	71	CHALFIELD BROOK	26.0
13173	LACOCK	SBI	719	170	RIVER AVON	27.1
17655	RUDGE	PRI	4	Max flow 1.6 m^3/d	RIVER BISS	27.7
13092	DILTON MARSH	SBI	1,609	430	RIVER BISS	28.2
13205	MELLS	SBI	328	85	RIVER MELLS	28.5
13020	BEWLEY	SBI	118	No flow limit	RIVER AVON	28.8
19783	STANDERWICK	SBI	14	22	HAM BROOK	29.2
13150	HINTON BLEWETT	SBI	148	55	MIDFORD BROOK	29.2
13227	NUNNEY	SBI	1,161	334	NUNNEY BROOK	29.6
13262	SEEND	TB2	1,961	207	SUMMERHAM BROOK	30.5
13257	ROWDE	SBI	2,736	1,205	SUMMERHAM BROOK	31.5
13244	POTTERNE	TA2	11,587	3,011	SEMINGTON BROOK	32.9
13390	CORSLEY HEATH	SBI	38	28	RIVER FROME (SOMERSET)	33.0
13178	LEIGH ON MENDIP	TB2	397	85	RIVER MELLS	33.1
13069	COLEFORD	SAE	2,011	525	RIVER MELLS	33.4

13116	ERLESTOKE	TB2	1,166	172	ERLESTOKE STREAM	33.5
13308	THINGLEY	TA2	17,507	3,750	BYDE MILL BROOK	33.6
13064	CHIPPENHAM	TA2	37,714	10,000	RIVER AVON	34.9
13090	DEVIZES	TB2	15,545	2,200	WAYLENS BROOK	35.3
13083	CRANMORE	SBI	365	95	WHATLEY BROOK	35.4
13113	EDFORD	SBI	1,645	365	RIVER MELLS	35.8
13177	LAVINGTON	SBI	3,973	1,212	SEMINGTON BROOK	36.3
13323	WANSTROW	SBI	258	69	RIVER MELLS	36.4
13229	OAKHILL	SBI	1,340	300	RIVER MELLS	38.7
13322	URCHFONT	TB2	1,123	295	SEMINGTON BROOK	41.8
13321	UPTON NOBLE	TB1	119	No flow limit	RIVER FROME (SOMERSET)	42.7
13044	CALNE	TB2	19,756	4,679	RIVER MARDEN	46.3
13298	SUTTON BENGER	TB2	5,144	1,965	RIVER AVON	47.0
13213	MILE ELM	SBI	32	No flow limit	RIVER MARDEN	49.4
13075	COMPTON BASSETT	SBI	2,799	600	Rivers Brook	51.8
13148	HILMARTON	SBI	543	120	COWAGE BROOK	52.9
13137	GREAT SOMERFORD	SBI	842	177	RIVER AVON	55.6
13522	LYNEHAM	TB2	3,913	1,200	SPRINGS WATERCOURSE	56.4
13314	TOCKENHAM	TB1	111	36	RIVER MARDEN	58.4
19509	BUSHTON	SBI	61	18	COWAGE BROOK	59.0
13035	BRINKWORTH	SAE	749	225	BRINKWORTH BROOK	59.9
13193	MALMESBURY	TB2	11,052	3,168	RIVER AVON (BRISTOL)	62.4
13157	HULLAVINGTON	SBI	873	250	GAUZE BROOK	66.7
13360	ROYAL WOOTTON BASSETT	TB2	13,739	2,917	HANCOCKS WATER	72.3
13307	TETBURY	TB2	5,949	1,200	RIVER AVON	74.8
13269	SHERSTON	SBI	1,338	220	RIVER AVON	76.0
13184	LUCKINGTON	SBI	341	101	LUCKINGTON BROOK	79.5
17273	ALDERTON	SBI	81	20	LUCKINGTON BROOK	79.5
13091	DIDMARTON	TB1	588	140	RIVER SHERSTON	80.6
13136	GREAT BADMINTON	SBI	588	140	RIVER SHERSTON	82.3

Key for treatment types: PRI Primary = septic tank only. SAE Secondary / aeration. SBI Secondary / traditional biological. TA2 Advanced Tertiary / plus aeration. TB1 Simple Tertiary / plus traditional biological, TB2 Advanced Tertiary / plus traditional biological.

Table A-2 WRCs upstream of Warleigh Weir, by population equivalent (largest to smallest)

Site ID	WRC	Treatment processes	PE	DWF (m^3/d)	Receiving watercourse	Distance upstream Warleigh Weir
13318	TROWBRIDGE	TB2	68,453	14,000	RIVER AVON	12.2
13064	CHIPPENHAM	TA2	37,714	10,000	RIVER AVON	34.9
13131	FROME	TB2	30,333	8,250	RIVER FROME	23.9
13338	WESTBURY	TA2	26,445	6,871	BITHAM BROOK	24.3
13252	RADSTOCK	TB2	22,341	5,984	WELLOW BROOK	18.6
13044	CALNE	TB2	19,756	4,679	RIVER MARDEN	46.3
13308	THINGLEY	TA2	17,507	3,750	BYDE MILL BROOK	33.6
13204	MELKSHAM	TB2	17,399	5,000	RIVER AVON	21.1
13090	DEVIZES	TB2	15,545	2,200	WAYLENS BROOK	35.3
13360	ROYAL WOOTTON BASSETT	TB2	13,739	2,917	HANCOCKS WATER	72.3
13244	POTTERNE	TA2	11,587	3,011	SEMINGTON BROOK	32.9
13193	MALMESBURY	TB2	11,052	3,168	RIVER AVON (BRISTOL)	62.4
13031	BRADFORD-ON-AVON	TB2	10,925	3,013	RIVER AVON	7.7
13235	PAULTON	TB2	10,607	2,252	CAM BROOK	20.7
13028	BOWERHILL	TA2	8,061	2,182	BERRYFIELD BROOK	20.6
13045	CAM VALLEY	SAE	7,479	1,750	CAM BROOK	14.5
13307	TETBURY	TB2	5,949	1,200	RIVER AVON	74.8
13298	SUTTON BENGER	TB2	5,144	1,965	RIVER AVON	47.0
13177	LAVINGTON	SBI	3,973	1,212	SEMINGTON BROOK	36.3
13522	LYNEHAM	TB2	3,913	1,200	SPRINGS WATERCOURSE	56.4
13164	KEEVIL	SBI	3,428	795	SEMINGTON BROOK	25.5
13075	COMPTON BASSETT	SBI	2,799	600	Rivers Brook	51.8
13257	ROWDE	SBI	2,736	1,205	SUMMERHAM BROOK	31.5
13069	COLEFORD	SAE	2,011	525	RIVER MELLS	33.4
13352	WINSLEY	SBI	1,974	430	RIVER AVON	5.4
13262	SEEND	TB2	1,961	207	SUMMERHAM BROOK	30.5
13274	SHOSCOMBE	SBI	1,786	505	MIDFORD BROOK	16.1
13061	CHILCOMPTON	TB2	1,668	423	SOMER STREAM	24.9
13113	EDFORD	SBI	1,645	365	RIVER MELLS	35.8
13092	DILTON MARSH	SBI	1,609	430	RIVER BISS	28.2
13130	FRESHFORD	SBI	1,528	460	RIVER AVON	4.5
13229	OAKHILL	SBI	1,340	300	RIVER MELLS	38.7
13269	SHERSTON	SBI	1,338	220	RIVER AVON	76.0
13116	ERLESTOKE	TB2	1,166	172	ERLESTOKE STREAM	33.5
13227	NUNNEY	SBI	1,161	334	NUNNEY BROOK	29.6
13293	STRATTON ON THE FOSSE	TB1	1,148	320	MIDFORD BROOK	25.6
13226	NORTON ST PHILIP	TB2	1,125	315	NORTON BROOK	13.5
13322	URCHFONT	TB2	1,123	295	SEMINGTON BROOK	41.8
13017	BECKINGTON	TB1	1,117	344	RIVER FROME (SOMERSET)	18.8
13256	RODE	SBI	1,009	230	RIVER FROME (SOMERSET)	15.2

13341	WESTWOOD	TB1	1,008	325	HAYGROVE STREAM	9.4
13157	HULLAVINGTON	SBI	873	250	GAUZE BROOK	66.7
13137	GREAT SOMERFORD	SBI	842	177	RIVER AVON	55.6
13035	BRINKWORTH	SAE	749	225	BRINKWORTH BROOK	59.9
13173	LACOCK	SBI	719	170	RIVER AVON	27.1
13091	DIDMARTON	TB1	588	140	RIVER SHERSTON	80.6
13136	GREAT BADMINTON	SBI	588	140	RIVER SHERSTON	82.3
13148	HILMARTON	SBI	543	120	COWAGE BROOK	52.9
13331	WELLOW	SBI	411	136	MIDFORD BROOK	11.0
13178	LEIGH ON MENDIP	TB2	397	85	RIVER MELLS	33.1
13083	CRANMORE	SBI	365	95	WHATLEY BROOK	35.4
13184	LUCKINGTON	SBI	341	101	LUCKINGTON BROOK	79.5
13205	MELLS	SBI	328	85	RIVER MELLS	28.5
13323	WANSTROW	SBI	258	69	RIVER MELLS	36.4
19556	SOUTH WRAXALL	TA2	194	71	CHALFIELD BROOK	26.0
13150	HINTON BLEWETT	SBI	148	55	MIDFORD BROOK	29.2
13321	UPTON NOBLE	TB1	119	No flow limit	RIVER FROME (SOMERSET)	42.7
13020	BEWLEY	SBI	118	No flow limit	RIVER AVON	28.8
13314	TOCKENHAM	TB1	111	36	RIVER MARDEN	58.4
17273	ALDERTON	SBI	81	20	LUCKINGTON BROOK	79.5
19509	BUSHTON	SBI	61	18	COWAGE BROOK	59.0
13390	CORSLEY HEATH	SBI	38	28	RIVER FROME (SOMERSET)	33.0
13213	MILE ELM	SBI	32	No flow limit	RIVER MARDEN	49.4
13356	WOODBOROUGH HILL	SBI	24	No flow limit	MIDFORD BROOK	18.9
19783	STANDERWICK	SBI	14	22	HAM BROOK	29.2
17655	RUDGE	PRI	4	Max flow 1.6 m3/d	RIVER BISS	27.7

Appendix B. Storm overflow EDM data

SiteID	SiteName	Type	Distance upstream of WW (km)	DWF m³/d	FFT (l/s)	Spills Per Year							
						2013	2014	2015	2016	2017	2018	2019	Average last 3 years
16790	MONKTON COMBE - MILL LANE CSO	CSO Network	3.96	540	50			42	68	10	0	66	25
13130	FRESHFORD O/F	Storm Tank at STW	4.48	460	11								
16789	SUMMER LANE MONKTON COMBE	CSO Network	5.06	173	27					22	46	34	34
14531	MIDFORD SPS (TUCKING MILL LANE)	Storm at PS	5.22	86	6								
13352	WINSLEY SETTLED STORM O/F	Storm Tank at STW	5.35	430	14								
16788	ADJACENT ABANDONED RAILWAY MIDFORD	CSO Network	5.67	87	22							3	3
14452	FRESHFORD - NEW INN	Storm at PS	5.86	13	5								
17390	FRESHFORD FIELDS OFF ROSEMARY LANE	CSO Network	6.62		7								
16920	BARTON FARM TERMINAL SPS	CSO Inlet	7.79										
16922	175 M DS BARTON BRIDGE BARTON FARM	CSO Network	8.38	1,961	415				1.33	11	8	4	8
16897	B O AVON - CULVER STREET RECREATION PARK OFF POUND LANE	CSO Network	8.51	968	47		112	56	66	43	76	72	64
16899	B O AVON - CHURCH STREET / MARKET STREET / TOWN BRIDGE	CSO Network	9.13	734	37		59	40	59	30	63	49	47
16925	B O AVON - SILVER STREET / MARKET STREET / TOWN BRIDGE	CSO Network	9.13	639	231					0	4	4	3
13341	WESTWOOD SETTLED STORM O/F	Storm Tank at STW	9.36	325	10							42	42
16898	B O AVON - JUNCTION OF SPRINGFIELD AND WOOLLEY STREET	CSO Network	9.51	398	88				6.65	2	7	12	7
13331	WELLOW SETTLED STORM O/F	Storm Tank at STW	10.96	136	5						40	44	42
15536	WELLOW - MILL HILL	Storm at PS	11.40	5	5						13	3	8
15527	DUNKERTON	Storm at PS	13.23	39	4								
16900	TROWBRIDGE - CANAL ROAD / LADYDOWN MILL	CSO Network	13.46	718	45							34	34
13226	NORTON ST PHILIP O/F	Storm Tank at STW	13.47	315	11								
13318	TROWBRIDGE STW SPS CSO/EO	CSO Inlet	14.36	14,000	857							10	10
13045	CAM VALLEY O/F	CSO Inlet	14.48	1,750	128								
16934	TROWBRIDGE - SHIRES CAR PARK BASEMENT	CSO Network	14.72	346	64							0	0
10011	Trowbridge (Bowyers Factory Culvert)	TBC	14.72										
16935	TROWBRIDGE - STALLARD STREET O/S 58	CSO Network	14.72	346	30								
19050	CAM VALLEY, SPLOTT FARM	CSO Network	14.94		107								
13256	RODE SETTLED STORM O/F	Storm Tank at STW	15.17	230	6				0	0	0	81	27
14528	CARLINGCOTT - STONEAGE LANE SPS	Storm at PS	15.37	608	50								
15537	SHOSCOMBE - SINGLE HILL	CSO Network	15.45	2	2								
15772	WELLOW LANE	Storm at PS	15.58	653	70								
12772	6 Wicker Hill (o/s Mane Event Hairdressers) CSO	CSO Network	15.64		130								
16546	RODE - BARROW FARM	Storm Network	15.66		55							3	3
14467	HOLT - THE STAR SPS	Storm at PS	16.09	397	101							45	45
13274	SHOSCOMBE SETTLED STORM O/F	Storm Tank at STW	16.13	505	10						0		0
12773	Trowbridge Rosecroft Polebarn Road CSO	CSO Network	16.58		155								
16770	CAMERTON - MH D19 (BRIDGE PLACE RD)	CSO Network	17.13		99						3	5	4
15535	PEASDOWN - WHITEBROOK LANE (NEW BUILDINGS)	Storm at PS	17.25	14	4								
15523	CAMERTON - SUNNYVALE	Storm at PS	17.42	39	4								
14444	WINGFIELD - CHURCH LANE FARM SPS	Storm at PS	18.61	63	3								
13252	RADSTOCK O/F	CSO Inlet	18.73	5,984	320							36	36
13252	RADSTOCK SETTLED STORM O/F	Storm Tank at STW	18.73	5,984	163							39	39
13017	BECKINGTON SETTLED STORM O/F	Storm Tank at STW	18.78	344	12							21	21

17286	RADSTOCK - WATERLOO RD / PINE CT	CSO Network	19.18		125								
17392	RADSTOCK - WALDEGRAVE TERRACE OPP 9	CSO Network	19.18	5	11								
16771	TIMSBURY - RADFORD HILL	CSO Network	19.41										
16764	RADSTOCK - FROME ROAD/ MILL LANE SO	CSO Network	19.48		25							1	1
14459	SOUTHWICK - CHANTRY GDNS	Storm at PS	19.66	401	22								
17350	RADSTOCK - WATERLOO ROAD BUILDERS YARD	CSO Network	19.73	112	35								
16769	RADSTOCK - KILMERSDON ROAD SYPHON EO	CSO Network	19.98		18								
14466	SEMINGTON BROOK SPS, SEMINGTON	Storm at PS	20.20	235	18								
14475	BROUGHTON GIFFORD - THE GREEN SPS	Storm at PS	20.21	160	12								
14468	MELKSHAM - SEMINGTON ROAD SPS	Storm at PS	20.40	265	7								
14462	BROUGHTON GIFFORD - CURTIS ORCHARD SPS	Storm at PS	20.40	34	3								
13028	BOWERHILL COMBINED STORM O/F	CSO Inlet	20.57	2,182	202							9	9
13028	BOWERHILL SETTLED STORM O/F	Storm Tank at STW	20.57	2,182	72							33	33
16912	MELKSHAM - HORNBEAM CRESCENT - VERGE	Storm at PS	20.57										
19717	SEMINGTON RD POLICE STATION, MELKSHAM	CSO Network	20.58	432						6	19	44	23
16778	RADSTOCK - SOMERVALE ROAD CSO	CSO Network	20.58	3,810	248							119	119
13235	PAULTON SETTLED STORM O/F	Storm Tank at STW	20.68	2,252	72						103	114	109
14426	PAULTON - GOOSARD BRIDGE SPS, BRISTOL ROAD	Storm at PS	20.84	588	50							58	58
16774	MIDSOMER NORTON - OLD STW SO	CSO Network	21.14	1,200	200					28	43	51	41
14458	NORTH BRADLEY - CHURCHLANDS SPS	Storm at PS	21.21	45	6								
13204	MELKSHAM O/F	CSO Inlet	21.46	4,666	250								
13204	MELKSHAM SETTLED STORM O/F	Storm Tank at STW	21.46	4,666	174								
16911	MELKSHAM - CSO OUTSIDE STW, BRADFORD RD	CSO Network	21.46										
16765	RADSTOCK - WATERSIDE SO	CSO Network	21.50		92						44	74	59
16786	PAULTON WORKS OFF BRISTOL ROAD	CSO Network	21.74	786	65					8	14	25	16
16773	MIDSOMER NORTON - WELTON SO	CSO Network	21.92		232								
16916	MELKSHAM - OFF ROAD, F/O SCOUT HALL, BATH ROAD	CSO Network	21.94	1,253	37					33	49	33	38
14102	KILMERSDON SPS	Storm at PS	22.53	40	5							0	0
16768	MIDSOMER NORTON - BERKELEY AVENUE SO	CSO Network	22.74		20							40	40
14427	HALLATROW SPS	Storm at PS	22.80	524	52								
14469	GREAT HINTON SPS	Storm at PS	23.19	31	2								
16766	RADSTOCK - WATERLOO ROAD SO (DOWNSTREAM)	CSO Network	23.55	228	25								
14533	MIDSOMER NORTON - STADDLESTONES ESTATE Cautletts Close CSO	CSO Network	23.56	69	13								
19985	MIDSOMER NORTON - NORTHMEAD BRIDGE SO new	CSO Network	23.63	193	19						8	21	15
16501	FROME - YOUTH CENTRE, FARRANT RD	CSO Network	24.02	72	11				15.96	13	12	48	24
16506	FROME - 20 WHATCOMBE RD	CSO Network	24.24	165	93					9	26	36	24
13338	WESTBURY O/F	CSO Inlet	24.28	6,871	260								
13338	WESTBURY SETTLED STORM O/F	Storm Tank at STW	24.28	6,871	120								
13131	FROME O/F	CSO Inlet	24.29	8,250	572							0	0
13131	FROME SSO O/F	Storm Tank at STW	24.29	8,250	572								
16909	MELKSHAM - PLAYING FIELD, SHAW C OF E SCHOOL	CSO Network	24.31	506	23					34	2	144	60
15544	TEMPLE CLOUD	Storm at PS	24.74		32					10	41	15	22
13061	CHILCOMPTON SETTLED STORM O/F	Storm Tank at STW	24.91	423	15							11	11
13061	CHILCOMPTON STW CSO	Storm Tank at STW	24.91	423	33							41	41
19297	FROGMORE ROAD OPP 67	CSO Network	25.03									0	0
16904	WESTBURY - OUTSIDE 36 WEST END	CSO Network	25.03	474	30						3	0	2
16507	FROME - CAR PARK, REAR of WESTWAY	CSO Network	25.15	1,435	100				31.92	27	27	50	35

16505	FROME - SINGERS CATTLE MARKET	CSO Network	25.27	201	60					4	3	14	7
16504	FROME - MERCHANT BARTON	CSO Network	25.38	4	1				0	1	23	23	16
16508	FROME - COURT HOUSE, KING ST	CSO Network	25.38	13	35				11.97	7	23	33	21
16901	WESTBURY - CONSERVATIVE CLUB, ALFRED ST	CSO Network	25.51	196	26					1	3	0	1
13293	STRATTON ON THE FOSSE SETTLED STORM O/F	Storm Tank at STW	25.65	320	14								
14425	CLUTTON SPS	Storm at PS	25.74	339	31								
16513	FROME - RODDEN ROAD	CSO Network	25.86	3,844	446				6.65	3	25	25	18
19556	SOUTH WRAXALL STW SSO/EO	CSO Inlet	26.00	71	3								
16782	CLUTTON - MAYPOLE FARM CSO	CSO Network	26.05	99	15								
16511	FROME - NORTH of CARPET FACTORY	CSO Network	26.38	3,129	331				11	28	16	6	17
16512	FROME - WALLBRIDGE	CSO Network	26.55	18	44						4	7	6
16510	FROME - PORTWAY/ LOCKS HILL	CSO Network	26.58	294	192								
13308	THINGLEY O/F	Storm Tank at STW	27.00	3,750	390				78				
13308	THINGLEY SETTLED STORM O/F	CSO Inlet	27.00	3,750	130				78			35	35
13173	LACOCK SETTLED STORM O/F	Storm Tank at STW	27.03	170	5								
15123	BELL HILL SPS, SEEND	Storm at PS	27.24	18	4								
16509	FROME - ADDERWELL CLOSE	CSO Network	27.49	1,010	70				37	48	60	66	58
16502	FROME - LOWER KEYFORD	CSO Network	27.49	804	140				22.61	21	58	61	47
16503	FROME - FELTHAM DRIVE	CSO Network	27.49	936	482				5.32	4	23	23	17
16902	WESTBURY - OUTBUILDINGS, BRIDGE FARM	CSO Network	27.71										
14457	WICKLEAZE SPS, BULKINGTON	Storm at PS	27.87	64	3								
16302	STON EASTON - Field Nr.WELLOW BROOK/TERRACE WOOD SO	CSO Network	27.98		20						0	34	17
14456	BRATTON - TROWBRIDGE RD SPS	Storm at PS	28.11	228	18								
13092	DILTON MARSH SETTLED STORM O/F	Storm Tank at STW	28.21	430	13								
14447	KEEVIL - THE STREET SPS	Storm at PS	28.25	536	37								
13205	MELLS SETTLED STORM O/F	Storm Tank at STW	28.52	85	5					8	0	13	7
16779	STON EASTON - S.of HOME FARM opp ESTATE OFFICE	CSO Network	28.59								33	35	34
14563	FROME - MARSTON LANE SPS	Storm at PS	28.75	63	8							0	0
16896	DILTON MARSH - REAR 127 HIGH STREET	CSO Network	28.94	285	35								
14108	MELLS SPS	Storm at PS	28.94	64	11							1	1
13150	HINTON BLEWETT O/F	CSO Inlet	29.20	55	4								
15106	TOWNSEND SPS, POULSHOT	Storm at PS	29.43	207	17								
14550	LACOCK - NETHERCOTE HILL SPS	Storm at PS	29.58	129	14							4	4
13227	NUNNEY SETTLED STORM O/F	Storm Tank at STW	29.60	334	10							18	18
16449	MILL LANE CSO, POULSHOT	CSO Network	29.98	127	16								
16523	NUNNEY - S.END of MARKET PLACE	CSO Network	30.45	20	47							4	4
13262	SEEND SETTLED STORM O/F	Storm Tank at STW	30.53	207	7								
15125	MILL ROAD SPS, WORTON	Storm at PS	31.01	127	11								
14450	COULSTON	CSO Network	31.72	26	3								
14490	TINHEAD TANK CSO	CSO Network	31.93										
13244	POTTERNE O/F	Storm Tank at STW	32.93	3,011	175		66	16	29				
13178	LEIGH ON MENDIP SETTLED STORM O/F	Storm Tank at STW	33.08	85	3							13	13
13069	COLEFORD O/F	CSO Inlet	33.42	525	36						41	38	40
13069	COLEFORD SETTLED STORM O/F	Storm Tank at STW	33.42	525	18						90	109	100
13116	ERLESTOKE SETTLED STORM O/F	Storm Tank at STW	33.52	172	7								
16498	COLEFORD - KINGS HEAD PH	CSO Network	33.88	243	25					31	32	32	32
13064	CHIPPENHAM O/F	CSO Inlet	34.87	10,000	550							1	1

13064	CHIPPENHAM SETTLED STORM O/F	Storm Tank at STW	34.87	10,000	266							61	61
13090	DEVIZES SETTLED STORM O/F	Storm Tank at STW	35.29	2,200	87								
14113	TRUDOXHILL SPS	Storm at PS	35.64	99	6							49	49
14057	Great Cheverell SPS	Storm at PS	35.65	106	8								
16451	ROUNDWAY HOSPITAL CSO, DEVIZES	CSO Network	35.68	2,834	331								
14147	CHIPPENHAM - WESTMEAD SPS	Storm at PS	35.86	1,253	155								
16455	VALLEY SEWER DEVIZES	CSO Network	35.90	1,329	204						0	3	2
13113	EDFORD O/F	CSO Inlet	36.01	365	33								
13113	EDFORD SETTLED STORM O/F	Storm Tank at STW	36.01	365	22								
15129	POTTERNEWICK	Storm at PS	36.11	16	6								
13177	LAVINGTON (WOODBRIDGE) SETTLED STORM O/F	Storm Tank at STW	36.30	1,212	31						14	10	12
14112	WANSTROW SPS	Storm at PS	36.73	65	7								
16606	CHIPPENHAM - WOOD LANE	CSO Network	36.77	49	21								
16603	CHIPPENHAM - CHARTER ROAD /THE IVY	CSO Network	36.84	2,886	374								
16947	CHIPPENHAM - HIGH STREET 3 (OUTSIDE NO. 29)	CSO Network	37.22	650	70								
16453	RUSSELL MILL LANE	CSO Network	37.34	57	9								
16587	CHIPPENHAM - MONKTON PARK OFFICES	CSO Network	37.43	724	56								
16572	CHIPPENHAM - DALLAS ROAD	CSO Network	37.56	355	45								
14110	STOKE HILL	CSO Network	37.64	170	11								
16577	CHIPPENHAM - GASTONS ROAD / AUDLEY ROAD	CSO Network	37.90	312	29								
16569	CHIPPENHAM - COMMONS SLIP	CSO Network	37.93	5	70						0	0	0
16564	CHIPPENHAM - BRISTOL ROAD	CSO Network	38.27	294	53								
16582	CHIPPENHAM - No. 16 LONG CLOSE	CSO Network	38.39		34								
13817	No. 22 Long Close, Chippenham, SN15 3JZ, ST92728602	TBC	38.49										
19984	CHURCHILL ARMS - WEST LAVINGTON new	CSO Network	38.55	45	20								
13229	OAKHILL SETTLED STORM O/F	Storm Tank at STW	38.73	300	13							1	1
14107	WITHAM FRIARY SPS	Storm at PS	39.07	48	5							15	15
16448	MANOR HOUSE EASTERTON	CSO Network	39.76	111	14								
14179	BIDDESTONE - MANOR COTTAGE SPS	Storm at PS	41.48	106	7		110	52	52				
14116	GURNEY SLADE SPS	Storm at PS	41.51	115	7							45	45
13322	URCHFONT SETTLED STORM O/F	Storm Tank at STW	41.79	295	10							9	9
13044	CALNE SETTLED STORM O/F	Storm Tank at STW	46.44	4,679	148						31	45	38
13044	CALNE STW CSO	CSO Inlet	46.44	4,679	245						8	26	17
13298	SUTTON BENGER SETTLED STORM O/F	Storm Tank at STW	47.02	1,965	58								
17485	CHRISTIAN MALFORD SPS	Storm at PS	47.52	4	2								
16588	CALNE - MOSSES MILL 2	CSO Network	48.17	1,625	107								
16609	MOSSES MILL 1	CSO Network	48.17	1,625	104								
16590	CALNE BANK RIVER MARDEN SOUTH MARDEN HOUSE NEW ROAD	CSO Network	49.41	1,219	223								
16566	CALNE - OXFORD ROAD/ WOOD STREET	CSO Network	49.43	424	70								
16611	MARKET HILL / STRAND	CSO Network	49.43	1,106	200								
16601	CALNE - STRAND/ CHURCH STREET	CSO Network	49.43	1,106	49							17	17
16585	CALNE - REAR MARDEN HOUSE CULVERT	CSO Network	49.45	1,219	126						11	32	22
16596	CALNE - QUEMERFORD BRIDGE	CSO Network	51.42	85	8						33	37	35
14152	CALNE - BROADS GREEN SPS	Storm at PS	51.81	87	8								
14157	CALNE - ROUGH LEAZE SPS	Storm at PS	52.90	190	20								
14139	DAUNTSEY - SWALLETTS GATE SPS	Storm at PS	53.33	91	10								
14176	KINGTON LANGLEY	Storm at PS	54.05	164	7							48	48

14161	THE POND SPS (MANOR FARM), C. BASSETT	Storm at PS	54.18	64	6								
14151	DAUNTSEY - THE GREEN SPS	Storm at PS	54.47	62	6								
13137	GREAT SOMERFORD SETTLED STORM O/F	Storm Tank at STW	55.62	177	6								
13522	LYNEHAM RAF MAIN STW SETTLED STORM	Storm Tank at STW	56.44	1,200	51							24	24
13314	TOCKENHAM O/F	CSO Inlet	58.41	36	3								
13035	BRINKWORTH SETTLED STORM O/F	Storm Tank at STW	59.86	225	8							83	83
13193	MALMESBURY SETTLED STORM O/F	Storm Tank at STW	62.35	3,168	87							67	67
19786	MILL LANE, CORSTON	CSO Network	62.88	27	8						15	24	20
14185	MALMESBURY - ST JOHNS SPS	Storm at PS	63.13	879	60								
16583	MALMESBURY - ST JOHNS BRIDGE/ LOWER HIGH ST	CSO Network	63.29		30								
14569	Avon Silk Mills SPS , Malmesbury, SN16 9LP	TBC	63.34										
16608	Malmesbury (Parliament Row) CSO	TBC	63.36		31								
14148	Holloway Hill SPS, Blicks Hill, Malmesbury, SN16 9HX	TBC	63.65										
14162	BURTON HILL	Storm at PS	64.07	33	8							1	1
16579	MALMESBURY - HARPERS LANE	CSO Network	64.16		60							0	0
16574	DARK LANE / 8 FOXLEY LANE	CSO Network	64.25		18								
14145	MINETY - TANNER BRIDGE SPS	Storm at PS	64.27	154	18							27	27
14188	LOWER STANTON ST QUINTON	Storm at PS	64.32	553	28		17	51	78				
19883	MALMESBURY - GLOUCESTER ROAD O/S 109	CSO Network	64.47	387	40						6	16	11
14200	LEA NORTH	Storm at PS	64.74	112	11								
16594	MALMESBURY - PARK ROAD	CSO Network	64.86		27						1	3	2
14158	RAF HULLAVINGTON	Storm at PS	65.34	35	5								
14196	NOAHS ARK SPS	Storm at PS	65.43	639	39							13	13
13157	HULLAVINGTON O/F	CSO Inlet	66.74	250	14							0	0
13157	HULLAVINGTON SETTLED STORM O/F	Storm Tank at STW	66.74	250	8							134	134
14549	Royal Wootton Bassett (Whitehill Lane) SPS	TBC	68.61										
16592	WOOTTON BASSETT - NEW ROAD	CSO Network	70.11	598	15								
14211	Westbury Park SPS, Royal Wootton Bassett, SN4 7DL	TBC	70.12										
16589	WOOTTON BASSETT - NEAR STW	CSO Network	72.17	2,307	110						1	16	9
13360	WOOTTON BASSETT SETTLED STORM O/F	Storm Tank at STW	72.28	2,917	77						9	52	31
16575	BRINKWORTH - FOUL SEW O/F	CSO Network	74.09	69	26								
13307	TETBURY O/F	CSO Inlet	74.65	1,200	96						64	96	80
13307	TETBURY SETTLED STORM O/F	Storm Tank at STW	74.65	1,200	49						36	108	72
13269	SHERSTON STW SETTLED STORM O/F	Storm Tank at STW	75.97	220	7							26	26
15723	TETBURY - SPRINGFIELDS	Storm at PS	76.10	17	4								
16604	THE TARTARS CSO, SHERSTON	CSO Network	76.27	187	30						16	30	23
13184	LUCKINGTON SETTLED STORM O/F	Storm Tank at STW	79.47	101	3							25	25
13091	DIDMARTON SETTLED STORM O/F	Storm Tank at STW	80.57	140	5								
13136	GREAT BADMINTON SETTLED STORM O/F	Storm Tank at STW	82.25	140	5						89	161	125

Appendix C. Warleigh Weir Water Quality Survey 15/09/2020

Appendix D. Tucking Mill intake water quality data

Figure D-1 and Figure D-2 show the number of intestinal enterococci and *E. coli* samples analysed from the Tucking Mill intake from the River Avon from 2006 to 2018. In terms of frequency by year, most samples were analysed in 2012 and 2006 and 2007. No samples were analysed in four years 2009-10 and 2016-17.

Figure D-1 Tucking Mill intake from River Avon, number of samples by year

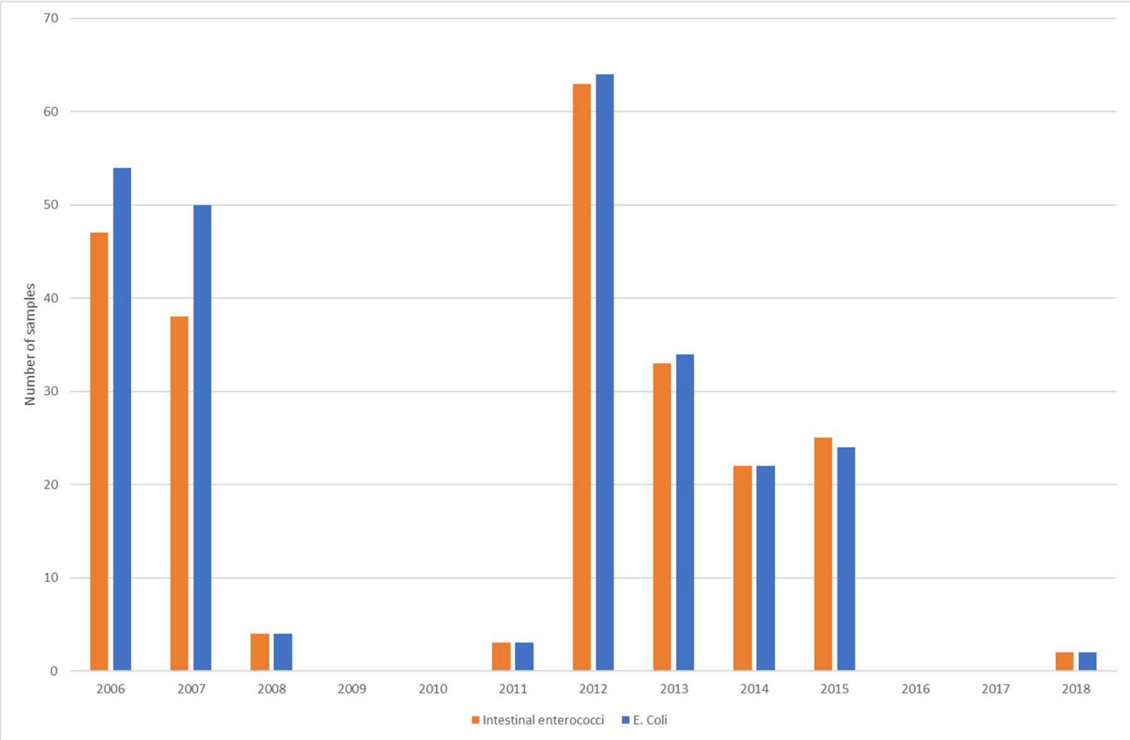


Figure D-2 shows that most data are available in the months in the second half of the year; from June onwards, with most data from September. Least data are available from January to April inclusive.

Figure D-2 Tucking Mill intake from River Avon, number of samples by month

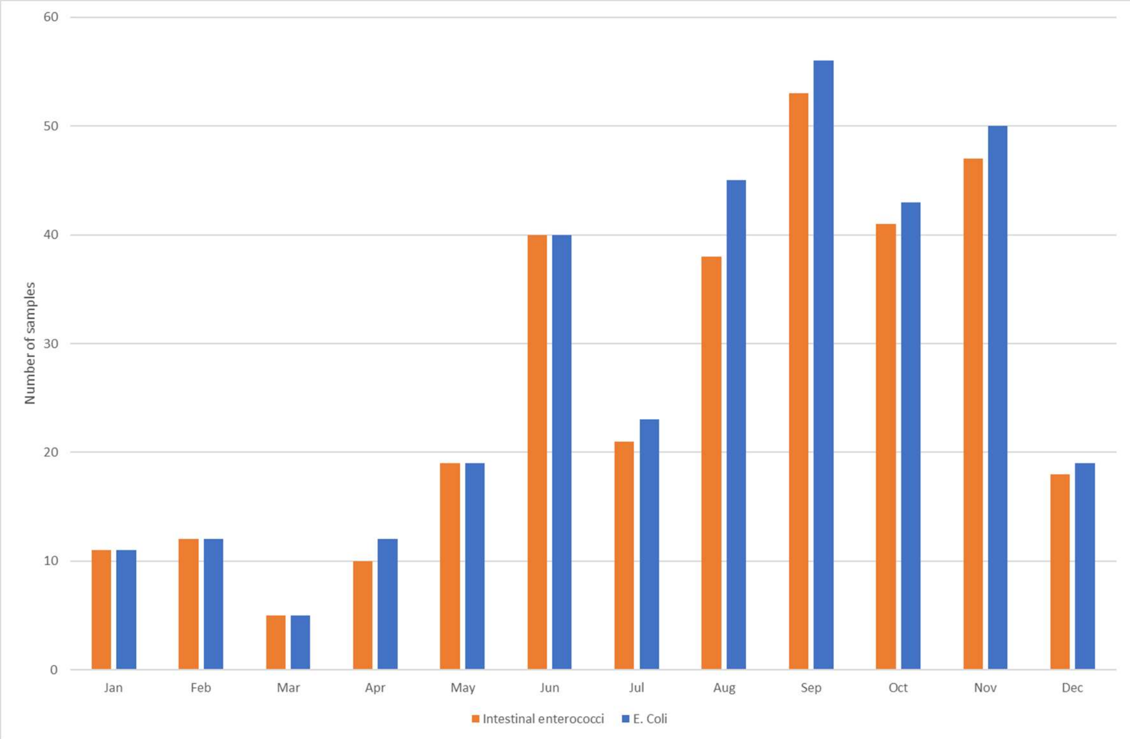


Figure D-3 and Figure D-4 show that there is significant variation in the availability of data within years. For example, the largest number of samples are available from June 2012 however, no data are available for January to April and from November and December of that year.

Figure D-3 *E. coli* data by month and year

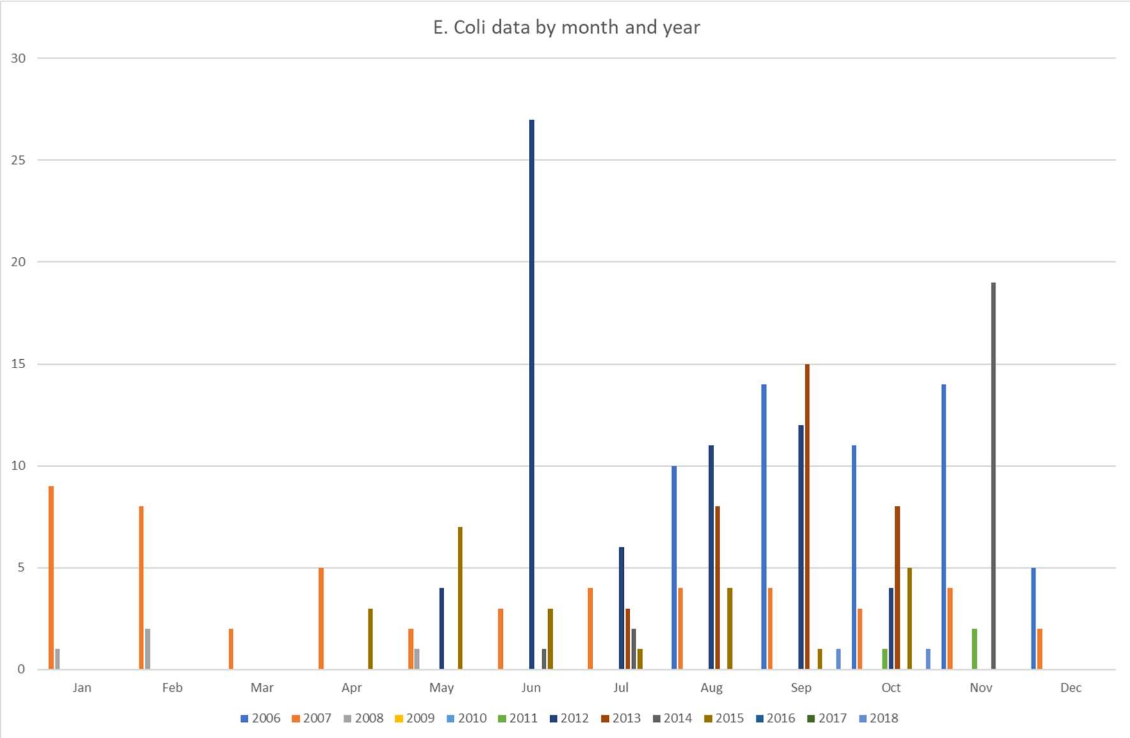
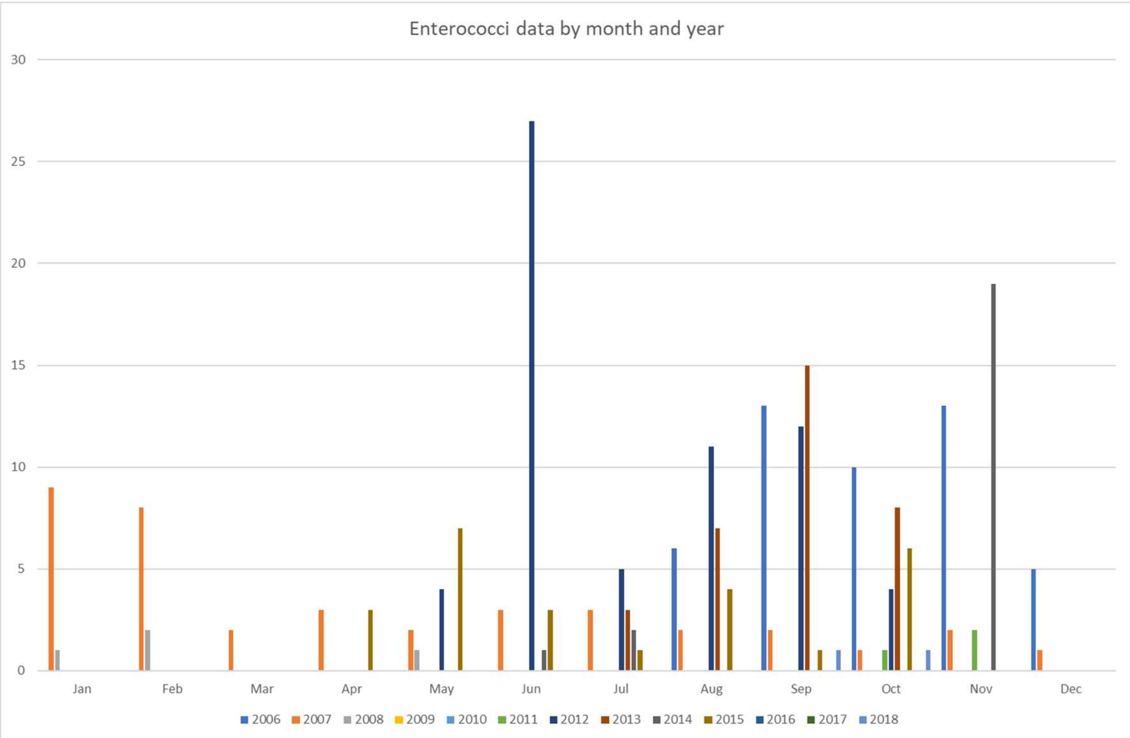


Figure D-4 Enterococci data by month and year



Appendix E. Tucking Mill microbiological data 2006-2018 – EA Review

Analysis of microbiological data for the Bristol Avon upstream of Warleigh Weir, Richard Acornley (Senior Environmental Monitoring Officer, Environment Agency.

Wessex Water provided microbiological data for an abstraction point on the Bristol Avon for their Tucking Mill water supply reservoir. This point is shortly upstream of the confluence of the Bristol Avon and Midford Brook and approximately 3 km upstream of Warleigh Weir. The dataset contained results for total coliforms, *E. coli* and intestinal enterococci (I.E.) for the period 2006 to 2018.

Data Analysis

In common with many microbiological datasets, the data for the Bristol Avon contained results that were enumerated exactly, results that were below a lower limit of detection, known as left-censored values, and results that were above an upper limit of detection, known as right-censored values (Table 1). This makes statistical analysis using standard procedures (such as those specified in the Bathing Water Directive) problematic. One way of estimating the distributional parameters of microbiological data with left and right censored values is maximum likelihood estimation (MLE).
Here, the data were analysed using the MLE procedures available in Minitab (see Helsel, 2012). Compliance statistics at Q_{50} flow during the bathing water season (May to September) were estimated from MLE regression models with river flow at Bathford, time of day and time of year (in or out of bathing season) as the independent variables and I.E. or E. coli as the dependent variables. River flow and I.E. or *E. coli* concentration were log transformed prior to analysis to improve normality of the model residuals (Figure 1).
The source load reduction required (s) to meet the sufficient standard of the Bathing Water Directive for inland waters was estimated using the statistical theory of rollback (see Ott, 1995).

Results

Log-likelihood statistics for the MLE regression models are given in Table 2. River flow and time of year were significant parameters in the regression model for I.E. whereas only river flow was a significant parameter in the regression model for *E. coli*. Time of sampling was not a significant parameter in either model and was excluded from the models used to estimate compliance statistics. Both I.E. and *E. coli* concentrations increased significantly with river flow.
Bathing Water compliance statistics for *E. coli* and I.E. at Q_{50} in the bathing water season are given in Table 3. Water quality at this site would be classed as Poor under the Bathing Water Directive, with *E. coli* being the parameter most limiting compliance. The analysis indicates that a source load reduction in *E. coli* of over 70% would be required for the site to be classed as sufficient.

References

Helsel (2012). Statistics for Censored Environmental Data Using Minitab and R.
Ott (1995). Environmental Statistics and Data Analysis

Table 1. Summary of the Tucking Mill dataset. Results of zero were not included in the analysis

	Uncensored	Left censored	Right censored
E. coli	227	6	22
I.E.	186	13	30

Table 2. Log likelihood statistics for MLE regression models

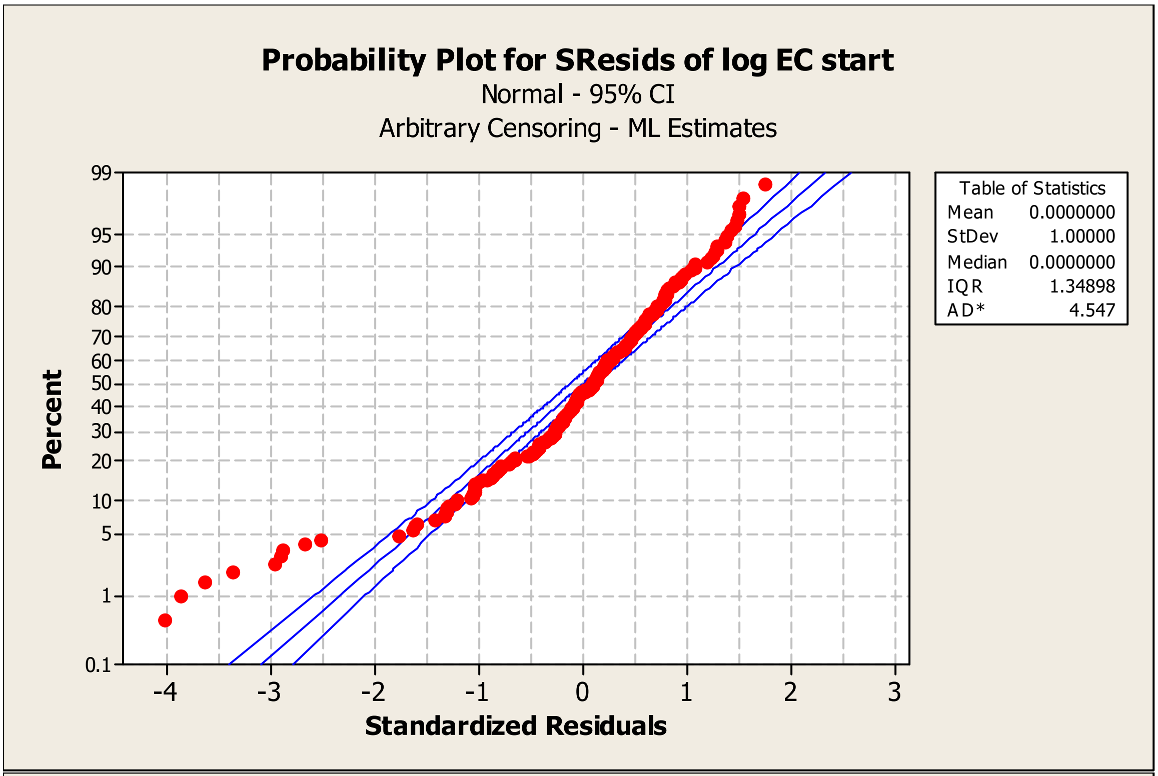
	E. coli		I.E.	
	Log-likelihood	p	Log-likelihood	p
Null model	-264.621	-	-261.883	-
log Flow	-245.540	0.0000	-232.605	0.0000
log Flow and bathing water season	-244.866	0.0000	-230.415	0.0000
Sampling time	-264.514	0.6437	-261.285	0.2741
Bathing water season	-264.111	0.3125	-252.903	0.0000

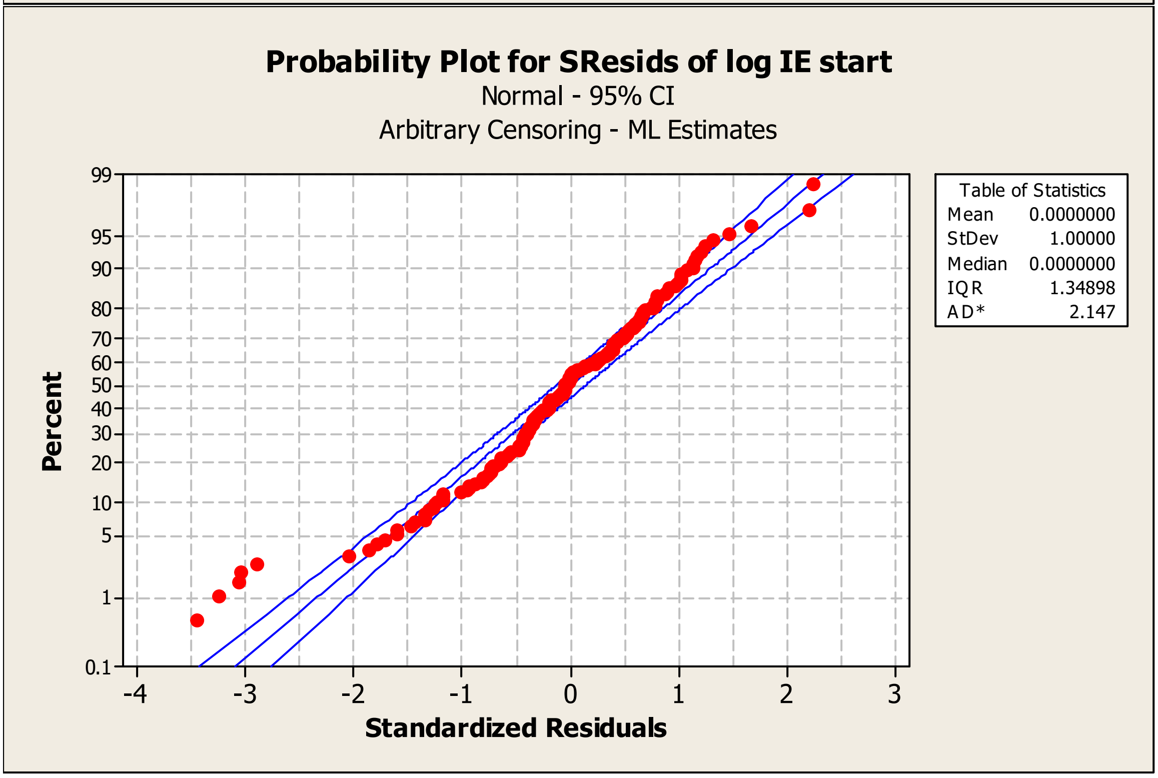
The best models were log Flow for *E. coli* and log Flow and BW season for I.E.

Table 3. Estimated compliance statistics at Q_{50} in the bathing water season

Parameter	μ	σ	90%ile per 100ml	95%ile per 100ml	r	s
E. coli	2.65	0.66	3,100	5,400	0.29	0.71
I.E.	1.91	0.71	670	1,200	0.50	0.50

Where:
μ is the arithmetic mean of the log transformed concentration data
σ is the standard deviation of the log transformed concentration data
r is the rollback factor
s is the source load reduction required to meet the sufficient standard (1 - r)


Probability Plot for SResids of log EC start
Normal - 95% CI
Arbitrary Censoring - ML Estimates
Table of Statistics
Mean 0.0000000
StDev 1.00000
Median 0.0000000
IQR 1.34898
AD* 4.547
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
0.1
-4
-3
-2
-1
0
1
2
3
Standardized Residuals


Probability Plot for SResids of log IE start
Normal - 95% CI
Arbitrary Censoring - ML Estimates
Table of Statistics
Mean 0.0000000
StDev 1.00000
Median 0.0000000
IQR 1.34898
AD* 2.147
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
0.1
-4
-3
-2
-1
0
1
2
3
Standardized Residuals

Appendix F. Flow and bacterial water quality data

Note that there is a period of no flow data from Bathford Weir from 22nd December 2012 to 24th June 2013 inclusive. The data set is otherwise complete

Figure F-1 Estimated flow data for Warleigh Weir, Jan 2006 to end October 2020

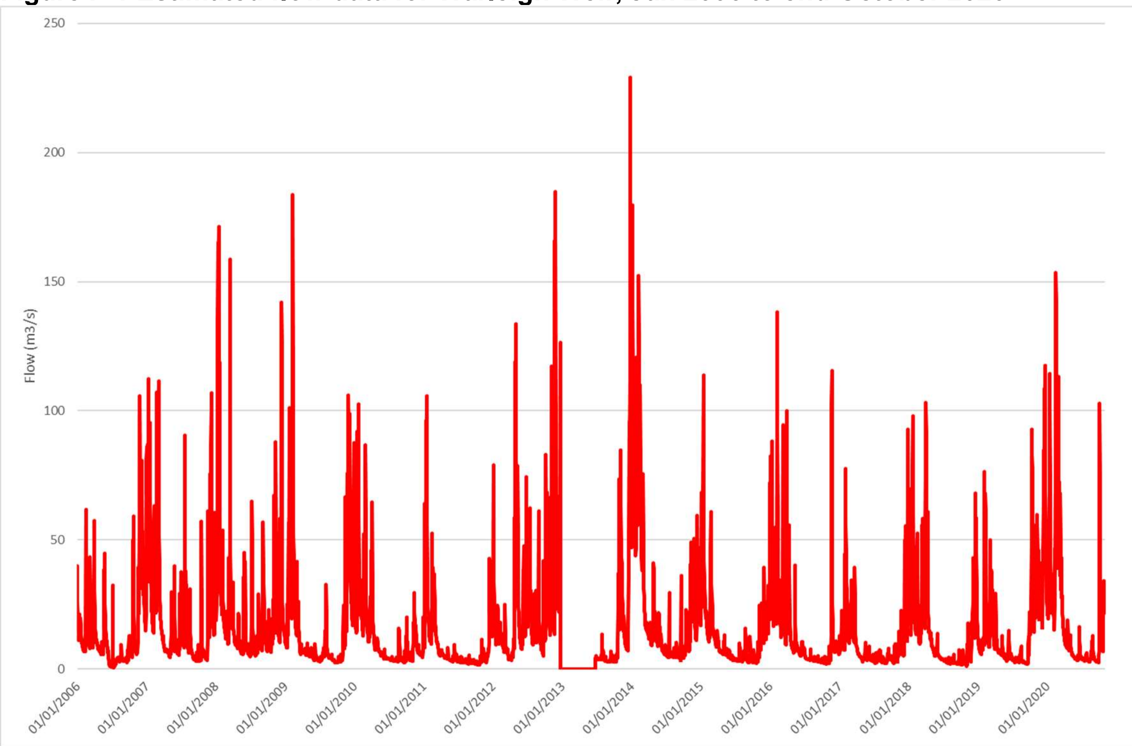


Figure F-2 *E.coli* data from Tucking Mill intake and estimated flow data for Warleigh Weir (2006, 2007, 2012, 2013, 2014)

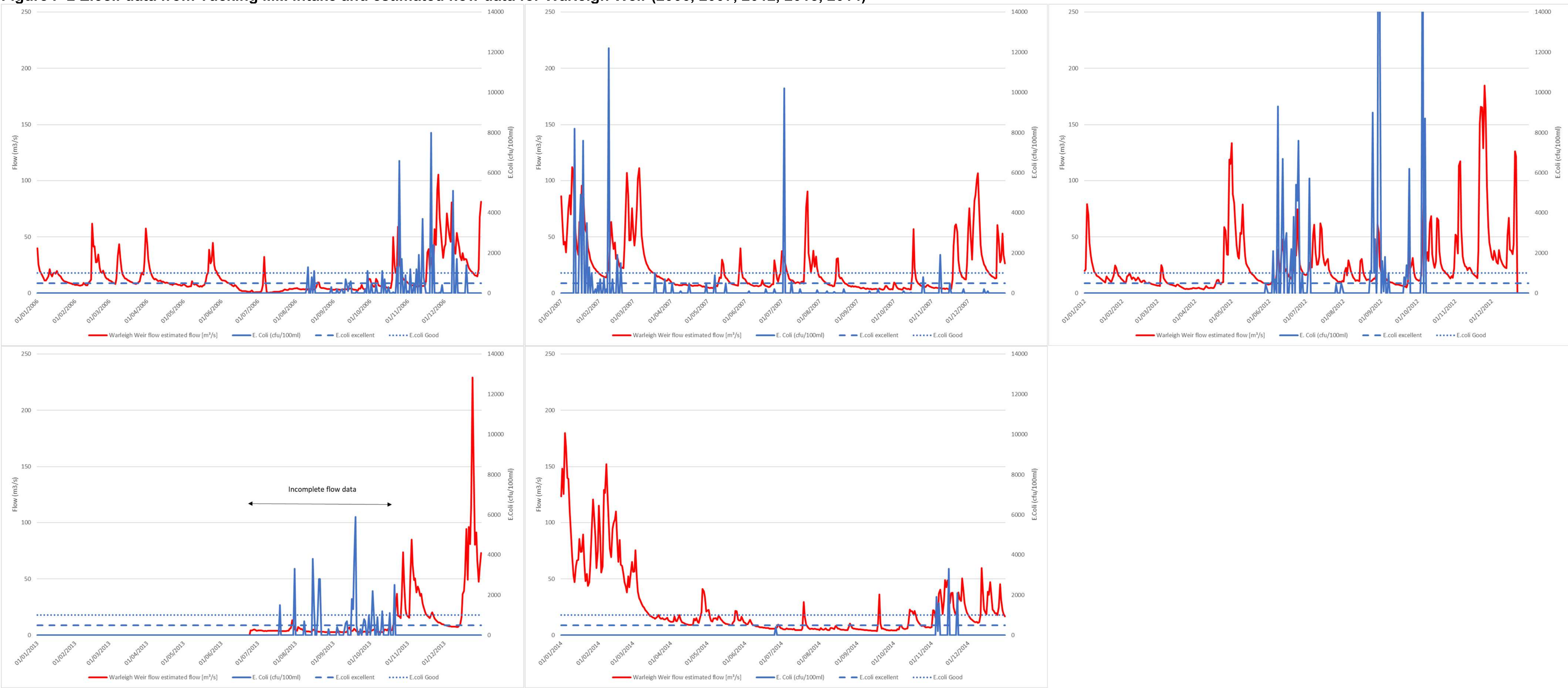
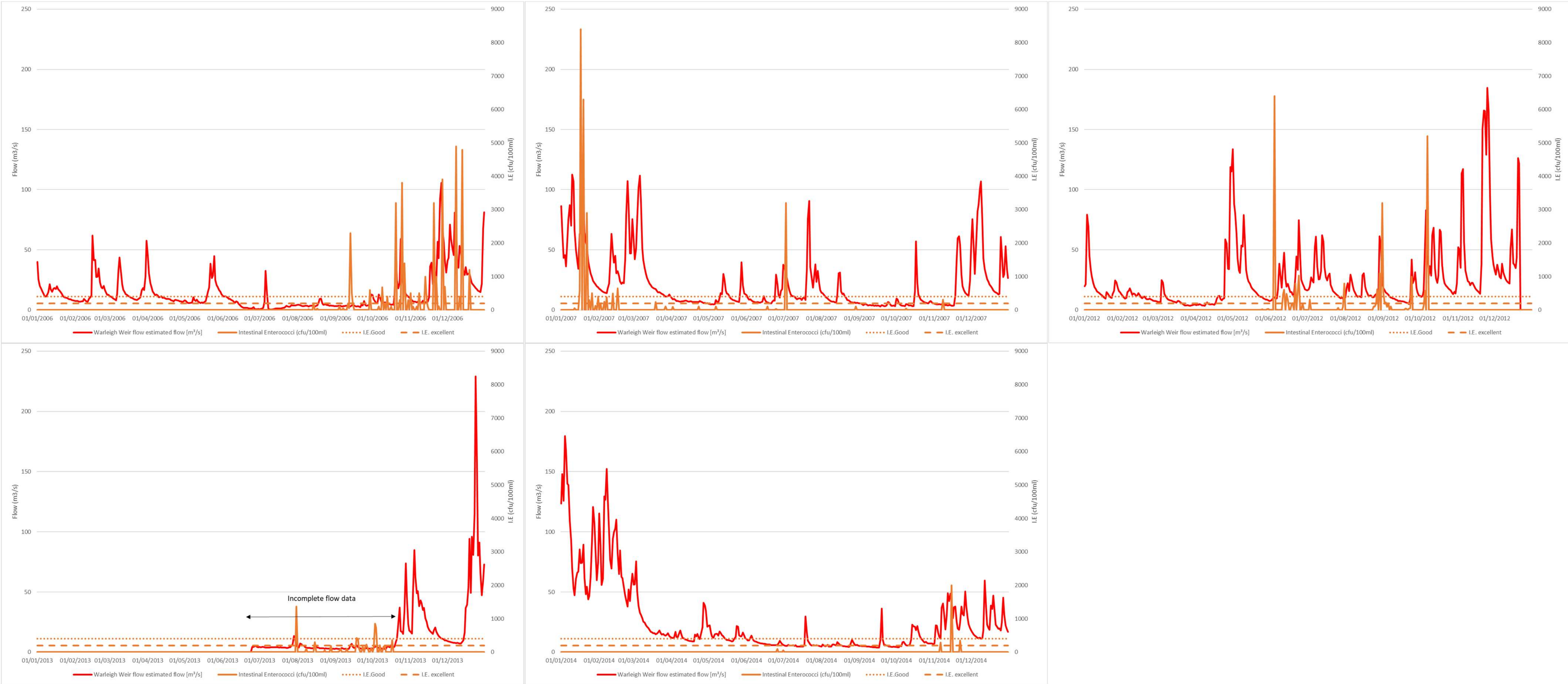


Figure F-3 *Enterococci* data from Tucking Mill intake and estimated flow data for Warleigh Weir (2006, 2007, 2012, 2013, 2014)



Appendix G. Estimated travel time to WRCs within 15km upstream of Warleigh Weir under a range of flows and T90s

Site ID	WRC	Treatment processes	PE	DWF (m³/d)	Receiving watercourse	Distance upstream Warleigh Weir (km)	Estimated travel time (hours) under different assumed velocities (m/s)							
							0.05	0.075	0.1	0.15	0.2	0.25	0.3	0.5
13130	FRESHFORD	SBI	1,528	460	RIVER AVON	4.5	25.0	16.7	12.5	8.3	6.3	5.0	4.2	2.5
13352	WINSLEY	SBI	1,974	430	RIVER AVON	5.4	30.0	20.0	15.0	10.0	7.5	6.0	5.0	3.0
13031	BRADFORD-ON-AVON	TB2	10,925	3,013	RIVER AVON	7.7	42.8	28.5	21.4	14.3	10.7	8.6	7.1	4.3
13341	WESTWOOD	TB1	1,008	325	HAYGROVE STREAM	9.4	52.2	34.8	26.1	17.4	13.1	10.4	8.7	5.2
13331	WELLOW	SBI	411	136	MIDFORD BROOK	11	61.1	40.7	30.6	20.4	15.3	12.2	10.2	6.1
13318	TROWBRIDGE	TB2	68,453	14,000	RIVER AVON	12.2	67.8	45.2	33.9	22.6	16.9	13.6	11.3	6.8
13226	NORTON ST PHILIP	TB2	1,125	315	NORTON BROOK	13.5	75.0	50.0	37.5	25.0	18.8	15.0	12.5	7.5
13045	CAM VALLEY	SAE	7,479	1,750	CAM BROOK	14.5	80.6	53.7	40.3	26.9	20.1	16.1	13.4	8.1
13256	RODE	SBI	1,009	230	RIVER FROME (SOMERSET)	15.2	84.4	56.3	42.2	28.1	21.1	16.9	14.1	8.4
13274	SHOSCOMBE	SBI	1,786	505	MIDFORD BROOK	16.1	89.4	59.6	44.7	29.8	22.4	17.9	14.9	8.9
13252	RADSTOCK	TB2	22,341	5,984	WELLOW BROOK	18.6	103.3	68.9	51.7	34.4	25.8	20.7	17.2	10.3
13017	BECKINGTON	TB1	1,117	344	RIVER FROME (SOMERSET)	18.8	104.4	69.6	52.2	34.8	26.1	20.9	17.4	10.4
13356	WOODBOROUGH HILL	SBI	24	No flow limit	MIDFORD BROOK	18.9	105.0	70.0	52.5	35.0	26.3	21.0	17.5	10.5
13028	BOWERHILL	TA2	8,061	2,182	BERRYFIELD BROOK	20.6	114.4	76.3	57.2	38.1	28.6	22.9	19.1	11.4
13235	PAULTON	TB2	10,607	2,252	CAM BROOK	20.7	115.0	76.7	57.5	38.3	28.8	23.0	19.2	11.5
13204	MELKSHAM	TB2	17,399	5,000	RIVER AVON	21.1	117.2	78.1	58.6	39.1	29.3	23.4	19.5	11.7
13131	FROME	TB2	30,333	8,250	RIVER FROME	23.9	132.8	88.5	66.4	44.3	33.2	26.6	22.1	13.3
13338	WESTBURY	TA2	26,445	6,871	BITHAM BROOK	24.3	135.0	90.0	67.5	45.0	33.8	27.0	22.5	13.5
13061	CHILCOMPTON	TB2	1,668	423	SOMER STREAM	24.9	138.3	92.2	69.2	46.1	34.6	27.7	23.1	13.8
13164	KEEVIL	SBI	3,428	795	SEMINGTON BROOK	25.5	141.7	94.4	70.8	47.2	35.4	28.3	23.6	14.2
13293	STRATTON ON THE FOSSE	TB1	1,148	320	MIDFORD BROOK	25.6	142.2	94.8	71.1	47.4	35.6	28.4	23.7	14.2
19556	SOUTH WRAXALL	TA2	194	71	CHALFIELD BROOK	26	144.4	96.3	72.2	48.1	36.1	28.9	24.1	14.4
13173	LACOCK	SBI	719	170	RIVER AVON	27.1	150.6	100.4	75.3	50.2	37.6	30.1	25.1	15.1
17655	RUDGE	PRI	4	Max flow 1.6 m³/d	RIVER BISS	27.7	153.9	102.6	76.9	51.3	38.5	30.8	25.6	15.4
13092	DILTON MARSH	SBI	1,609	430	RIVER BISS	28.2	156.7	104.4	78.3	52.2	39.2	31.3	26.1	15.7
13205	MELLS	SBI	328	85	RIVER MELLS	28.5	158.3	105.6	79.2	52.8	39.6	31.7	26.4	15.8
13020	BEWLEY	SBI	118	No flow limit	RIVER AVON	28.8	160.0	106.7	80.0	53.3	40.0	32.0	26.7	16.0
19783	STANDERWICK	SBI	14	22	HAM BROOK	29.2	162.2	108.1	81.1	54.1	40.6	32.4	27.0	16.2
13150	HINTON BLEWETT	SBI	148	55	MIDFORD BROOK	29.2	162.2	108.1	81.1	54.1	40.6	32.4	27.0	16.2
13227	NUNNEY	SBI	1,161	334	NUNNEY BROOK	29.6	164.4	109.6	82.2	54.8	41.1	32.9	27.4	16.4
13262	SEEND	TB2	1,961	207	SUMMERHAM BROOK	30.5	169.4	113.0	84.7	56.5	42.4	33.9	28.2	16.9
13257	ROWDE	SBI	2,736	1,205	SUMMERHAM BROOK	31.5	175.0	116.7	87.5	58.3	43.8	35.0	29.2	17.5
13244	POTTERNE	TA2	11,587	3,011	SEMINGTON BROOK	32.9	182.8	121.9	91.4	60.9	45.7	36.6	30.5	18.3
13390	CORSLEY HEATH	SBI	38	28	RIVER FROME (SOMERSET)	33	183.3	122.2	91.7	61.1	45.8	36.7	30.6	18.3
13178	LEIGH ON MENDIP	TB2	397	85	RIVER MELLS	33.1	183.9	122.6	91.9	61.3	46.0	36.8	30.6	18.4
13069	COLEFORD	SAE	2,011	525	RIVER MELLS	33.4	185.6	123.7	92.8	61.9	46.4	37.1	30.9	18.6
13116	ERLESTOKE	TB2	1,166	172	ERLESTOKE STREAM	33.5	186.1	124.1	93.1	62.0	46.5	37.2	31.0	18.6

13308	THINGLEY	TA2	17,507	3,750	BYDE MILL BROOK	33.6	186.7	124.4	93.3	62.2	46.7	37.3	31.1	18.7
13064	CHIPPENHAM	TA2	37,714	10,000	RIVER AVON	34.9	193.9	129.3	96.9	64.6	48.5	38.8	32.3	19.4
13090	DEVIZES	TB2	15,545	2,200	WAYLENS BROOK	35.3	196.1	130.7	98.1	65.4	49.0	39.2	32.7	19.6
13083	CRANMORE	SBI	365	95	WHATLEY BROOK	35.4	196.7	131.1	98.3	65.6	49.2	39.3	32.8	19.7
13113	EDFORD	SBI	1,645	365	RIVER MELLS	35.8	198.9	132.6	99.4	66.3	49.7	39.8	33.1	19.9
13177	LAVINGTON	SBI	3,973	1,212	SEMINGTON BROOK	36.3	201.7	134.4	100.8	67.2	50.4	40.3	33.6	20.2
13323	WANSTROW	SBI	258	69	RIVER MELLS	36.4	202.2	134.8	101.1	67.4	50.6	40.4	33.7	20.2
13229	OAKHILL	SBI	1,340	300	RIVER MELLS	38.7	215.0	143.3	107.5	71.7	53.8	43.0	35.8	21.5
13322	URCHFONT	TB2	1,123	295	SEMINGTON BROOK	41.8	232.2	154.8	116.1	77.4	58.1	46.4	38.7	23.2
13321	UPTON NOBLE	TB1	119	No flow limit	RIVER FROME (SOMERSET)	42.7	237.2	158.1	118.6	79.1	59.3	47.4	39.5	23.7
13044	CALNE	TB2	19,756	4,679	RIVER MARDEN	46.3	257.2	171.5	128.6	85.7	64.3	51.4	42.9	25.7
13298	SUTTON BENGER	TB2	5,144	1,965	RIVER AVON	47	261.1	174.1	130.6	87.0	65.3	52.2	43.5	26.1
13213	MILE ELM	SBI	32	No flow limit	RIVER MARDEN	49.4	274.4	183.0	137.2	91.5	68.6	54.9	45.7	27.4
13075	COMPTON BASSETT	SBI	2,799	600	Rivers Brook	51.8	287.8	191.9	143.9	95.9	71.9	57.6	48.0	28.8
13148	HILMARTON	SBI	543	120	COWAGE BROOK	52.9	293.9	195.9	146.9	98.0	73.5	58.8	49.0	29.4
13137	GREAT SOMERFORD	SBI	842	177	RIVER AVON	55.6	308.9	205.9	154.4	103.0	77.2	61.8	51.5	30.9
13522	LYNEHAM	TB2	3,913	1,200	SPRINGS WATERCOURSE	56.4	313.3	208.9	156.7	104.4	78.3	62.7	52.2	31.3
13314	TOCKENHAM	TB1	111	36	RIVER MARDEN	58.4	324.4	216.3	162.2	108.1	81.1	64.9	54.1	32.4
19509	BUSHTON	SBI	61	18	COWAGE BROOK	59	327.8	218.5	163.9	109.3	81.9	65.6	54.6	32.8
13035	BRINKWORTH	SAE	749	225	BRINKWORTH BROOK	59.9	332.8	221.9	166.4	110.9	83.2	66.6	55.5	33.3
13193	MALMESBURY	TB2	11,052	3,168	RIVER AVON (BRISTOL)	62.4	346.7	231.1	173.3	115.6	86.7	69.3	57.8	34.7
13157	HULLAVINGTON	SBI	873	250	GAUZE BROOK	66.7	370.6	247.0	185.3	123.5	92.6	74.1	61.8	37.1
13360	ROYAL WOOTTON BASSETT	TB2	13,739	2,917	HANCOCKS WATER	72.3	401.7	267.8	200.8	133.9	100.4	80.3	66.9	40.2
13307	TETBURY	TB2	5,949	1,200	RIVER AVON	74.8	415.6	277.0	207.8	138.5	103.9	83.1	69.3	41.6
13269	SHERSTON	SBI	1,338	220	RIVER AVON	76	422.2	281.5	211.1	140.7	105.6	84.4	70.4	42.2
13184	LUCKINGTON	SBI	341	101	LUCKINGTON BROOK	79.5	441.7	294.4	220.8	147.2	110.4	88.3	73.6	44.2
17273	ALDERTON	SBI	81	20	LUCKINGTON BROOK	79.5	441.7	294.4	220.8	147.2	110.4	88.3	73.6	44.2
13091	DIDMARTON	TB1	588	140	RIVER SHERSTON	80.6	447.8	298.5	223.9	149.3	111.9	89.6	74.6	44.8
13136	GREAT BADMINTON	SBI	588	140	RIVER SHERSTON	82.3	457.2	304.8	228.6	152.4	114.3	91.4	76.2	45.7

Key

Travel time is less than the Lower average T90 of 54 hours	Travel time is less than the Upper average T90 of 96
Travel time is less than the Typical average T90 of 75 hours	Travel time exceeds the Upper average T90 of 96 hours