River Ems Investigation

Flow Augmentation Monitoring Trial

Portsmouth Water

23 February 2023

5204159-08-091

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This document has 56 pages including the cover.

Document history

Document title: Flow Augmentation Monitoring Trial

Document reference: 5204159-08-091

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
1.0	Initial working draft for Portsmouth Water and EA comment	EE/LH	LMcW	LMcW	-	16/12/2022
2.0	Draft report for Portsmouth Water and EA comment	EE/LH	EM	LMcW	PMU	10/01/2023
3.0	Finalised report following Portsmouth Water and EA comment	EE/LH	EE	LMcW	PMU	23/02/2023

Client signoff

Client	Portsmouth Water
Project	River Ems Investigation
Job number	5204159
Client signature/date	

Contents

Tables

Figures

1. Introduction

1.1. Background

The River Ems is a chalk stream, approximately 9 km in length. At its greatest extent it flows from Stoughton in the north, through Westbourne, to Emsworth in the south. The river exhibits ephemeral behaviour (i.e. intermittent flow) in some reaches in dry weather conditions.

Portsmouth Water currently operates two groundwater abstractions in the River Ems catchment at Walderton (Licence 10/41/511007) and Woodmancote (Licence 10/41/520101). The Walderton licence is used for potable supply whilst the Woodmancote licence is used for flow augmentation only (pumping a compensation flow of groundwater into the river when flow conditions require it). In 2016, following completion of a programme of river restoration work within the River Ems, Portsmouth Water voluntarily reduced its licence at Walderton and permanently changed the use of Woodmancote to augmentation, at the same time moving the augmentation point approximately 0.5 km upstream.

In 2020, Portsmouth Water commissioned Atkins to undertake a data collation and review, with a particular focus on hydrology and hydrogeology in the River Ems catchment. This 'Phase 1 investigation' (Atkins, 2021) collated and summarised all available historical data and identified further tasks. The work was first reported to Portsmouth Water, the Environment Agency and catchment stakeholders (i.e. Friends of the Ems (FotE)) in April 2021. The work identified that there were issues with the efficiency of the current augmentation regime and that not all flows released were recorded at the Environment Agency gauging station at Westbourne.

In discussion with Portsmouth Water, the Environment Agency and FotE, it was decided that the priority of further work should be evidence gathering to understand the relationship between groundwater levels, abstraction, and river flows. In May 2021, Atkins started work to develop a hydrometric monitoring network to provide groundwater and surface water level data. Level data have been collected since July 2021 with data downloads undertaken by FotE and data processing undertaken by Atkins.

Whilst the long-term strategy for abstraction at Walderton is subject to the Water Resource Management Planning (WRMP) cycle, including the findings of the Water Resources South East (WRSE) regional model, it was recommended that in the short term opportunities were explored to improve the effectiveness of the augmentation flow regime. This would provide benefits to the local environment whilst the mid- to longer-term changes were considered.

In June 2022, Atkins was commissioned to undertake a programme of further evidence gathering including investigation of the flow augmentation discharge. Portsmouth Water and the Environment Agency together agreed to trial adjustments to the flow augmentation discharge location.

The trial took place in summer/autumn 2022, which followed a period of very low rainfall and a 'drought' being declared across much of South East England. The trial comprised a temporary alteration of the augmentation discharge location combined with spot flow gauging at various points along the augmented reach to try to quantify any gains or losses to and from the channel. A ground investigation to establish the nature of the shallow geology around the augmentation discharge locations was also undertaken to inform the investigation.

1.2. Purpose of this report

The objectives of this report are to:

- Present the monitoring results from the augmentation trial[1]
- Present the results from the ground investigation
- Consider the fate of the augmentation discharge and further characterise the flow characteristics of the augmented stretch of the River Ems.

1.3. Structure of this report

The document is structured as follows:

- Section 2 provides details of the augmentation trial

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[1] Note that an annual report reviewing data from the hydrometric monitoring network on the River Ems (from Stoughton to Westbourne) for the period April 2022 to March 2023 will be produced separately.

- Section 3 presents an overview of the data collated and an initial review
- Section 4 presents data analysis from the augmentation trial
- Section 5 provides a summary of the ground investigation
- Section 6 provides a concluding summary and outlines next steps.

2. Augmentation trial

2.1. Background

A detailed account of the River Ems catchment is provided in the River Ems Flow Investigation Phase 1 report (Atkins, 2021). A brief summary of the historical abstraction and augmentation (taken from that report) is presented below to provide context.

The abstraction at Woodmancote was the first borehole to be developed for public water supply in the River Ems catchment. Holmes (2007) reports that it had been operated ‘for many decades’ prior to the 1960s at a rate of approximately 1,000 m^3/day. Woodmancote borehole was constructed south of the southern edge of the Chalk outcrop, and here the Chalk aquifer is confined beneath 17 m of Lambeth Group clays.

The abstraction at Walderton was licensed for abstraction of up to 2 million gallons per day (9,092 m^3/day) in 1962, and abstraction started in 1963 or 1964 (Holmes, 2007). The Walderton supply comprises three boreholes which abstract water from the unconfined Chalk aquifer. In 1968 the maximum rate at Walderton was increased to 6 million gallons per day (27,277 m^3/day), and at the same time the need for augmentation of the Lower River Ems, by Portsmouth Water, was established.

From 1968 to 2015 the augmentation scheme discharged water into the river at a location at the edge of Westbourne (just upstream of ‘The Canal’). The augmentation discharge of 1,136 m^3/day was triggered when the measured flows at Westbourne gauging station were below 2,273 m^3/day. A portion of the abstracted water at Walderton was used for the augmentation, therefore the water entering the River Ems was chlorinated water.

In April 2016, licence variations were issued for both Walderton and Woodmancote. Abstraction volumes were reduced and the augmentation points and trigger levels were changed. The current licence conditions for augmentation can be paraphrased as follows:

> *When the non-augmented flow at the [Environment Agency] Westbourne gauge falls below 31 l/s (2,678 m^3/day) there should be a discharge of at least 25 l/s (2,160 m^3/day) from Woodmancote via the discharge point at NGR SU 76986 08244. If, thereafter, the augmented river flow falls below 25 l/s (2,160 m^3/day) for 30 consecutive days, or if at any time it falls below 15 l/s (1,296 m^3/day), then the augmentation from Woodmancote should cease and be replaced by a discharge of at least 13 l/s (1,123 m^3/day) from Walderton via the discharge point at NGR SU 76290 07830. Augmentation from whichever borehole should continue until the ‘natural’ flow at Westbourne exceeds 38 l/s (3,283 m^3/day).*

The licence changes followed a period in which Portsmouth Water together with the Arun and Western Streams Catchment Partnership and the Environment Agency delivered a number of restoration projects in the middle reaches of the River Ems (i.e. downstream of Racton Dell), with a view of mitigating some of the habitat impacts identified in an earlier report (AMEC, 2013). This included resolving issues with channel braiding, in-channel structures and fish passage in the reach between the new augmentation point and ‘The Canal’.

As part of the licence variation, the augmentation discharge point was moved about 500 m upstream to provide more regular flow through the middle reaches of the River Ems which had recently been restored. Since the licence change, the augmentation discharge has been sourced directly from the Woodmancote abstraction and the discharge is raw water[2]. Abstraction locations and augmentation discharge points are shown in Figure 2-1.

The effects of augmentation on flows at Westbourne were examined in the Phase 1 report (Atkins, 2021). By naturalising the flows as they might have been without augmentation and also through groundwater model simulations, the analysis showed that the augmentation discharge is essential in maintaining perennial flows downstream. However, the analysis indicated that since 2016 there appeared to be more losses than before 2016. In 2020, it was reported that there was a period during which the River Ems dried up within the middle Ems, downstream of the location where the augmentation flow discharges. A diagram illustrating the conceptual understanding of the behaviour of the augmentation scheme at the 2016 location was produced (Atkins, 2022) and this is included in Appendix C.

To further investigate the flow augmentation discharge, a trial alteration of the augmentation discharge location was proposed. The details of the augmentation trial are presented in the following sub-sections.

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[2] Note that although the 2016 licence states that if flows at the Westbourne gauge fall below 15 l/s (1,296 m^3/day), the Woodmancote augmentation should cease and be replaced by a discharge from Walderton, this condition has not been applied as the Environment Agency no longer considers discharge of chlorinated water to be appropriate.

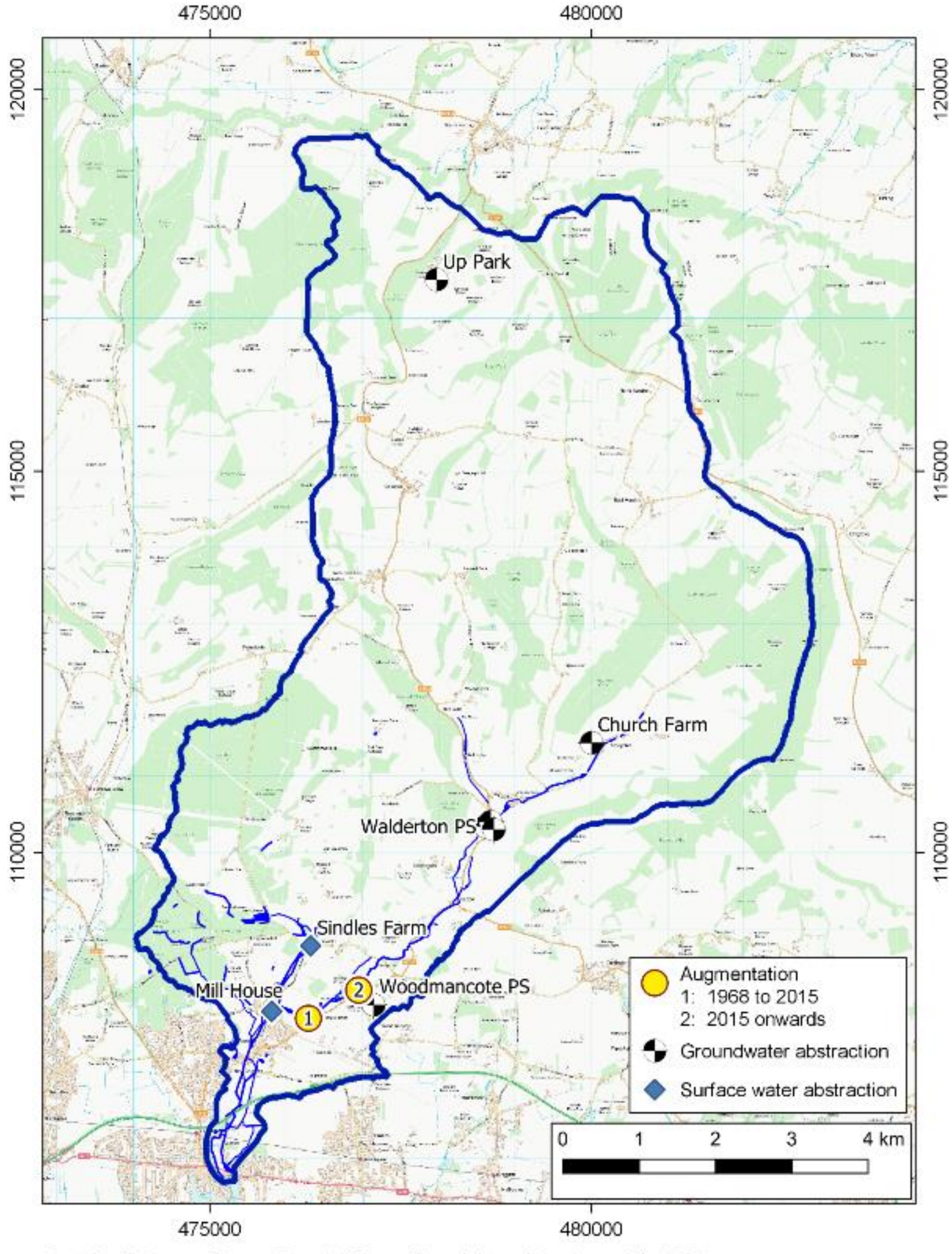

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Figure 2-1 - River Ems licensed abstractions and augmentation discharge points[3]

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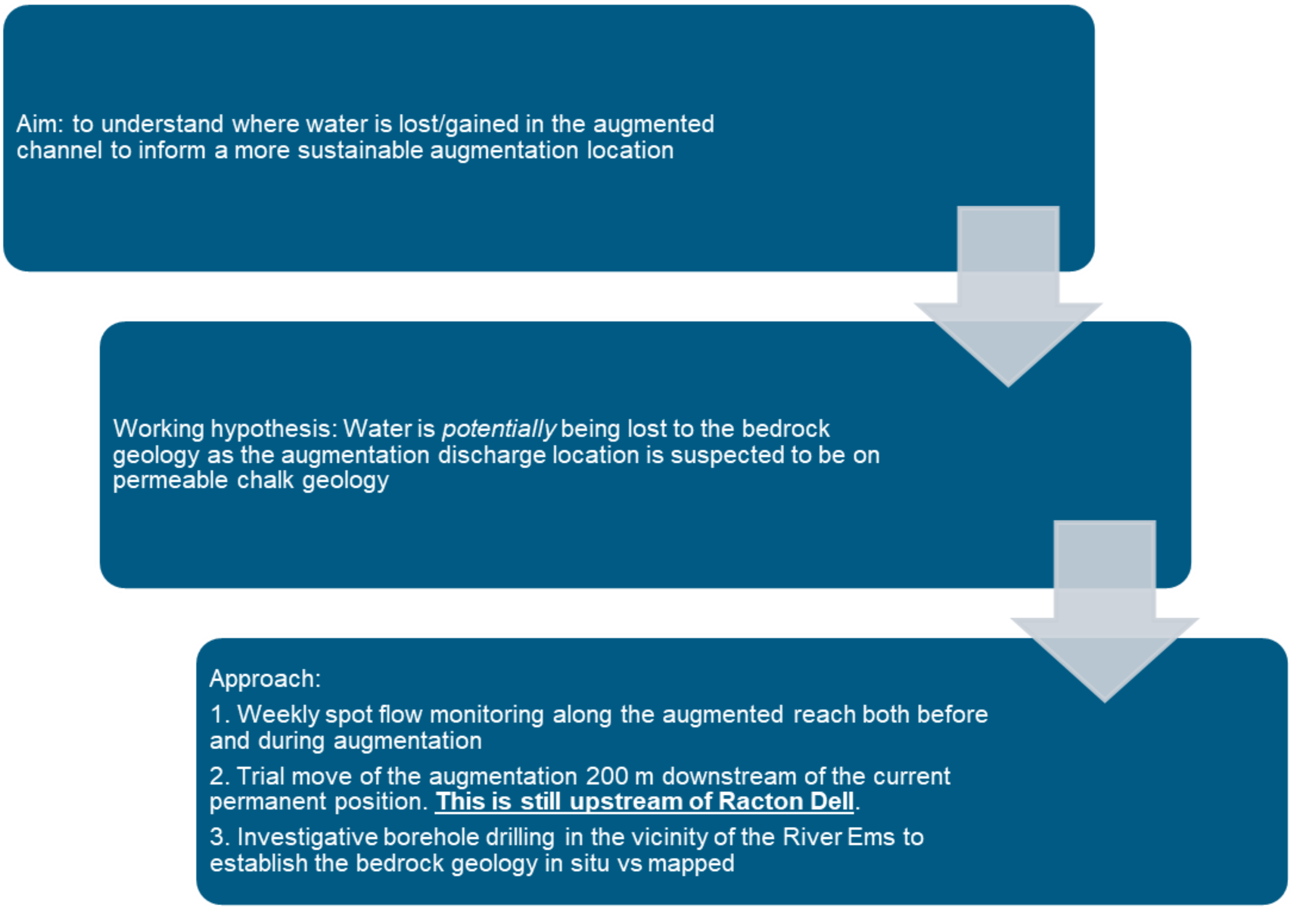
[3] This map has been replicated from the River Ems Phase 1 report (Atkins, 2021). Note that augmentation from point 2 is from 2016 onwards, not 2015 as stated.

2.2. Aim of augmentation trial

The aim of the augmentation trial was to further characterise the flow characteristics of the augmented stretch of the River Ems. The objective was to collect further data in the River Ems catchment and trial a different location for the augmentation discharge[4] to better understand where water is being lost or gained in the augmented river channel.

The aim, working hypothesis and approach are summarised in Figure 2-2.



Aim: to understand where water is lost/gained in the augmented channel to inform a more sustainable augmentation location

Working hypothesis: Water is *potentially* being lost to the bedrock geology as the augmentation discharge location is suspected to be on permeable chalk geology

Approach:

1. Weekly spot flow monitoring along the augmented reach both before and during augmentation
2. Trial move of the augmentation 200 m downstream of the current permanent position. **This is still upstream of Racton Dell**.
3. Investigative borehole drilling in the vicinity of the River Ems to establish the bedrock geology in situ vs mapped

Figure 2-2 - Augmentation investigation overview

2.3. Augmentation trial design

Portsmouth Water consulted with the Environment Agency, FotE, landowners and other interested parties to consider options available to move the discharge point. This included identifying potential locations, practicalities and necessary permissions.

It was determined that running temporary pipework from the current discharge point down the riverbed to a discharge location approximately 200 m downstream was the most practical solution. The new discharge location took into account the hydraulic limitations of extending the pipework along the river bed and the desire to discharge upstream of Racton Dell to maintain the Lord’s Pond within it and protect Racton Dell ecology. It was identified that some modifications would be needed to the existing outfall before sections of temporary pipe could added. A mechanism for diffusing the discharge at the new outfall location was required, to prevent any scouring of the channel. A strainer that dissipates the water was incorporated for this purpose.

Atkins identified river reaches with access and commissioned Hydrologic Ltd to undertake spot flow gauging at a series of locations along the reach of interest with the intention that the first site visit would require further reconnaissance and some vegetation clearance. The flow monitoring locations are shown in Figure 2-3

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[4] A Local Enforcement Position to trial a new augmentation scheme discharge point for the River Ems was agreed with the Environment Agency prior to works commencing.

together with the augmentation discharge locations. The most upstream spot flow location (Site No 1) was slightly upstream of the licensed augmentation point (augmentation point in use since 2016). The furthest downstream location (Site No. 7) was at the Environment Agency gauge in Westbourne.

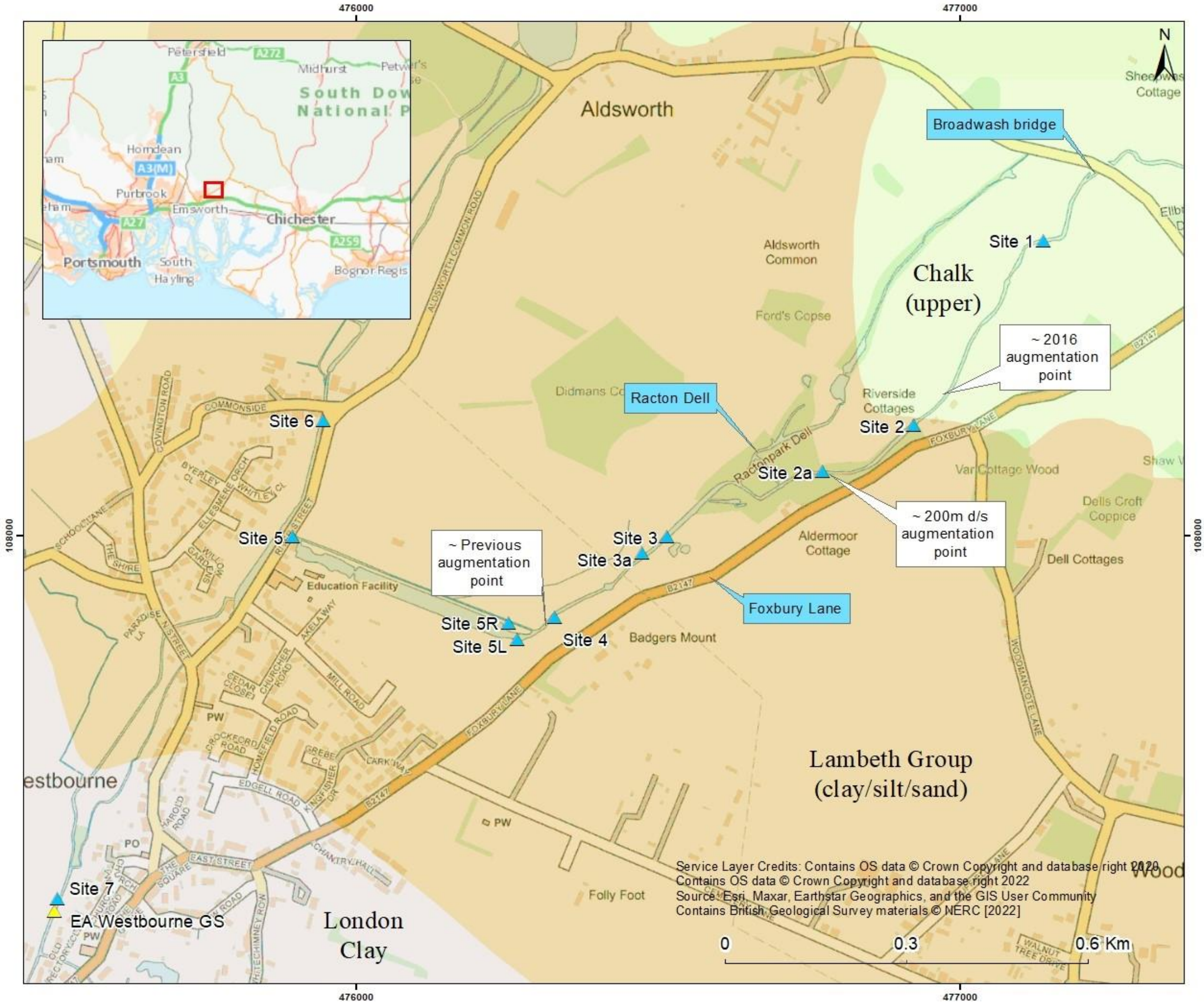

Figure 2-3 - River Ems augmentation monitoring locations with BGS 1:50 k mapped geology[5]

2.4. Augmentation trial operation

Weekly spot flow monitoring commenced on 5th July 2022. The unusually dry conditions triggered the requirement for augmentation (based on the flow at the Environment Agency Westbourne gauge), on 18th July 2022. This was earlier than anticipated and as a result, augmentation commenced at the licensed discharge point at a rate of approx. 30 l/s (2,592 m^3/day).

After gaining formal permission from the Environment Agency, the temporary pipework was mobilised and installed and augmentation switched to the trial location (approx. 200 m downstream) on 12th August 2022. The augmentation discharge was continued at the same rate, as measured at Woodmancote Pumping Station (PS). The water available is determined by the yield from the boreholes (via fixed rate pumps), therefore the discharge volume shows slight variation over time (see section 3.5).

Augmentation discharge continued until 22nd November 2022, when the flow at the Environment Agency Westbourne gauge had remained in excess of the stipulated 38 l/s (3,283 m^3/day) and both groundwater and

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[5] BGS (2022) https://mapapps2.bgs.ac.uk/geoindex/home.html

flow recovery were apparent. Following a meeting between Portsmouth Water and the Environment Agency on 29th November 2022, arrangements were made to remove the temporary pipework.

Weekly spot flow monitoring continued until 8th November 2022 at which point land access was no longer possible at all locations due to the start of the shooting season. A download of continuous level data (recorded at loggers at key locations within the catchment) was also completed prior to the start of the shooting season. Figure 2-4 shows a timeline of key dates. Figure 2-5 shows a selection of photos from the augmentation trial.

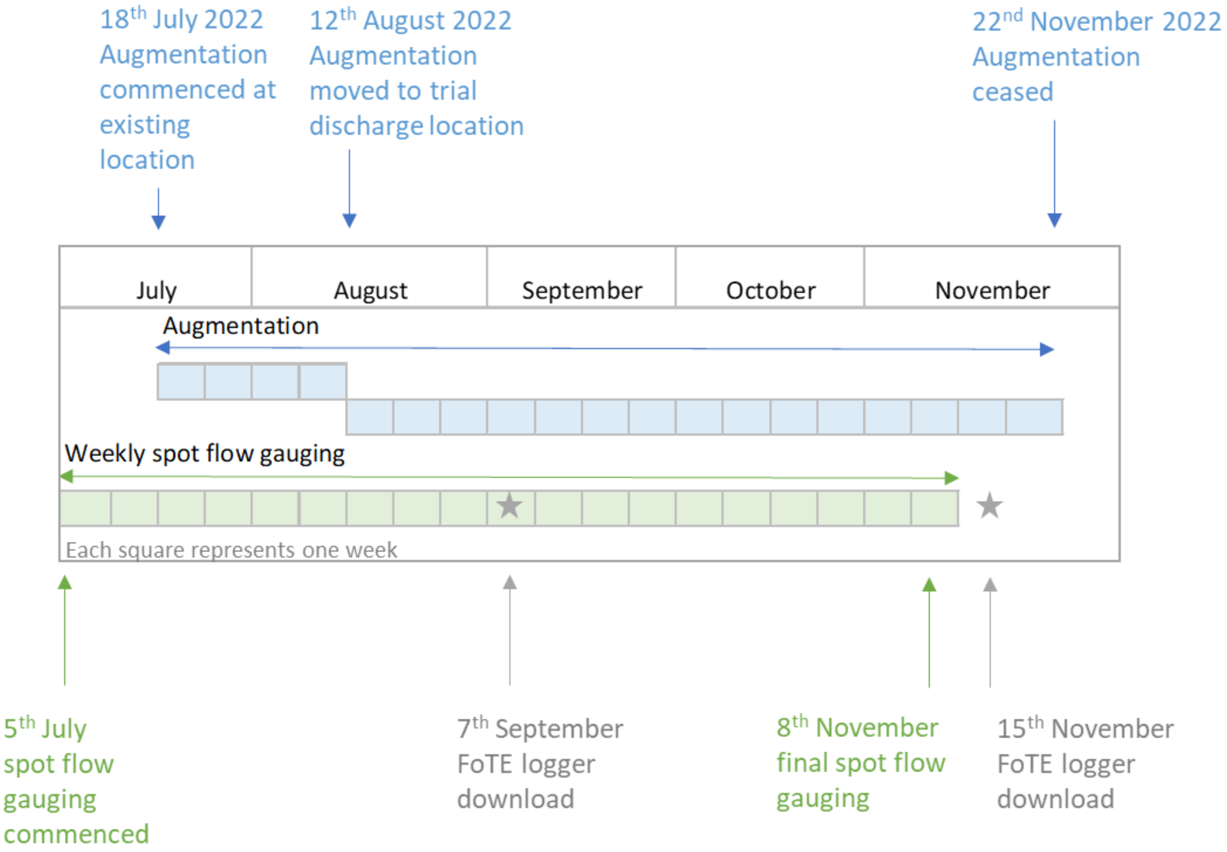


Figure 2-4 – 2022 augmentation trial timeline

Photos of the 2022 augmentation trial	
	
Temporary pipework connection (12/08/2022)	Temporary pipework in channel downstream of Riverside Cottages (12/08/2022)
	
Augmentation discharge (12/08/2022)	Augmentation pipe in channel at Riverside Cottages (31/08/2022)
	
Augmentation pipe in channel (07/11/2022)	Augmentation pipe in channel (07/11/2022)

Figure 2-5 – Photographs of the augmentation trial in operation

3. Data collation and review

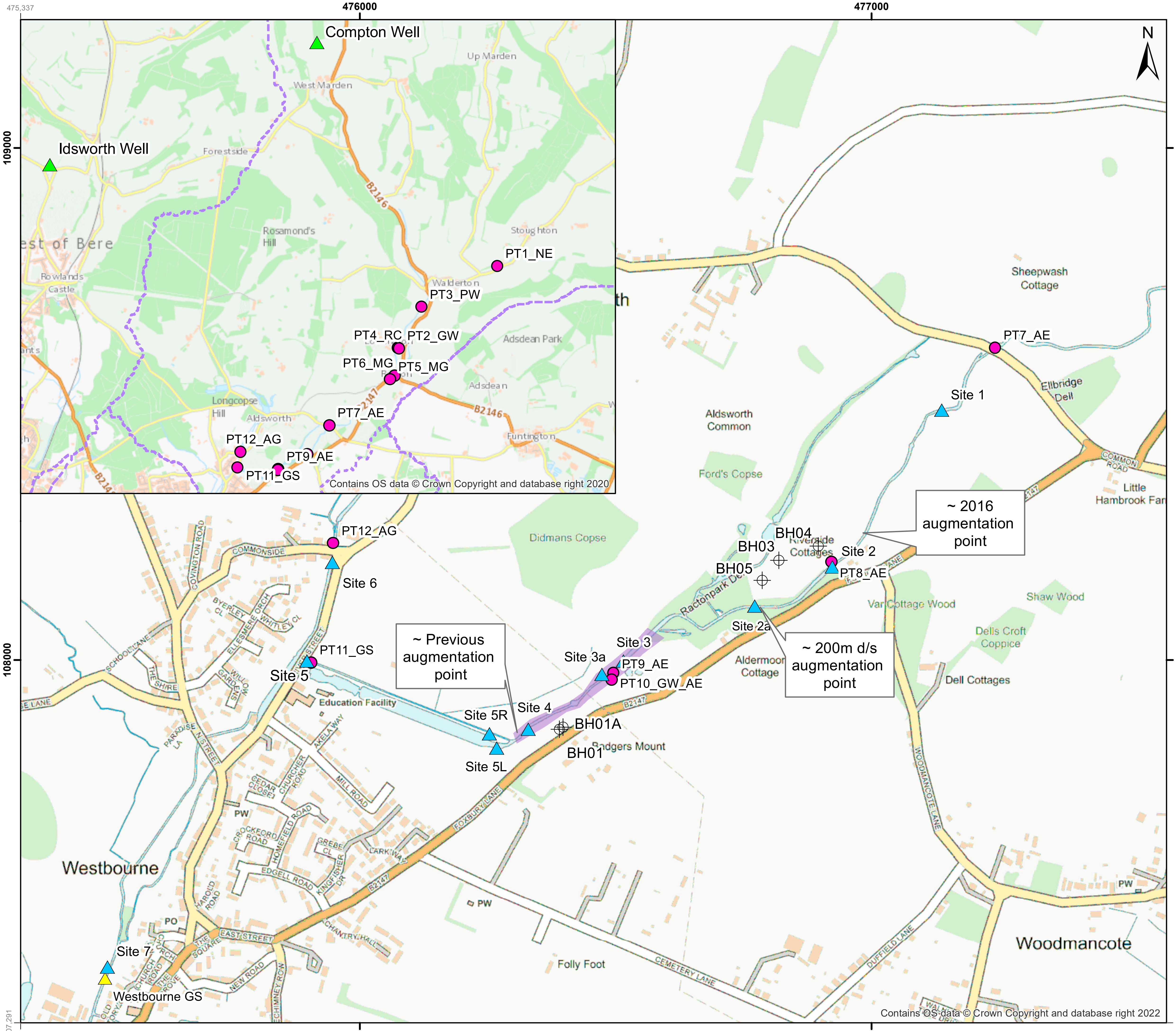
3.1. Data overview

The monitoring data available are summarised in Table 3-1. Locations are shown in Figure 3-1 together with the location of exploratory boreholes which will be further discussed in section 5.

Table 3-1 – Monitoring data collated

Monitoring type	Site name	Site location	Frequency	Data period
Rainfall	Walderton (E11040)	Walderton	15-minute	2016 - present
Flow (continuous)	Westbourne GS (41015)	Westbourne	Daily average	1967 - present
Spot flow gauging	Site 1	River Ems, upstream of augmentation	Weekly	05/07/2022 to 08/11/2022
	Site 2 / 2a	River Ems upstream Lord's Fish Pond / downstream Lord's Fish Pond		
	Site 3 / 3a	River Ems downstream of Racton Dell		
	Site 4	River Ems upstream of 'The Canal'		
	Site 5 (5R,5L and 5)	River Ems upstream of Watersmeet and Aldsworth Arm confluence		
	Site 6	Aldsworth Arm, upstream of River Ems		
	Site 7	River Ems at Westbourne GS		
River levels (logger data)	PT1_NE	River Ems at Mitchmere Farm	15-minute	02/07/21 to 15/11/22
	PT3_PW	River Ems at Walderton PS		
	PT4_RC	River Ems at Lordington		
	PT5_MG	River Ems at Monument Lane		
	PT6_MG	Tributary joining at Monument Lane		
	PT7_AE	River Ems at Broadwash Bridge		
	PT8_AE	River Ems downstream new augmentation point, upstream Racton Dell and Lord's Fish Pond		
	PT9_AE	River Ems downstream Racton Dell		
	PT11_GS	River Ems upstream Aldsworth Arm confluence		
	PT12_AG	Aldsworth Arm upstream of River Ems		
Groundwater levels (logger data)	PT2_GW_RC	Lordington Well	15-minute	02/07/21 to 15/11/22
	PT10_GW_AE	Logger installed in shallow monitoring well downstream of Racton Dell		

Monitoring type	Site name	Site location	Frequency	Data period
Groundwater level (OBH)	Compton Well	Compton, West Sussex	Daily average	1893 - present
	Idsworth Well	Rowlands Castle	Weekly average	1972 - present
Augmentation discharge	Woodmancote PS	Woodmancote PS	15-minute	18/07/2022 - 22/11/2022
Walderton abstraction	Walderton PS	Walderton PS	15-minute	01/01/2022 – 16/11/2022



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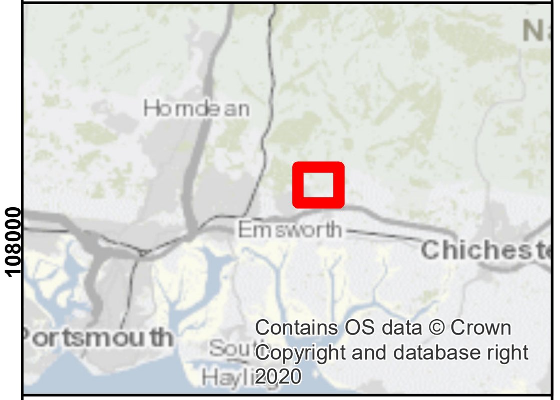
Project: \\wsatkins.com\project\GBEMC\WGE\Projects\Water\20210062 Portsmouth Water River Ems Investigation\7 WIP\7.4 GIS\2_WIP\R Ems data summary map v0.3.mxd

Portsmouth Water River Ems Investigation

Investigation area highlighting the spatial distribution of available data

△	Westbourne GS
△	Spot flow monitoring locations
⌖	Exploratory borehole locations
△	Compton and Idsworth wells
●	Level monitoring (logger)
▭	WFD River Water Body Catchment Boundary
■	Restored reach



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Data sources: Environment Agency, Ordnance Survey, Portsmouth Water

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3.2. Rainfall

3.2.1. Longer term record

Figure 3-2 shows total monthly rainfall data recorded at Walderton in 2020, 2021 and 2022 with average rainfall for the preceding four years shown for context. This illustrates that 2022 was a very dry year, with below average rainfall and notably low rainfall through spring and summer (from March to August).

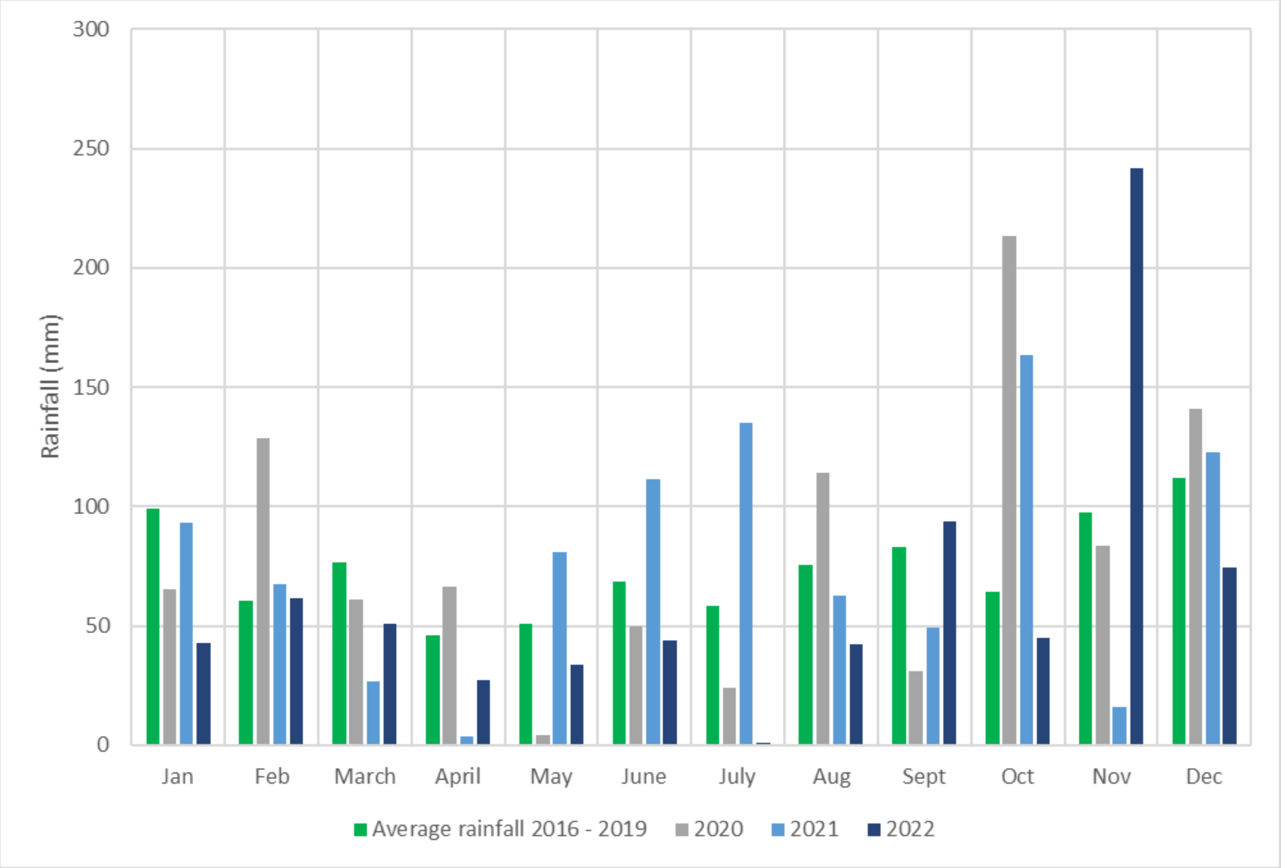

Figure 3-2 – Monthly rainfall record at Walderton

3.2.2. Augmentation trial

Figure 3-3 shows daily rainfall at Walderton for the period of the augmentation trial. This shows that there was virtually no rainfall through most of July and August. Most of the August rainfall was recorded in one event at the end of the month. There were smaller rainfall events in September and early October with a larger rainfall event towards the end of October and further large events in November.

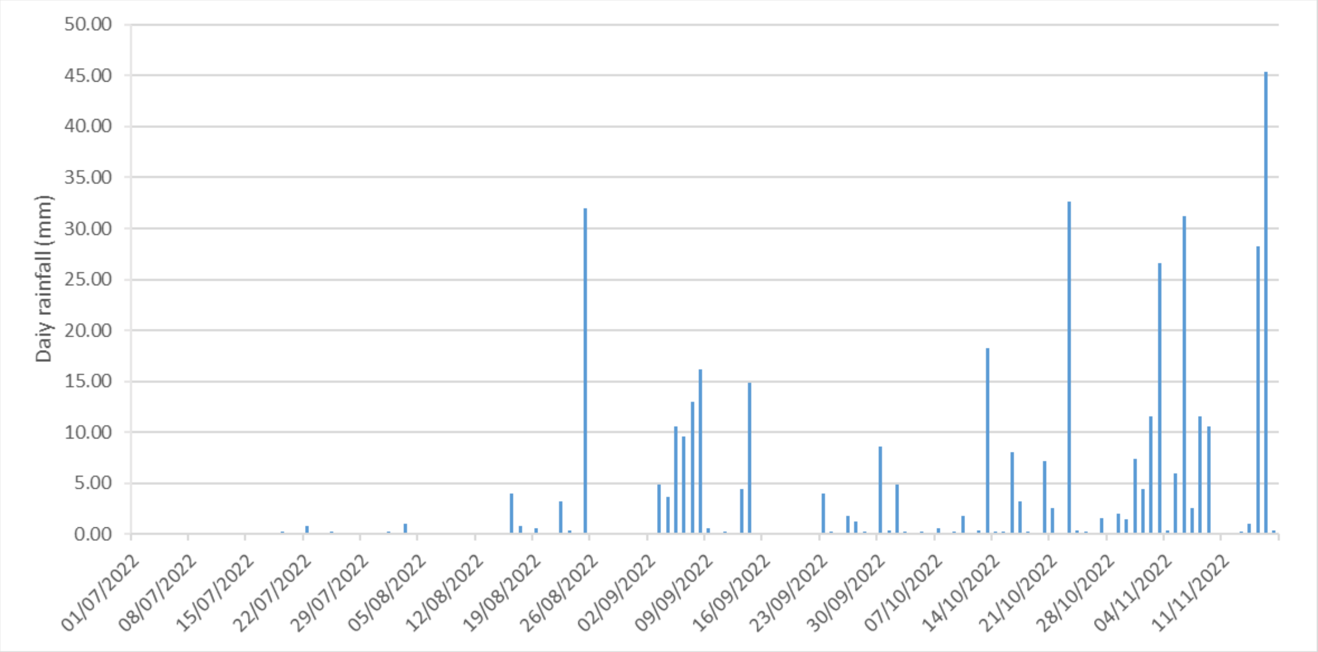

Figure 3-3 – Daily rainfall at Walderton from 1st July to 17th November 2022

3.3. Groundwater

3.3.1. Long term monitoring

Groundwater level observation data are available from Idsworth Well and Compton Well, both located near to the River Ems (Figure 3-1). Groundwater level data are also available from the abstraction boreholes at Walderton PS.

The Idsworth Well at Rowlands Castle is used as an indicator borehole in the Portsmouth Water catchment. It has been monitored for over 80 years, is considered to be unaffected by abstraction and is located approximately 6 km from the River Ems. It is therefore useful in the understanding of the wider hydrogeological setting.

Figure 3-4 summarises groundwater levels throughout key drought years and includes a long-term average (LTA) and groundwater levels from 2021-2022. This shows levels in the spring and summer of 2022 to decline significantly in a pattern similar to the 1989-1991 drought. In late October 2022, groundwater levels were similar to those experiences in the 1989-1991 drought and in fact lower for the time of year than observed in the 1975-1977 drought.

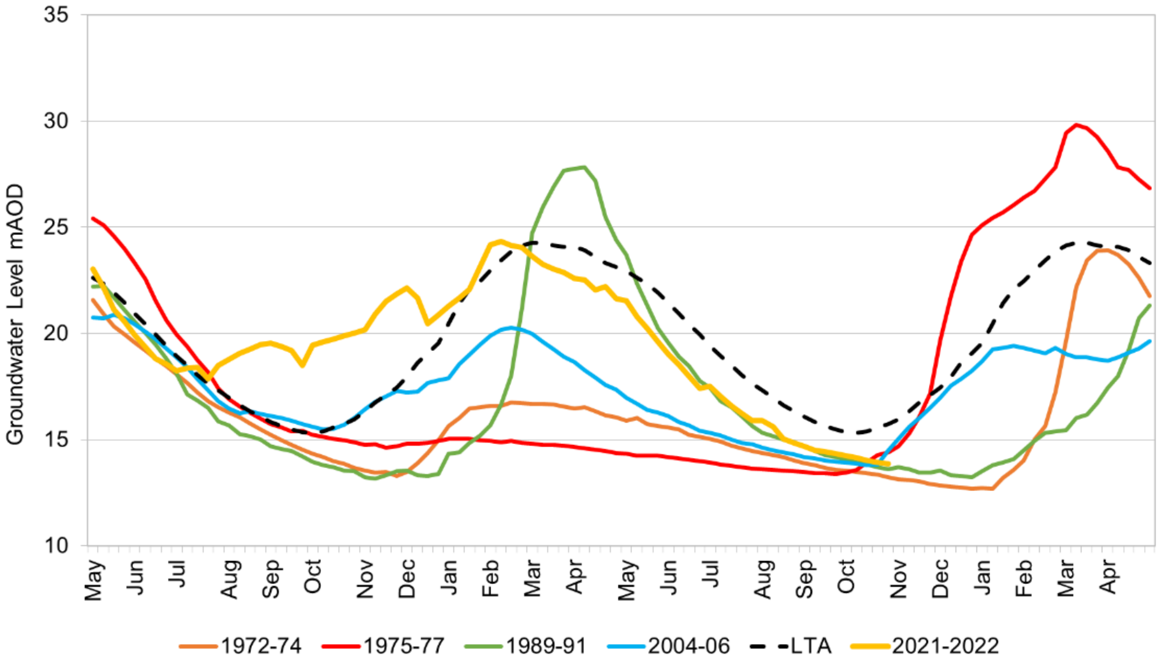

Figure 3-4 - Idsworth Well - drought water levels

Compton Well is located within the Ems catchment, approximately 5 km north of augmented reach and holds one of the longest groundwater records in the Chalk. Figure 3-5 presents groundwater levels at Compton Well from 2020-2022 and average groundwater level from 2016 to 2019.

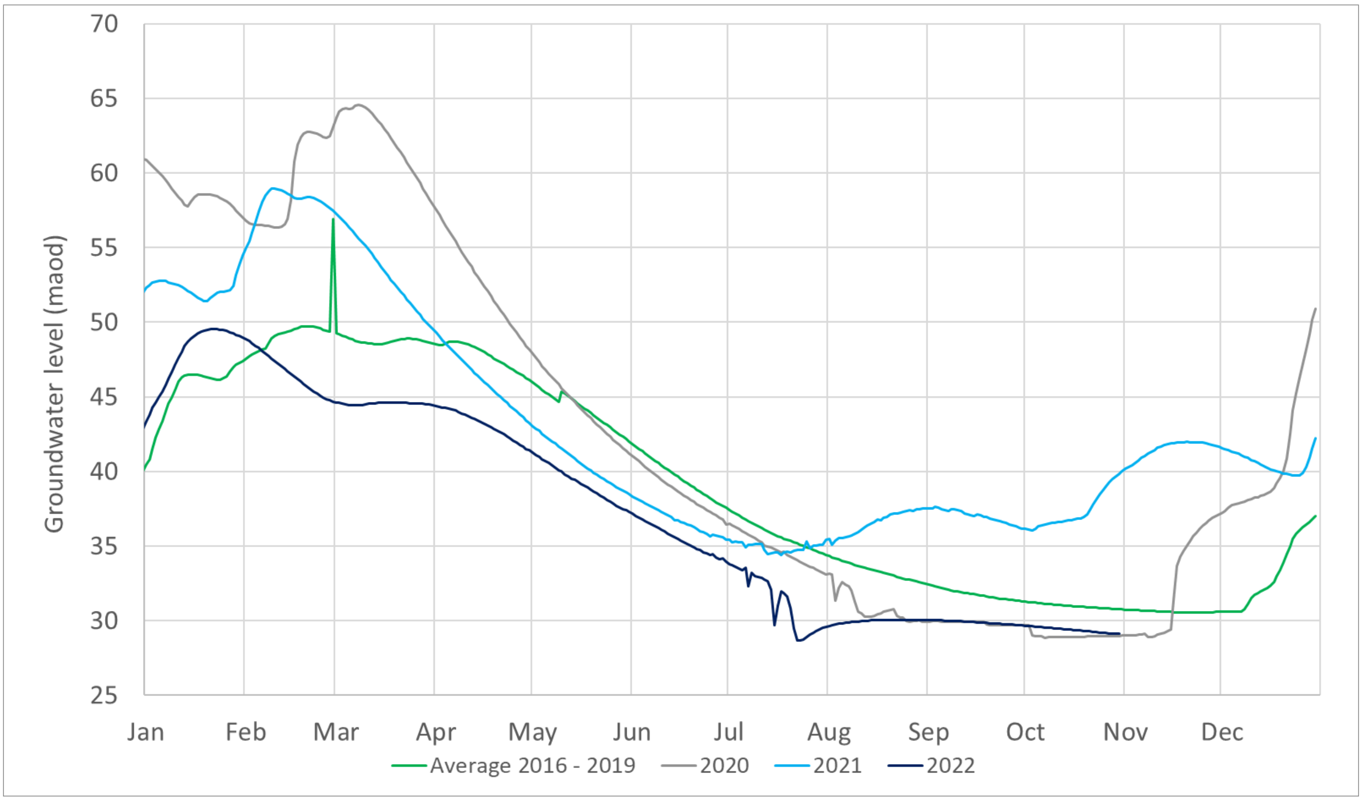

Figure 3-5 – Groundwater levels at Compton Well

Figure 3-5 shows that in general levels at Compton are lower than in previous years, particularly in early 2022 when there should be the typical seasonal groundwater high. The 2022 record shows an overall decline in groundwater level from late January onwards. It should be noted that the data recorded over the summer period (July onwards) are currently under review by the Environment Agency due to apparent issues with the data logger[7]. The record appears to show a sudden and out of character change in the groundwater record during a period of stable and sustained dry conditions. Although there are questions surrounding the reliability of the logger during the summer, the record shows 2022 to have lower groundwater levels in comparison to previous years. This is not surprising given the rainfall record summarised in section 3.2 but reiterates the low volume of water within the catchment due to regional drought conditions.

Figure 3-6 shows groundwater levels in the abstraction boreholes at Walderton PS. Although the groundwater levels are heavily influenced by the pumping regime, the data provide a useful record of average groundwater levels at the pumping station. This shows a steep decline in groundwater levels between May 2022 and November 2022. The volume abstracted from Walderton PS also shows a slight decline over the same period as the drop in groundwater levels influenced the borehole yield.

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[7] Pers. comm. between Alison Matthews (EA) and Lucy Hardisty (Atkins) via email on 01/11/2022

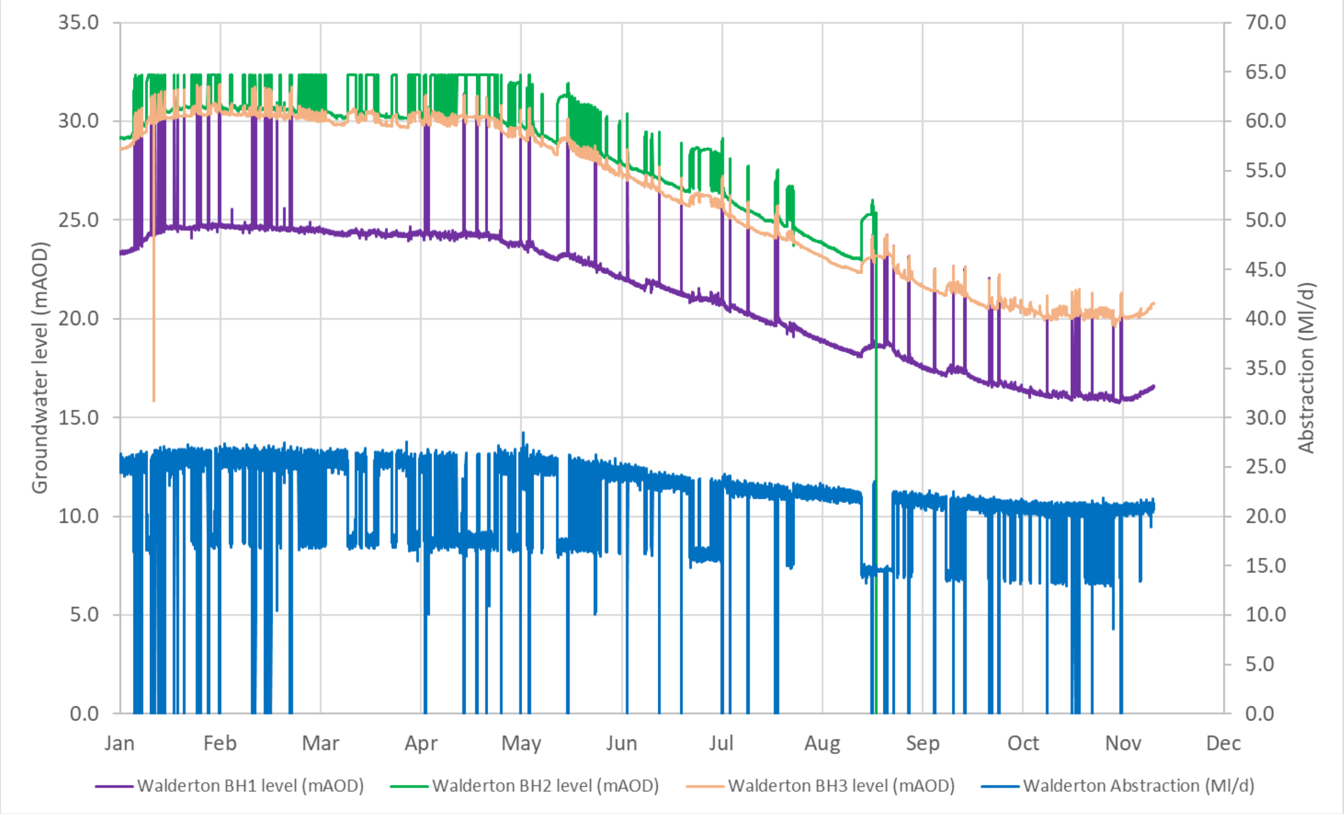

Figure 3-6 – Abstraction volumes and groundwater levels at Walderton PS in 2022

3.3.2. Augmentation trial

In addition to established Environment Agency and Portsmouth Water monitoring within the catchment, data are also available from the two loggers installed to record groundwater levels as part of the hydrometric network for the River Ems Investigation.

The logger at PT2_GW_RC records groundwater levels at Lordington Well, ~1.5 km to the north of Broadwash Bridge, whilst the logger at PT10_GW_AE is installed in a shallow monitoring well downstream of Racton Dell, adjacent to the augmented reach (see Figure 3-1).

Figure 3-7 shows the data from the two groundwater loggers over the augmentation trial period.

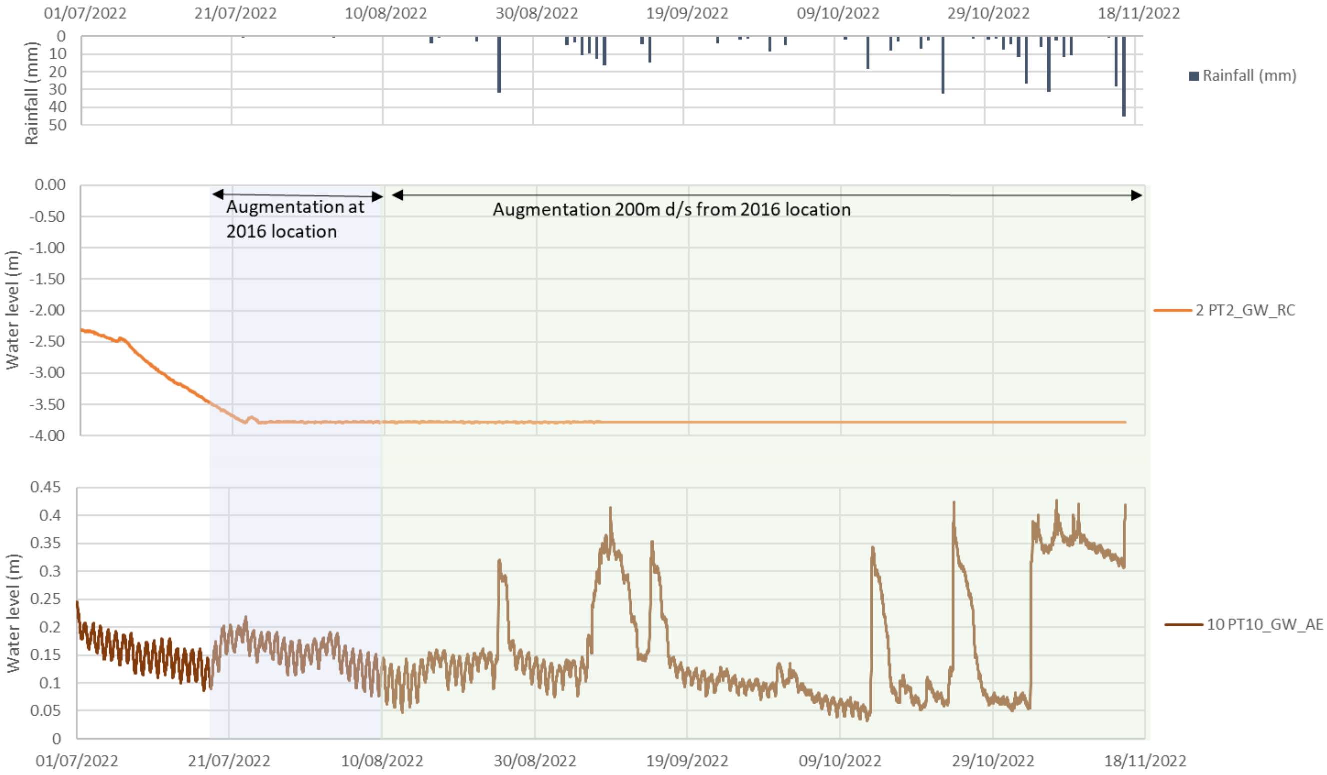

Figure 3-7 – Groundwater logger data for the augmentation trial period

The data from PT2 (Lordington Well) shows a decline in groundwater levels through July 2022, after which the flat response suggests the well is dry. The data from PT10 also shows an initial decline in groundwater level in July but shows an increase in groundwater level in response to the augmentation. The shallow groundwater in PT10 also appears to be very responsive to rainfall. This suggests the potential for close interaction between the river and shallow groundwater at this location. Further analysis will be presented in section 4.2.

3.4. Surface water flows and levels

3.4.1. Continuous river flow data

Continuous river flow data are available from the Environment Agency gauging station at Westbourne, site reference 41015 (see Figure 3-1). The gauging station has a compound weir, so that at low flows water only flows over a small section of the structure. This allows for reasonably accurate measurement even in low flow conditions[8].

Figure 3-8 presents the flows recorded at the gauging station in 2020, 2021 and 2022 and the average flows from 2016 to 2019. Flows in 2022 are shown to be lower than recent years. The period of peak flows during

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[8] Pers. comm. between Alison Matthews (EA) and Emma Everard (Atkins) via email on 01/09/2022

January to April is much lower in comparison to other years. This aligns with the groundwater levels seen at Compton OBH in early 2022 (Figure 3-5) and reflects the low rainfall and decreased volume of water in the catchment. The receding limb of the hydrograph from May 2022 onwards appears to show a similar rate of decline to 2021 however due to the lower amount of water in the river to start with, flows in 2022 reached the augmentation trigger earlier than in previous years (for example, 2-3 weeks earlier than in 2020).

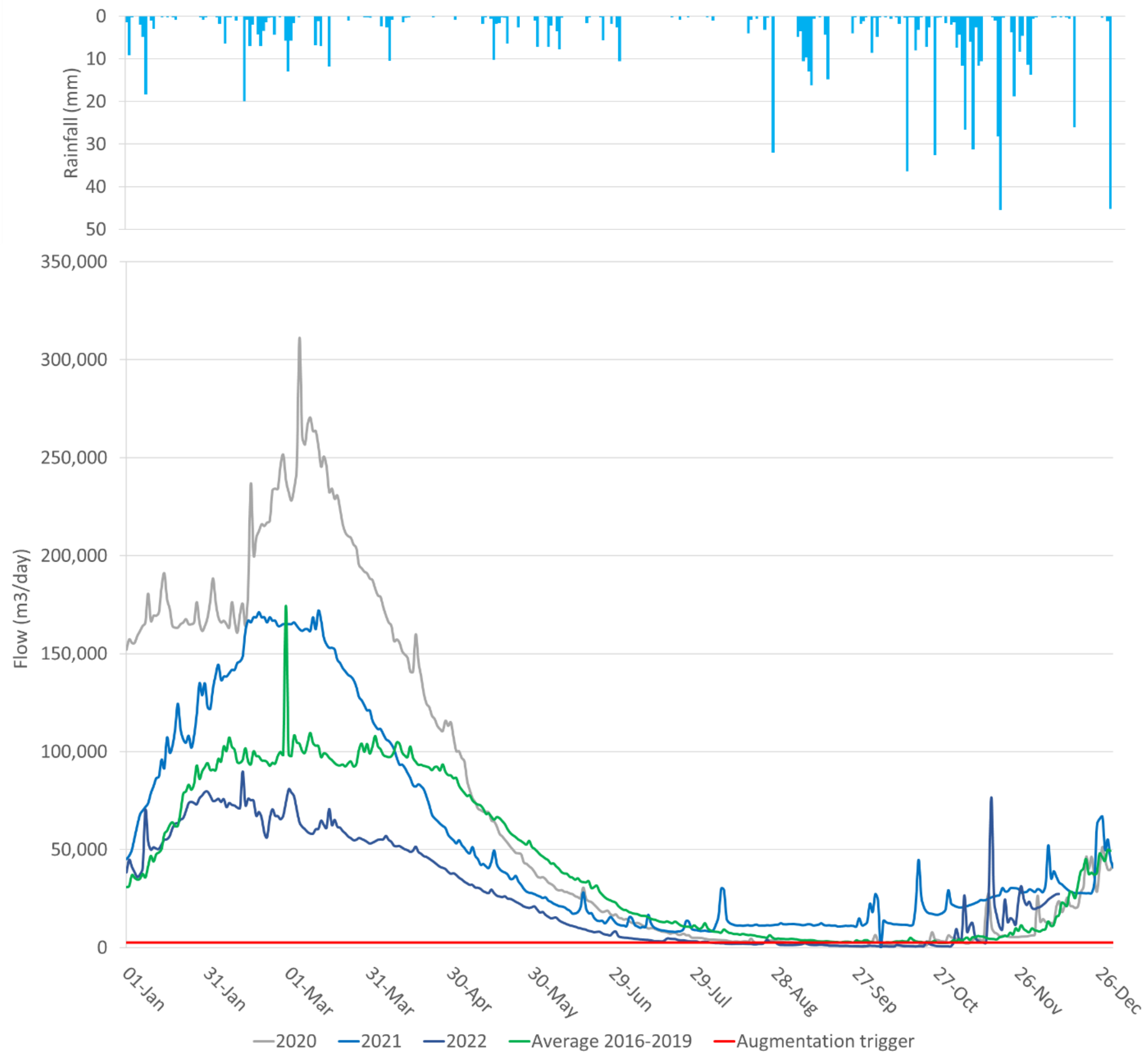


Figure 3-8 – Average daily flow record at Westbourne Gauging Station with 2022 rainfall

It is evident by looking at the long-term record of rainfall, groundwater level and flows that 2022 was an exceptionally dry year. Low water levels were experienced throughout the groundwater and surface water system which is to be expected due to the connectivity between groundwater and surface water in Chalk environments. The low flows in the River Ems in 2022 were due to an unprecedented decrease in rainfall and subsequent regional drought throughout the summer and autumn months of 2022. This is reported in the monthly hydrological summaries for the United Kingdom produced by the UK Centre for Ecology and Hydrology which also record that by August, declarations of drought were enacted for much of England and Wales (UK CEH, August 2022).

Flows measured at the gauging station for the duration of the augmentation trial are shown in Figure 3-9. This shows the decline in flow through the summer drought and the response to autumn recharge in late October/early November. The influence from flow augmentation is also clearly visible.

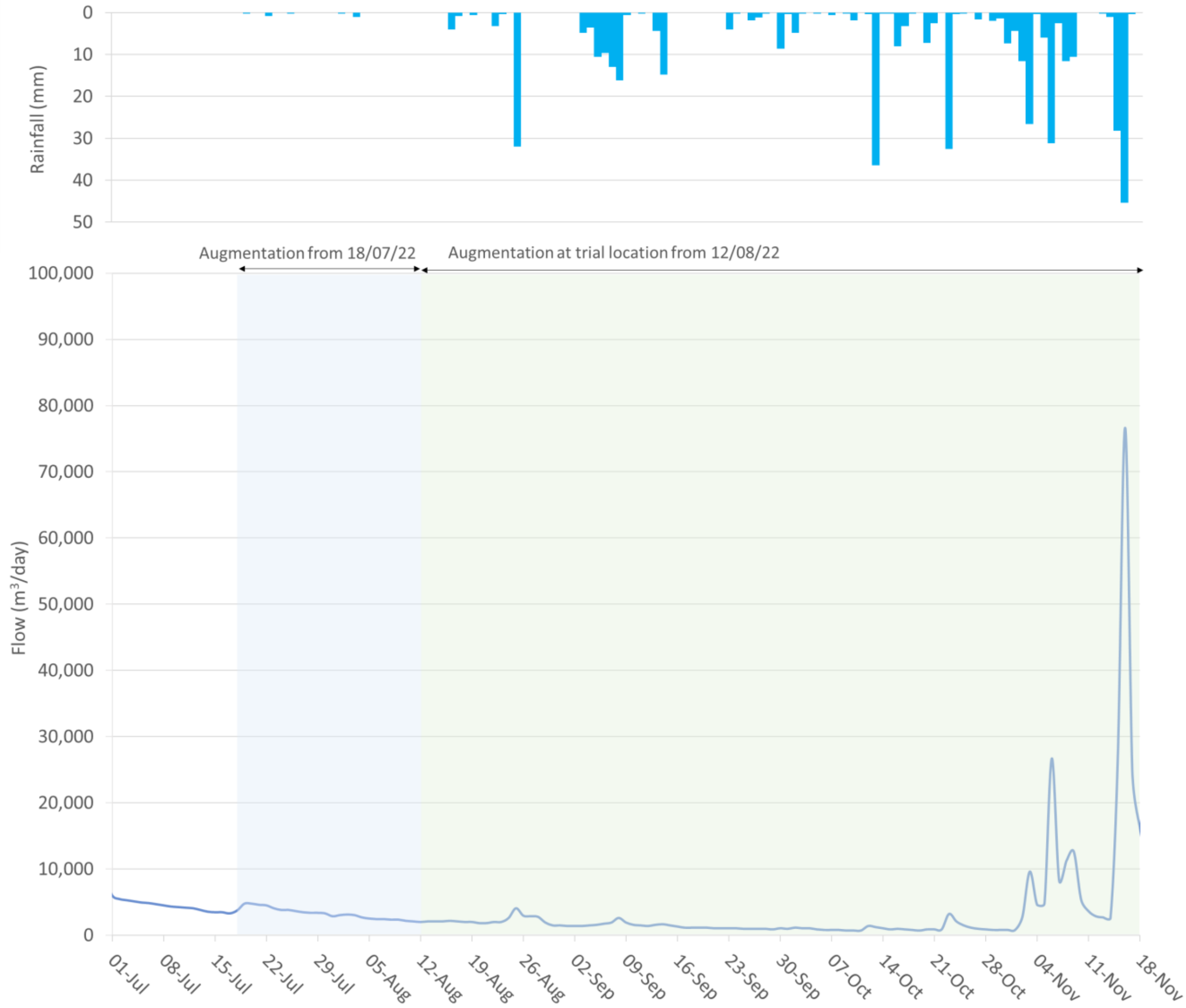


Figure 3-9 – Average daily flows at Westbourne gauging station during the augmentation trial period

3.4.2. Flow monitoring during augmentation trial

Weekly spot flow gauging was undertaken along the augmented reach of the River Ems between 5th July and 8th November 2022 to:

- establish a baseline prior to augmentation switch-on
- record flows and flow behaviour along the augmented reach following commencement of augmentation
- record flows and flow behaviour along the augmented reach following augmentation relocation 200 m d/s
- record the initial recovery of the river during autumn recharge.

The monitoring locations were initially chosen to give a spread along the augmented reach, taking into account accessibility and locations where flow was most likely to be measurable. During each of the flow monitoring rounds, a dynamic approach was taken whereby the most appropriate gauging locations were selected. Gauging locations were therefore not exactly the same from week-to-week although were kept consistent where possible. As data were reviewed, alterations were also made to some of the monitoring locations, in order to better characterise the flow behaviour along the reach.

Monitoring low flows in natural channels is not always straightforward; in most situations flow gauging was undertaken using either a rotating element current meter or an electromagnetic current meter in accordance with hydrometric standards (ISO 748:2007). On occasions where gauging by standard methods was not possible in some locations, float tests (the time taken for a floated object to travel over a given distance) were attempted instead to give an approximate measure of flow. Although these measurements provide some useful information, they have a much larger margin of error and are far more uncertain.

Throughout the monitoring period, observations were made when locations were dry and alternative gauging locations were selected where appropriate. Table 3-2 summarises the gauging locations and the observations made throughout the weekly spot flow monitoring.

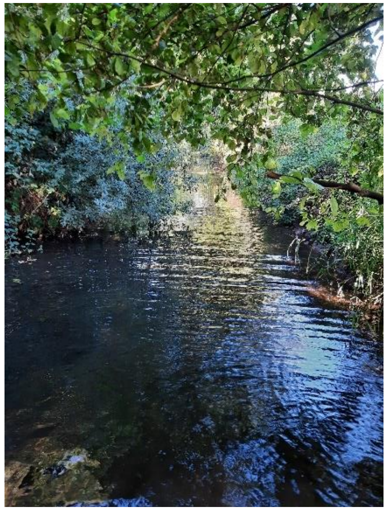
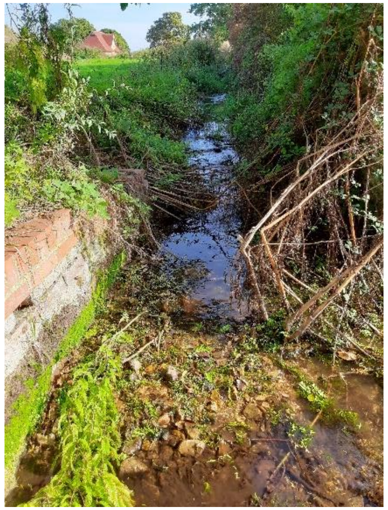
Appendix A provides a series of annotated maps, summarising the flow gauging results for each monitoring round. Further analysis of the flow monitoring data is presented in section 4.

Table 3-2 - Spot flow gauging locations and observations

Site	Gauging location and observations	Supporting photos	
Site 1	River Ems upstream of 2016 augmentation This location was consistently dry throughout the monitoring period with no measurable flow upstream of the augmentation discharge point		
		View upstream at Site 1 (08/09/2022)	View downstream at Site 1 (08/09/2022)
Site 2/ 2a	River Ems upstream Lord's Fish Pond/downstream Lord's Fish Pond Site 2 was either dry or without measurable flow throughout the monitoring period, even though located downstream of the 2016 augmentation point. An alternative location slightly downstream was identified (Site 2a). The alternative location was downstream of the Lord's Fish Pond and both the 2016 and the trial augmentation point. Flows were gauged prior to augmentation initially being switched on but afterwards the depth was too deep to safely gauge (and towards the end of the augmentation period too silty). Flows were estimated by the float test method instead. Estimated flows peaked at 45 l/s (3,888 m^3/day) but the channel was dry at the end of October 2022.		
		View upstream at Site 2 (31/08/2022)	View downstream at Site 2a (22/08/2022)

Site 3	River Ems downstream of Racton Dell This location was downstream of Racton Dell, upstream of the restored reach. Flow was sustained throughout the monitoring period and weekly spot flow gauging measurements were possible. Flow was highest at 51 l/s (4406.4 m^3/day) on 21/07/2022, lowest at 6 l/s (518.4 m^3/day) on 21/09/2022 and averaged 18 l/s (1555.2 m^3/day) for the period in which the augmentation has been active.	 View at Site 3, 32 l/s (22/08/2022)	 View at Site 3, 11 l/s (11/10/2022)
Site 3a	River Ems further downstream of Racton Dell Site 3a was added as a new monitoring point on 05/10/2022. It is located slightly further downstream than Site 3 and was included to try and gain additional data in the augmented reach of the River Ems during the trial (to inform understanding of flow gains and losses). Flow was consistently recorded in the channel. The highest recorded flow was 21 l/s (1814.4 m^3/day, recorded on both 5/10/2022 and 8/11/2022). The lowest was 10 l/s (864 m^3/day recorded on 19/10/2022).	 View at Site 3a, 9.9 l/s (19/10/2022)	 View at Site 3a, 11.5 l/s (11/10/2022)

Site 4	River Ems upstream of 'The Canal' This location was upstream of the location where the River Ems changes direction to flow through the stretch known as 'The Canal'. Flow was recorded in the channel throughout the monitoring period except on 21/09/2022 when two gaugings were attempted (at slightly different grid references) and both gave anomalous negative results. The highest flow recorded during the monitoring was 58 l/s (5011.2 m^3/day on 14/7/2022), the lowest was 7 l/s (604.8 m^3/day on 11/10/2022).		
		View upstream at Site 4, 44 l/s (22/08/2022)	View upstream at Site 4, 12 l/s (27/10/2022)
	It should be noted that downstream of Site 4, the channel changes direction and splits. There is penstock weir with wooden boards on the channel entering 'the Canal'. It is not known the extent to which the position of the boards was altered during the course of the monitoring but it is likely that any movement could have influenced the flow monitoring data.		
		River Ems inflow into mill pond downstream of Site 4 (historical photo from 30/09/2020)	River Ems penstock sluice on 05/07/2022 and on 12/08/2022

Site 5	River Ems upstream of Watersmeet and Aldsworth Arm confluence (R and L) For the first six gaugings (from 5/7/2022 to 12/8/2022), gauging was attempted on both the left channel (5L or 'The Canal') and the right channel (5R or 'Mill Race'). These were added together to give an approximation of total flow. Site 5L & 5R had highly variable flow throughout the monitoring period, thought to be at least in part attributable to the difficulties gauging in non-ideal gauging sections. In general, however, the two flows added together appeared lower than flows measured upstream at Site 4. As a result of access difficulties (cattle in field), a new gauging point was selected from 18/08/2022.		
		Left channel 15 l/s (12/08/2022)	Right channel 18 l/s (12/08/2022)
	River Ems upstream of Watersmeet and Aldsworth Arm confluence (gauged total flow) The new location for Site 5 was located further downstream, just upstream of the convergence with the Aldsworth Arm of the Ems (see Figure 3-1). This location doesn't include any Mill bypass flow, although visual observations were made to record this. The highest recorded flows at this location were 23 l/s (1987.2 m^3/day on 3/11/22 and 8/11/22) the lowest recorded flows were 4 l/s (345.6 m^3/day on 19/10/22).		
		View upstream at Site 5, 4 l/s (19/10/2022)	View upstream at Site 5, 23 l/s (08/11/2022)

Site 6

Aldsworth Arm, upstream of River Ems

This monitoring location is on a tributary of the River Ems, the Aldsworth Arm. It is located upstream of the confluence with the River Ems at Watersmeet.

Flows were low at the start of the monitoring period (5 l/s (432 m^3/day) on 05/07/2022) and declined throughout July, with the last recorded flow on 03/08/2022. The channel was reported to be dry over three months until 03/11/2002 when a peak flow of 32 l/s (2764.8 m^3/day) was recorded (following a period of heavy rainfall).

View upstream at Site 6, no flow (31/08/2022)

View upstream at Site 6, 23 l/s (08/11/2022)

Site 7

River Ems at Westbourne Gauging Station

Spot flow gauging was undertaken at the gauging station as part of the weekly monitoring round. Monitoring was not undertaken at this location during October to allow additional spot flow measurements to be taken in the stretch of interest upstream (at Site 3a).

Flows recorded at Site 7 were similar to the Westbourne GS record. Some discrepancies are expected due to difficulties and inaccuracies through gauging in very low flow conditions. There will also be some differences when comparing average daily flow at the GS to instantaneous spot flow measurements.

The highest flow measured was 122 l/s (10,540.8 m^3/day on 08/11/2022) and the lowest was 15 l/s (1,206 m^3/day on 28/09/2022).

View downstream at Site 7, 122 l/s (08/11/2022)

View downstream at Site 7, 21 l/s (31/08/2022)

3.4.3. River level monitoring during augmentation trial

River level data are available from the loggers installed as part of the hydrometric network for the River Ems Investigation. The loggers at PT8, PT9 and PT11 are each located along the augmented reach. The logger at PT12 is located on the Aldsworth Arm, upstream of its confluence with the River Ems (see Figure 3-1).

Figure 3-10 shows the river level data from the loggers over the augmentation trial period.

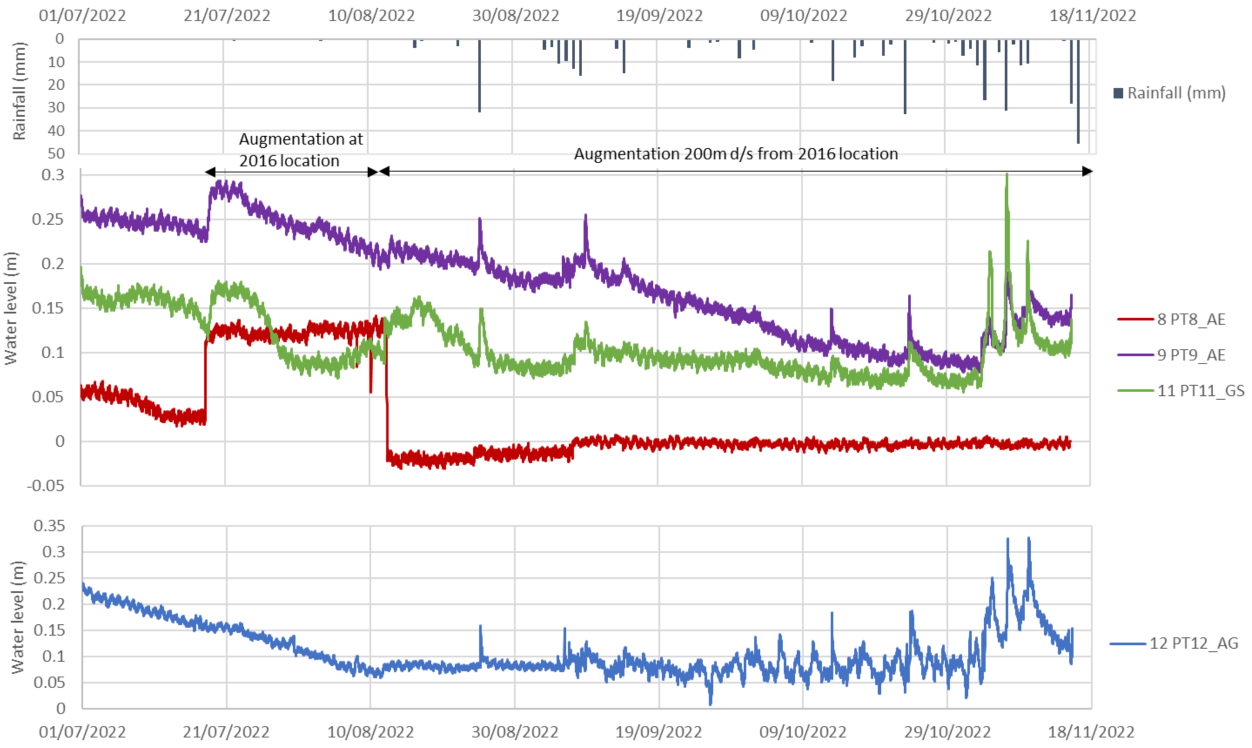


Figure 3-10 – River level logger data for the augmentation trial period

The logger data at PT 8 show a clear response to the augmentation, with a sharp increase in water level when the augmentation is switched on and a sharp decrease when it is moved to the trial location downstream. This is not unexpected, as PT 8 is located close to the pre-trial augmentation discharge. It also shows no response to rainfall as the logger records no water level (i.e. is dry) for the later part of the record when rainfall occurred.

The data at PT 9 show a more muted response to the augmentation start and move to the trial location. Interestingly, PT 11 (located downstream) appears to show the same magnitude of response to the augmentation start as PT 9 and a larger increase in response to the move to the trial location.

The data from PT 12 show the surface water levels in the Aldsworth Arm to decline over time through July and August corresponding with high temperatures, extremely low rainfall in these months and resultant ongoing drought conditions. There does appear to be a very slight increase in water levels on 12th August in response to the augmentation being moved to the trial location. The water levels at this location appear to show a clear response to rainfall.

Further analysis will be presented in section 4.

3.5. Augmentation discharge

Figure 3-11 shows the record of groundwater abstraction from Woodmancote pumping station (15 minute frequency). This abstraction of untreated groundwater is discharged directly into the River Ems for augmentation purposes. The groundwater abstraction data therefore represent the augmentation discharge volume. The target augmentation discharge was 30 l/s (2,592 m^3/day), however there was some variation over time as the groundwater was abstracted via fixed rate pumps with the yield dependent on groundwater level.

The average augmentation discharge to the trial augmentation location from 12th August to 22nd November was 26.7 l/s (2,393.3 m^3/day).

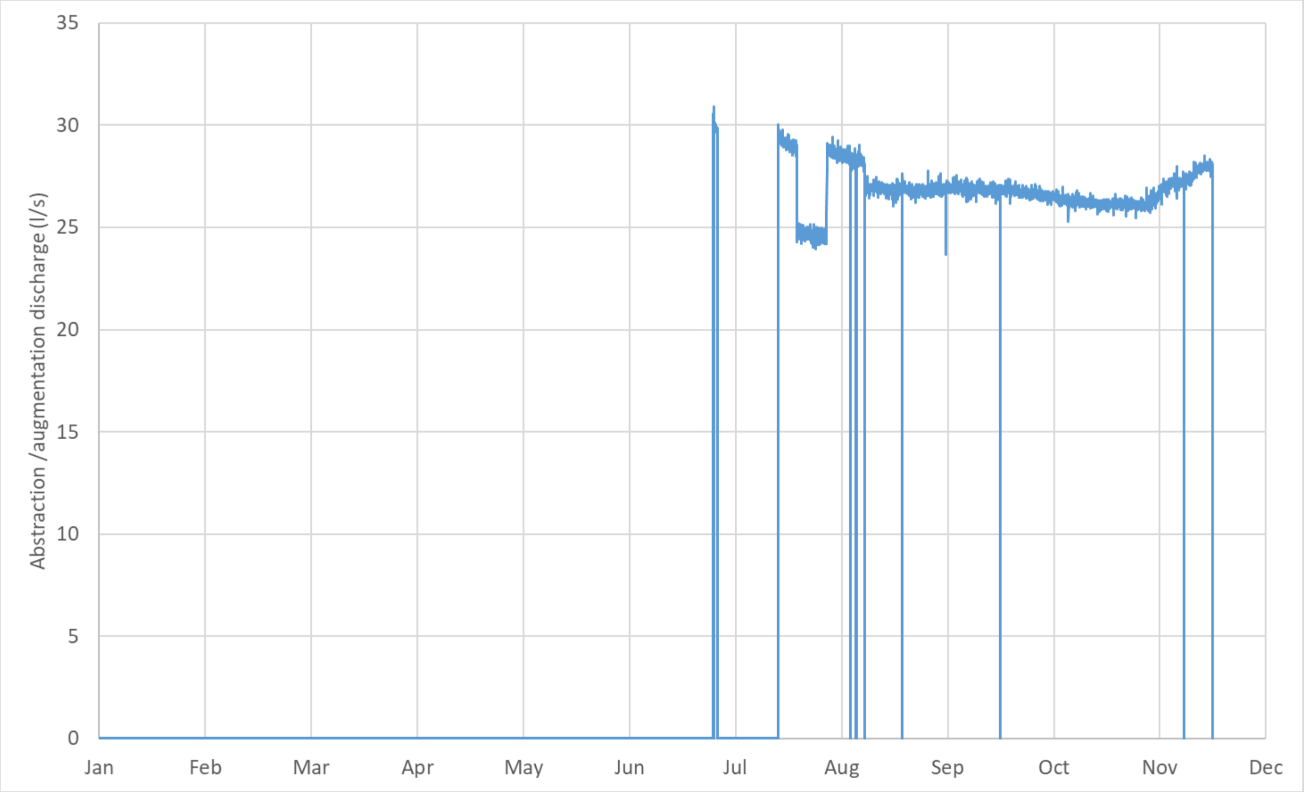


Figure 3-11 – Augmentation discharge from Woodmancote PS in 2022

4. Augmentation trial data analysis

4.1. Surface water flows and flow accretion

Figure 4-1 shows the spot flow gauging records for each location on the River Ems and Figure 4-2 shows a combined plot (note that in both figures, Sites 1 and 2 are omitted as the channel at these locations was dry throughout and Site 6 is not included as it located on the Aldsworth Arm, see Figure 3-1).

In interpreting the data, the gauging errors in extremely low flows, and non-standard channel sections needs to be borne in mind. At times the velocities and water depths are on the limit of what can be measured by current meters. Nevertheless, the data collated provide a valuable record of flow conditions during the 2022 summer drought conditions that comprised high temperatures and extremely low rainfall. The following can be observed:

- Site 2 (upstream of Lord's Fish Pond and adjacent to Riverside Cottages, not included in Figure 4-1) remained dry throughout the monitoring period even though it is located downstream of the 2016 augmentation point. **This suggests that all augmentation discharge at Site 2 (upstream of Lord's Fish Pond) was lost straight to ground.**
- Site 2a (downstream of the Lord's Fish Pond and downstream of both the 2016 and the trial augmentation point) had flow in the channel prior to the start of augmentation. When the augmentation was initially switched on, the water depth became too deep to safely access for gauging. The estimated flows (via float test method) at Site 2a showed an increase following the move to the trial augmentation point on 12th August. **Flows at site 2a (downstream of the Lord's Fish Pond) appeared to be sustained for approximately five weeks until 13th September, after which they declined.**
- The gauged flows at Site 3 (downstream of Racton Dell) showed an increase following the start of augmentation on 18th July, however flows declined over the following two weeks. This suggests that the benefit of the augmentation discharge from the 2016 location on flows at this location may be short lived. The flows at Site 3 appeared to show another slight increase when the augmentation point was moved to the trial location on 12th August. **After the initial increase, flows at Site 3 were maintained at a fairly similar level following the move to the trial location over a period of four weeks until 13th September, after which they declined.**
- **Flows at Site 4 (River Ems upstream of 'The Canal') did not appear to show a discernible increase in direct response to the augmentation, although flows did appear to show a general increase from 3rd August to 8th September, after which point they declined.**
- There is uncertainty with the flow gauging data at Site 5 (upstream of Watersmeet, see observations in Table 3-2), however the data may potentially show a slight increase in flows both in response to the start of augmentation and the move to the trial augmentation point. **Flows at Site 5 do generally appear to be higher after the augmentation discharge was moved downstream on 12th August than before.**
- The flows at Site 7 (gauging station) appeared to show an increase following the start of augmentation, albeit short lived. There was a further increase in response to the move to the trial augmentation point. **Flows at Site 7 appear to be sustained reasonably until 8th September, after which they declined.**

The detail from the flow gauging data shows a complex picture with potential influences from rainfall, management of structures and inherent difficulties in measuring low flows. However, the flow data generally indicate a benefit to flows in the River Ems from augmentation which declines through time through the course of the summer drought and when hot, dry weather was experienced (virtually no rainfall through July and August and low rainfall in September 2022). The flow data collected appear to suggest that moving the augmentation point to the trial location downstream, may help sustain flows for a longer duration from location Site 2a down to the gauging station.

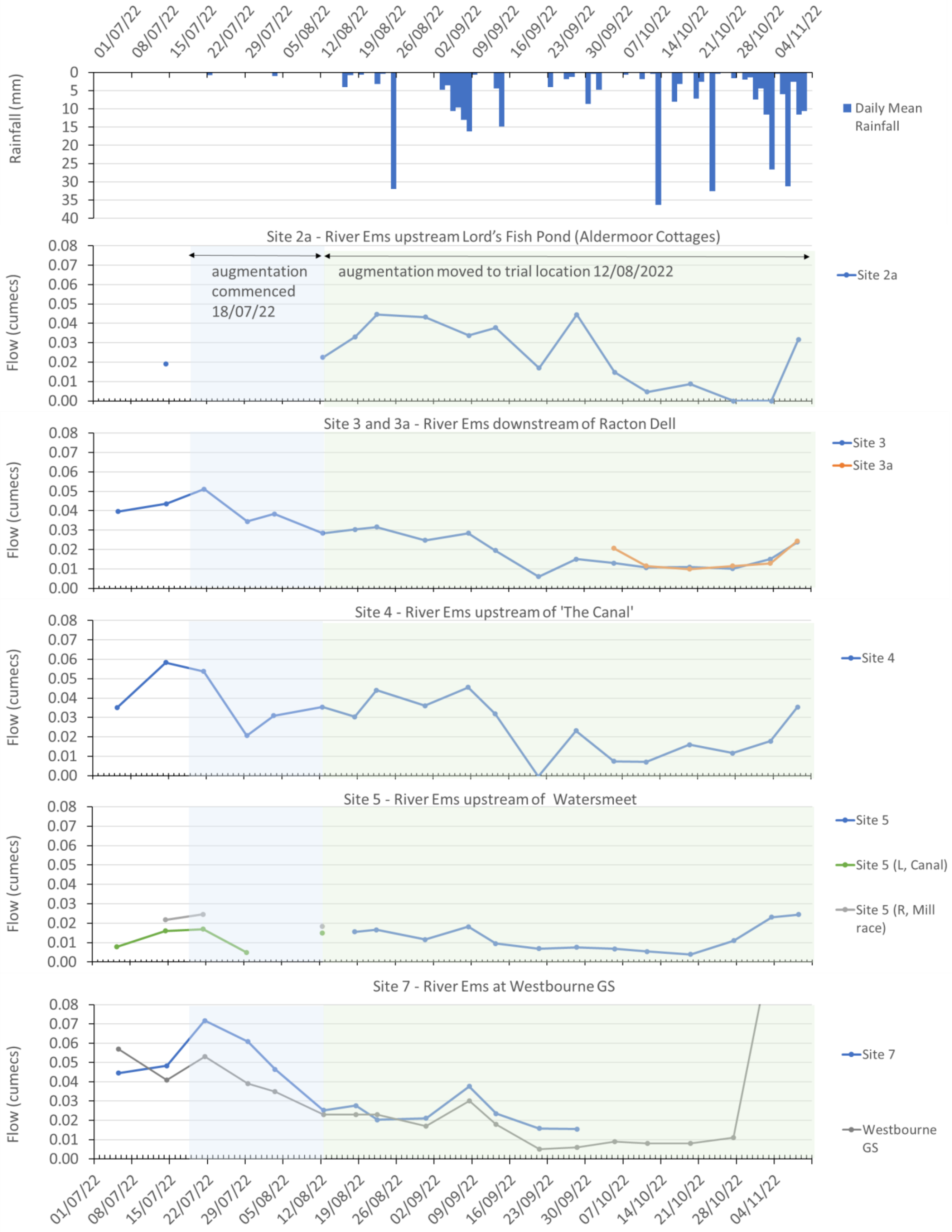


Figure 4-1 – Spot flow gauging data at each Site along the River Ems

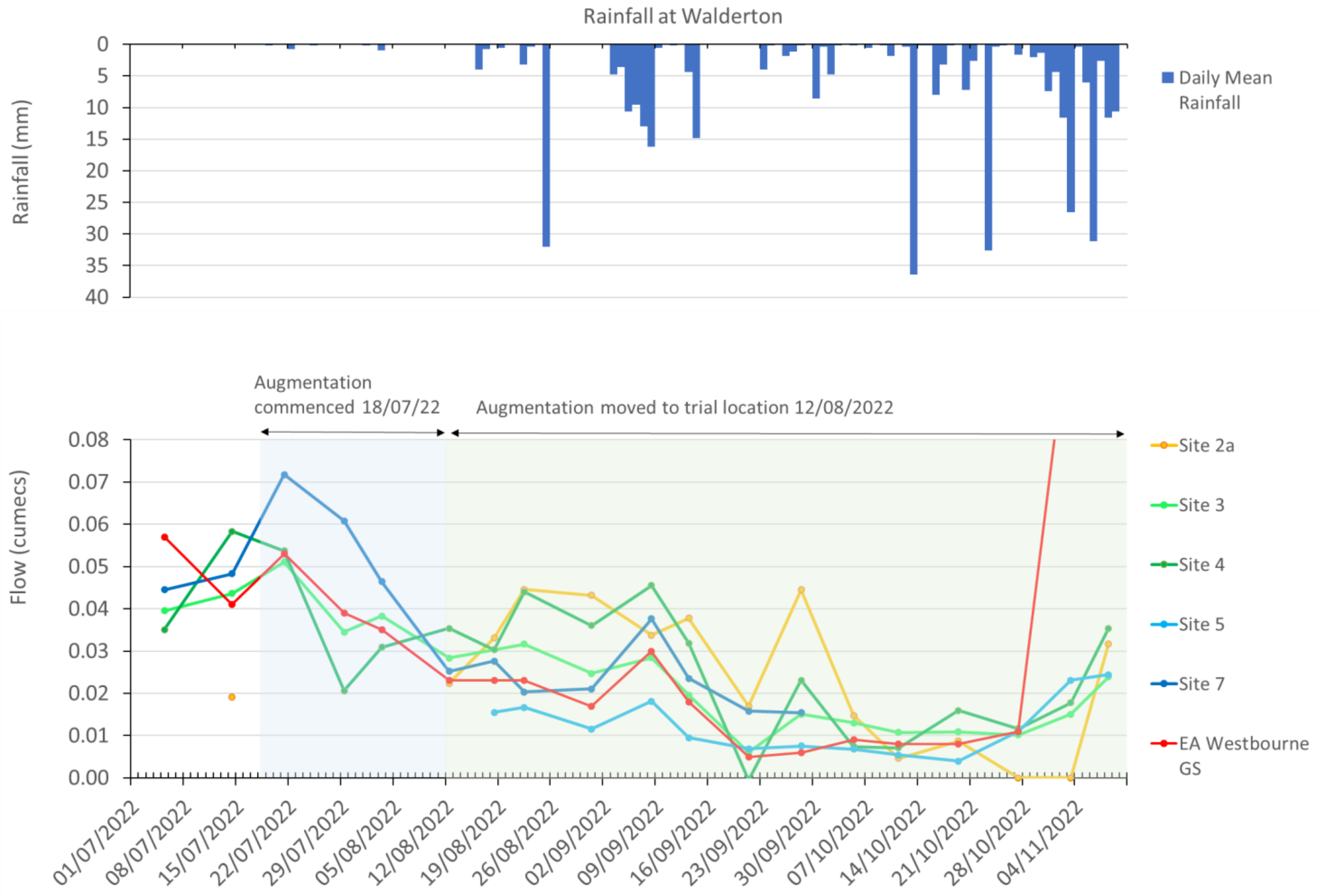


Figure 4-2 – Combined spot flow gauging data for the River Ems

Figure 4-2 indicates that flows are generally lost downstream i.e. flows are typically higher at Site 2a than at Site 3 or the Westbourne gauging station. There are some anomalies in the spot flow record at Site 4 (River Ems upstream of ‘The Canal’) which shows a variable pattern and at Site 5 (upstream of Watersmeet) which shows lower flows than other locations on the River Ems, including at the flow gauging station downstream. The data may reflect flow gauging inaccuracies, water level management or a proportion of bypass flow.

Figure 4-3 shows flow accretion plots for selected dates through the monitoring period. This shows a complex pattern but an increase in flow in response to augmentation can be seen with some losses between Sites 4 and 5 as described previously.

In terms of flow accretion, it is worth noting the Aldsworth Arm appears to have made relatively little contribution to flow in the River Ems throughout the majority of the augmentation period. The Aldsworth Arm was observed to be dry between August and October 2022 (see Table 3-2). Although considered a significant tributary of the River Ems, this is clearly not the case during lower flow periods. Flows in the Aldsworth Arm were observed to increase rapidly in response to rainfall at the end of October, and this will have contributed to the flow peak observed at the Westbourne gauging station on the River Ems.

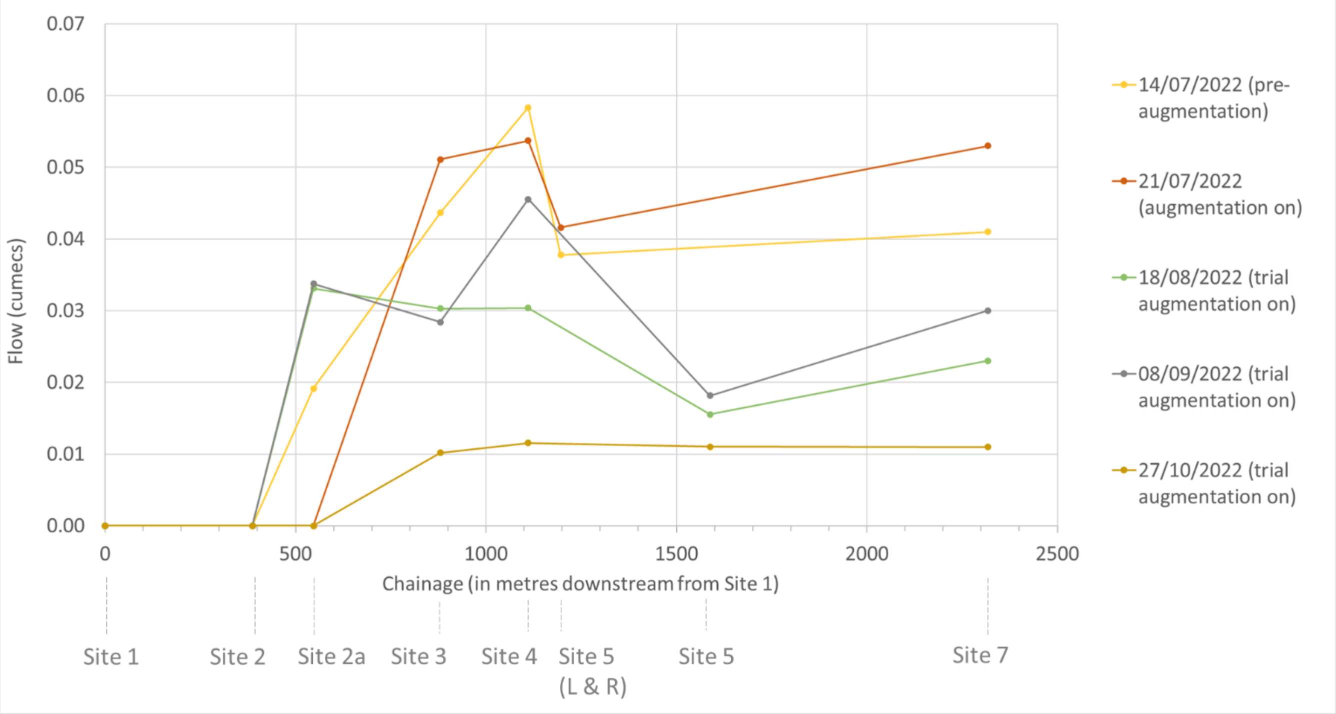


Figure 4-3 – River Ems flow accretion

4.2. Groundwater – surface water interaction

Section 3.3.2 presented groundwater logger data over the augmentation trial period and noted the data from PT10 appeared to show an increase in groundwater level in response to the augmentation. Figure 4-4 presents the surface water flow and level data collected in the vicinity of PT10, together with rainfall to examine this in more detail.

Figure 4-4 indicates that there is a close relationship between groundwater level, river level and flow in the vicinity of PT10 (downstream of Racton Dell), as described below:

- Both the groundwater levels and river levels show an initial decline in levels in July and an increase in response to augmentation starting on 18th July 2022.
- The river level appears to be quick to peak in response to the augmentation (c.1 day), whilst the groundwater response appears to be delayed by approximately 1 day and take 4 days to peak.
- Both river levels and groundwater levels appear to decline from 23rd July 2022, however this can be partly attributed to a temporary reduction in the augmentation discharge rate.
- The river level at PT9 shows an increase in response to augmentation being moved to the trial location on 12th August 2022. Groundwater levels also appear to show a slight increase but this is delayed by approximately two days.
- Both groundwater and surface water levels show peaks in response to rainfall, for example on 25th August, 8th September, 14th September and this is very notable in the groundwater level data.
- The spot flow measurements generally appear to correlate well with the pattern in river levels at the nearby monitoring point PT9, although the spot flow data on 21st September appears slightly lower.

The data presented in Figure 4-4 suggest that the groundwater levels in the shallow monitoring well at PT10 responds to rainfall and changes in river levels, showing a degree of hydraulic connection. The increase in groundwater levels when augmentation first commences, suggests that some water discharged into the river is lost to ground.

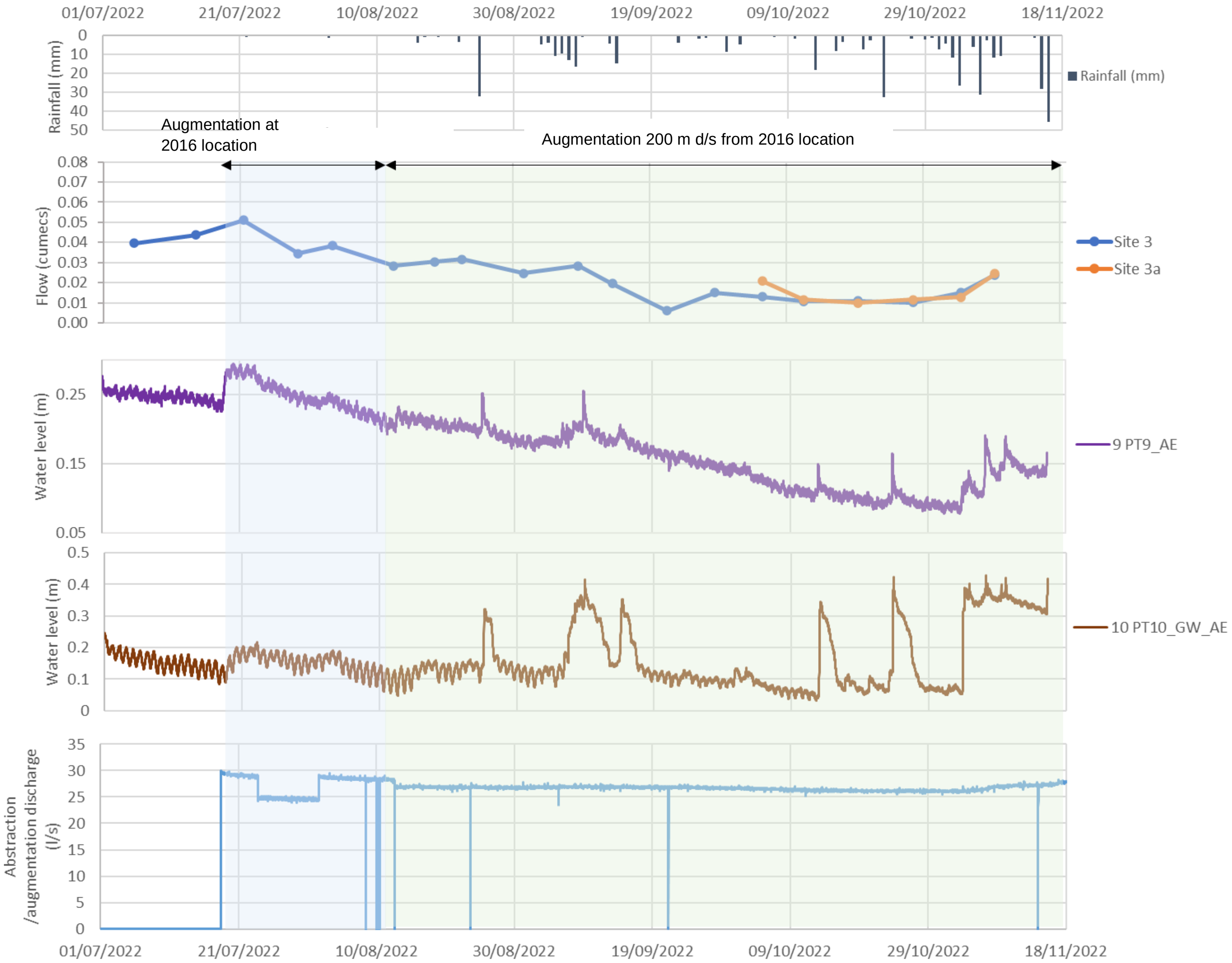


Figure 4-4 – Influence of abstraction, rainfall and augmentation discharge downstream of Racton Dell

The river level data from other monitoring installations were discussed in section 3.4.3. It was noted that PT11 (located downstream from PT 9) appeared to show the same magnitude of water level response to the augmentation start as PT 9 and a larger increase in response to the move to the trial location. Figure 4-5 shows the river level data together with groundwater level data to examine this in more detail.

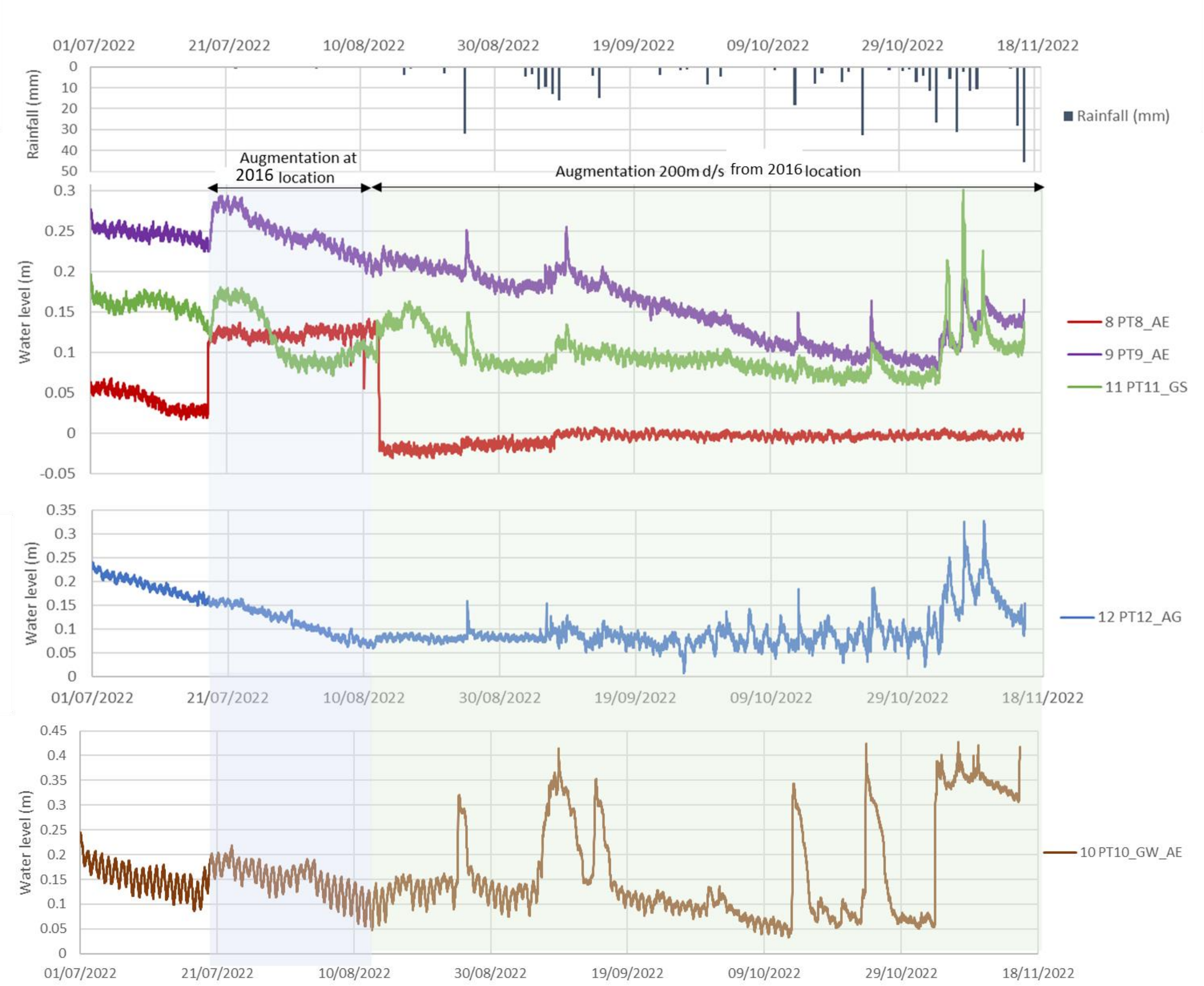


Figure 4-5 – Groundwater and surface water levels along the augmented stretch

It may be that the larger magnitude of water level response at PT11 than at PT9 shown in Figure 4-5 reflects the narrower dimensions of the channel at this location, such that a change in flow has a more pronounced effect, however this would not explain the relative difference in response at the two locations when the augmentation was moved to the trial location. The difference might indicate that rivers levels at PT9 decline over time due to the influence of abstraction from Woodmancote PS and loss of water in the channel to groundwater. This might also explain the steeper rate of decline in river levels over time at PT9 compared to PT11.

It is worth noting that there does appear to be a small increase in water levels at PT12 on 12th August in response to the augmentation being moved to the trial location. This is slightly unexpected as PT12 is recording water levels on the Aldsworth Arm and moreover the channel was reported to be dry at this time (the last recorded spot flow in the river channel at Site 6 was on 3rd August). It is possible (although not certain) that this water level logger was recording very shallow surface water levels (e.g. from ponding or water trapped in the stilling well) or even potentially shallow groundwater levels on 12th August. The stilling well installation has been driven into the river bed. It is interesting that there is a very sharp break in the trend of declining level and step up in the data on 12th August. This suggests that there might be some groundwater connectivity with some water lost to ground in the augmented stretch of the River Ems potentially flowing towards the Aldsworth Arm.

4.3. Influence on flows from augmentation discharge

In order to further consider the extent to which augmentation discharge remains within the river channel, the spot flow record at Site 3, downstream of Racton Dell, has been compared with the flow record at Westbourne gauging station.

The spot flow gauging records presented and discussed in section 4.1 suggest that the spot flow gauging record at Site 3 is fairly reliable as spot flow measurements were made at the same location throughout the monitoring period. In addition, Figure 4-4 showed a good correlation between spot flows at Site 3 and nearby river level monitoring at PT9.

Figure 4-6 presents a comparison between the spot flow record at Site 3 and the daily flow recorded at Westbourne gauging station and shows the average augmentation discharge from Woodmancote on each of the spot flow monitoring dates. Rainfall is also shown for reference.

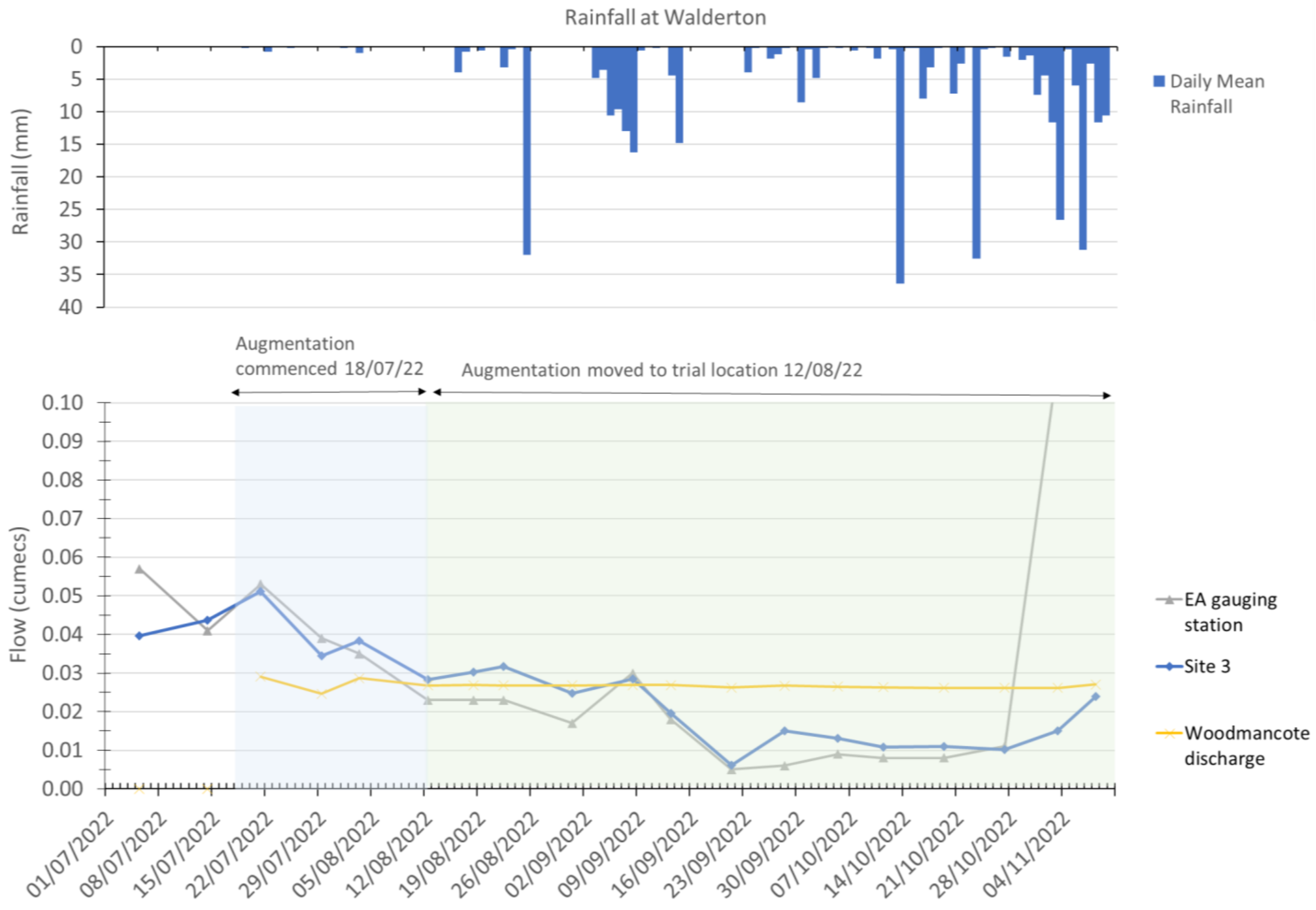


Figure 4-6 – Comparison of river flows and augmentation discharge

From Figure 4-6 it can be seen that:

- Similar flows are recorded at Site 3 and the Westbourne gauging station, with both following the same pattern of decline in flow through the summer drought.
- At the start of the augmentation period, flows at both Site 3 and the downstream gauging station are greater than the volume of augmentation discharge.
- **By 12th August 2022, flows at the gauging station had dropped below the volume of augmentation discharge**, indicating that not all the water being discharged to the river channel was reaching the gauging station. **This change is not necessarily a function of the augmentation discharge move, but likely due to the increased drying of the river and its catchment over time through the drought conditions.**
- After 8th September 2022, flows at both Site 3 and the downstream gauging station had dropped substantially below the volume of augmentation discharge **suggesting a loss of augmentation water through the river bed upstream of Site 3.**

Table 4-1 summarises the percentage change in flow relative to augmentation discharge. The results of the following calculations are shown:

- Difference between flow at Site 3 and augmentation discharge quantity, as % of augmentation discharge
- Flow lost between Site 3 and Westbourne gauging station, as % of augmentation discharge

- Difference between flow at Westbourne gauging station and augmentation discharge quantity, as % of augmentation discharge

Table 4-1 – Flow gains and losses compared to augmentation flow

Date	Status of augmentation	In period rainfall (mm)	Augmentation compared to Site 3 (d/s Racton Dell) flow	Flow at Site 3 compared to flow at Westbourne GS	Augmentation compared to Westbourne GS flow
			Flow lost (-) or gained (+) as % of augmented flow		
05/07/2022	Off	N/A	N/A no augmentation		
14/07/2022	Off	0	N/A no augmentation		
21/07/2022	On (2016 Location)	0.2	76%	4%	83%
29/07/2022		1.0	40%	13%	58%
03/08/2022		1.2	34%	-9%	22%
12/08/2022	On (Trial Location)	0	6%	-19%	-14%
18/08/2022		0	13%	-24%	-15%
22/08/2022		8.6	18%	-27%	-14%
31/08/2022		32.4	-8%	-31%	-37%
08/09/2022		57.8	6%	6%	11%
13/09/2022		5.2	-27%	-8%	-33%
21/09/2022		14.8	-77%	-18%	-81%
28/09/2022		7.4	-44%	-60%	-78%
05/10/2022		14.2	-51%	-31%	-66%
11/10/2022		2.6	-59%	-26%	-70%
19/10/2022		48.6	-58%	-27%	-69%
27/10/2022		44.6	-61%	8%	-58%
03/11/2022		53.4	-42 %	635%	325%
08/11/2022		51.8	-12%	444%	381%

Table 4-1 is another way of looking at the data presented in Figure 4-6. It is a simplistic representation based on spot flow data and does not specifically account for any other influences on flow (although rainfall data is shown for comparison). The data do indicate that the upper reach (from augmentation to Site 3) gains significantly when the augmentation is switched on, whilst the reach below Site 3 either gains a small amount or loses as time progresses. The percentage of augmentation water reaching the gauging station declines with time (July to September) with most losses initially occurring downstream of Site 3. After 13th September, there appears to be a much greater percentage of augmented flow lost between the augmentation point and Site 3. The somewhat binary change at Site 3 in early September might be indicative of change in behaviour, potentially as groundwater levels drop and springs in Racton Dell become sinks.

Figure 4-6 and Table 4-1 both show the influence of rainfall at the end of October resulting in a large increase in flows at the gauging station. The response to rainfall was not instantaneous with most benefit shown in the downstream reaches. The large increase in flows at the gauging station compared to the spot flow gauging locations suggests a large runoff component is reaching the gauging station. The response is thought to indicate the start of autumn recharge, with groundwater levels gradually responding and providing increasing flows in the upper parts of the catchment.

5. Ground investigation

5.1. Investigation purpose

To support the augmentation trial, a ground investigation (GI) was undertaken to obtain more information about the geology in the vicinity of the augmentation discharge. The aim was to investigate the boundary between the comparatively impermeable Lambeth Group, which is mapped in the lower augmented reach, and the more permeable Chalk in the upper reaches. This was to ascertain whether the augmentation discharge was discharging directly on to the Chalk and thus being more readily lost to ground, or on to less permeable Lambeth Group deposits.

The intention was that obtaining additional geological information would support an evidence-based approach and installing monitoring installations would enable data to be collected to help characterise the surface water and groundwater interactions.

5.2. Methodology

A total of four boreholes were drilled along the augmented reach. The southernmost borehole (BH1) was drilled to confirm the presence of the Lambeth Group. The central boreholes (BH3, BH4, BH5) were intended to confirm the mapped Lambeth-Chalk boundary. A dynamic approach was adopted with the results of each borehole informing the next. Figure 5-1 summarises the targeted borehole locations with mapped geology (noting that BH2 was not drilled).

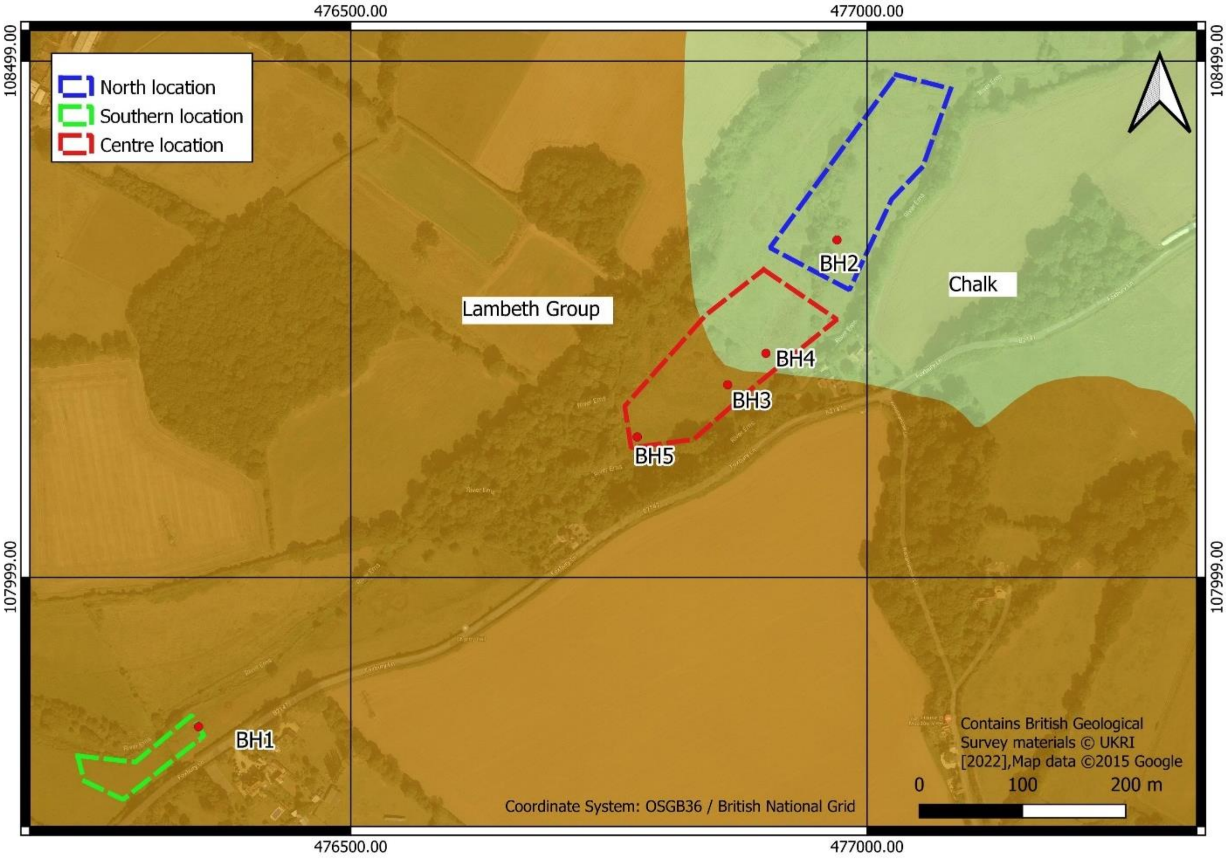


Figure 5-1 - Targeted ground investigation locations with BGS mapped geology

5.3. Results

The boreholes were drilled between 7th and 11th November 2022 using a multi-utility rig. Heavy rainfall (both preceding and during the site work) resulted in soft ground and some delay to the drilling progress. The encountered geology proved to be different to the mapped geology, and drilling BH2 was considered unnecessary. Four boreholes were drilled in total, three (BH1,4 and 5) were completed as monitoring installations and instrumented with data loggers measuring groundwater level, the other (BH3) was backfilled. The results of the GI are summarised in Table 5-1. Borehole logs are provided in Appendix B.

Table 5-1 - Ground investigation results

Borehole	Expected (BGS Mapped)	Encountered (GI)	Comments
BH1	Lambeth	Lambeth	As expected, i.e. GI aligns with BGS map
BH3	Lambeth	Chalk	Not as expected. GI confirmed Chalk where BGS predicts Lambeth. A thin weathered horizon was found on top of structural Chalk (which was 'blocky').
BH4	Chalk	Chalk	As expected, i.e. GI aligns with BGS map
BH5	Lambeth	Chalk	Not as expected. GI confirmed no Lambeth Group where previously mapped. This means Chalk was still found just north / upgradient of Racton Dell and identifies the Chalk boundary to be at least 200 m further downstream than previously thought. GI confirmed putty Chalk (weathered chalk with high clay content) on top of structural Chalk (blocky).

5.4. Interpretation

Establishing the difference in the mapped vs encountered geology has proved to be very useful and has identified that the Chalk-Lambeth boundary is at least ~200 m further downstream than previously thought. BH5 encountered Chalk and was the most southerly location that could be accessed upstream of Racton Dell. The location of the Chalk-Lambeth boundary is uncertain but there is a reasonable chance that the boundary may lie within Racton Dell itself, as this is where various springs are encountered. Figure 5-2 and Figure 5-3 show the revised geological understanding with the dashed lines indicating potential locations for the extent of the Chalk. These are purely indicative.

On the assumption that the geology encountered adjacent to the river continues to the river itself, the results from the GI show that both the 2016 augmentation location and the trial augmentation location discharge on to the Chalk bedrock. The trial augmentation location results in the augmentation discharge flowing a shorter distance over the more permeable Chalk bedrock where water is considered more likely to be lost to the ground under low groundwater conditions.

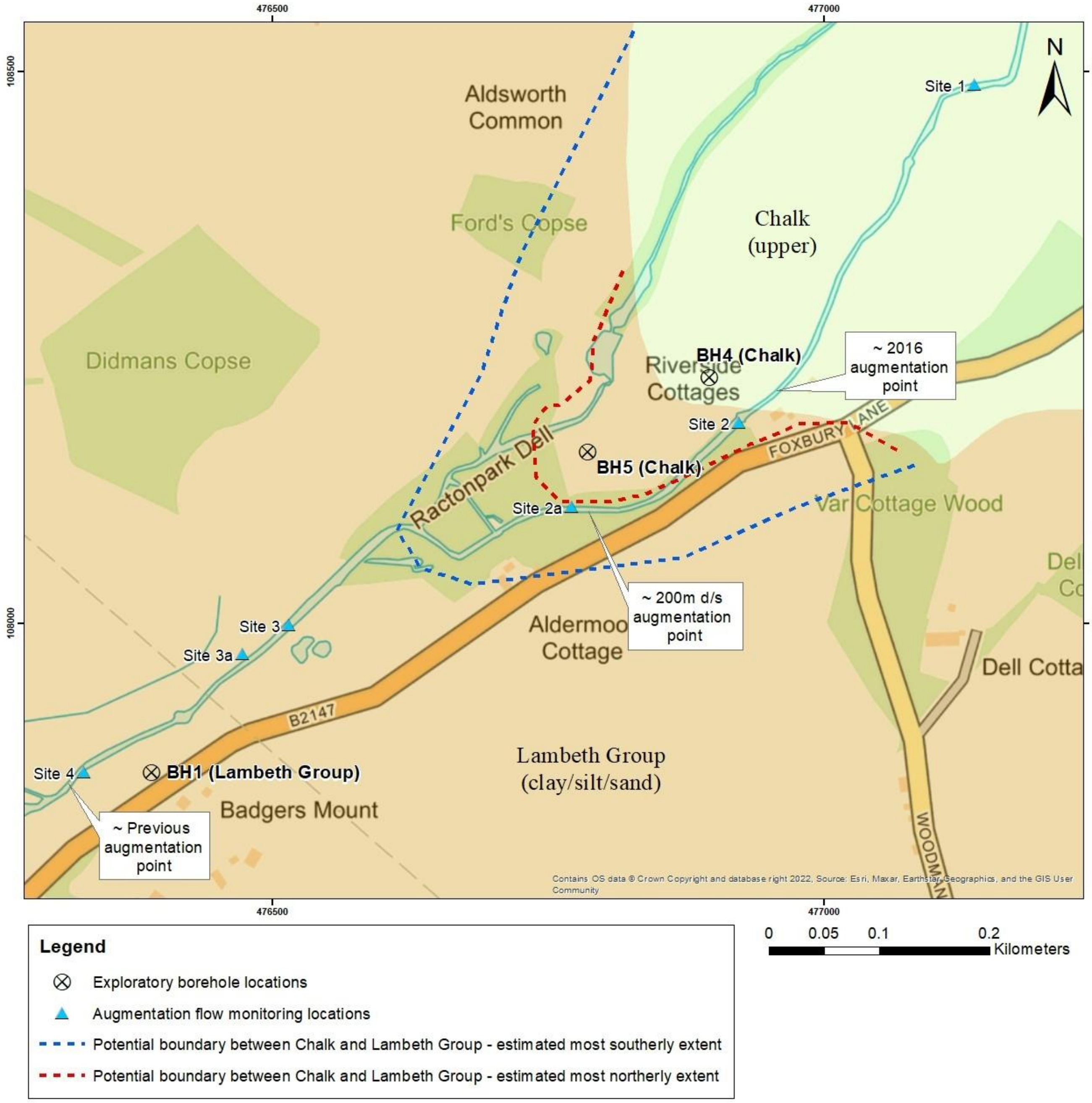


Figure 5-2 - Revised geological understanding – aerial view (indicative)

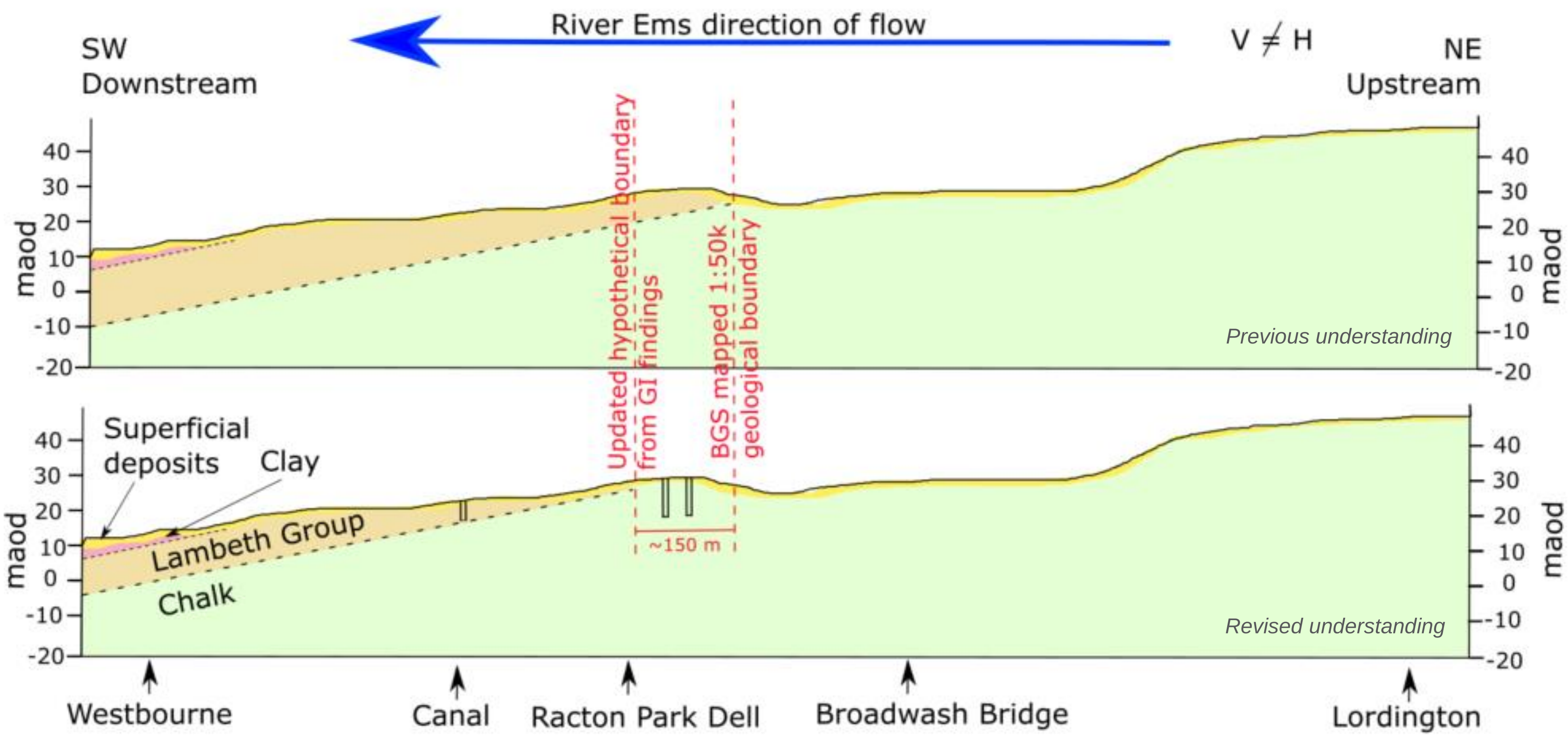


Figure 5-3 – Revised geological understanding – cross section (indicative)

6. Concluding summary

An augmentation trial was undertaken on the River Ems during the drought period in 2022 with extensive weekly spot flow monitoring undertaken in the reach between Broadwash Bridge and the EA Westbourne gauging station over a period of 19 weeks between 5th July and 9th November 2022.

The augmentation trial has provided a valuable record of flow conditions during the 2022 summer drought and greatly increased the understanding of fate of augmentation discharge and flow characteristics of this stretch of the River Ems. The ground investigation provided geological evidence to support the observed flow behaviour.

The key points from the augmentation trial are summarised in the following sections.

6.1. General observations

The following general observations can be made:

- Drought conditions were experienced in 2022 and the River Ems augmentation scheme was triggered on 18th July 2022 as flows at Westbourne gauging station dropped below 31 l/s (2,678 m^3/day).
- There was virtually no rainfall through most of July and August and most of the August rainfall was recorded in one event at the end of the month. There were smaller rainfall events in September and early October with a larger rainfall event towards the end of October and further large events in November.
- Augmentation initially commenced at the licensed (2016) discharge location and flow monitoring indicated that flow was not retained in the channel adjacent to Riverside Cottages. Instead, flow was observed downstream of Lord’s Fish Pond. The data appear to suggest a loss to permeable chalk at the 2016 augmentation location. This is supported by the results from the 2022 GI.
- A Local Enforcement Position to trial a new augmentation scheme discharge point for the River Ems was agreed with the Environment Agency and augmentation was switched to the trial location, 200m downstream on 12th August 2022. The new discharge location took into account the hydraulic limitations of extending the pipework along the river bed and the desire to discharge upstream of Racton Dell to maintain the Lord’s Pond within it and protect Racton Dell ecology.
- The spot flow data indicated a benefit to flows in the River Ems from augmentation throughout the stretch from Site 2a (River Ems 200 m d/s from the original augmentation point, upstream of Racton Dell) to the gauging station at Westbourne. The amount of benefit provided declined over time through the course of the summer 2022 drought.
- Augmentation flows were lost downstream along the River Ems. Flows were typically higher at Site 2a than at Site 3 (River Ems downstream of Racton Dell), indicating a loss to ground within this reach. The GI results indicated that Site 2a may still be on permeable Chalk.
- The 2022 GI showed that the Chalk outcrop extended further south than on BGS mapped bedrock geology and potentially the Chalk – Lambeth Group boundary lies within/close to Racton Dell.
- The shallow groundwater level data available at Site 3 (the only location where groundwater level data were available in the augmented reach) show there is a degree of hydraulic connection between surface and groundwater and supports the understanding that some augmentation flow discharged into the river is lost to ground.
- Flows at Site 3 were similar to those observed at Westbourne gauging station, although there is some evidence to indicate further losses to ground downstream of Site 3.
- The river level data (from data loggers) appear to support the conceptual understanding that the benefit of augmentation may decline over time due to loss of water in the channel to ground.
- Augmentation ceased on 22nd November 2022, after flows at Westbourne gauging station had risen above 38 l/s (3,283 m^3/day) and there was evidence of rainfall recharge and flow recovery within the catchment.

6.2. Observations on 2022 trial to change the augmentation location

The flow data collected appear to suggest that moving the augmentation point to the trial location downstream, may help sustain flows in the river for longer, although ultimately there are still flow losses before reaching the gauging station at Westbourne. In terms of specific observations, based on 2022 data:

- The flows at Site 2a and Site 3 appeared to be sustained for four to five weeks following the move to the trial augmentation location in 2022. When compared to the original location, flows had started to decline following augmentation from the 2016 discharge location after two weeks. **This suggests that flows may be sustained for longer at the trial augmentation point before they decline.**

- Comparison of spot flow data from Site 3 and flows at the Westbourne gauging station showed both sites registered a small increase in flows in response to the augmentation being moved to the trial location. **The move to the trial augmentation point appeared to slow the rate of decline at Site 3 and the Westbourne gauging station and to sustain flows for longer.**

6.3. Other observations and hypotheses

It is clear from the data collected during the augmentation trial that the pattern of flows along the River Ems shows a complex pattern with gains and losses. Groundwater levels and flow in different stretches of the river are subject to a variety of influences including rainfall, groundwater abstraction, augmentation discharge and the management of structures.

A number of other observations were made from the data for which hypotheses are put forward below.

6.3.1. Potential switch from springs to sinks around Racton Dell

The observed flow behaviour at Site 3 is quite unusual. The sudden switch from flows being supported by augmentation discharge to showing a loss is reminiscent of karstic behaviour. It is hypothesised that as groundwater levels drop, the springs in Racton Dell could potentially become sinks.

The area around Racton Dell is hydrologically complex with a number of different springs as well as a small tributary which feeds some historical watercress beds and can have substantial flows at times. There is a clear link between groundwater and surface water with a route for groundwater discharge which could potentially be reversed, leading to a loss of surface water to ground. The likely localised variation in the thickness of geological deposits and the presence of clays/putty chalk from weathering may contribute to the hydrological behaviour observed at Racton Dell. It is possible that isolated pockets of thicker clay may retain water in the channel and areas of thin to no clay may potentially lead to localised water loss.

6.3.2. Potential for bypass flow around Mill Pond

There were some anomalies in the spot flow record at Site 4 (River Ems upstream of ‘The Canal’) and at Site 5 (River Ems upstream of Watersmeet). Site 5 showed lower flows than other locations on the River Ems, including at the flow gauging station downstream. Whilst the data may reflect difficulty in gauging at these locations and/or the influence from structures in the channel, it could also indicate that some flow may be lost to ground in this stretch and return to the River Ems downstream (perhaps flowing in a paleochannel). This would not be entirely unexpected considering the historical modification to the channel towards Westbourne Mill, seen by the sharp change in direction of the river channel at this location.

6.3.3. Groundwater flow to the Aldsworth Arm

Flow contributions from the Aldsworth Arm (Site 6) to the River Ems were relatively low throughout the majority of the augmentation period and the channel was observed to be largely dry between August and October 2022. The level data collected indicate a possibility that there may be some groundwater flow (supported by losses from the augmentation discharge) from the River Ems towards the Aldsworth Arm.

6.4. Next steps

The augmentation trial undertaken on the River Ems has greatly increased understanding of the fate of augmentation discharge and flow characteristics of the Middle Ems between Broadwash Bridge and the confluence with the Aldsworth Arm.

The ground investigation has also provided evidence that supports the flow data and helps explain initial high losses from augmentation discharge in the River Ems channel.

The augmentation trial and ground investigation has indicated that there are a variety of influences on groundwater level and flow that need to be considered in conjunction with the original conceptual understanding of how the augmentation scheme operates at the 2016 location. The conceptual understanding and updates from the trial augmentation are both presented in Appendix C.

The intention is that the results of this augmentation trial will be used by Portsmouth Water and the Environment Agency to consider the relative merits of augmentation of the River Ems and the optimal location for future augmentation. The data can also be used to determine how augmentation discharge can be used most appropriately to support flows in the River Ems and to inform new licence conditions.

7. References

AMEC (2013). Portsmouth Water PIM and WFD Investigations.

Atkins (2021). River Ems Flow Investigation Phase 1 Baseline Report. Draft report to Portsmouth Water.

Atkins (2022). Augmentation failure conceptual understanding. Annotated conceptual diagram.

Holmes, N. (2007). Environmental Quality Appraisal of the River Ems.

UK Centre for Ecology and Hydrology (2022). Hydrological summary for the United Kingdom: August 2022 [Monthly Hydrological Summaries | National River Flow Archive (ceh.ac.uk)]

Appendices

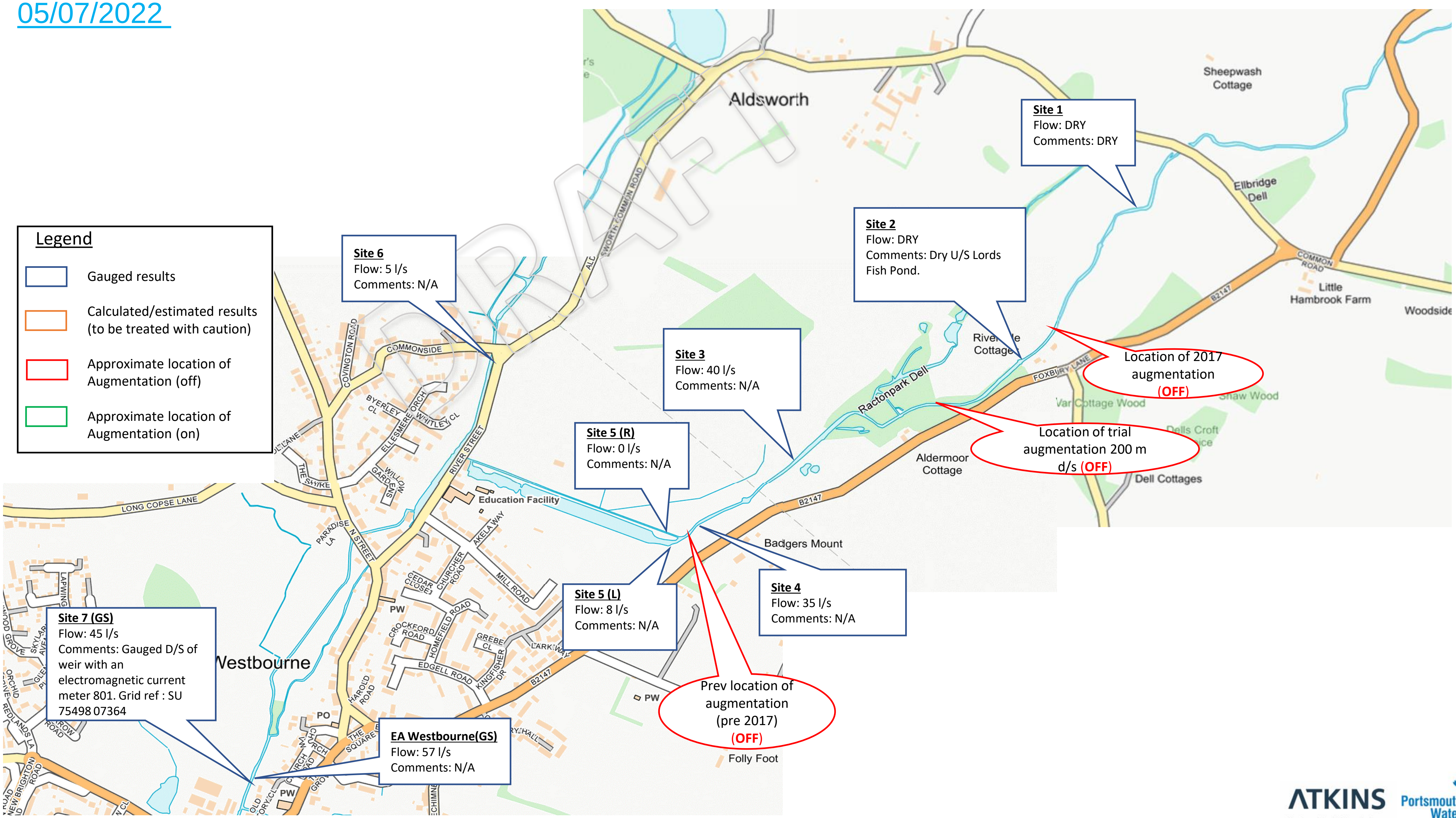
Appendix A. Spot flow gauging results

A.1. Annotated maps

05/07/2022

Legend

🟦	Gauged results
🟧	Calculated/estimated results (to be treated with caution)
🟥	Approximate location of Augmentation (off)
🟩	Approximate location of Augmentation (on)



Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: Dry U/S Lords Fish Pond.

Site 3
Flow: 40 l/s
Comments: N/A

Site 4
Flow: 35 l/s
Comments: N/A

Site 5 (R)
Flow: 0 l/s
Comments: N/A

Site 5 (L)
Flow: 8 l/s
Comments: N/A

Site 6
Flow: 5 l/s
Comments: N/A

Site 7 (GS)
Flow: 45 l/s
Comments: Gauged D/S of weir with an electromagnetic current meter 801. Grid ref : SU 75498 07364

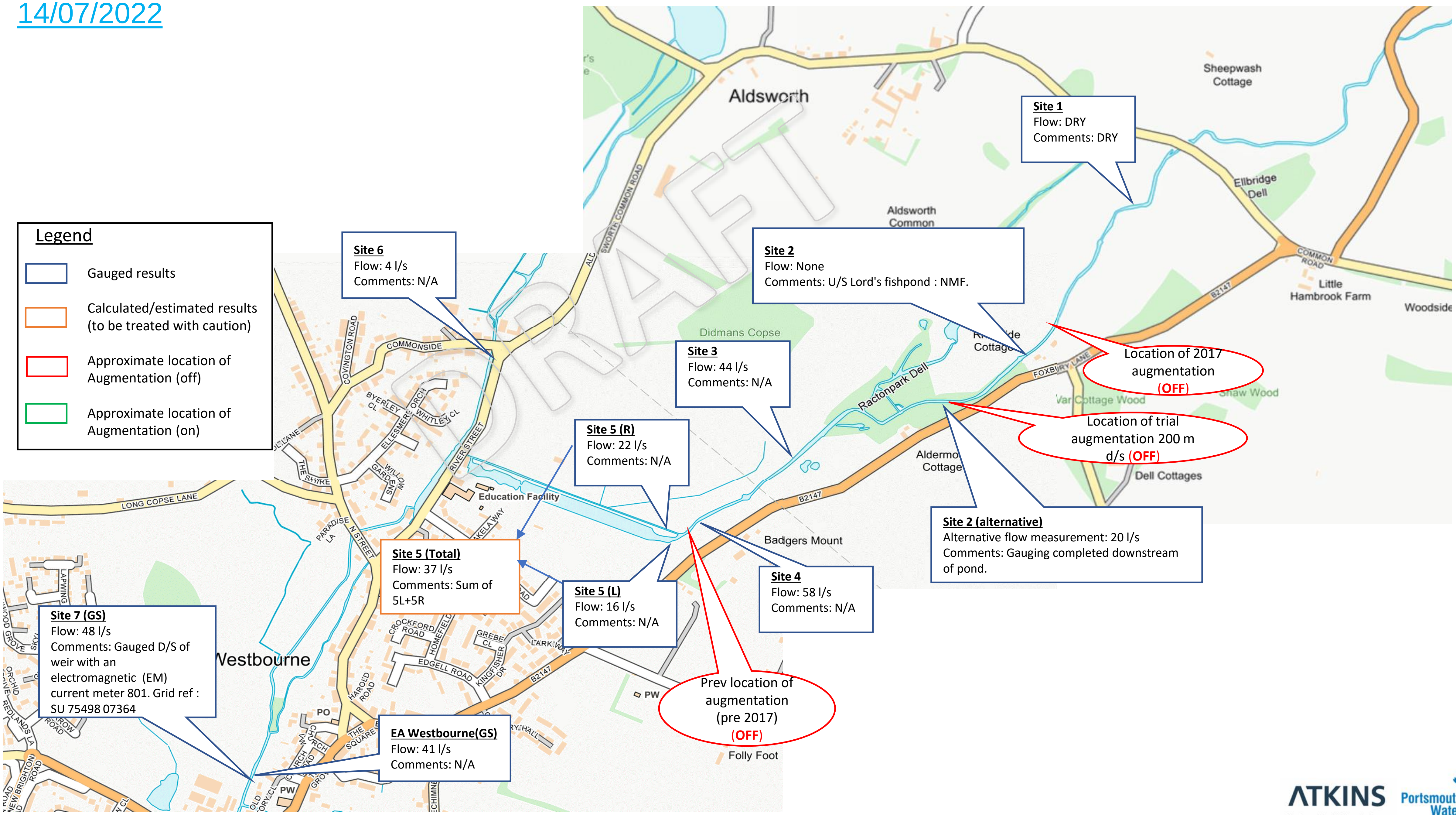
EA Westbourne(GS)
Flow: 57 l/s
Comments: N/A

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (OFF)

Prev location of augmentation (pre 2017) (OFF)

14/07/2022



Legend

- 🟦 Gauged results
- 🟧 Calculated/estimated results (to be treated with caution)
- 🟥 Approximate location of Augmentation (off)
- 🟩 Approximate location of Augmentation (on)

Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: None
Comments: U/S Lord's fishpond : NMF.

Site 2 (alternative)
Alternative flow measurement: 20 l/s
Comments: Gauging completed downstream of pond.

Site 3
Flow: 44 l/s
Comments: N/A

Site 4
Flow: 58 l/s
Comments: N/A

Site 5 (R)
Flow: 22 l/s
Comments: N/A

Site 5 (L)
Flow: 16 l/s
Comments: N/A

Site 5 (Total)
Flow: 37 l/s
Comments: Sum of 5L+5R

Site 6
Flow: 4 l/s
Comments: N/A

Site 7 (GS)
Flow: 48 l/s
Comments: Gauged D/S of weir with an electromagnetic (EM) current meter 801. Grid ref : SU 75498 07364

EA Westbourne(GS)
Flow: 41 l/s
Comments: N/A

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (OFF)

Prev location of augmentation (pre 2017) (OFF)

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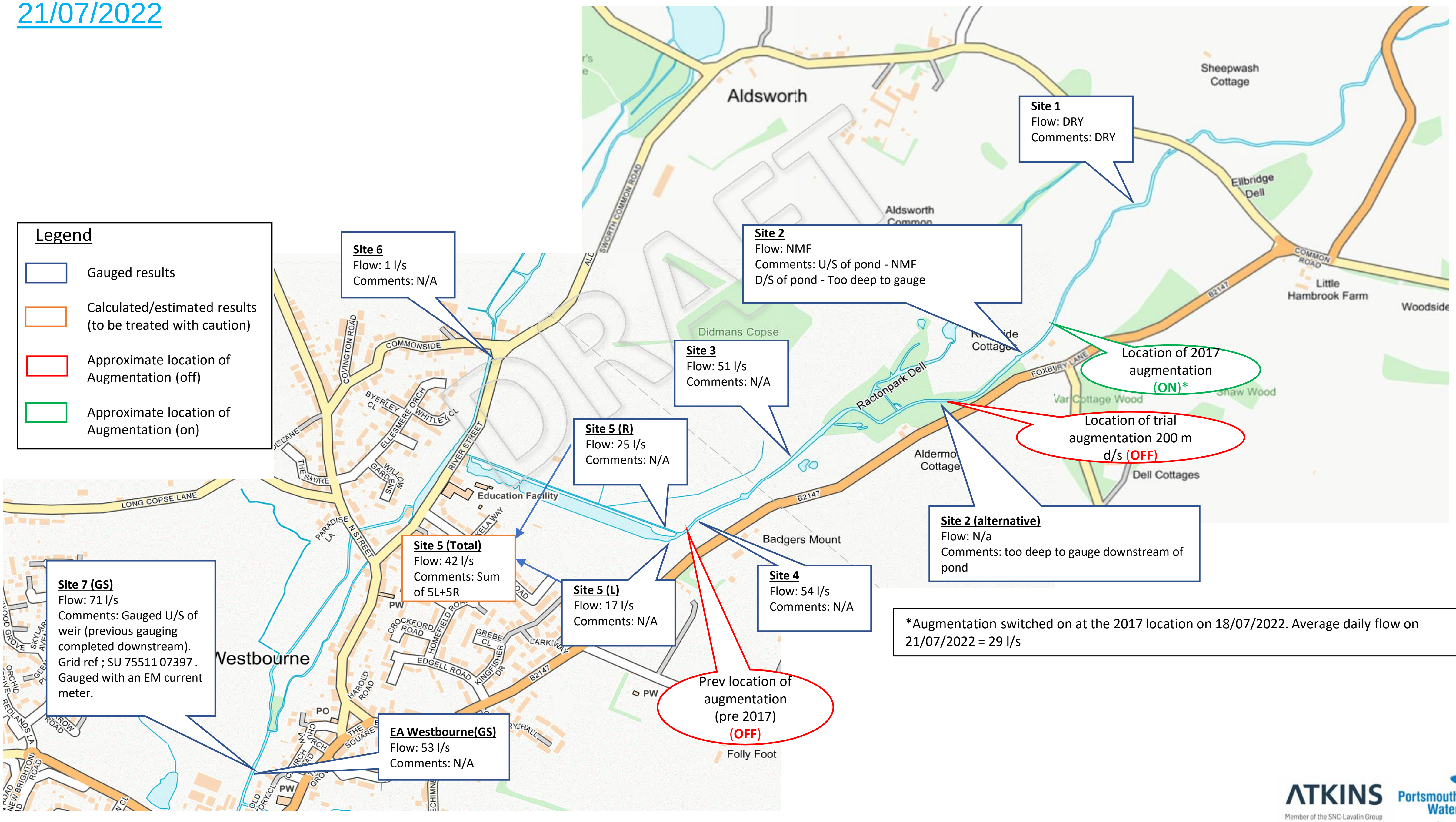
21/07/2022



Legend

🟦	Gauged results
🟧	Calculated/estimated results (to be treated with caution)
🟥	Approximate location of Augmentation (off)
🟩	Approximate location of Augmentation (on)

Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: NMF
Comments: U/S of pond - NMF
D/S of pond - Too deep to gauge

Site 6
Flow: 1 l/s
Comments: N/A

Site 3
Flow: 51 l/s
Comments: N/A

Location of 2017 augmentation (ON)*

Site 5 (R)
Flow: 25 l/s
Comments: N/A

Location of trial augmentation 200 m d/s (OFF)

Site 2 (alternative)
Flow: N/a
Comments: too deep to gauge downstream of pond

Site 5 (Total)
Flow: 42 l/s
Comments: Sum of 5L+5R

Site 7 (GS)
Flow: 71 l/s
Comments: Gauged U/S of weir (previous gauging completed downstream). Grid ref ; SU 75511 07397 . Gauged with an EM current meter.

Site 5 (L)
Flow: 17 l/s
Comments: N/A

Site 4
Flow: 54 l/s
Comments: N/A

Prev location of augmentation (pre 2017) (OFF)

EA Westbourne(GS)
Flow: 53 l/s
Comments: N/A

*Augmentation switched on at the 2017 location on 18/07/2022. Average daily flow on 21/07/2022 = 29 l/s

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29/07/2022

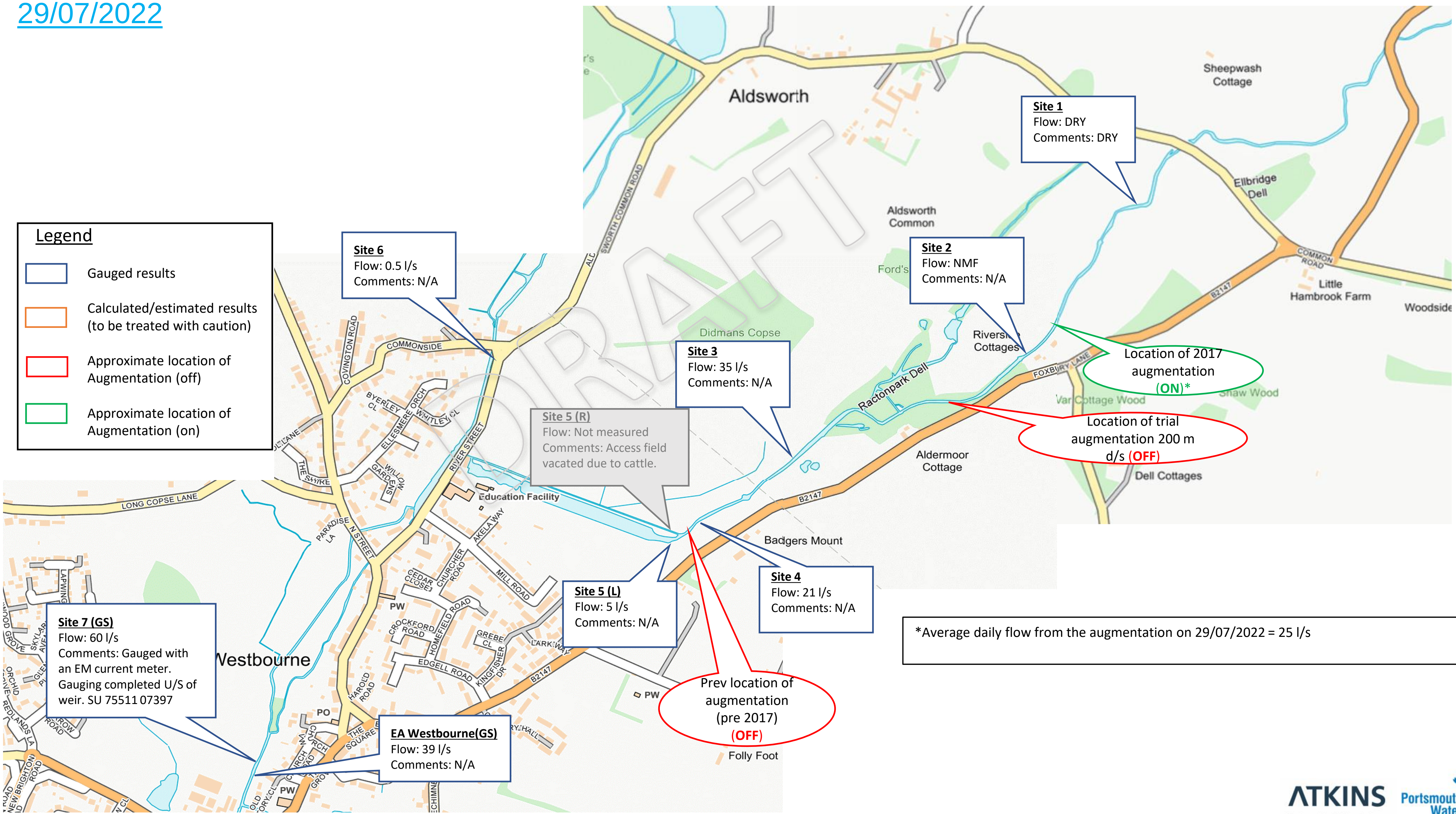
Legend

🟦 Gauged results

🟧 Calculated/estimated results (to be treated with caution)

🟥 Approximate location of Augmentation (off)

🟩 Approximate location of Augmentation (on)



Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: NMF
Comments: N/A

Site 3
Flow: 35 l/s
Comments: N/A

Site 4
Flow: 21 l/s
Comments: N/A

Site 5 (R)
Flow: Not measured
Comments: Access field vacated due to cattle.

Site 5 (L)
Flow: 5 l/s
Comments: N/A

Site 6
Flow: 0.5 l/s
Comments: N/A

Site 7 (GS)
Flow: 60 l/s
Comments: Gauged with an EM current meter. Gauging completed U/S of weir. SU 75511 07397

EA Westbourne(GS)
Flow: 39 l/s
Comments: N/A

Location of 2017 augmentation (ON)*

Location of trial augmentation 200 m d/s (OFF)

Prev location of augmentation (pre 2017) (OFF)

*Average daily flow from the augmentation on 29/07/2022 = 25 l/s

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03/08/2022

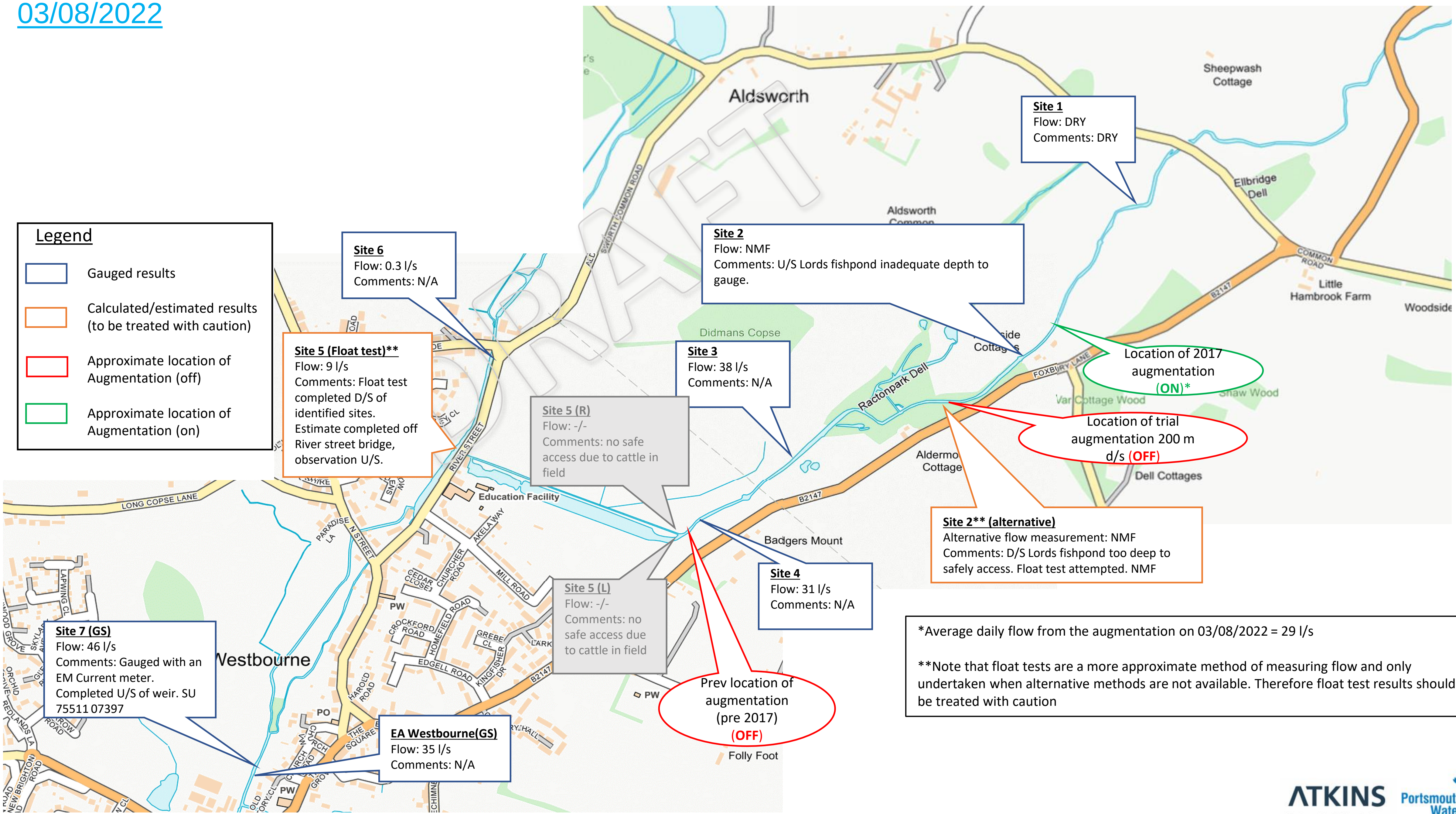
Legend

🟦 Gauged results

🟧 Calculated/estimated results (to be treated with caution)

🟥 Approximate location of Augmentation (off)

🟩 Approximate location of Augmentation (on)



Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: NMF
Comments: U/S Lords fishpond inadequate depth to gauge.

Site 6
Flow: 0.3 l/s
Comments: N/A

Site 5 (Float test)**
Flow: 9 l/s
Comments: Float test completed D/S of identified sites. Estimate completed off River street bridge, observation U/S.

Site 3
Flow: 38 l/s
Comments: N/A

Location of 2017 augmentation (ON)*

Site 5 (R)
Flow: -/-
Comments: no safe access due to cattle in field

Location of trial augmentation 200 m d/s (OFF)

Site 2 (alternative)**
Alternative flow measurement: NMF
Comments: D/S Lords fishpond too deep to safely access. Float test attempted. NMF

Site 4
Flow: 31 l/s
Comments: N/A

Site 5 (L)
Flow: -/-
Comments: no safe access due to cattle in field

Site 7 (GS)
Flow: 46 l/s
Comments: Gauged with an EM Current meter. Completed U/S of weir. SU 75511 07397

EA Westbourne(GS)
Flow: 35 l/s
Comments: N/A

Prev location of augmentation (pre 2017) (OFF)

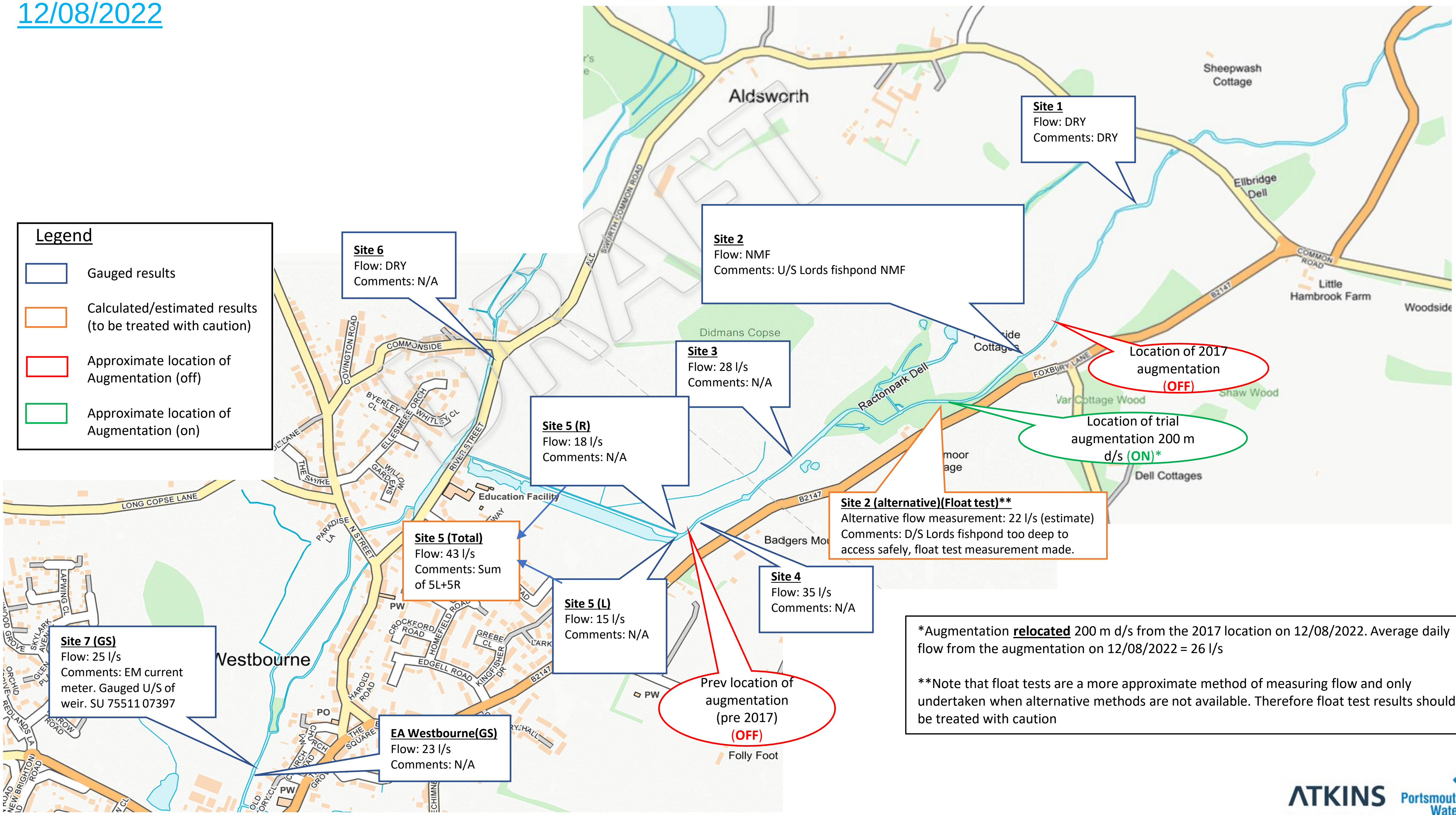
*Average daily flow from the augmentation on 03/08/2022 = 29 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

12/08/2022

Legend

🟦	Gauged results
🟧	Calculated/estimated results (to be treated with caution)
🟥	Approximate location of Augmentation (off)
🟩	Approximate location of Augmentation (on)



Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: NMF
Comments: U/S Lords fishpond NMF

Site 6
Flow: DRY
Comments: N/A

Site 3
Flow: 28 l/s
Comments: N/A

Site 5 (R)
Flow: 18 l/s
Comments: N/A

Site 5 (Total)
Flow: 43 l/s
Comments: Sum of 5L+5R

Site 5 (L)
Flow: 15 l/s
Comments: N/A

Site 4
Flow: 35 l/s
Comments: N/A

Site 2 (alternative)(Float test)**
Alternative flow measurement: 22 l/s (estimate)
Comments: D/S Lords fishpond too deep to access safely, float test measurement made.

Site 7 (GS)
Flow: 25 l/s
Comments: EM current meter. Gauged U/S of weir. SU 75511 07397

EA Westbourne(GS)
Flow: 23 l/s
Comments: N/A

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (ON)*

Prev location of augmentation (pre 2017) (OFF)

*Augmentation **relocated** 200 m d/s from the 2017 location on 12/08/2022. Average daily flow from the augmentation on 12/08/2022 = 26 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

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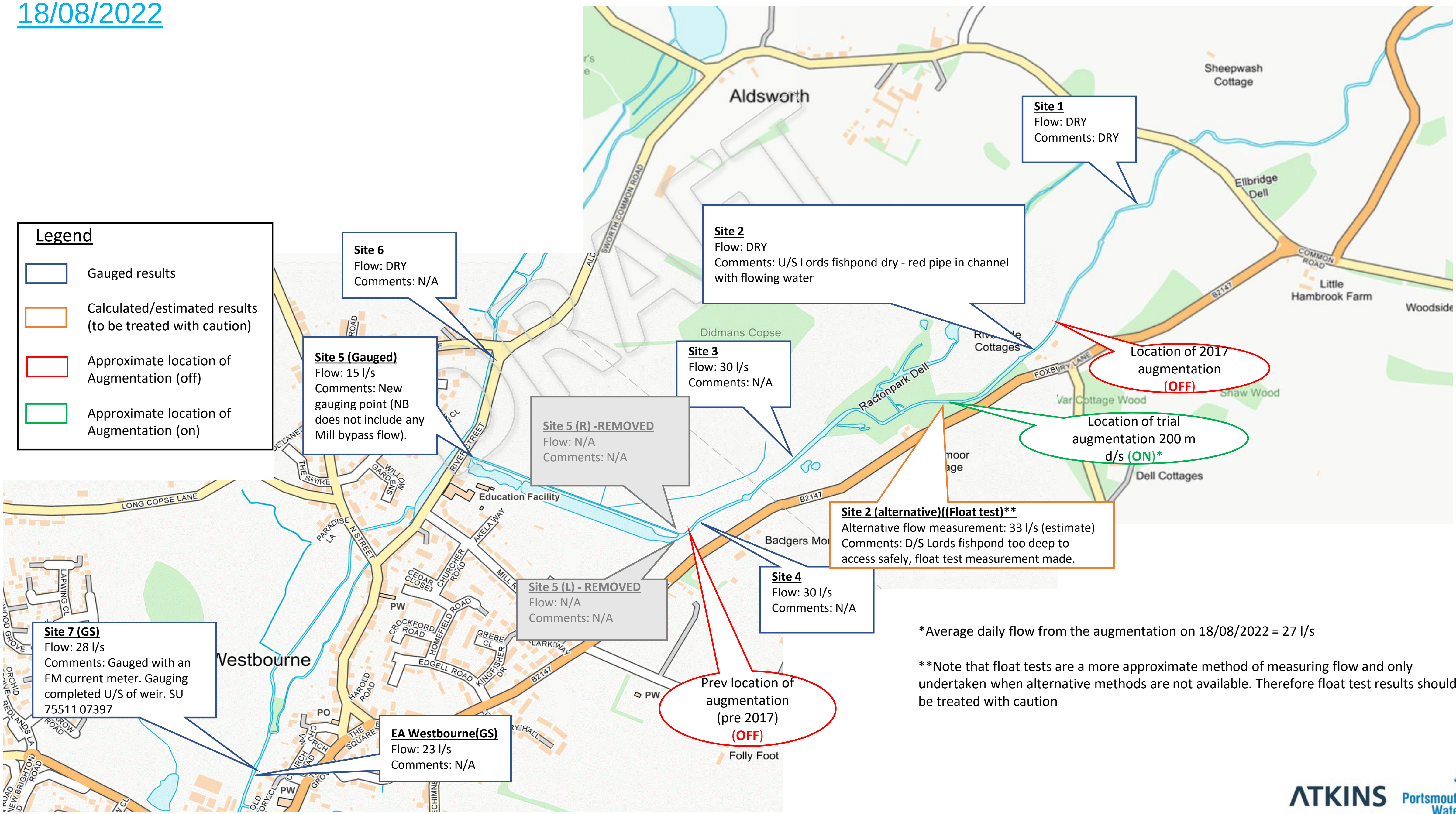
18/08/2022



Legend

🟦 Gauged results

🟧 Calculated/estimated results (to be treated with caution)

🟥 Approximate location of Augmentation (off)

🟩 Approximate location of Augmentation (on)

Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 3
Flow: 30 l/s
Comments: N/A

Site 4
Flow: 30 l/s
Comments: N/A

Site 2 (alternative)((Float test)**
Alternative flow measurement: 33 l/s (estimate)
Comments: D/S Lords fishpond too deep to access safely, float test measurement made.

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 5 (Gauged)
Flow: 15 l/s
Comments: New gauging point (NB does not include any Mill bypass flow).

Site 6
Flow: DRY
Comments: N/A

Site 7 (GS)
Flow: 28 l/s
Comments: Gauged with an EM current meter. Gauging completed U/S of weir. SU 75511 07397

EA Westbourne(GS)
Flow: 23 l/s
Comments: N/A

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (ON)*

Prev location of augmentation (pre 2017) (OFF)

*Average daily flow from the augmentation on 18/08/2022 = 27 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

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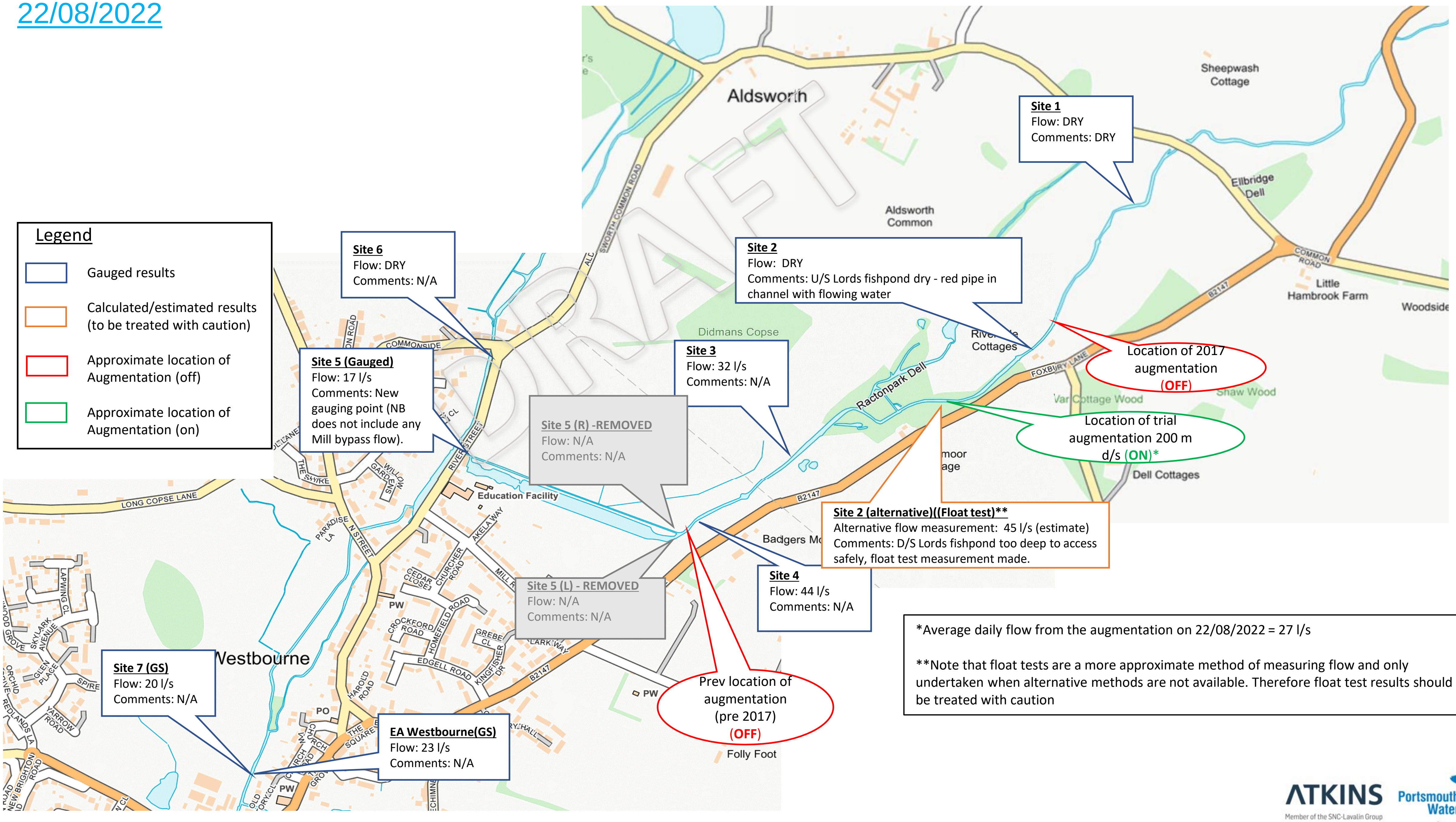
22/08/2022

Legend

🟦	Gauged results
🟧	Calculated/estimated results (to be treated with caution)
🟥	Approximate location of Augmentation (off)
🟩	Approximate location of Augmentation (on)



Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 3
Flow: 32 l/s
Comments: N/A

Site 4
Flow: 44 l/s
Comments: N/A

Site 2 (alternative)((Float test)**
Alternative flow measurement: 45 l/s (estimate)
Comments: D/S Lords fishpond too deep to access safely, float test measurement made.

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 5 (Gauged)
Flow: 17 l/s
Comments: New gauging point (NB does not include any Mill bypass flow).

Site 6
Flow: DRY
Comments: N/A

Site 7 (GS)
Flow: 20 l/s
Comments: N/A

EA Westbourne(GS)
Flow: 23 l/s
Comments: N/A

Location of 2017 augmentation (OFF)

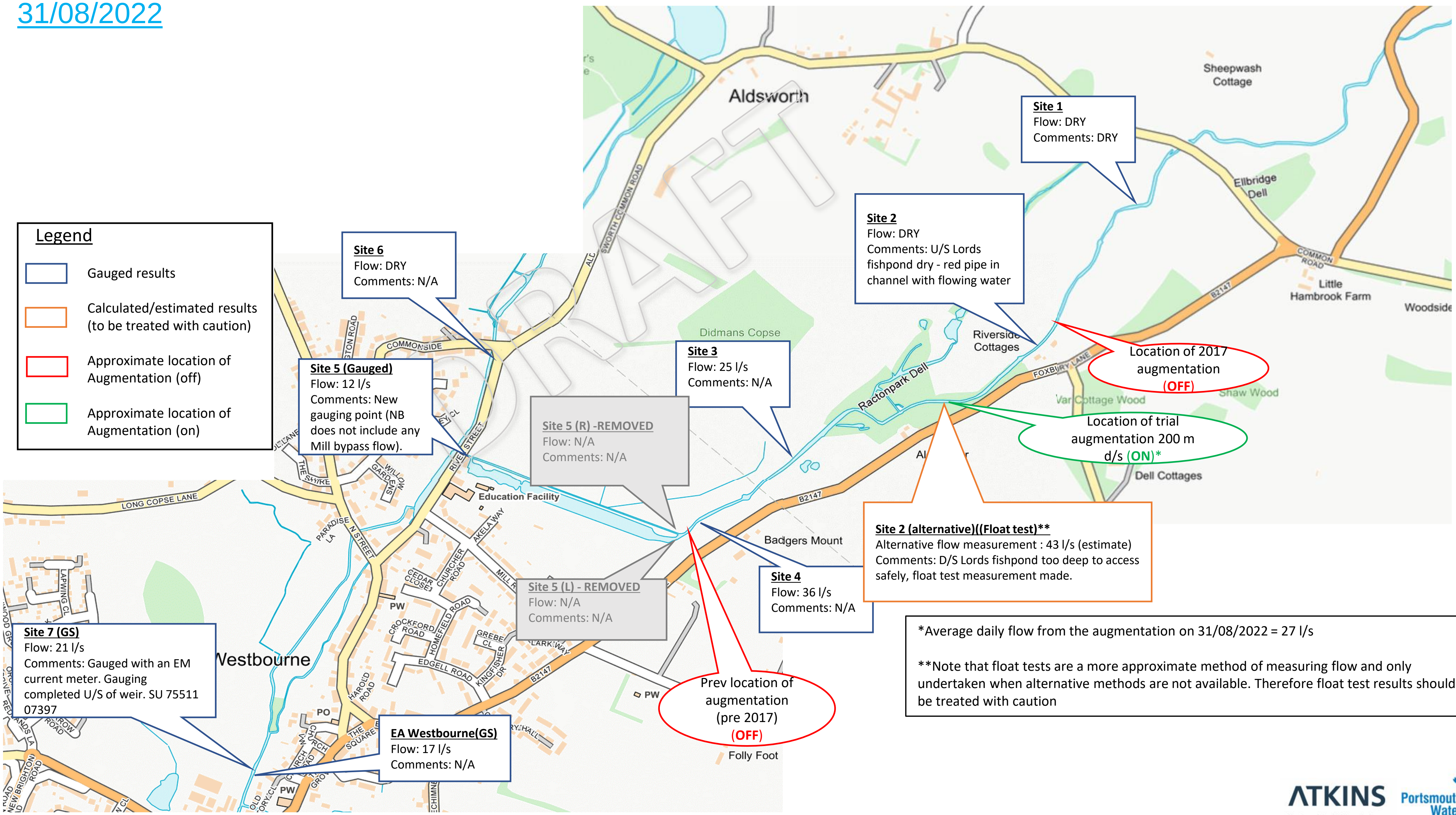
Location of trial augmentation 200 m d/s (ON)*

Prev location of augmentation (pre 2017) (OFF)

*Average daily flow from the augmentation on 22/08/2022 = 27 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

31/08/2022



Legend

🟦 Gauged results

🟧 Calculated/estimated results (to be treated with caution)

🟥 Approximate location of Augmentation (off)

🟩 Approximate location of Augmentation (on)

Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 2 (alternative)((Float test)**
Alternative flow measurement : 43 l/s (estimate)
Comments: D/S Lords fishpond too deep to access safely, float test measurement made.

Site 3
Flow: 25 l/s
Comments: N/A

Site 4
Flow: 36 l/s
Comments: N/A

Site 5 (Gauged)
Flow: 12 l/s
Comments: New gauging point (NB does not include any Mill bypass flow).

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 6
Flow: DRY
Comments: N/A

Site 7 (GS)
Flow: 21 l/s
Comments: Gauged with an EM current meter. Gauging completed U/S of weir. SU 75511 07397

EA Westbourne(GS)
Flow: 17 l/s
Comments: N/A

Location of 2017 augmentation
(OFF)

Location of trial augmentation 200 m d/s (ON)*

Prev location of augmentation (pre 2017)
(OFF)

*Average daily flow from the augmentation on 31/08/2022 = 27 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

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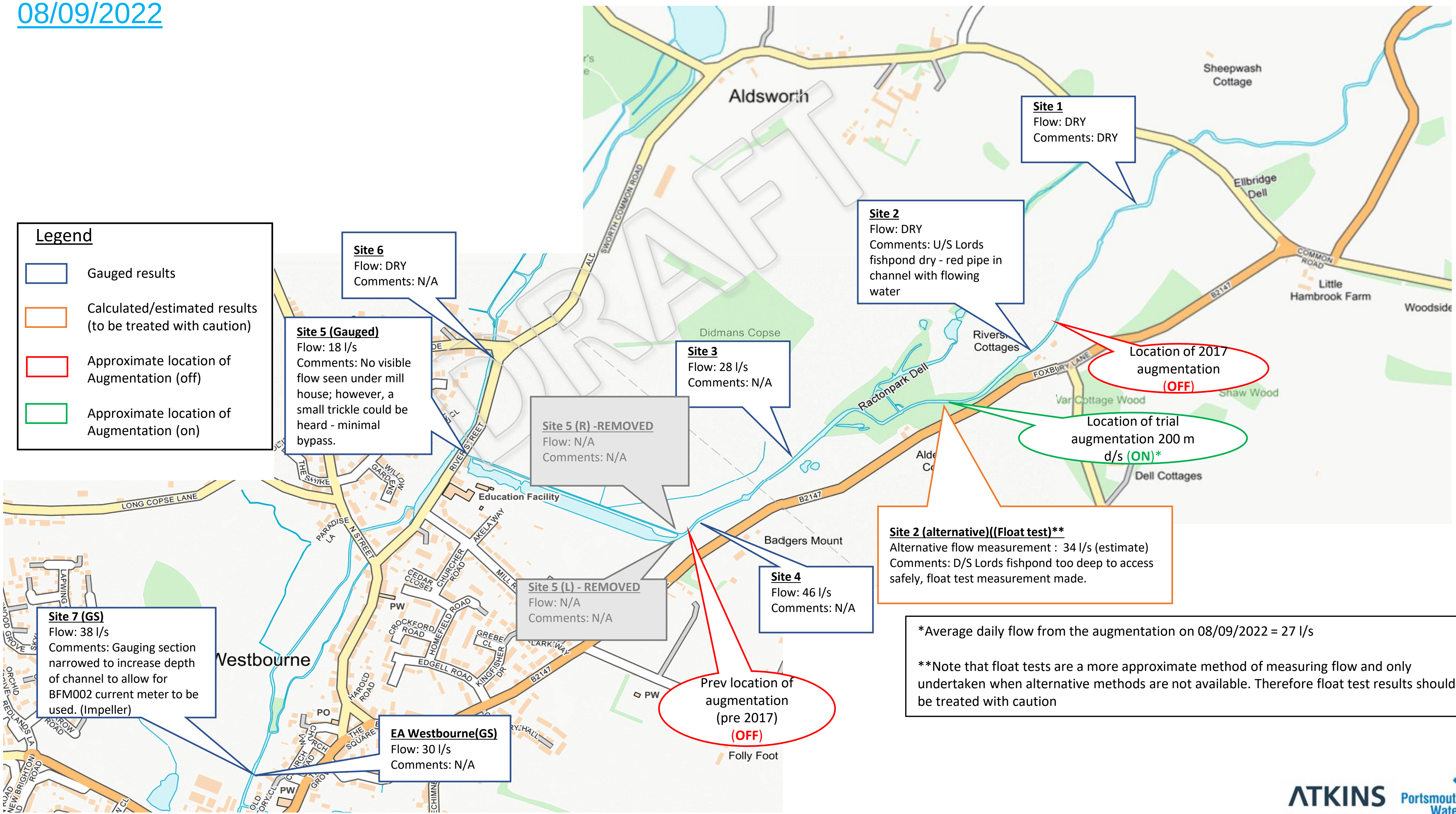
08/09/2022



Legend

- 🟦 Gauged results
- 🟧 Calculated/estimated results (to be treated with caution)
- 🟥 Approximate location of Augmentation (off)
- 🟩 Approximate location of Augmentation (on)

Site 6
Flow: DRY
Comments: N/A

Site 5 (Gauged)
Flow: 18 l/s
Comments: No visible flow seen under mill house; however, a small trickle could be heard - minimal bypass.

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Site 3
Flow: 28 l/s
Comments: N/A

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 1
Flow: DRY
Comments: DRY

Location of 2017 augmentation
(OFF)

Location of trial augmentation 200 m d/s (ON)*

Site 2 (alternative)((Float test)**
Alternative flow measurement : 34 l/s (estimate)
Comments: D/S Lords fishpond too deep to access safely, float test measurement made.

Site 4
Flow: 46 l/s
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 7 (GS)
Flow: 38 l/s
Comments: Gauging section narrowed to increase depth of channel to allow for BFM002 current meter to be used. (Impeller)

EA Westbourne(GS)
Flow: 30 l/s
Comments: N/A

Prev location of augmentation (pre 2017)
(OFF)

*Average daily flow from the augmentation on 08/09/2022 = 27 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

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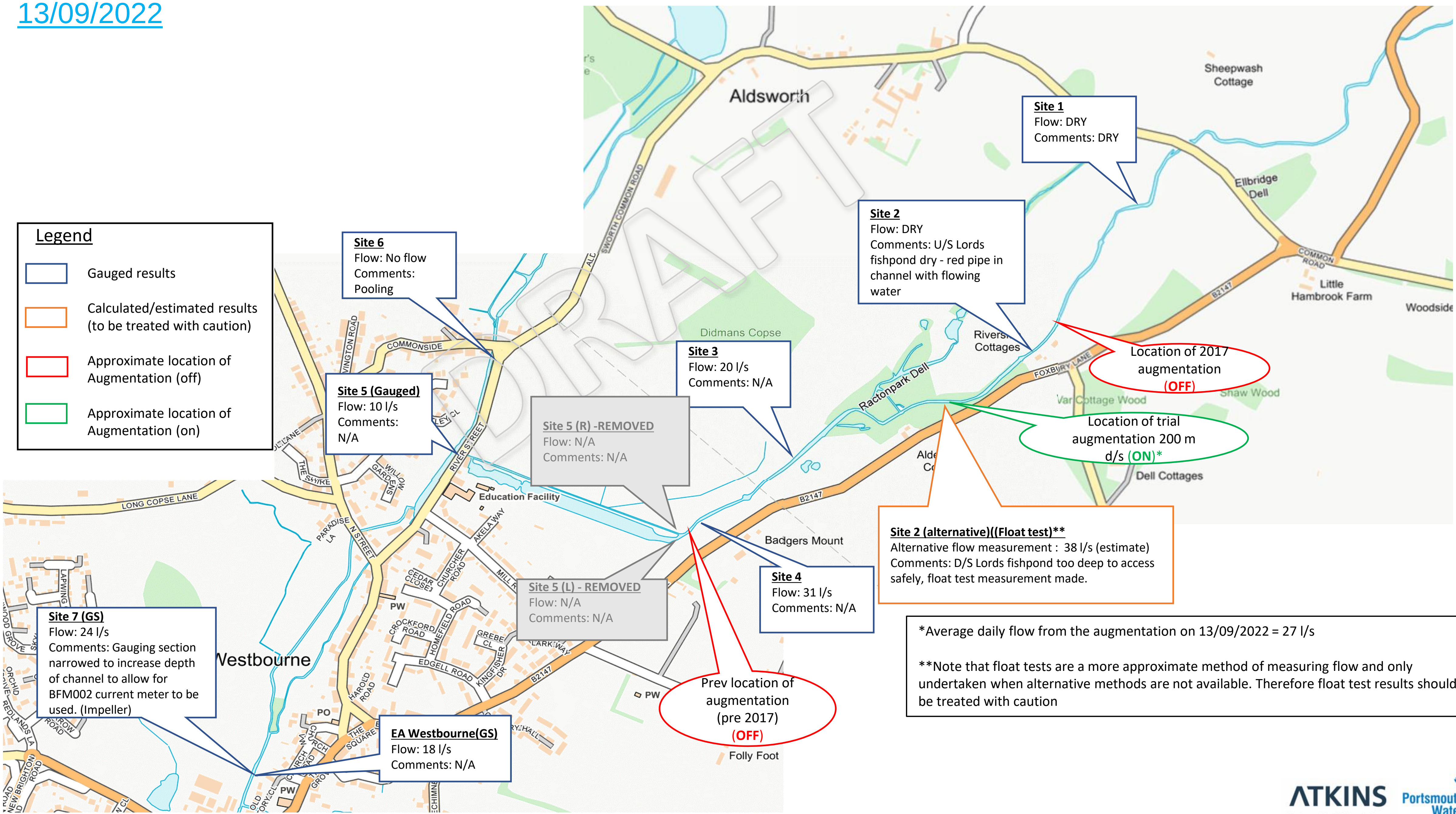
Portsmouth Water

13/09/2022



Legend

🟦 Gauged results

🟧 Calculated/estimated results (to be treated with caution)

🟥 Approximate location of Augmentation (off)

🟩 Approximate location of Augmentation (on)

Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 6
Flow: No flow
Comments: Pooling

Site 3
Flow: 20 l/s
Comments: N/A

Site 5 (Gauged)
Flow: 10 l/s
Comments: N/A

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (ON)*

Site 2 (alternative)((Float test)**
Alternative flow measurement : 38 l/s (estimate)
Comments: D/S Lords fishpond too deep to access safely, float test measurement made.

Site 4
Flow: 31 l/s
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 7 (GS)
Flow: 24 l/s
Comments: Gauging section narrowed to increase depth of channel to allow for BFM002 current meter to be used. (Impeller)

EA Westbourne(GS)
Flow: 18 l/s
Comments: N/A

Prev location of augmentation (pre 2017) (OFF)

*Average daily flow from the augmentation on 13/09/2022 = 27 l/s

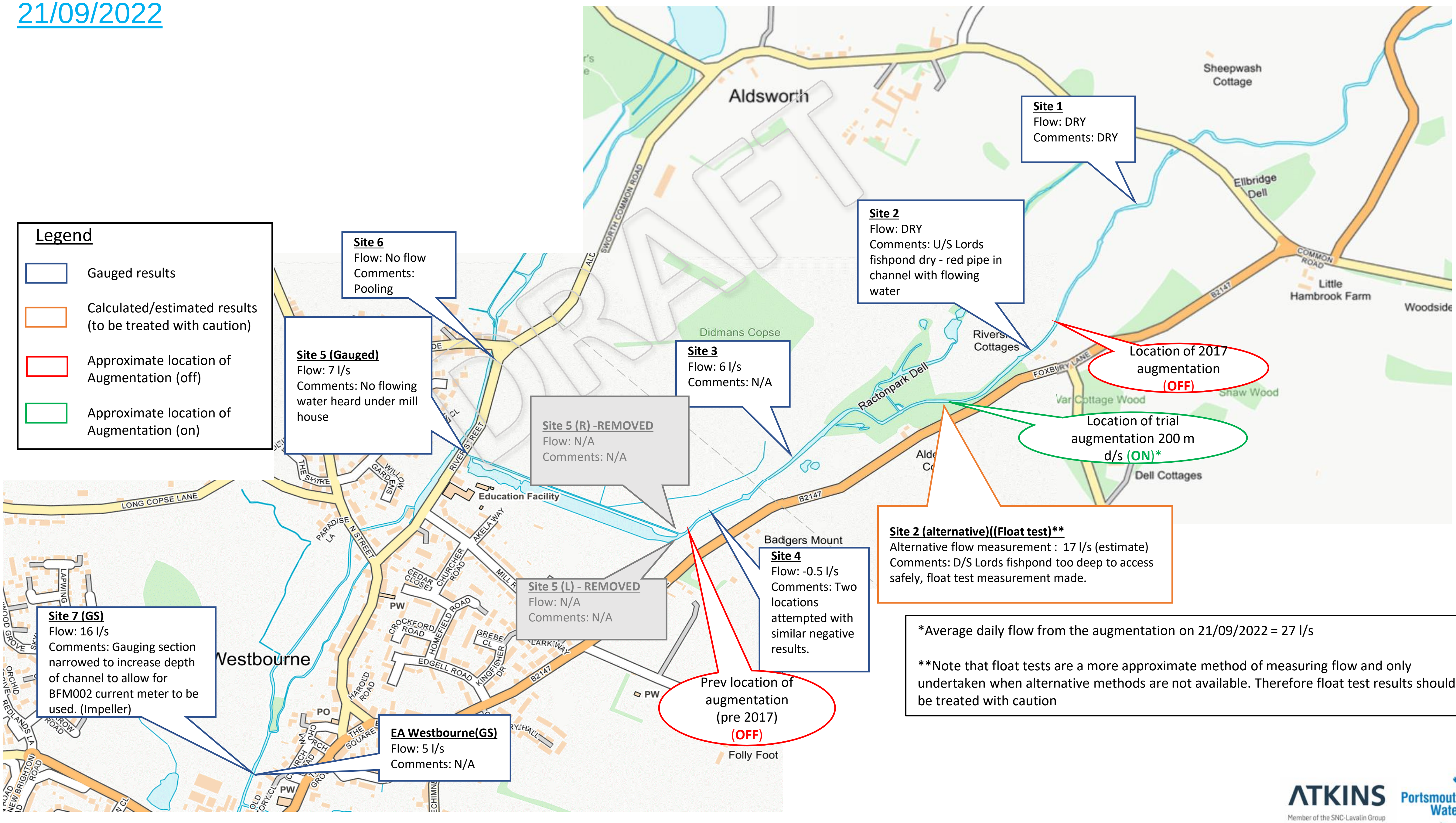
**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

ATKINS
Member of the SNC-Lavalin Group
Portsmouth Water

21/09/2022

Legend

- 🟦 Gauged results
- 🟧 Calculated/estimated results (to be treated with caution)
- 🟥 Approximate location of Augmentation (off)
- 🟩 Approximate location of Augmentation (on)



Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 6
Flow: No flow
Comments: Pooling

Site 5 (Gauged)
Flow: 7 l/s
Comments: No flowing water heard under mill house

Site 3
Flow: 6 l/s
Comments: N/A

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (ON)*

Site 2 (alternative)((Float test)****
Alternative flow measurement : 17 l/s (estimate)
Comments: D/S Lords fishpond too deep to access safely, float test measurement made.

Site 4
Flow: -0.5 l/s
Comments: Two locations attempted with similar negative results.

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 7 (GS)
Flow: 16 l/s
Comments: Gauging section narrowed to increase depth of channel to allow for BFM002 current meter to be used. (Impeller)

EA Westbourne(GS)
Flow: 5 l/s
Comments: N/A

Prev location of augmentation (pre 2017) (OFF)

*Average daily flow from the augmentation on 21/09/2022 = 27 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

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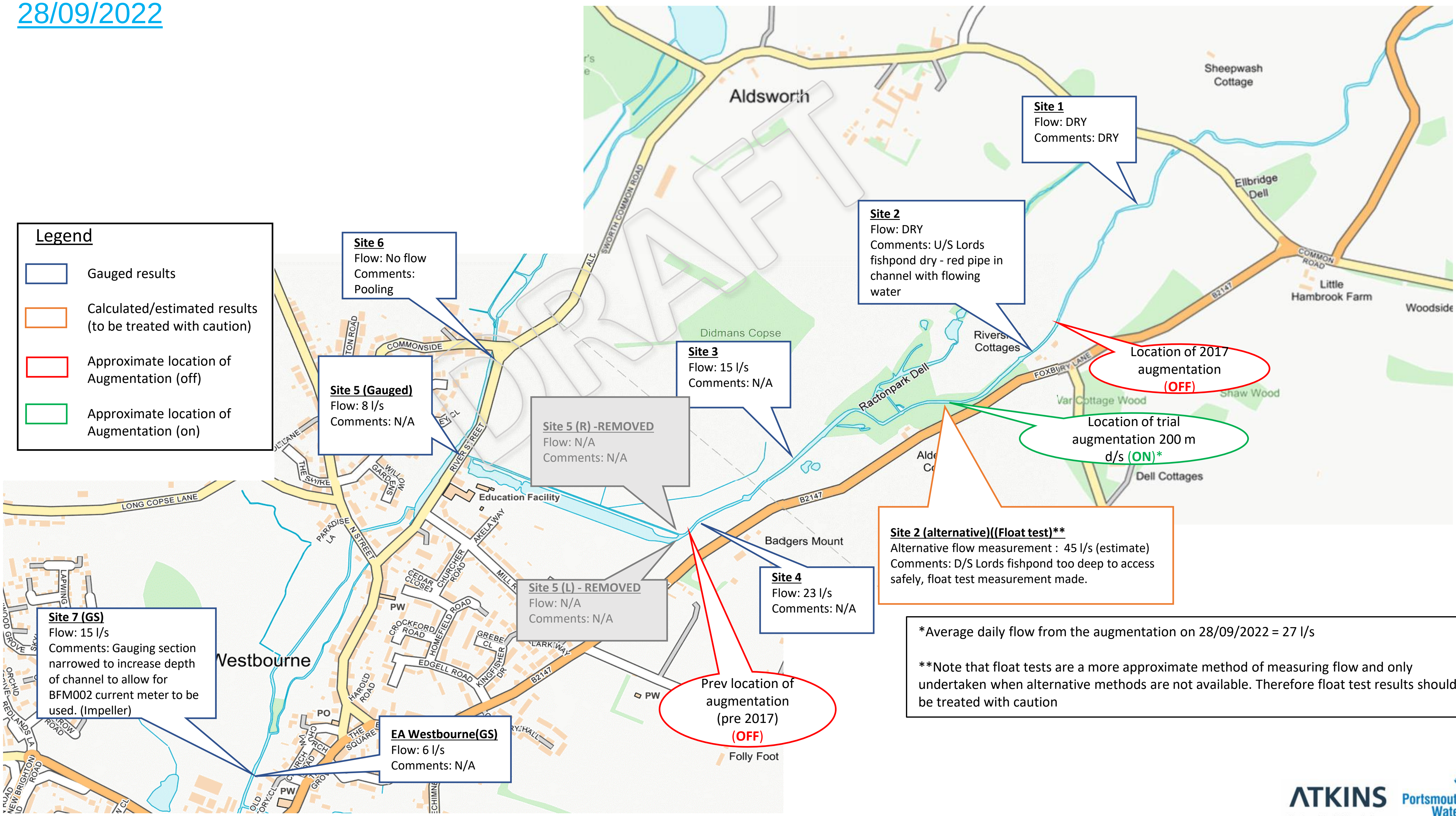
Portsmouth Water

28/09/2022



Legend

🟦 Gauged results

🟧 Calculated/estimated results (to be treated with caution)

🟥 Approximate location of Augmentation (off)

🟩 Approximate location of Augmentation (on)

Site 6
Flow: No flow
Comments: Pooling

Site 5 (Gauged)
Flow: 8 l/s
Comments: N/A

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Site 3
Flow: 15 l/s
Comments: N/A

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 1
Flow: DRY
Comments: DRY

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (ON)*

Site 2 (alternative)((Float test)**
Alternative flow measurement : 45 l/s (estimate)
Comments: D/S Lords fishpond too deep to access safely, float test measurement made.

Site 4
Flow: 23 l/s
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 7 (GS)
Flow: 15 l/s
Comments: Gauging section narrowed to increase depth of channel to allow for BFM002 current meter to be used. (Impeller)

EA Westbourne(GS)
Flow: 6 l/s
Comments: N/A

Prev location of augmentation (pre 2017) (OFF)

*Average daily flow from the augmentation on 28/09/2022 = 27 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

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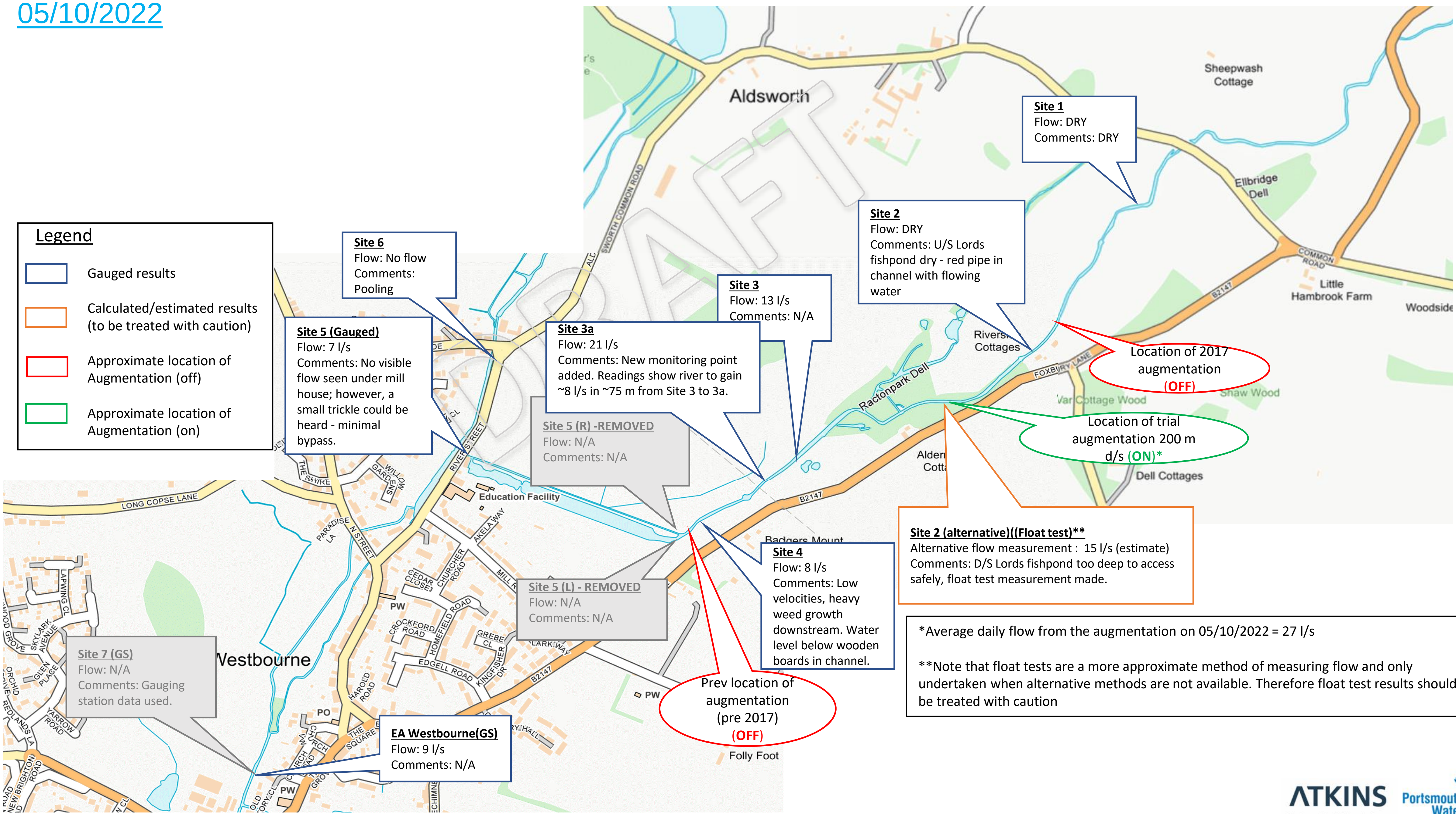
Portsmouth Water

05/10/2022

Legend

- 🟦 Gauged results
- 🟧 Calculated/estimated results (to be treated with caution)
- 🟥 Approximate location of Augmentation (off)
- 🟩 Approximate location of Augmentation (on)



Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 3
Flow: 13 l/s
Comments: N/A

Site 3a
Flow: 21 l/s
Comments: New monitoring point added. Readings show river to gain ~8 l/s in ~75 m from Site 3 to 3a.

Site 6
Flow: No flow
Comments: Pooling

Site 5 (Gauged)
Flow: 7 l/s
Comments: No visible flow seen under mill house; however, a small trickle could be heard - minimal bypass.

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 4
Flow: 8 l/s
Comments: Low velocities, heavy weed growth downstream. Water level below wooden boards in channel.

Site 7 (GS)
Flow: N/A
Comments: Gauging station data used.

EA Westbourne(GS)
Flow: 9 l/s
Comments: N/A

Location of 2017 augmentation
(OFF)

Location of trial augmentation 200 m d/s (ON)*

Prev location of augmentation (pre 2017)
(OFF)

Site 2 (alternative)((Float test)**
Alternative flow measurement : 15 l/s (estimate)
Comments: D/S Lords fishpond too deep to access safely, float test measurement made.

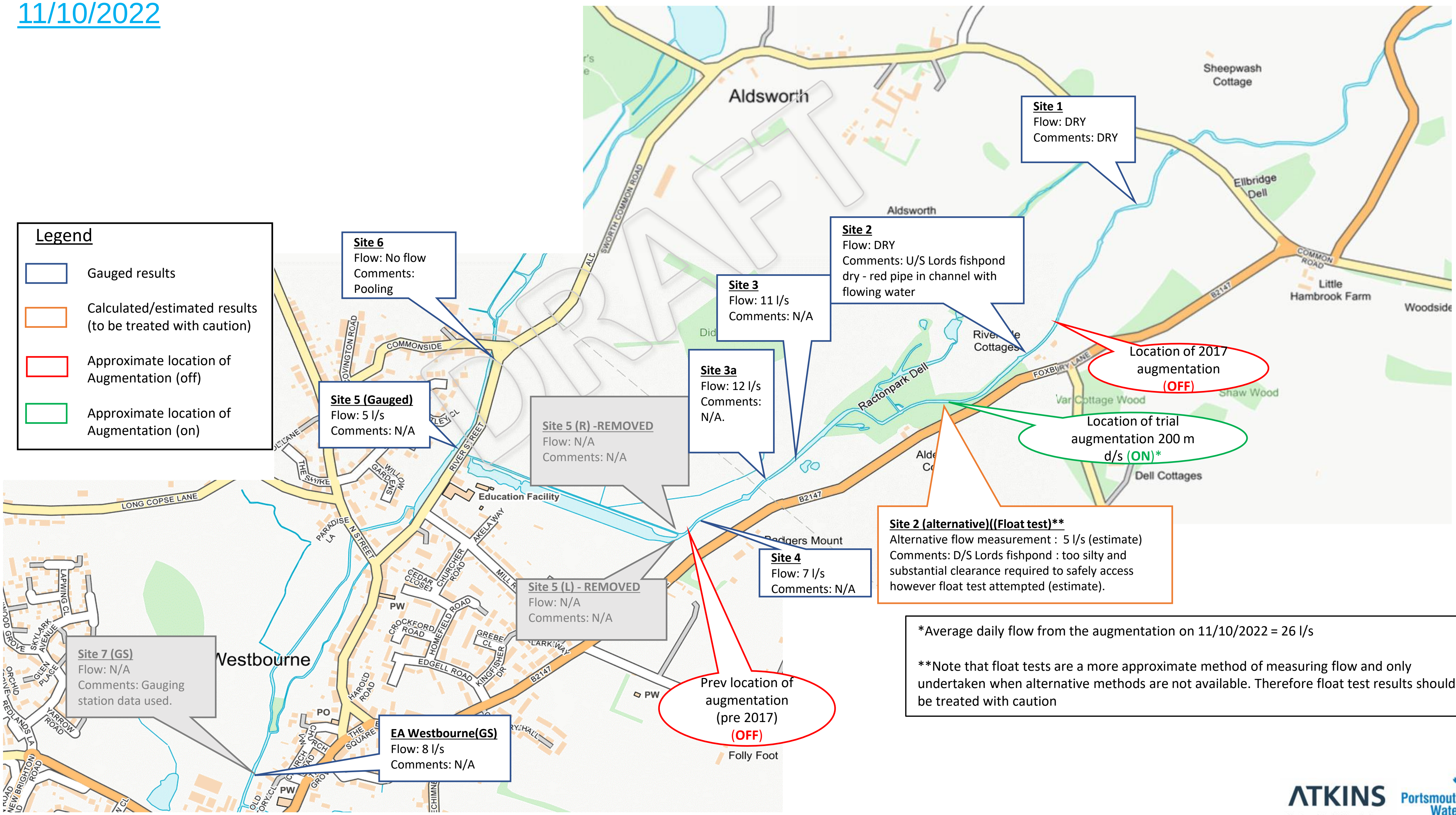
*Average daily flow from the augmentation on 05/10/2022 = 27 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

11/10/2022

Legend

- 🟦 Gauged results
- 🟧 Calculated/estimated results (to be treated with caution)
- 🟥 Approximate location of Augmentation (off)
- 🟩 Approximate location of Augmentation (on)



Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 3
Flow: 11 l/s
Comments: N/A

Site 3a
Flow: 12 l/s
Comments: N/A.

Site 6
Flow: No flow
Comments: Pooling

Site 5 (Gauged)
Flow: 5 l/s
Comments: N/A

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 4
Flow: 7 l/s
Comments: N/A

Site 7 (GS)
Flow: N/A
Comments: Gauging station data used.

EA Westbourne(GS)
Flow: 8 l/s
Comments: N/A

Site 2 (alternative)((Float test)**
Alternative flow measurement : 5 l/s (estimate)
Comments: D/S Lords fishpond : too silty and substantial clearance required to safely access however float test attempted (estimate).

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (ON)*

Prev location of augmentation (pre 2017) (OFF)

*Average daily flow from the augmentation on 11/10/2022 = 26 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

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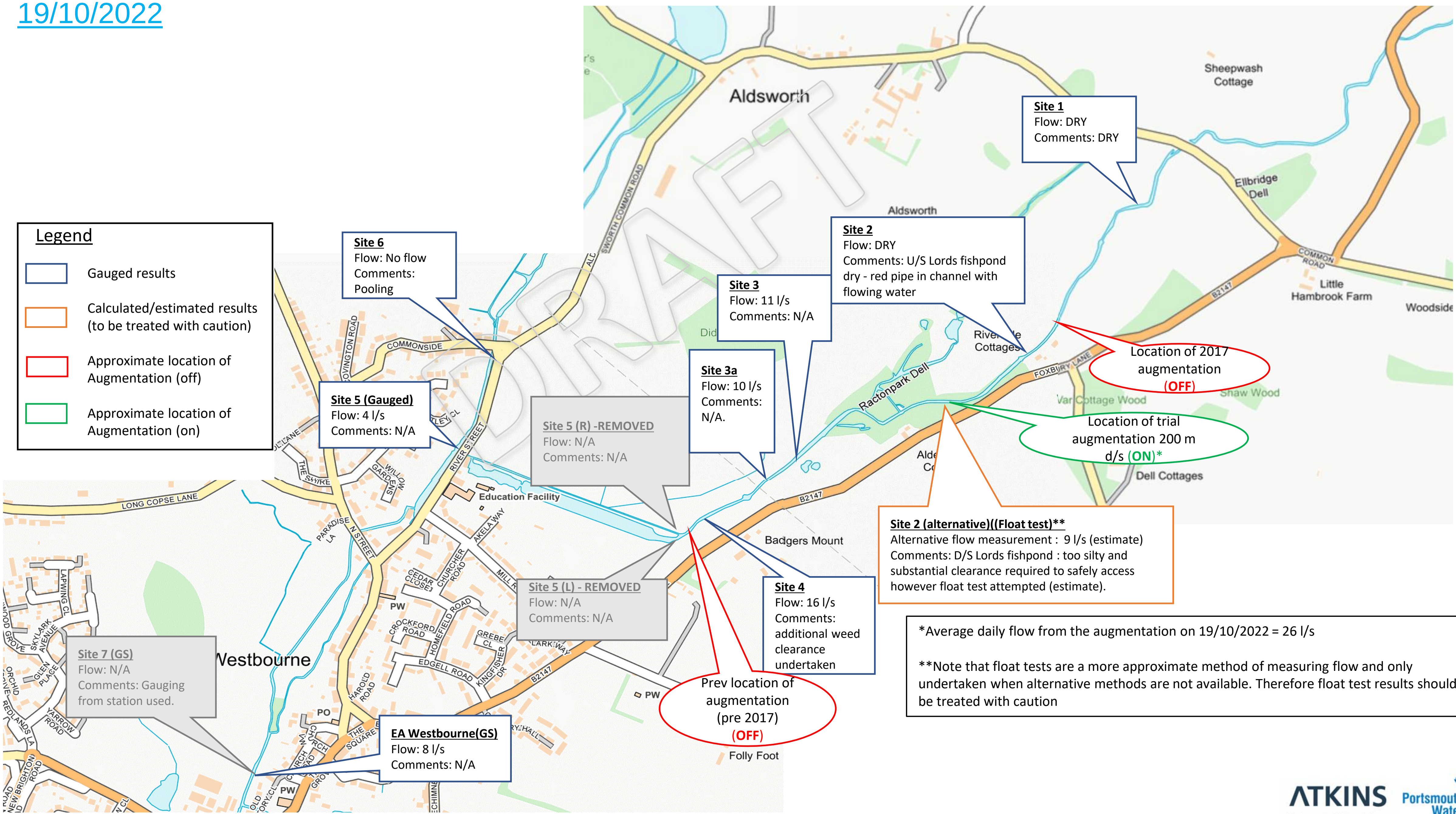
19/10/2022



Legend	
🟦	Gauged results
🟧	Calculated/estimated results (to be treated with caution)
🟥	Approximate location of Augmentation (off)
🟩	Approximate location of Augmentation (on)

Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 3
Flow: 11 l/s
Comments: N/A

Site 3a
Flow: 10 l/s
Comments: N/A.

Site 6
Flow: No flow
Comments: Pooling

Site 5 (Gauged)
Flow: 4 l/s
Comments: N/A

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 4
Flow: 16 l/s
Comments: additional weed clearance undertaken

Site 7 (GS)
Flow: N/A
Comments: Gauging from station used.

EA Westbourne(GS)
Flow: 8 l/s
Comments: N/A

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (ON)*

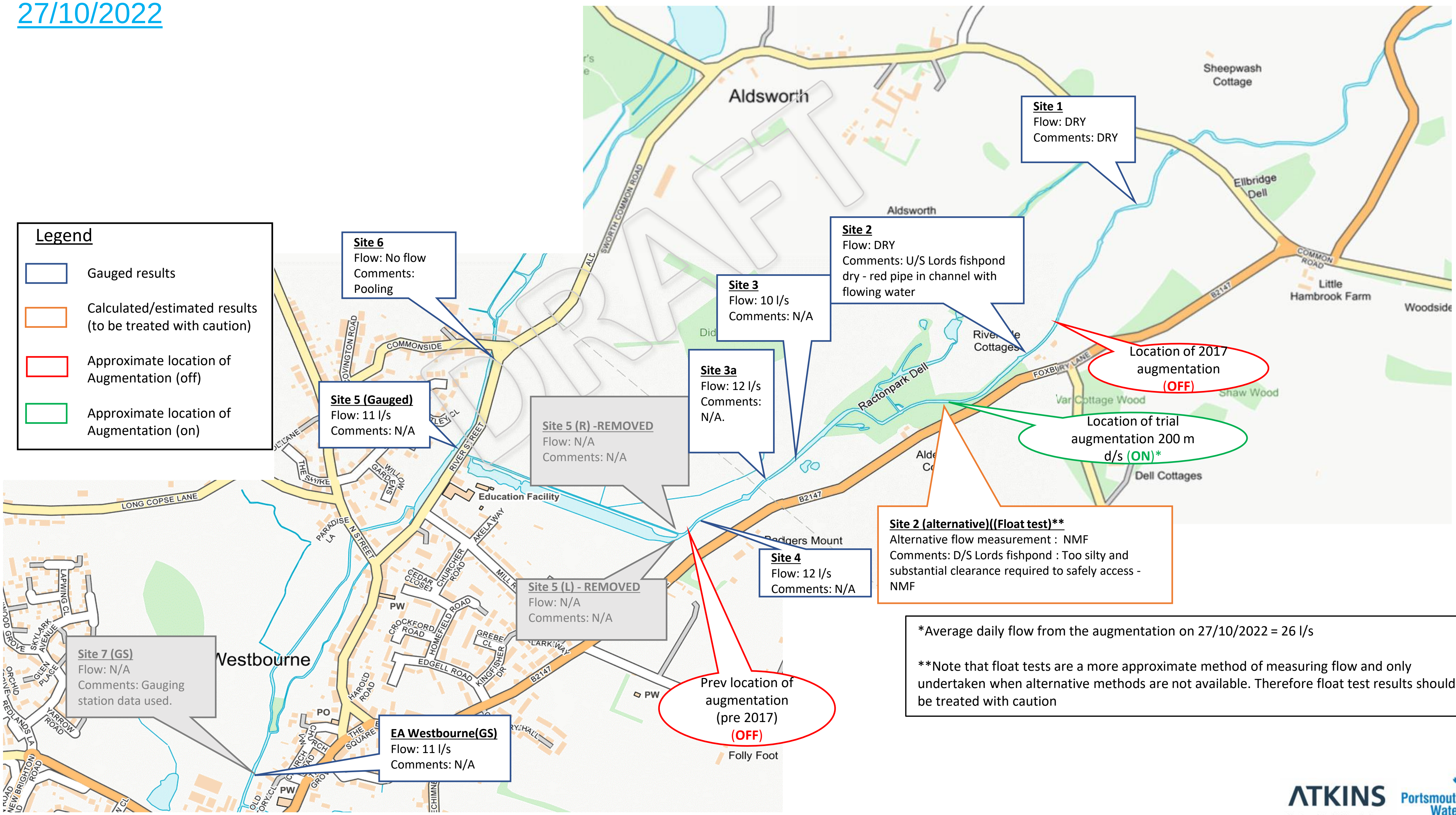
Prev location of augmentation (pre 2017) (OFF)

Site 2 (alternative)((Float test)**
Alternative flow measurement : 9 l/s (estimate)
Comments: D/S Lords fishpond : too silty and substantial clearance required to safely access however float test attempted (estimate).

*Average daily flow from the augmentation on 19/10/2022 = 26 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

27/10/2022



Legend

🟦	Gauged results
🟧	Calculated/estimated results (to be treated with caution)
🟥	Approximate location of Augmentation (off)
🟩	Approximate location of Augmentation (on)

Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 3
Flow: 10 l/s
Comments: N/A

Site 3a
Flow: 12 l/s
Comments: N/A.

Site 6
Flow: No flow
Comments: Pooling

Site 5 (Gauged)
Flow: 11 l/s
Comments: N/A

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (ON)*

Site 2 (alternative)((Float test)**
Alternative flow measurement : NMF
Comments: D/S Lords fishpond : Too silty and substantial clearance required to safely access - NMF

Site 4
Flow: 12 l/s
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Prev location of augmentation (pre 2017) (OFF)

Site 7 (GS)
Flow: N/A
Comments: Gauging station data used.

EA Westbourne(GS)
Flow: 11 l/s
Comments: N/A

*Average daily flow from the augmentation on 27/10/2022 = 26 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

03/11/2022

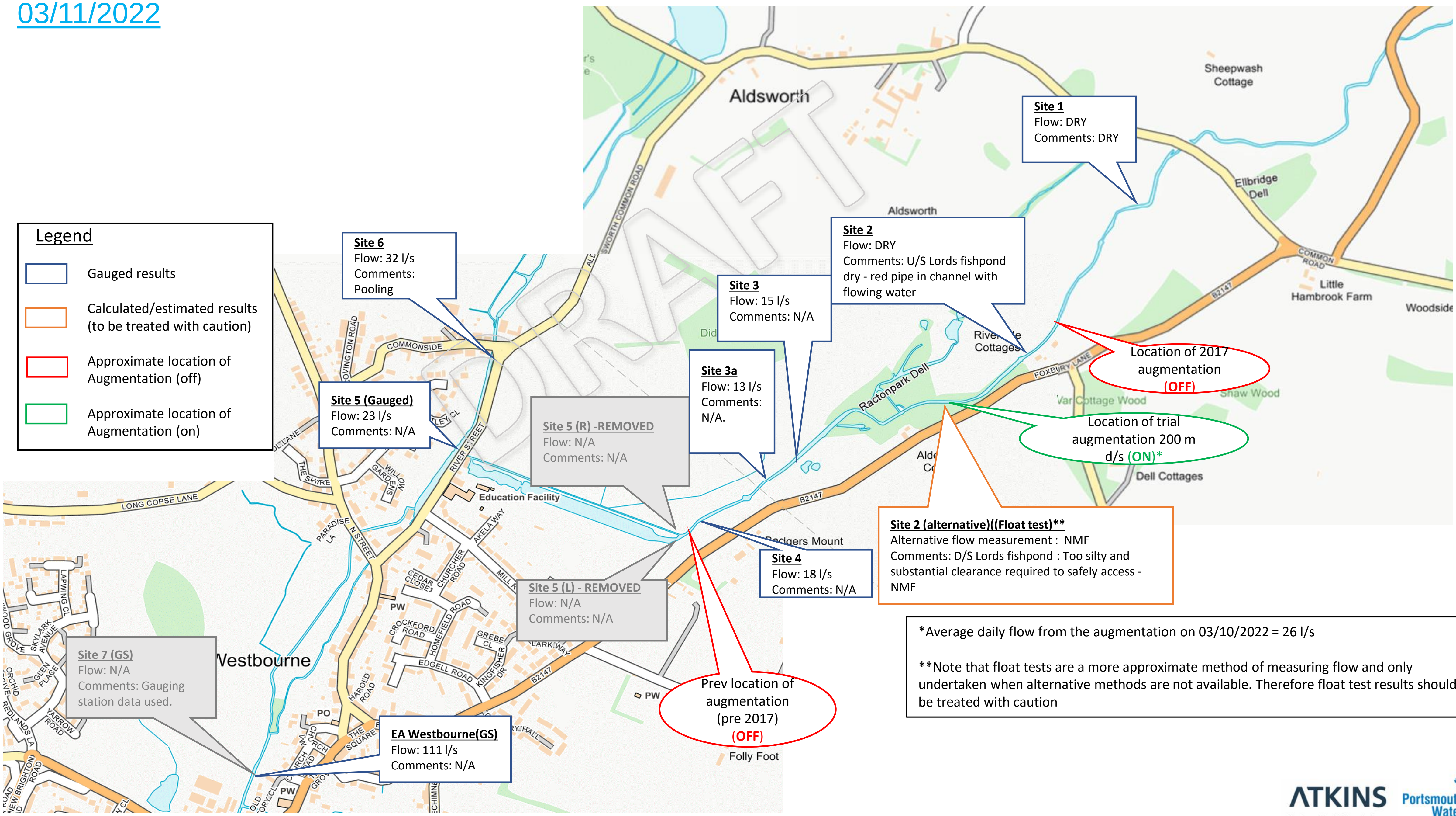
Legend

🟦 Gauged results

🟧 Calculated/estimated results (to be treated with caution)

🟥 Approximate location of Augmentation (off)

🟩 Approximate location of Augmentation (on)



Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 3
Flow: 15 l/s
Comments: N/A

Site 3a
Flow: 13 l/s
Comments: N/A.

Site 4
Flow: 18 l/s
Comments: N/A

Site 5 (Gauged)
Flow: 23 l/s
Comments: N/A

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 6
Flow: 32 l/s
Comments: Pooling

Site 7 (GS)
Flow: N/A
Comments: Gauging station data used.

EA Westbourne(GS)
Flow: 111 l/s
Comments: N/A

Site 2 (alternative)((Float test)**
Alternative flow measurement : NMF
Comments: D/S Lords fishpond : Too silty and substantial clearance required to safely access - NMF

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (ON)*

Prev location of augmentation (pre 2017) (OFF)

*Average daily flow from the augmentation on 03/10/2022 = 26 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

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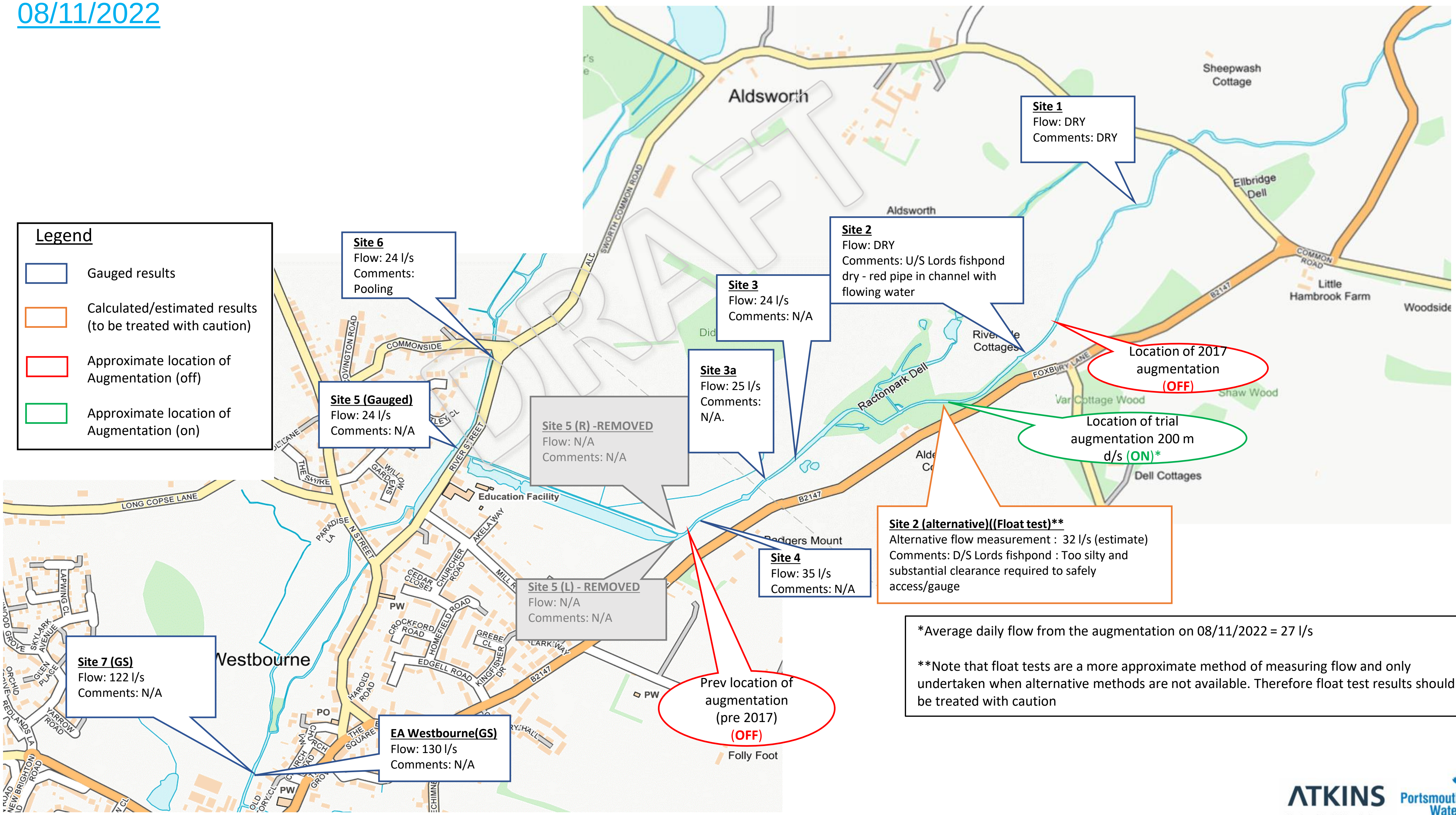
Portsmouth Water

08/11/2022



Legend

🟦	Gauged results
🟧	Calculated/estimated results (to be treated with caution)
🟥	Approximate location of Augmentation (off)
🟩	Approximate location of Augmentation (on)

Site 1
Flow: DRY
Comments: DRY

Site 2
Flow: DRY
Comments: U/S Lords fishpond dry - red pipe in channel with flowing water

Site 3
Flow: 24 l/s
Comments: N/A

Site 3a
Flow: 25 l/s
Comments: N/A.

Site 6
Flow: 24 l/s
Comments: Pooling

Site 5 (Gauged)
Flow: 24 l/s
Comments: N/A

Site 5 (R) -REMOVED
Flow: N/A
Comments: N/A

Site 5 (L) - REMOVED
Flow: N/A
Comments: N/A

Site 4
Flow: 35 l/s
Comments: N/A

Site 2 (alternative)((Float test)**
Alternative flow measurement : 32 l/s (estimate)
Comments: D/S Lords fishpond : Too silty and substantial clearance required to safely access/gauge

Site 7 (GS)
Flow: 122 l/s
Comments: N/A

EA Westbourne(GS)
Flow: 130 l/s
Comments: N/A

Location of 2017 augmentation (OFF)

Location of trial augmentation 200 m d/s (ON)*

Prev location of augmentation (pre 2017) (OFF)

*Average daily flow from the augmentation on 08/11/2022 = 27 l/s

**Note that float tests are a more approximate method of measuring flow and only undertaken when alternative methods are not available. Therefore float test results should be treated with caution

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Portsmouth Water

Appendix B. Borehole logs

B.1. Borehole logs

Borehole Log

BH01

Page 1 of 1

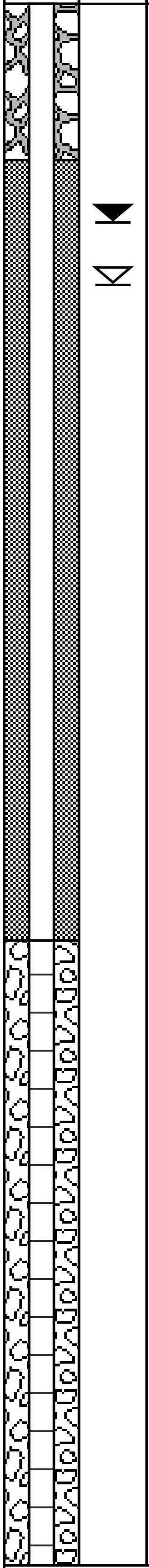
Project Name: River Ems   Project No: P22411

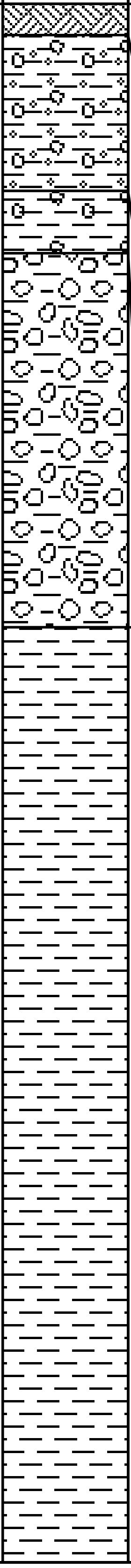
Location: River Ems, Emsworth   Co-ords: 476390 - 107865   Level:

Hole Type: BH Logged By: JB Dates: 14/11/2022 - 15/11/2022

Client: Atkins Consultant: RW/JB

Plant Used: Comacchio 205 SPT Hammer Serial No:





Samples Depth (m)	Samples Type	Depth	Stratum Descriptions	Detailed Description
0.1 - 0.4	B	0.10	Grass covered topsoil with abundant rootlets.	
0.4 - 0.7	B	0.60	Soft, dark brown, slightly sandy, gravelly CLAY. Sand is fine. Gravel is fine to coarse, predominantly medium, sub angular to angular of flint. Fine shell fragments and abundant rootlets. (RIVER TERRACE DEPOSITS)	At 0.3-0.6m bgl: Increasing clay content.
0.7 - 1.0	B	0.80	Soft, orangish brown, slightly gravelly CLAY. Gravel is fine, angular of flint. Patches of dark organic material and fine shell fragments. (RIVER TERRACE DEPOSITS)	At 1.2m bgl: Becoming predominantly medium gravel and continuing to fine with depth
1.0 - 2.0	B	2.00	Orangish brown, slightly clayey, slightly sandy GRAVEL. Gravel is fine to coarse, predominantly coarse, with occasional cobbles up to 7cm diameter, sub angular to angular of flint. (RIVER TERRACE DEPOSITS)	
2.0 - 3.0 3.0 - 4.0 4.0 - 5.0	B B B		Firm, grey occasionally mottled red CLAY. Occasional to rare white shell fragments less than 1cm in size. Common rootlets (LAMBETH GROUP)	At 2.7m bgl: Mottling becoming common At 3-3.7m bgl: Rootlets becoming occasional to rare At 3.75m bgl: Occasional red and brown mottling, rootlets absent At 4m bgl: Becoming blueish grey clay mottled brown, shell fragments absent

Depth m: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5

Borehole cleared with CAT and genny and hand dug service pit to 1.0m bgl. Position terminated at 7.0m bgl at Client's instruction. Borehole cased to 4m bgl and installed with 3m plain, 3m slotted and 1m plain pipe surrounded with geowrap.

Borehole Log

BH01

Page 2 of 2

Project Name: River Ems Project No: P22411

Location: River Ems, Emsworth Co-ords: 476390 - 107865 Level:

Hole Type: BH Logged By: JB Dates: 14/11/2022 - 15/11/2022

Client: Atkins Consultant: RW/JB

Plant Used: Comacchio 205 SPT Hammer Serial No:

Well	Water	Samples		Depth	Legend	Stratum Descriptions	Detailed Description	Depth m
		Depth (m)	Type					
		5.0 - 6.0 6.0 - 7.0	B B	7.00		Firm, grey occasionally mottled red CLAY. Occasional to rare white shell fragments less than 1cm in size. Common rootlets (LAMBETH GROUP)	At 2.7m bgl: Mottling becoming common At 3-3.7m bgl: Rootlets becoming occasional to rare At 3.75m bgl: Occasional red and brown mottling, rootlets absent At 4m bgl: Becoming blueish grey clay mottled brown, shell fragments absent	5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5

Borehole cleared with CAT and genny and hand dug service pit to 1.0m bgl. Position terminated at 7.0m bgl at Client's instruction. Borehole cased to 4m bgl and installed with 3m plain, 3m slotted and 1m plain pipe surrounded with geowrap.

Borehole Log

BH03

Page 1 of 1

Project Name: River Ems Project No: P22411

Location: River Ems, Emsworth Co-ords: 476819 - 108195 Level:

Hole Type: BH Logged By: RLW Dates: 17/11/2022 - 17/11/2022

Client: Atkins Consultant: RW/JB

Plant Used: Comacchio 205 SPT Hammer Serial No:

Well	Water	Samples		Depth	Legend	Stratum Descriptions	Detailed Description	Depth m
		Depth (m)	Type					
				0.10		Grass covered topsoil with abundant rootlets.		
				0.50		Soft, dark brown, slightly sandy, gravelly CLAY. Sand is coarse. Gravel is fine to coarse, sub angular to angular of flint and fine chalk. Abundant rootlets throughout. (RIVER TERRACE DEPOSITS)		0.5
				1.70		Dark brown, slightly sandy, clayey GRAVEL. Sand is coarse. Gravel is fine to coarse, predominantly coarse, with frequent cobbles, sub angular to angular of flint and fine chalk. Cobbles up to 12cm. (RIVER TERRACE DEPOSITS)	At 1.5-1.7m bgl: Gravel becoming predominantly fine.	1.0 1.5
		1.7 - 2.5	B	2.50		Structureless CHALK composed of light orangish brown, gravelly, slightly silty SAND. Gravel is fine to coarse, sub angular to angular of flint and low density chalk. Rare flint cobbles. Grade Dm. (WHITE CHALK)		2.0 2.5
								3.0 3.5 4.0 4.5

Borehole cleared with CAT and genny and hand dug service pit to 1m bgl. Borehole terminated at 2.5m bgl within White Chalk at Clients instruction. Position backfilled with arisings.

Borehole Log

BH04

Page 1 of 1

Project Name: River Ems   Project No: P22411

Location: River Ems, Emsworth   Co-ords: 476896 - 108223   Level:

Hole Type: BH   Logged By: RLW   Dates: 16/11/2022 - 16/11/2022

Client: Atkins   Consultant: RW/JB

Plant Used: Comacchio 205   SPT Hammer Serial No:

Samples Depth (m)	Samples Type
0.0 - 0.2	B
0.2 - 0.4	B
0.4 - 0.6	B
0.6 - 0.8	B
0.8 - 1.0	B
1.0 - 1.2	B
1.2 - 2.5	B
2.5 - 4.0	B
4.0 - 5.5	B

Depth	Stratum Descriptions	Detailed Description
0.10	Grass covered topsoil with abundant rootlets.	
0.40	Dark brown, slightly sandy, gravelly CLAY. Sand is fine. Gravel is fine to coarse, predominantly medium, sub angular to angular of flint, sandstone and brick. Fine shell fragments and abundant rootlets. Occasional flint cobbles up to 16cm. (RIVER TERRACE DEPOSITS)	At 0.4m bgl: Increasing frequency of chalk fragments with depth. At 0.7m bgl: Flint boulder ~26cm.
0.80	Soft, dark brown, slightly sandy, gravelly CLAY. Sand is fine. Gravel is fine to coarse, predominantly medium, sub angular to angular of flint and fine, sub rounded chalk. (RIVER TERRACE DEPOSITS)	At 0.95m bgl: Becoming mottled off-white.
1.00	Soft, dark brown, silty, slightly sandy GRAVEL. Sand is fine. Gravel is fine to coarse, sub angular to angular of flint. (RIVER TERRACE DEPOSITS)	
1.20	Structureless CHALK composed of off-white, gravelly, sandy SILT. Sand is medium to coarse. Gravel is fine to medium, sub angular of flint and low density chalk. Grade Dm. (WHITE CHALK)	
1.60	Structureless CHALK composed of off-white mottled light brown, very gravelly, slightly sandy SILT. Sand is fine. Gravel is fine to coarse, sub angular to angular of flint and fine, low density chalk. Grade Dm. (WHITE CHALK)	At 2.4m bgl: Flint cobble ~8cm. At 2.5m bgl: Chalk fragments becoming coarse.
3.30	Structureless CHALK composed of off-white gravelly, slightly sandy SILT. Sand is coarse. Gravel is fine to coarse, sub angular to angular of flint and fine, low density chalk. Grade Dm. (WHITE CHALK)	
	Grey, slightly silty, slightly sandy GRAVEL. Gravel is fine to coarse, predominantly coarse, with cobbles, angular of flint. (WHITE CHALK)	

Depth m: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5

Borehole cleared with CAT and genny and hand dug service pit to 1.2m bgl. Borehole cased to 5.5m bgl. Position terminated at target depth of 10m bgl and installed with 1.5m of plain 8m of slotted and 0.5m of plain pipe surrounded with geowrap.

Borehole Log

BH04

Page 2 of 2

Project Name: River Ems Project No: P22411

Location: River Ems, Emsworth Co-ords: 476896 - 108223 Level:

Hole Type: BH Logged By: RLW Dates: 16/11/2022 - 16/11/2022

Client: Atkins Consultant: RW/JB

Plant Used: Comacchio 205 SPT Hammer Serial No:

Well	Water	Samples		Depth	Legend	Stratum Descriptions	Detailed Description	Depth m
		Depth (m)	Type					
				5.50		Grey, slightly silty, slightly sandy GRAVEL. Gravel is fine to coarse, predominantly coarse, with cobbles, angular of flint. (WHITE CHALK)		
		5.5 - 7.0	B	6.60		Structureless CHALK composed of off-white, gravelly, slightly sandy SILT. Sand is medium to coarse. Gravel is fine to coarse, rounded to subrounded of chalk and flint. Chalk clasts are low to medium density. Grade Dm. (WHITE CHALK)	At 6m bgl: 7cm cobble of chalk.	5.5 6.0 6.5
		7.0 - 8.5	B	7.00		Structureless CHALK composed of light grey, slightly silty, gravelly SAND. Sand is coarse. Gravel is fine to coarse, sub angular to angular of flint. Occasional shell fragments. Grade Dm. (WHITE CHALK)		7.0
		8.5 - 10.0	B	9.30		Structureless CHALK composed of off-white, very gravelly, slightly sandy SILT. Sand is fine. Gravel is fine to coarse, sub rounded of chalk and flint. Chalk clasts are low to medium density. Grade Dm. (WHITE CHALK)	At 7.5m bgl: Light brown discolouration surrounding a 16cm flint cobble. At 8.5m bgl: Becoming increasingly gravelly. At 8.8m bgl: Parting of brown, fine sand.	7.5 8.0 8.5 9.0
				10.00		Structureless CHALK composed of off-white, slightly silty, slightly sandy GRAVEL. Sand is fine. Gravel is fine to angular of medium density chalk. Grade Dc. (WHITE CHALK)		9.5

Borehole cleared with CAT and genny and hand dug service pit to 1.2m bgl. Borehole cased to 5.5m bgl. Position terminated at target depth of 10m bgl and installed with 1.5m of plain 8m of slotted and 0.5m of plain pipe surrounded with geowrap.

Borehole Log

BH05

Page 1 of 1

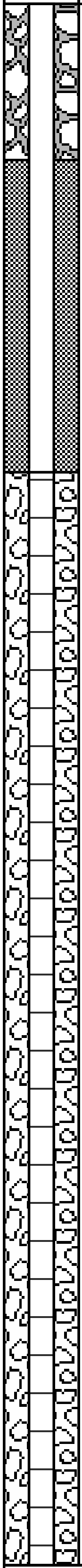
Project Name: River Ems   Project No: P22411

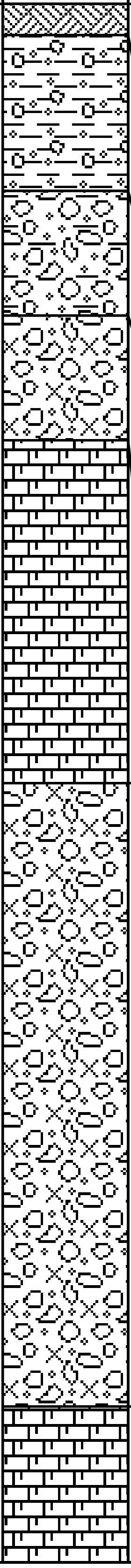
Location: River Ems, Emsworth   Co-ords: 476786 - 108156   Level:

Hole Type: BH   Logged By: RLW   Dates: 17/11/2022 - 17/11/2022

Client: Atkins   Consultant: RW/JB

Plant Used: Comacchio 205   SPT Hammer Serial No:





Water	Samples		Depth	Stratum Descriptions	Detailed Description	Depth m
	Depth (m)	Type				
	0.0	B	0.10	Grass covered topsoil with abundant rootlets.		
	0.2 - 0.4 0.4 - 0.6	B B	0.60	Dark brown, slightly sandy, slightly gravelly CLAY. Sand is fine. Gravel is fine to coarse, with occasional cobbles, sub angular of flint and fine chalk. Abundant rootlets. (RIVER TERRACE DEPOSITS)		0.5
▽	0.6 - 0.8 0.8 - 0.9 0.9 - 1.0	B B B	1.00	Dark brown, very clayey, slightly sandy GRAVEL. Sand is fine. Gravel is fine to coarse, with cobbles, angular of flint. (RIVER TERRACE DEPOSITS)		1.0
	1.0 - 2.5	B	1.40	Light brown, very sandy, slightly silty, GRAVEL. Sand is fine to coarse. Gravel is fine to coarse, sub-angular to angular of flint. Occasional cobbles up to 9cm and occasional shell fragments. (RIVER TERRACE DEPOSITS)		
			2.50	Structureless CHALK composed of off-white gravelly, sandy SILT with cobbles. Sand is medium to coarse. Gravel is fine to coarse, sub angular to sub rounded of flint and fine chalk. Grade Dm. (WHITE CHALK)		1.5 2.0
	2.5 - 4.0 4.0 - 5.5	B B	4.50	Light brown silty, sandy GRAVEL with cobbles. Sand is medium to coarse. Gravel is fine to coarse, sub angular to sub rounded of flint and fine chalk. (WHITE CHALK)		2.5 3.0 3.5 4.0
				Structureless CHALK composed of off-white, slightly sandy, gravelly SILT. Sand is fine. Gravel is fine to coarse of rounded chalk and sub angular flint. Occasional cobbles. Chalk clasts are low density. Grade Dm. (WHITE CHALK)	Increasing clast size of chalk with depth.	4.5

Borehole cleared with CAT and genny and hand dug service pit to 1.0m bgl. Borehole cased to 5.5m bgl. Position terminated at target depth of 10m bgl and installed with 1.5m of plain 8m of slotted and 0.5m of plain pipe surrounded with geowrap.

Borehole Log

BH05

Page 2 of 2

Project Name: River Ems Project No: P22411

Location: River Ems, Emsworth Co-ords: 476786 - 108156 Level:

Hole Type: BH Logged By: RLW Dates: 17/11/2022 - 17/11/2022

Client: Atkins Consultant: RW/JB

Plant Used: Comacchio 205 SPT Hammer Serial No:

Well	Water	Samples		Depth	Legend	Stratum Descriptions	Detailed Description	Depth m
		Depth (m)	Type					
						Structureless CHALK composed of off-white, slightly sandy, gravelly SILT. Sand is fine. Gravel is fine to coarse of rounded chalk and sub angular flint. Occasional cobbles. Chalk clasts are low density. Grade Dm. (WHITE CHALK)	Increasing clast size of chalk with depth.	
		5.5 - 7.0	B	5.50		Structureless CHALK composed of white slightly sandy, silty GRAVEL with cobbles. Sand is coarse. Gravel is fine to coarse of chalk and flint. Chalk clasts are low to medium density. Grade Dc. (WHITE CHALK)	At 6m bgl: Chalk cobble of 9cm. At 9.8m bgl: Chalk cobble of 10cm.	5.5
								6.0
								6.5
		7.0 - 8.5	B					7.0
								7.5
								8.0
		8.5 - 10.0	B					8.5
								9.0
								9.5
				10.00				

Borehole cleared with CAT and genny and hand dug service pit to 1.0m bgl. Borehole cased to 5.5m bgl. Position terminated at target depth of 10m bgl and installed with 1.5m of plain 8m of slotted and 0.5m of plain pipe surrounded with geowrap.

B.2. Ground investigation photographs

BH01 0-1m bgl

BH01 0-1m bgl hand pit

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

Yellow Sub Geo Ltd
7 Neptune Court, Vanguard Way
Cardiff, CF24 5PJ

PROJECT NAME: River Ems

PROJECT NO: P22411

HOLE NO: BH01

SAMPLE ID:

DATE: 8/11/22

DEPTH FROM: 1.0 m TO: 2.5 m

BH01 1-2.5 bgl

BH01 1-2.5m bgl

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

	
BH01 2.5-4 bgl	BH01 4-5.5m bgl

Project	River Ems, Emsworth	YELLOW SUB GEO
Project No.	22411	
Client	Atkins	

BH01 5.5-7 bgl

BHB01 prior to installation of headworks

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

BH04 0-0.6m bgl	Flint cobble at 0.7m bgl within BH04

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

BH04 hand pit

BH04 0.6-1.2m bgl arisings

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

Chalk encountered at 1-1.2m bgl in BH04

PROJECT NAME: River Ems

PROJECT NO: P22411

HOLE NO: BH04

SAMPLE ID: B07 - BH04

DATE: 9/11/22

DEPTH FROM: 1.2 m TO: 2.5 m

BH04 1.2-2.5m bgl

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

BH04 2.5-4m bgl

BH04 4-5.5m bgl

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

BH04 5.5-10m bgl

Yellow Sub Geo Ltd
7 Neptune Court, Vanguard Way,
Cardiff, CF24 5PJ

PROJECT NAME: River Ems

PROJECT NO: P22411

HOLE NO: BH04

SAMPLE ID: B07 - BH04

DATE: 9/11/22

DEPTH FROM: 7 m TO: 8.5 m

BH04 7-8.5m bgl

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

Yellow Sub Geo Ltd
7 Neptune Court, Vanguard Way
Cardiff, CF24 5PJ

PROJECT NAME: River Ems
PROJECT NO: P22411
SAMPLE ID: B67 - BH04
HOLE NO: BH04
DATE: 9/11/22
DEPTH FROM: 8.5 m TO: 10 m

BH04 8.5-10m bgl	BH04 8.5-10m bgl

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

BH05 0-1m bgl

BH05 0-0.2m bgl

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

BH05 0.2-0.4m bgl

BH05 0.4-0.6m bgl

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

BH05 0.6-0.8m bgl

BH05 0.8-0.9m bgl

Project	River Ems, Emsworth	YELLOW SUB GEO
Project No.	22411	
Client	Atkins	

	
BH05 0.9-1.0m bgl	BH05 1-2.5m bgl

PROJECT NAME: River Ems
PROJECT NO: P22411
HOLE NO: BH05.
SAMPLE ID: B01-BH05
DATE: 1/11/22
DEPTH FROM: 0.9 m TO: 1.0 m

PROJECT NAME: River Ems
PROJECT NO: P22411
HOLE NO: BH05.
SAMPLE ID: B07-BH05
DATE: 10/11/22
DEPTH FROM: 1 m TO: 2.5 m

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

BH05 2.5-4m bgl	BH05 5.5-4m bgl

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

BH05 5.5-7m bgl

BH05 7-8.5m bgl

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

PROJECT NAME: River Ems

PROJECT NO: P22411

HOLE NO: BH05.

DATE: 10/11/22

SAMPLE ID: B12 - BH05

DEPTH FROM: 8.5 m TO: 10 m

BH05 8.5-10m bgl

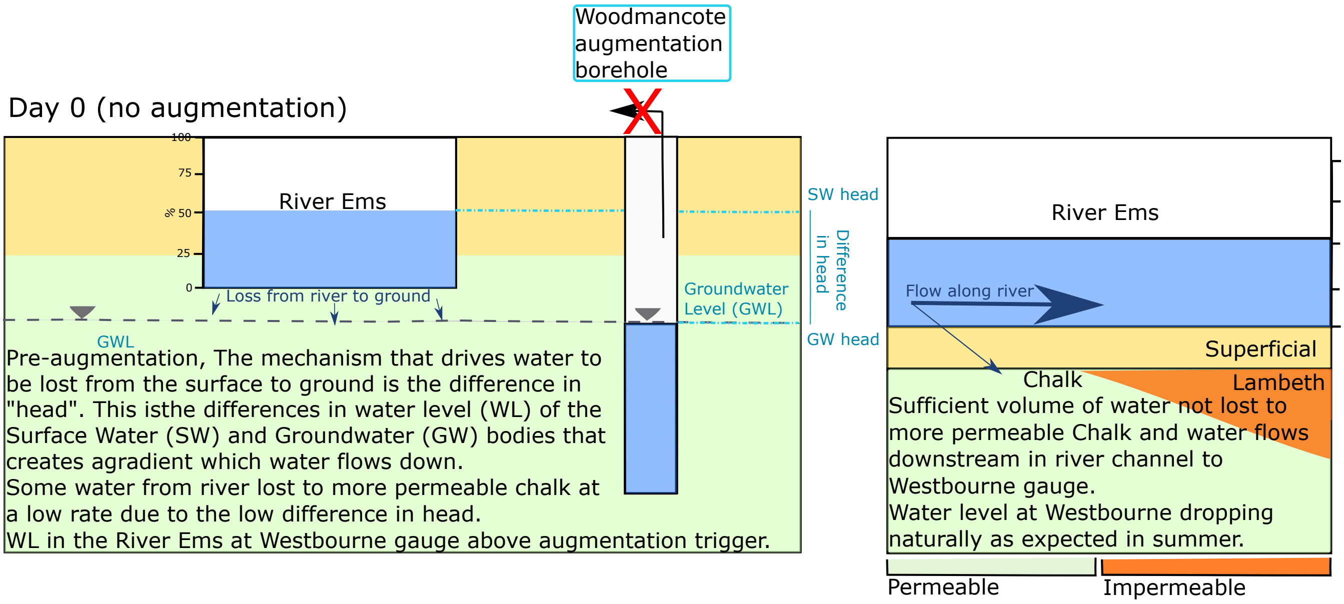
BH05 development

Project	River Ems, Emsworth
Project No.	22411
Client	Atkins

Appendix C. Augmentation scheme conceptual understanding

C.1. Original conceptual understanding (Atkins, 2022)

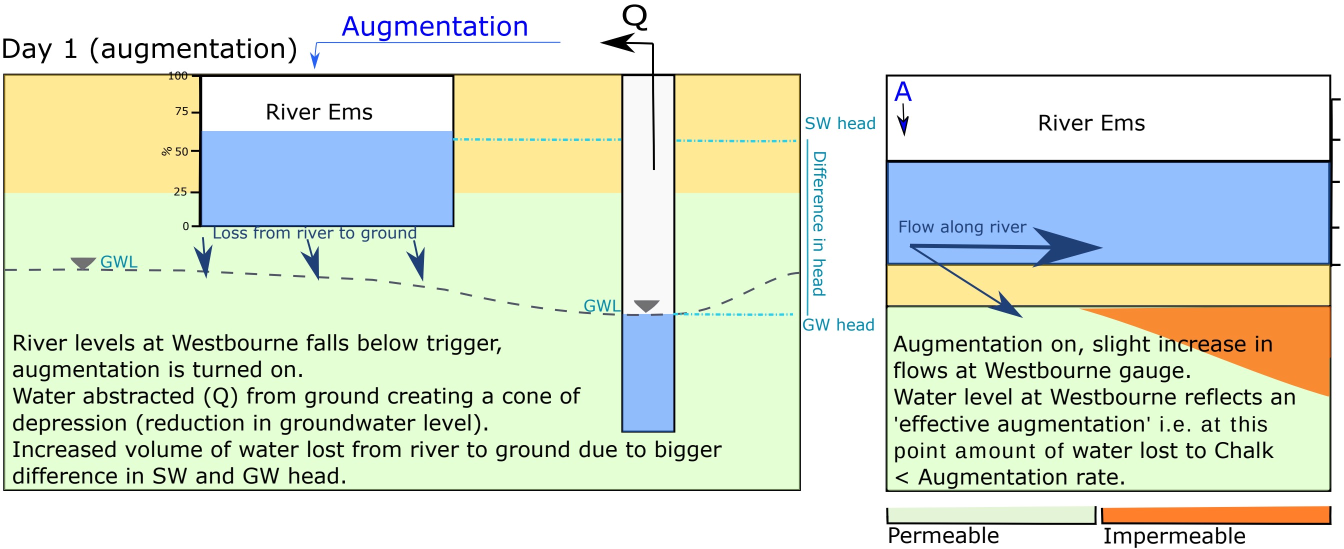
Day 0 (no augmentation)



Pre-augmentation, The mechanism that drives water to be lost from the surface to ground is the difference in "head". This isthe differences in water level (WL) of the Surface Water (SW) and Groundwater (GW) bodies that creates agradient which water flows down.
Some water from river lost to more permeable chalk at a low rate due to the low difference in head.
WL in the River Ems at Westbourne gauge above augmentation trigger.

Sufficient volume of water not lost to more permeable Chalk and water flows downstream in river channel to Westbourne gauge.
Water level at Westbourne dropping naturally as expected in summer.

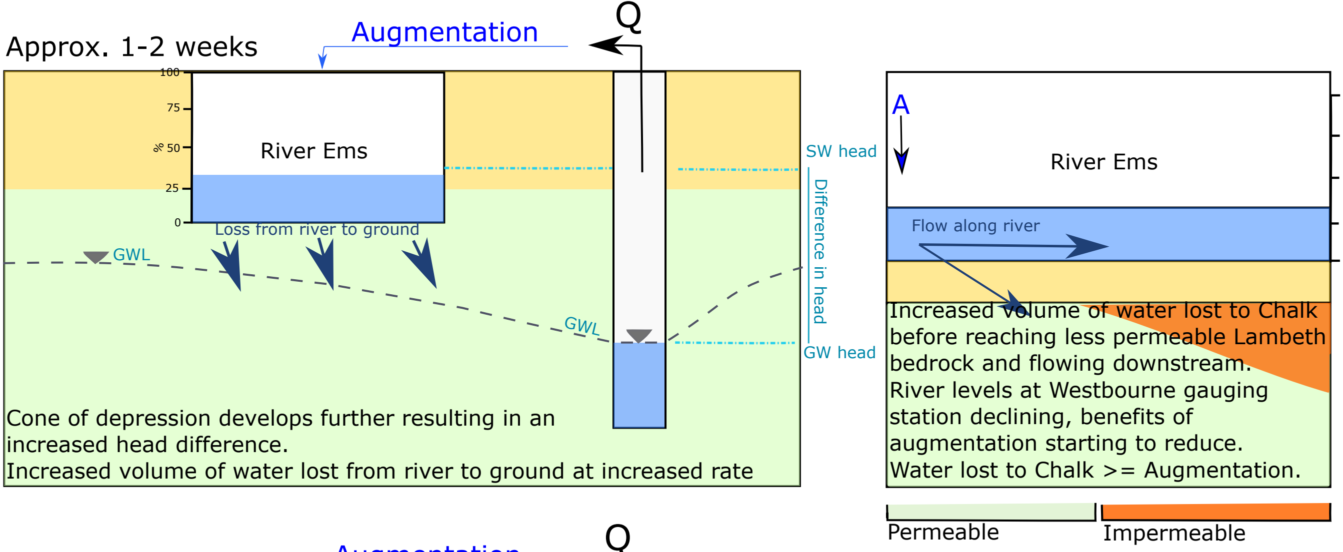
Day 1 (augmentation)



River levels at Westbourne falls below trigger, augmentation is turned on.
Water abstracted (Q) from ground creating a cone of depression (reduction in groundwater level).
Increased volume of water lost from river to ground due to bigger difference in SW and GW head.

Augmentation on, slight increase in flows at Westbourne gauge.
Water level at Westbourne reflects an 'effective augmentation' i.e. at this point amount of water lost to Chalk < Augmentation rate.

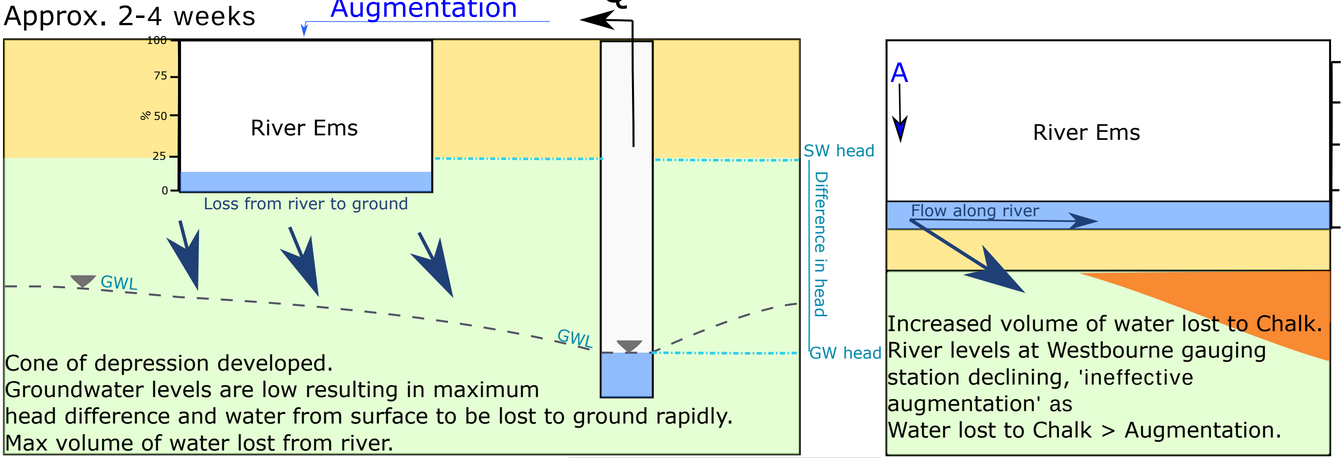
Approx. 1-2 weeks



Cone of depression develops further resulting in an increased head difference.
Increased volume of water lost from river to ground at increased rate

Increased volume of water lost to Chalk before reaching less permeable Lambeth bedrock and flowing downstream.
River levels at Westbourne gauging station declining, benefits of augmentation starting to reduce.
Water lost to Chalk >= Augmentation.

Approx. 2-4 weeks



Cone of depression developed.
Groundwater levels are low resulting in maximum head difference and water from surface to be lost to ground rapidly.
Max volume of water lost from river.

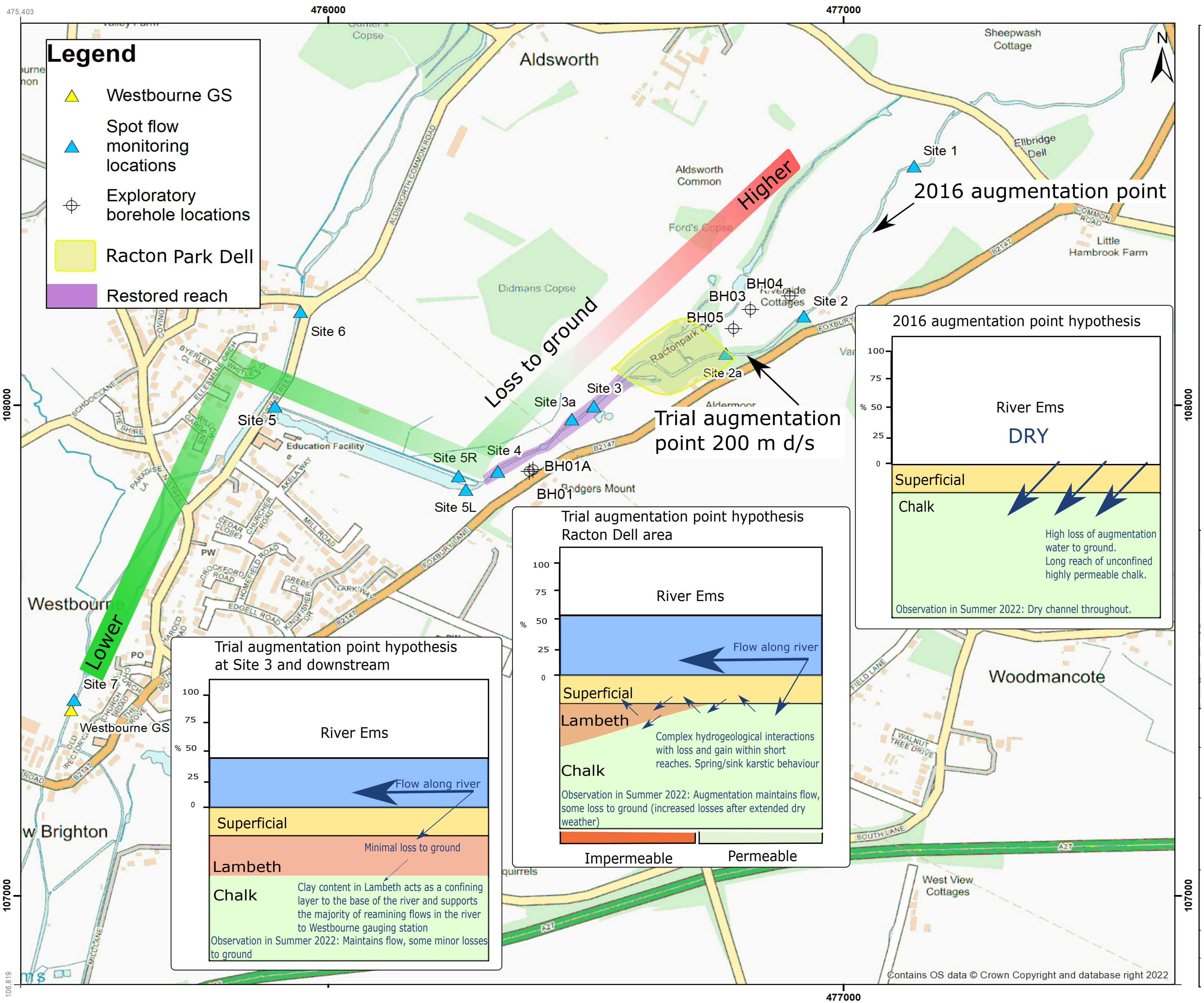
Increased volume of water lost to Chalk.
River levels at Westbourne gauging station declining, 'ineffective augmentation' as
Water lost to Chalk > Augmentation.

Permeable Impermeable

Atkins ref: 053 Augmentation failure conceptual understanding v1.0

Drawn:	Checked:	Reviewed:	Authorised
LH	EE	EE	PM
26/07/22	26/07/22	26/07/22	02/08/22

C.2. Updated conceptual understanding



High loss of augmentation water to ground. Long reach of unconfined highly permeable chalk.

Observation in Summer 2022: Dry channel throughout.

Complex hydrogeological interactions with loss and gain within short reaches. Spring/sink karstic behaviour

Observation in Summer 2022: Augmentation maintains flow, some loss to ground (increased losses after extended dry weather)

Clay content in Lambeth acts as a confining layer to the base of the river and supports the majority of reamining flows in the river to Westbourne gauging station

Observation in Summer 2022: Maintains flow, some minor losses to ground

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