3. Restoration of Hydrological Function and Reconnection with the Floodplain

3.1 Background

The New Forest streams are of considerable geomorphological and ecological interest in their own right, but they also contribute to the function and condition of other SAC habitats – notably alluvial/riverine woodland, mires, wet grassland and bog woodland. Seasonal flooding within the floodplain is particularly important and mires control the source and flow of water to the head streams.

However, the New Forest streams have been subject to historic drainage and channel modification since the 1870's (possibly as early as 1840's) with further large scale modifications though the 1950's –1970's to improve ground conditions for forestry and grazing. This drainage has had a number of undesirable effects:

- Canalisation through straightening, over deepening and over widening of the river channels has led to a change in channel morphology and width/depth ratio. The resulting loss of meanders and overall reduction in stream length causes water to run through the shortened channel section more rapidly. In addition, over deepening and bank-side spoil reduces the opportunity for out of bank flow and flooding of the floodplain.

- Prevention of natural flooding means that more energy is concentrated within the river channel itself resulting in increased erosion and transport of gravel. These gravels are deposited further downstream where the channel gradient reduces. This can result in the reduction of the channel capacity downstream, which in turn may cause drainage problems elsewhere.

- As the river tries to adapt to its new lowered stream bed level it creates headward erosion, often into the valley mires. In some places, creeping headward erosion has led to deeply incised channels in the order of 1.5m deep and lowered the water table in the surrounding floodplain. Tuckfield (1976, 1980) studied the effects of channel and drainage modification of the New Forest Streams and noted that headward erosion could exceed 1 metre per year and volume of material eroded due to human intervention has been found to exceed 0.5m3 per metre of channel per year.

- Where new Inclosures were created following the Deer Removal Act, streams inside the Inclosures were often straightened and side drains cut into tributary valleys. The straightening of channels was usually restricted to within the Inclosure Boundary and indeed the 1870 1:2500 Ordnance Survey maps show many of these new drains originating at the boundary of the Inclosure. Over the years these drains have deepened significantly and migrated headward well beyond the boundary fence onto the Open Forest.

- Spoil heaps adjacent to watercourses act like flood banks which reduce the potential for over banking and flooding on to the natural floodplain. Conversely, they also prevent water from draining back into the streams during periods of high rainfall.

- Canalisation also leads to development of an in-stream mono habitat. Loss of bed substrate can lead to a reduction in trout spawning habitat.

Wetland restoration techniques have sought to restore the natural hydrological function by remedying many of these historic channel modifications through:

- Removal of spoil banks
- Restoration of the original meandering channel through scraping out/excavation of the paleo-meanders which are usually still evident either visually or from topographic survey
- Bed level raising
- Infilling of straightened channels.
- Drain blocking

A key aim of the wetland restoration work has been to restore natural flooding to areas of floodplain within the Forest. This natural flooding is characterised by the retention of water in the floodplain to slow the hydrological response of the catchment so it takes longer for water to reach the main river channel and hence slow the magnitude of flood peaks. Bed level raising reduces the capacity of the channel meaning that the river should spill onto the floodplain more frequently and flow over the floodplain more slowly than in the channel thus reducing the magnitude of the flood peaks. In addition, the re-introduction of meanders to reaches of river, increases the channel length, which will again slow the catchment response, and drains blocking also slows the hydrological response of the catchment as it will take longer for water to reach the main river channel.

The New Forest rivers and streams are flashy nature which means they are quick to rise and fall with flooding only lasting for a few hours or a few days. The extent and depth of the flooding will vary according to a number of different factors including:

- Antecedent conditions - if the ground is already saturated then run-off will be more rapid
- Size, shape and topography of the catchment supplying water for that area of flood plain
- Intensity and duration of rainfall
- Geomorphology of the floodplain
- Channel characteristics
- Local land-use

A key role of the New Forest HLS project has been to improve the condition of the New Forest Special Sites of Scientific Interest (SSSI) from ‘unfavourable’ to ‘favourable’ condition. In order to improve and achieve favourable condition of SSSI habitats and features, a vital requirement is the reconnection of floodplain habitats and re-activation of floodplain morphology and function.

3.2 Restoration Objectives

- To reconnect the river channels with the flood plain and restore floodplain morphology

- To slow the flood peak and response times downstream

3.3 HLS Monitoring Sites

In order to understand how the HLS wetland restoration programme has improved floodplain connection and to monitor the behaviour of the rivers, Forestry England have installed:

- Timelapse cameras to visually capture the behaviour of the rivers at Amberslade, Claypits, Dockens, Harvestlade, Millersford, Pondhead and Wootton.

The location and details of the cameras are shown in Table 3-1 and Figure 3.1a:

Forestry England, in partnership with the Environment Agency, are also collecting water level data at four wetland sites.

- Pondhead – restored site
- Wootton – restored site
- Latchmore – unrestored site (baseline data)
- Millersford – unrestored site (baseline data)

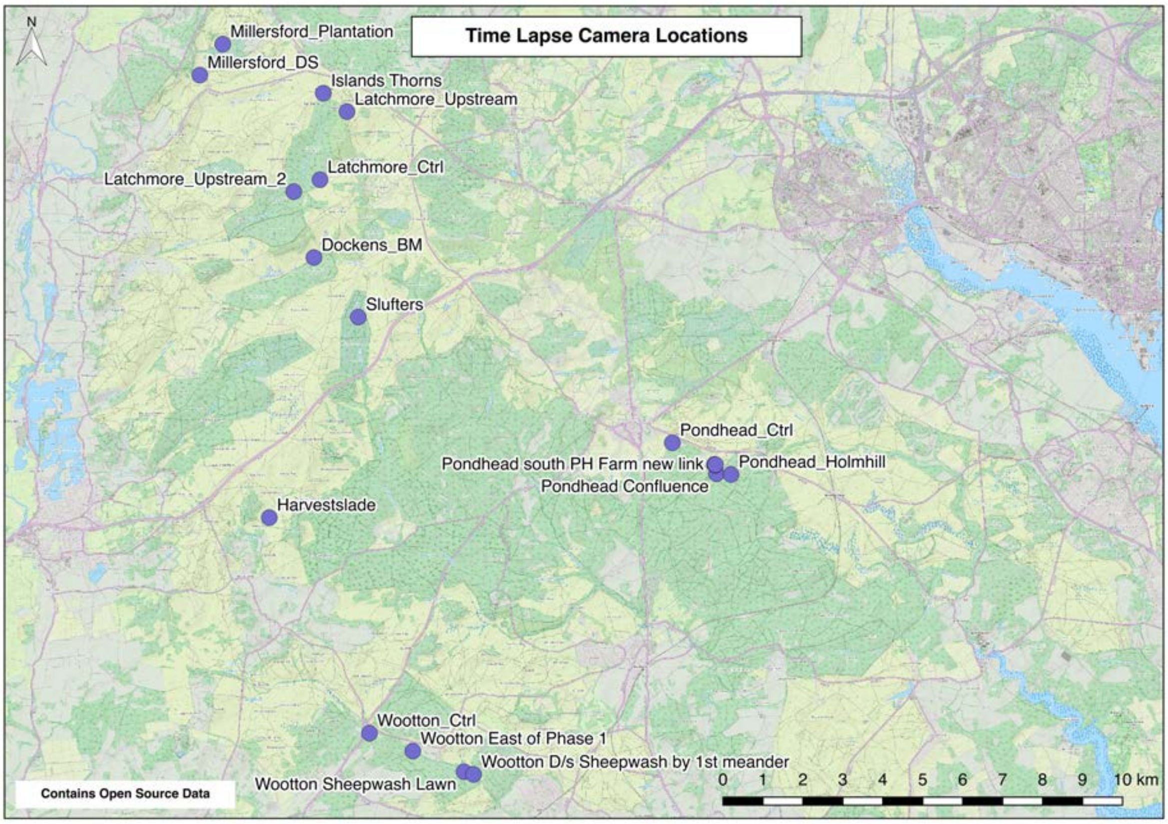
There are 3 data loggers positioned along a stretch of the Avon Water at Wootton – Wootton Upstream (control), Wootton Bridge (impact) and Wootton Downstream (impact). The locations of the data loggers are shown in Figure 3.2. A number of additional data loggers have recently been installed as shown in Figure 3.1b.

Table 3-1: Timelapse Cameras

Location	Description	Bank	NGR	View	MoRPH	Curent Intervals	Frames/ Second	Start Date	Date Captured to:
Millersford	Wooded Section across from Pylons	Left	SU196176	Upstream Facing N	N/a	15 Minutes	10	16/02/2018	17/12/2018
Millersford Downstream	Access via track by cottage	Right	SU19054 16857	Facing downstream	M1	15 Minutes	10	30/08/2019	On-going
Latchmore Upstream	Studley Wood/Claypits	Right	SU22738 15944	Facing downstream	M1	15 Minutes	10	10/06/2019	On-going
Latchmore Control	Island Thorns	Left	SU22062 14242	Facing downstream	M1	15	10	30/08/2019	On-going
Latchmore Upstream _2	Amberwood Inclosure	Left	SU21405 13944	Upstream	M10	15 Minutes	10	01/04/2019	On-going
Dockens Water	DS Rakes Brakes footbridge	Left	SU21905 12296	Upstream	M10	15 Minutes	10	30/08/2019	On-going
Wootton Control	On narrow drain	Right	SU23302 00404	Upstream	MorpH (near to M7)	15	10	06/09/2019	On-going
Wootton Phase 1	East of Phase 1	Left	SZ24383 99952	Downstream SE facing	N/a	15 Minutes	10	17/02/2016	22/05/2019
Wootton Phase 2	D/S of Sheepwash on first meander to left of Channel	Right	SZ25903 99367	Downstream - facing East	N/a	15 Minutes	10	22/11/2017	On-going
Pondhead	South of PH Farm New Link	Left	SU31954 07110	Downstream - South Facing	N/a	15 Minutes	10	06/01/2017	19/06/2019
Pondhead	Nr farm boundary - Lyndhurst drain	Left	SU31952 07100	Downstream	N/a	15 Minutes	10	13/12/2017	13/06/2019
Pondhead	Holmhill	Right	SU1982 06886	Upstream	N/a	15 Minutes	10	09/10/2019	On-going
Pondhead	Control	Left	SU308770766 5	Upstream	M1	15 Minutes	10	22/10/2019	On-going

Figure 3.1: Location of Time Lapse Cameras & Water Level Data Loggers

a) Time Lapse Cameras



b) Water Level Data Loggers

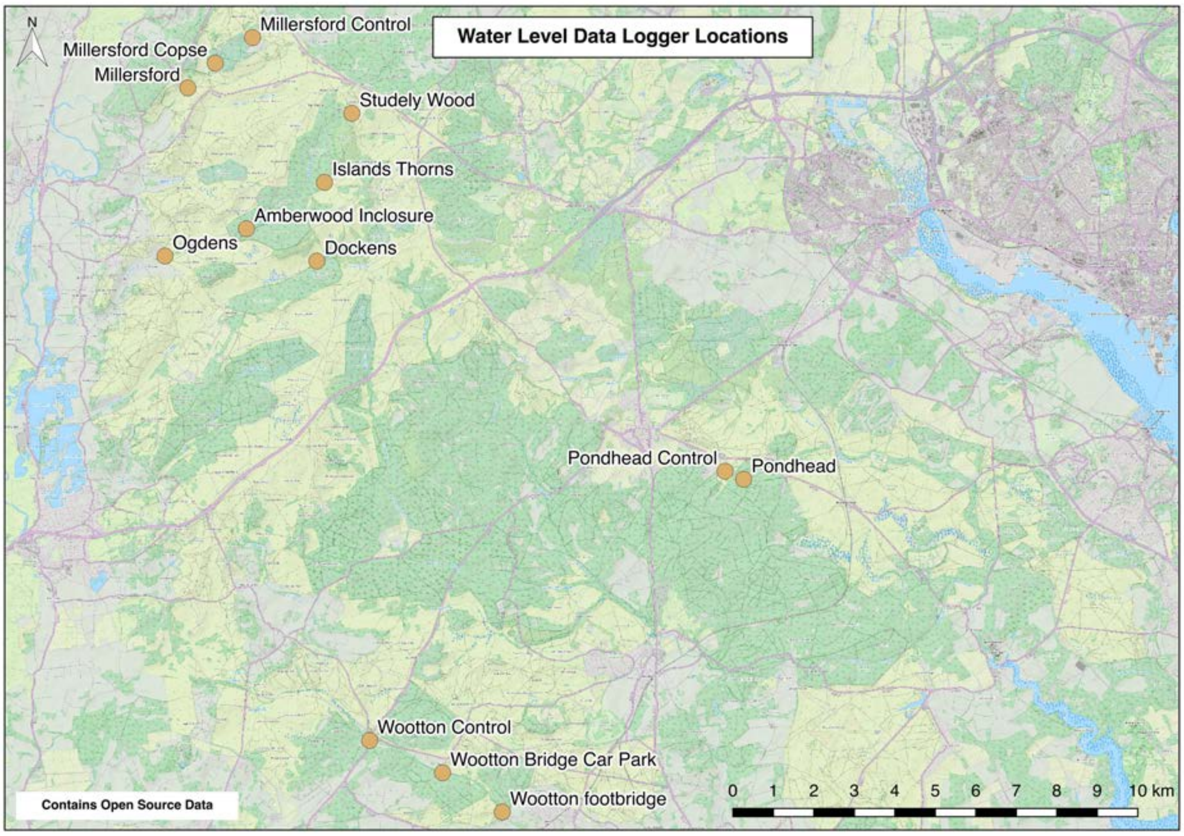
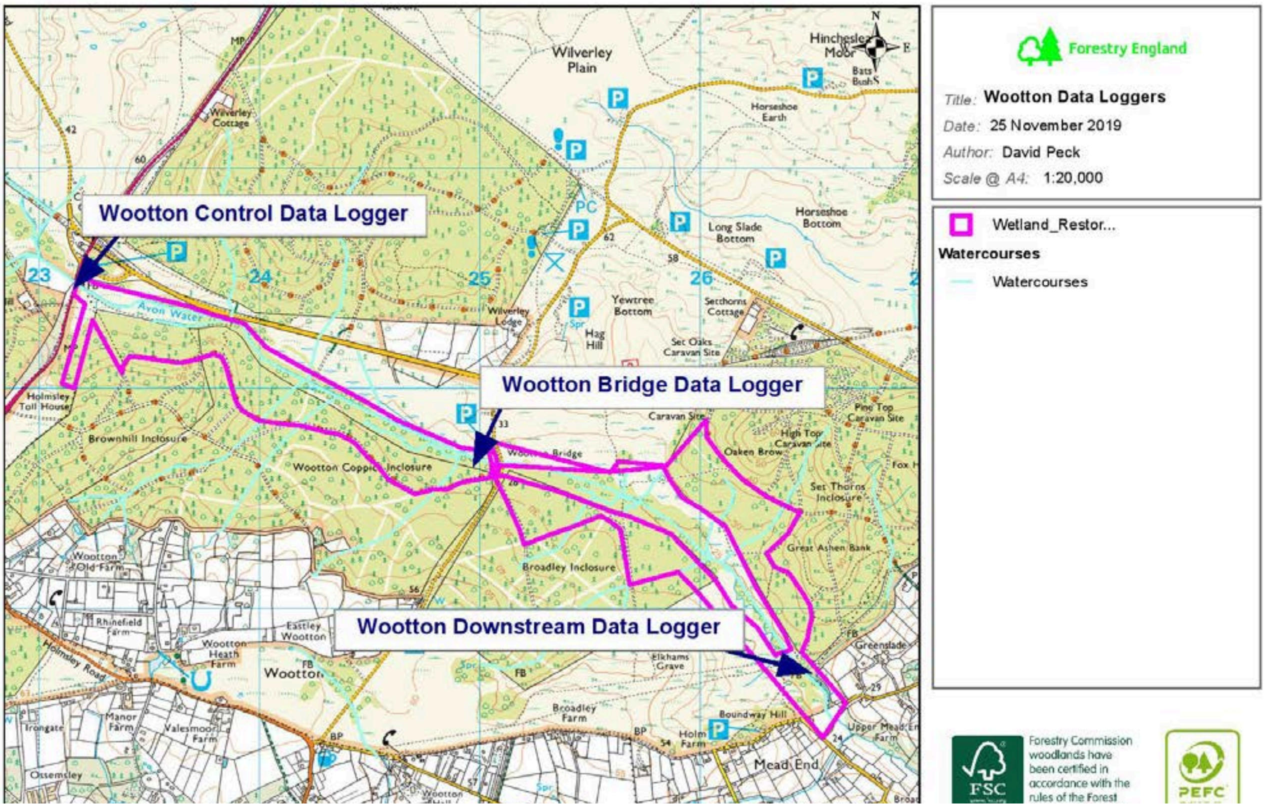
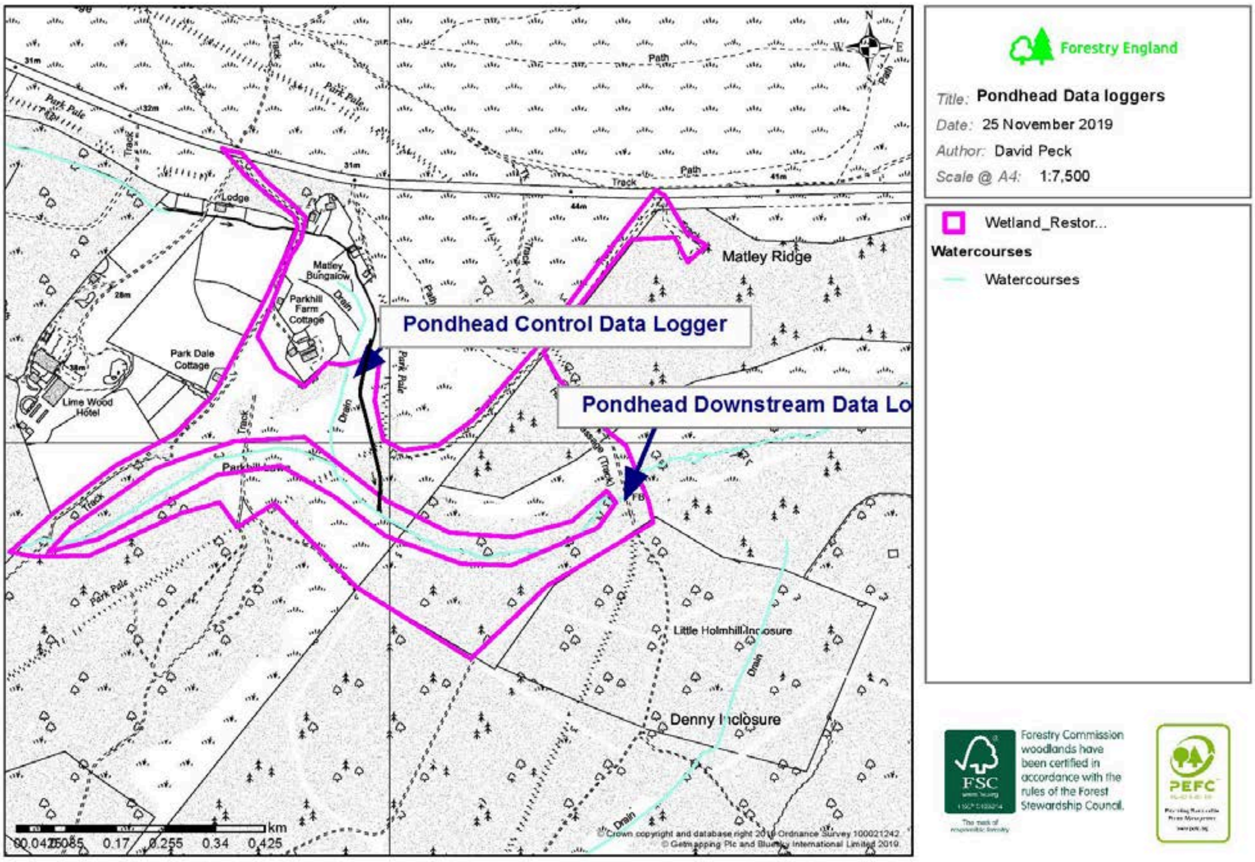


Figure 3-2: Water Level Data Loggers – Wootton & Pondhead





3.4 Methodology

In order to evaluate the success of restoration objectives in relation to reconnection with the floodplain and hydrological function, Forestry England have analysed the data logger data for Wootton and Pondhead. As part of this monitoring review, sections of timelapse camera footage have also been examined relative to rainfall events to visually observe river behaviour at Wootton, Pondhead, Millersford, Amberslade, and Studley Wood. Available timelapse camera footage has also been used to observe river behaviour for the rainfall events analysed for the data loggers.

The data loggers take an accurate reading of the water level, at each specific location along the course of the river, at 15-minute intervals, 24 hours a day. Through collating this data and aligning it with rainfall data obtained from The Environment Agency's weather station in Lyndhurst, it is possible to identify events of heavy rainfall and examine variations and patterns in water level of the river over time. Forestry England collect the data from the loggers and have used the findings to investigate the differences in these patterns before and after the HLS restoration work.

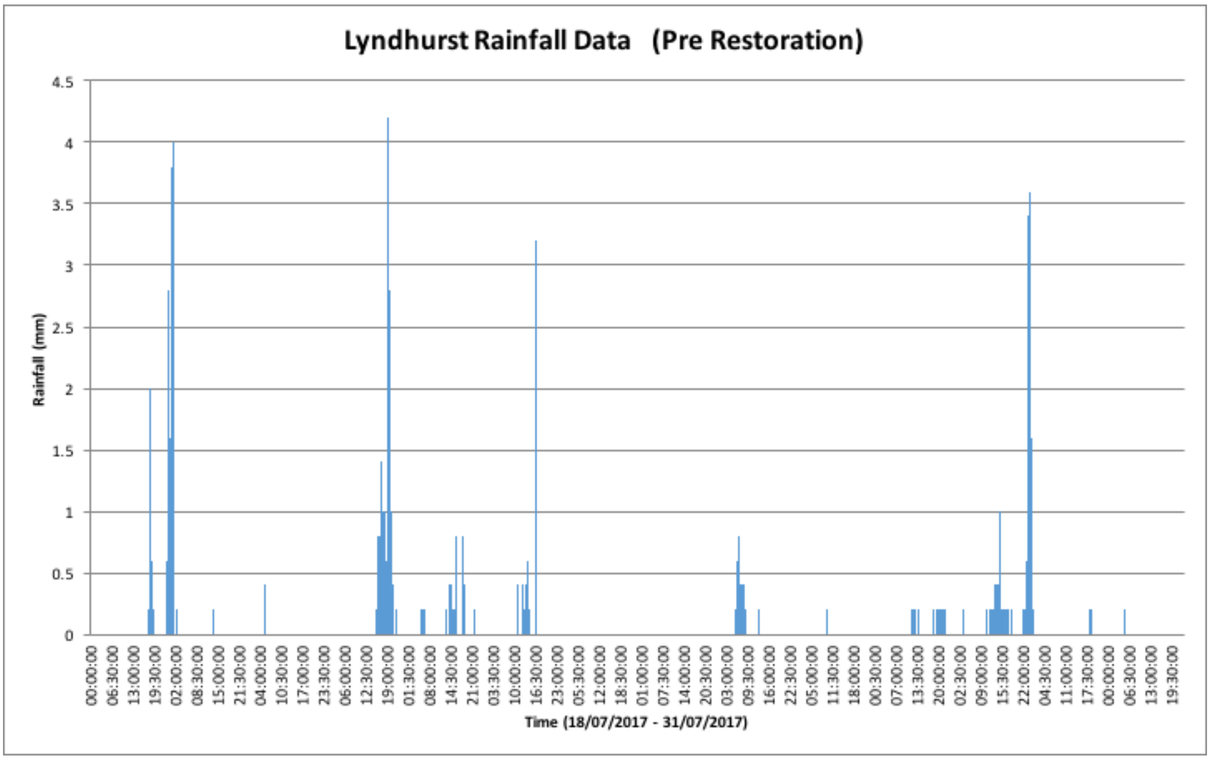
It is important to recognise that no rainfall event is exactly the same and so it is impossible to eradicate the variance caused by this. To minimise this variable, rainfall events have been selected to ensure they take place over a similar duration and include similar levels of precipitation. Due to variables in rainfall, rather than analysing the exact increase/decrease value of the water level at each data logger site, it is more beneficial to follow the pattern at which the water levels change and the rate of increase/decrease.

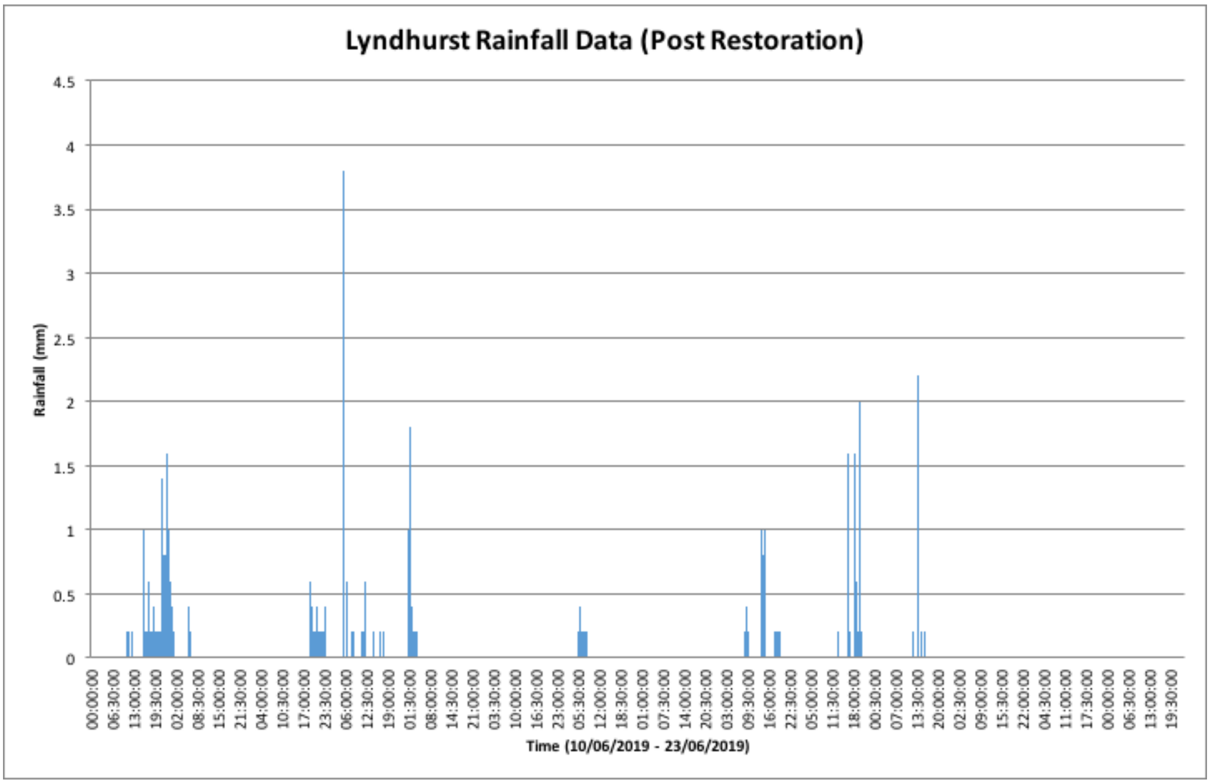
3.5 Analysis & Discussion of Results

3.5.1 Wootton Water Level Analysis

In order to make a close comparison between pre and post restoration water level data at this site, high rainfall events, both over a 13-day period, have been selected from the Environmental Agency's rainfall data in Lyndhurst. The rainfall data between 18/07/2017 to 31/07/2017 was used in order to display water level change pre-restoration and 10/06/2019 to 23/06/2019 to display the post-restoration effects (Figure 3.3). From these two extended periods of high rainfall, the analysis of water level changes within the Avon Water have also been conducted during more isolated high rainfall events over the duration of a 3-day period 20/07/2017 to 23/07/2017 pre-restoration and 12/06/2019 to 05/06/2019 post- restoration .

Figure 3.3: Rainfall Data





When assessing Wootton pre-restoration rainfall and water level data for the upstream data over an extended period, it is clear that the water level responds quickly and dramatically to periods of high rainfall (Figure 3.4a). Water levels within the river can be seen to peak rapidly after high rainfall is recorded showing a short lag time, indicating that the precipitation is entering the river at a fast rate. The peaks in water level are also relatively substantial in relation to the level of rainfall experienced. This can be evidenced by the high level of rainfall on 29/07/2017 which saw a maximum rainfall of 3.6mm. This brought about a rapid, but short lived, increase in water level of over 0.4m at Wootton Downstream prior to restoration. Water levels, as expected, then return to what can be assumed as the base flow at a slightly slower rate than that of the increase, but still at an overall fast rate.

Data from the loggers at Wootton Bridge and Wootton Downstream shows that water levels follow a pattern of less dramatic change after isolated rainfall events. Peak water level curves are noticeably more gently sloping, with an increasingly convex downward shape, and water levels do not reach such high maximum water levels in comparison to its base level. The lag time of the river does slightly increase it moves downstream, but not by a significant amount. Water levels can be seen to decrease at an increasingly slower rate at Wootton Bridge and then further still at Wootton Downstream data logger. This leads to the overall hydrograph displaying a flatter, more drawn out shape over the 13-day period of high rainfall as we move downstream. This is as expected from many typical river hydrographs as you move downstream along the rivers course due to a reducing gradient and the widening of floodplains and river basins.

When comparing this to the pattern shown by the post-restoration water level data, over the extended 13-day period shown in Figure 3.4b **(**10/06/2019 – 23/06/2019), it is clear that the river has become far less responsive to individual high rainfall events. The general hydrograph shape at Wootton Upstream, in comparison to the same site pre-restoration, is much flatter with smaller, more rounded curves symbolising slower and less significant water level increases after heavy precipitation. It must be noted that the difference in rainfall events for the pre- and post-restoration dates could be seen to cause these differences, however the two 13-day periods of heavy rainfall have been chosen in the aim to be as similar as possible in order to allow a close comparison. However, after a relatively high period of rainfall on 19th and 20th June 2019, there is only a very slight increase in water level, almost unnoticeable, and this then returns to its base level at a very slow rate.

The hydrograph for Wootton Downstream displays a contrast to that of the pre-restoration hydrograph it is almost flat post restoration, with increases in water levels appearing as small rounded curves. This evidences flow stabilisation and the subsequent ability of river restoration in reducing flood risk, connection to the floodplain and reducing the impacts of heavy rainfall events. The lag time for the river post-restoration is slightly longer at Wootton Upstream than before the work, with a longer duration of time between peak rainfall and peak water level; this evidences further the ability that the restoration has enable the water to connect to the floodplain.

Although it is difficult to determine an accurate overall base water level for each of these data logger sites, without looking at the data for a more prolonged period, it could be possible to make a general comparison of base water levels from the pre to post restoration using the 13-day hydrographs. The Avon Water displays the following changes to base water level from pre to post restoration: over 0.2m water level increase at Wootton Control, Wootton Bridge remained constant, over 0.25m decrease in base water level at Wootton Downstream. This could suggest that at the upstream site of Wootton Control, the restoration work is causing water to be held back and retained and would explain the increase in water level here. At the downstream site, water is being held upstream longer due to the restoration work and therefore water levels at this point can be seen to have reduced.

Within the post-restoration water level data from Wootton, it is also possible to make comparisons between the water level hydrographs of the three data logger sites, based upon their locations along the course of the river. Variations can then be based on the length of river that has been restored upstream of that site, using the pre-restoration water level data as a control. Wootton Bridge data logger is located downstream of a 2.2km stretch of the Avon Water which has been restored, whilst the Wootton Downstream data logger is located further downstream with nearly 4km of river restoration upstream of it.

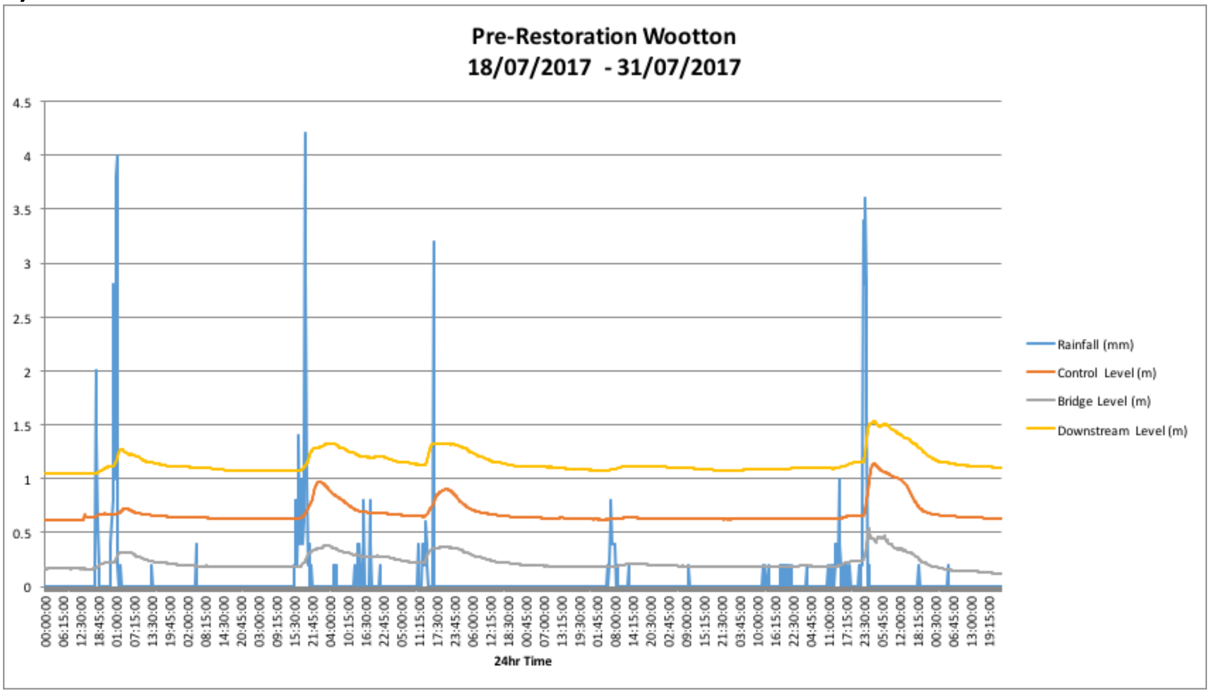
When analysing the effects of a shorter heavy rainfall event between 12th and 15th June 2019 (Figure 3.5b), with peak rainfall reaching 3.8mm at 05:15:00 on 13th June, it is clear that the duration of time each data logger site takes to get to, and remains at, peak water level, differs based upon their locations along the course of the river. Wootton Upstream, remains at its peak level for only 15 mins; Wootton Bridge downstream of 2.2km of restoration for 3 hr 45 mins; and lastly the data logger at Wootton Downstream, downstream of nearly 4km of restored river, remains at peak level for 7 hr 45 mins. These water levels show a direct correlation between the length of restored river upstream of the site and the duration at which that point in the river remains at high water level. This pattern could begin to suggest that the restoration work completed on the Avon Water has caused slower movement and flow of water in a downstream direction, meaning that water level remains at its peak for a longer period.

In an attempt to link the rivers ability to stabilise flow and hold peak water levels upstream for a more sustained period to the restoration work the HLS Scheme have completed to date, it is necessary to use a similar pre-restoration heavy rainfall event as a comparison. A suitable event occurred 20/07/2017 to 23/07/2017 (Figure 3.5a*).* Although differences in peak water level duration can also be found during this similar heavy rainfall event within the pre-restoration water level data, the duration differences do not follow the same pattern. Peaks last for 30 mins, 2 hr 15 mins, 1 hr 45 mins (starting from upstream, moving down). In order to further eliminate the possibility for any other variables to skew these results, the rainfall events used for the pre- and post-restoration analysis are taken over a three day period, with precipitation recorded in a relatively similar pattern and with similar total rainfall amounts – with the pre-restoration rainfall event only 5.1mm over that of the post-restoration.

In conclusion, the analysis of the water level hydrographs at Wootton has displayed some clear changes which have the probability been achieved by the restoration work.

Figure 3.4: Hydrograph data relative to rainfall data (13 day sequence)

a)



b)

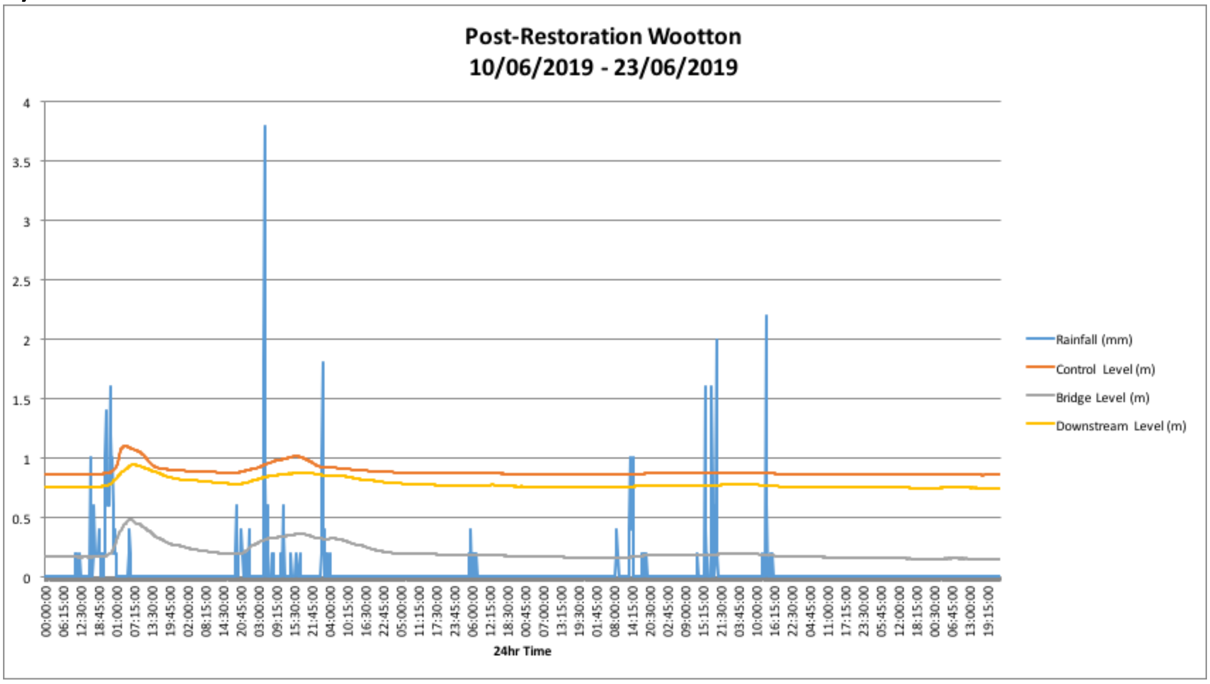
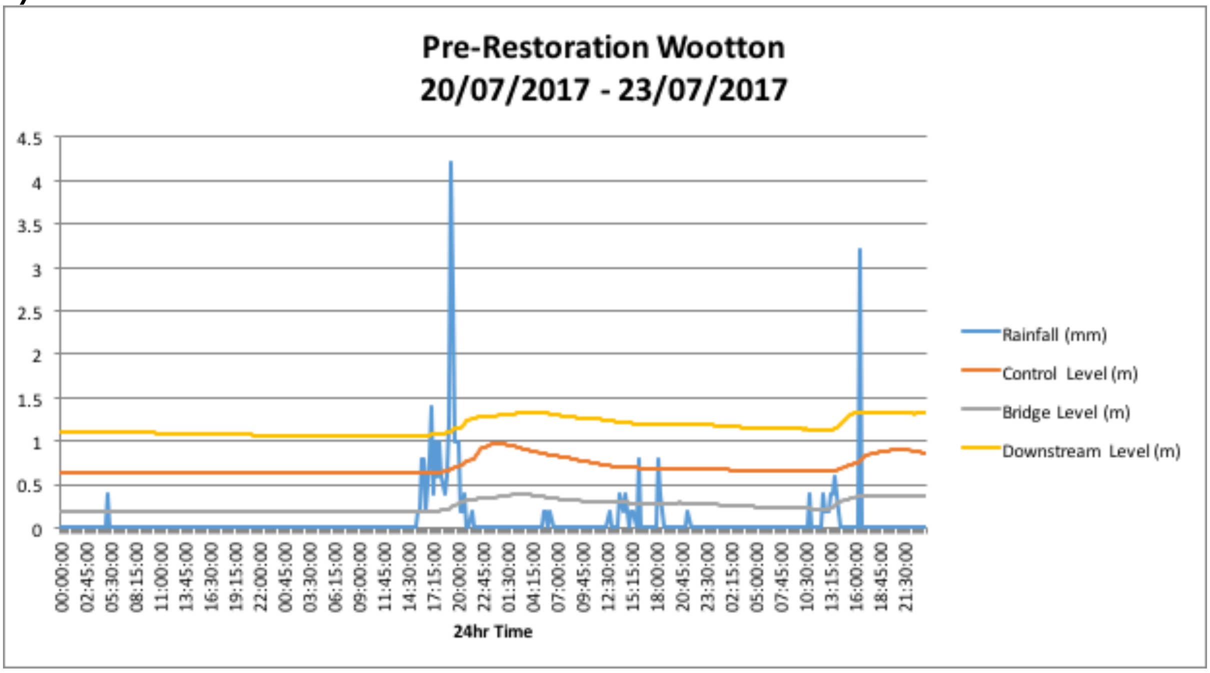


Figure 3.5: Hydrograph data relative to rainfall data (3 day sequence)

a)



b)

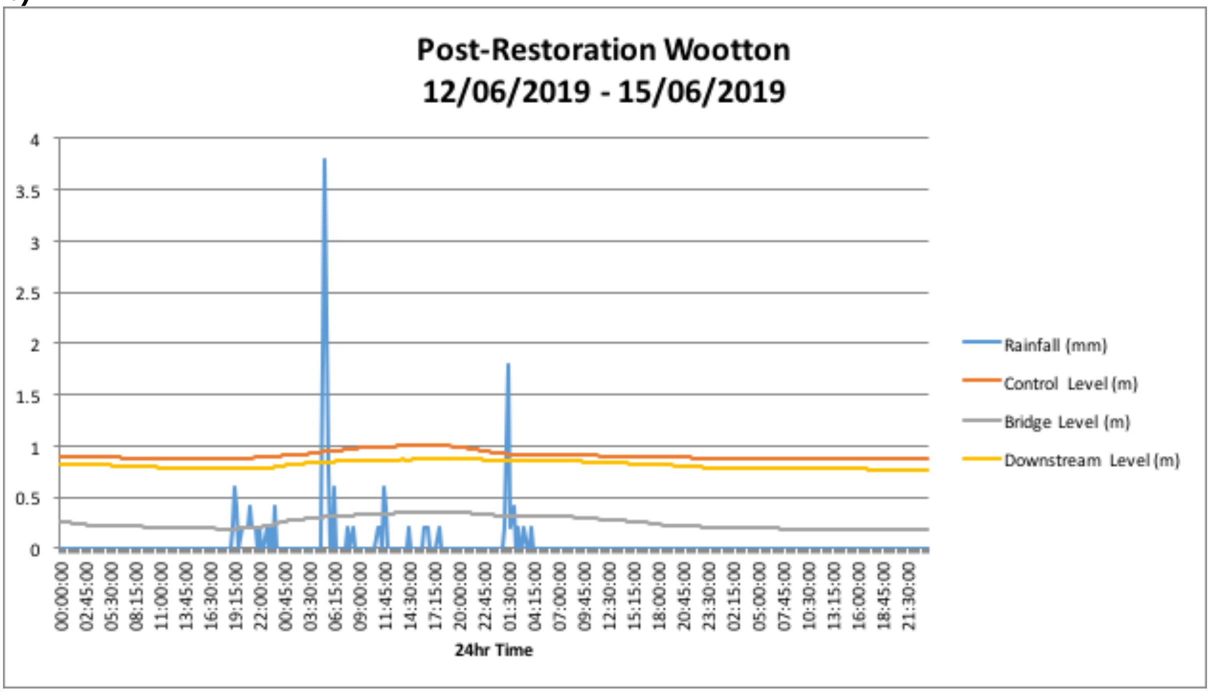
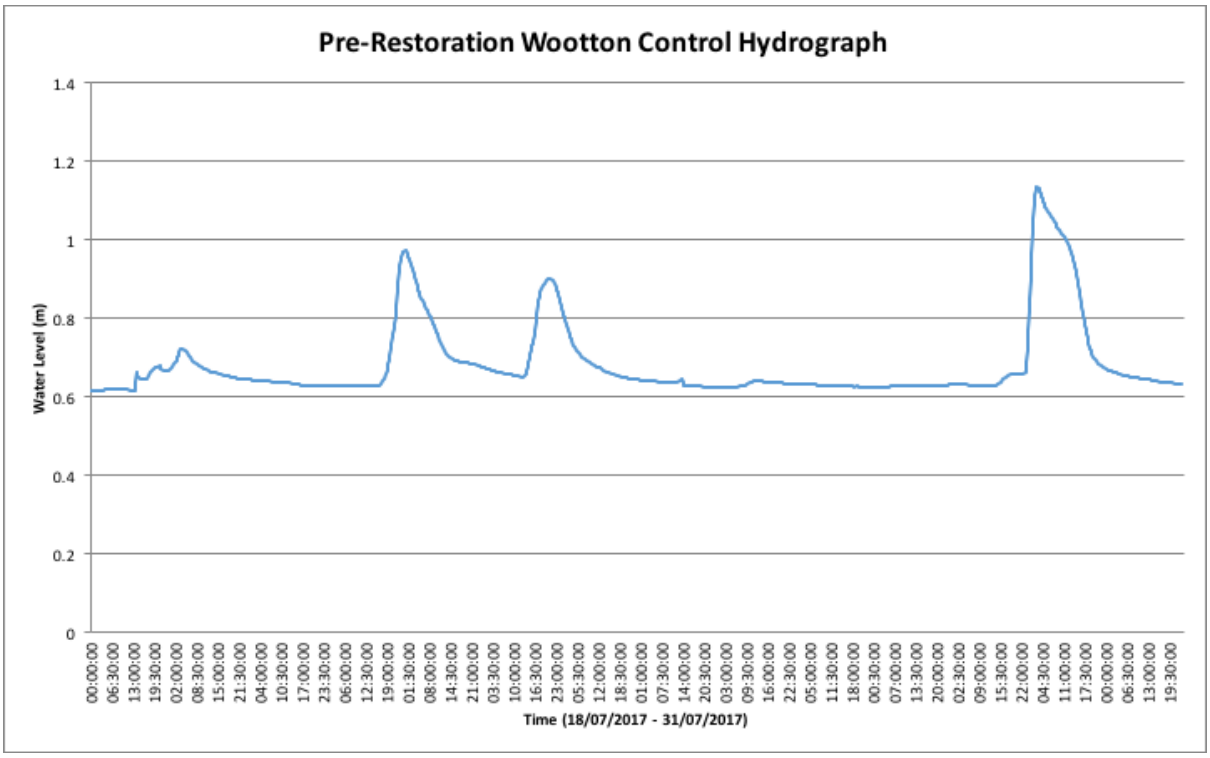
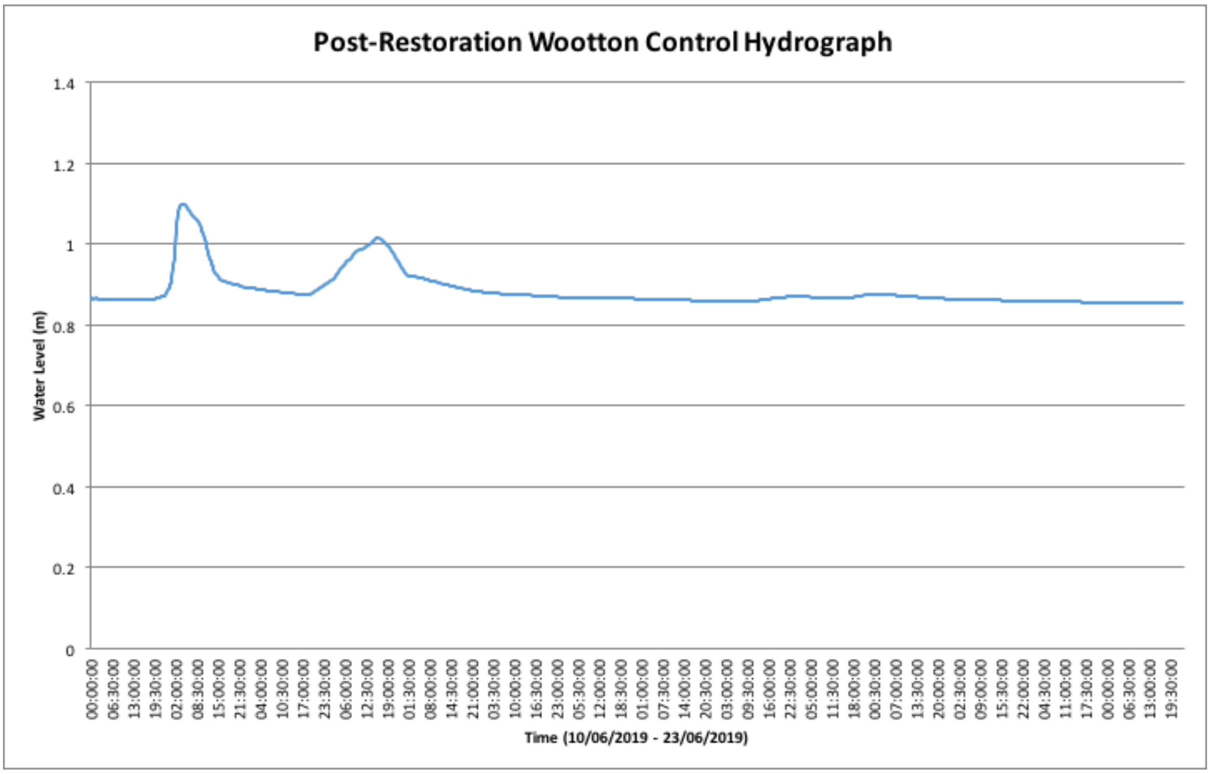
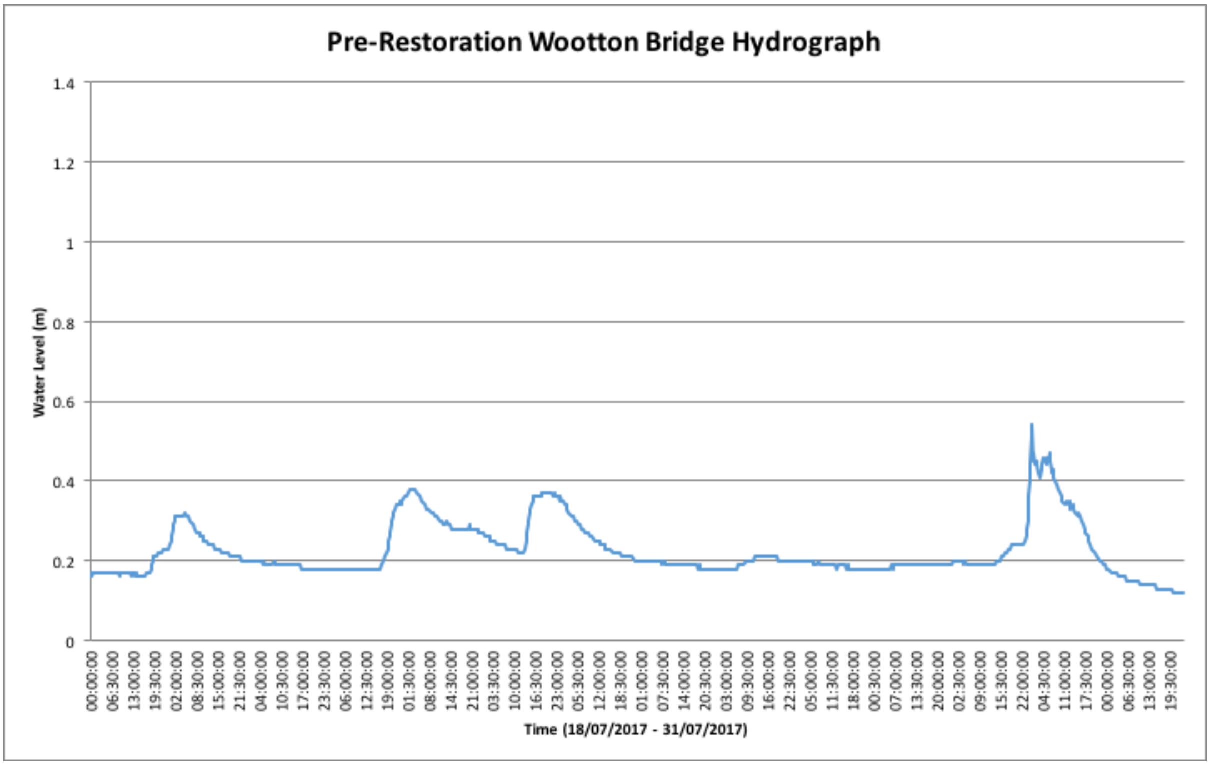
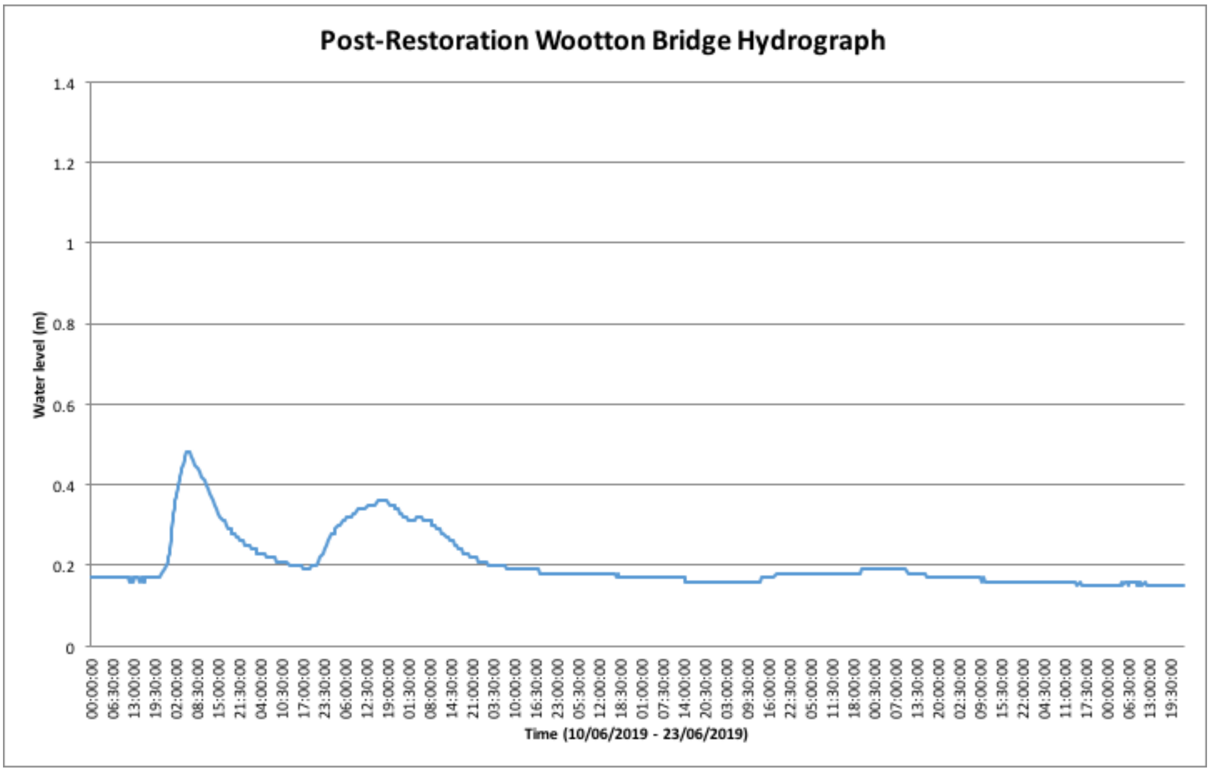


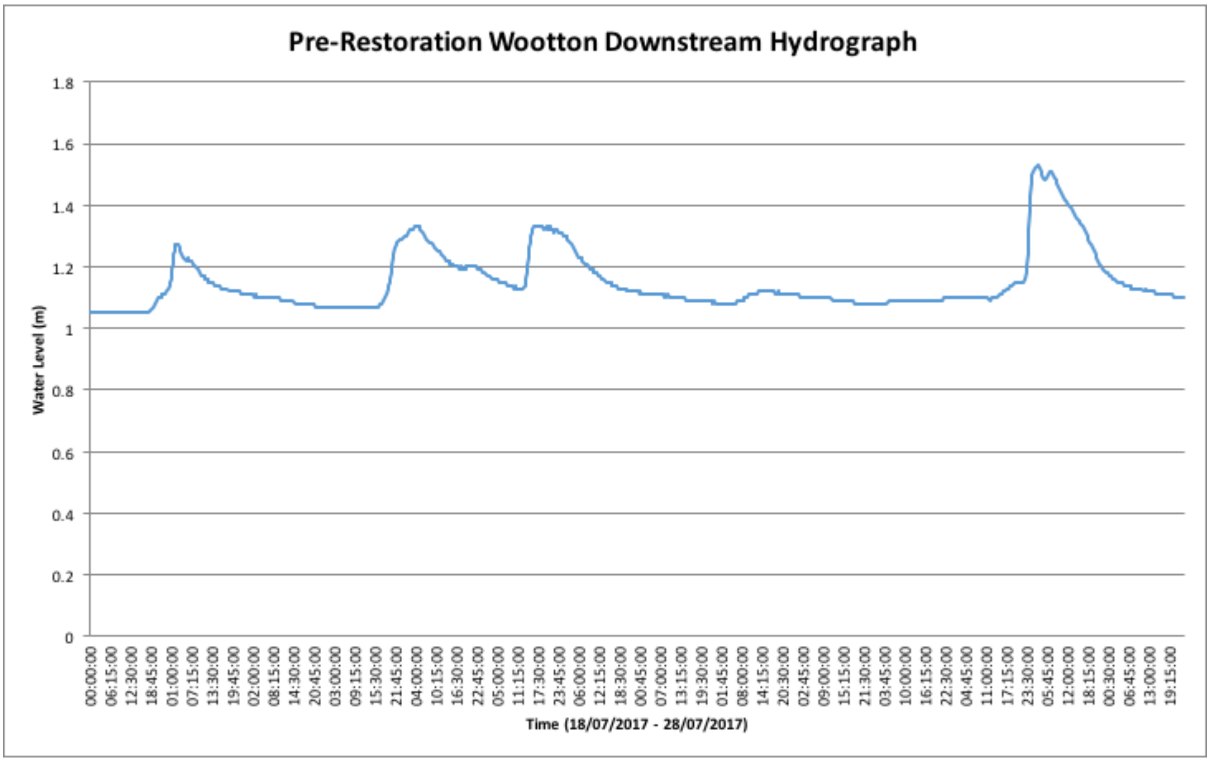
Figure 3.6: Individual station hydrographs

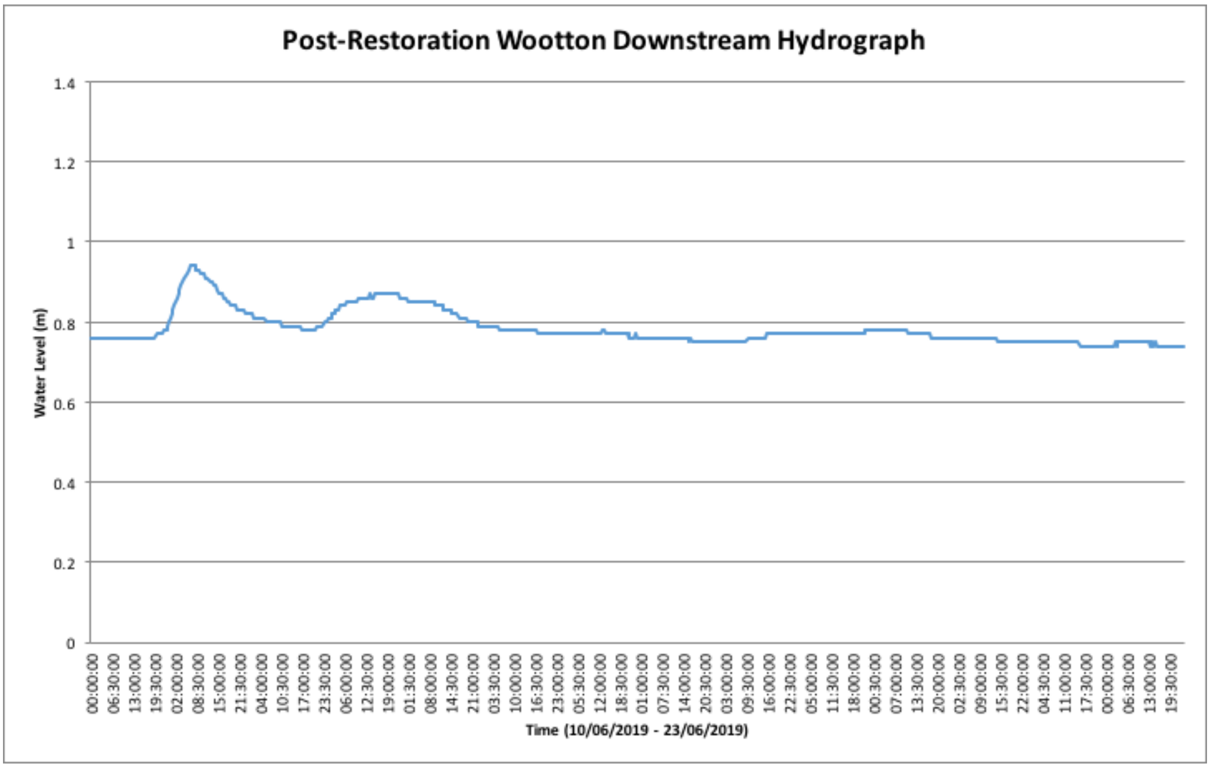





Pre-Restoration Wootton Bridge Hydrograph
Water Level (m)
Time (18/07/2017 - 31/07/2017)


Post-Restoration Wootton Bridge Hydrograph
Water level (m)
Time (10/06/2019 - 23/06/2019)


Pre-Restoration Wootton Downstream Hydrograph
Water Level (m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
00:00:00
06:15:00
12:30:00
18:45:00
01:00:00
07:15:00
13:30:00
19:45:00
02:00:00
08:15:00
14:30:00
20:45:00
03:00:00
09:15:00
15:30:00
21:45:00
04:00:00
10:15:00
16:30:00
22:45:00
05:00:00
11:15:00
17:30:00
23:45:00
06:00:00
12:15:00
18:30:00
00:45:00
07:00:00
13:15:00
19:30:00
01:45:00
08:00:00
14:15:00
20:30:00
02:45:00
09:00:00
15:15:00
21:30:00
03:45:00
10:00:00
16:15:00
22:30:00
04:45:00
11:00:00
17:15:00
23:30:00
05:45:00
12:00:00
18:15:00
00:30:00
06:45:00
13:00:00
19:15:00
Time (18/07/2017 - 28/07/2017)


Post-Restoration Wootton Downstream Hydrograph
Water Level (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
00:00:00
06:30:00
13:00:00
19:30:00
02:00:00
08:30:00
15:00:00
21:30:00
04:00:00
10:30:00
17:00:00
23:30:00
06:00:00
12:30:00
19:00:00
01:30:00
08:00:00
14:30:00
21:00:00
03:30:00
10:00:00
16:30:00
23:00:00
05:30:00
12:00:00
18:30:00
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07:30:00
14:00:00
20:30:00
03:00:00
09:30:00
16:00:00
22:30:00
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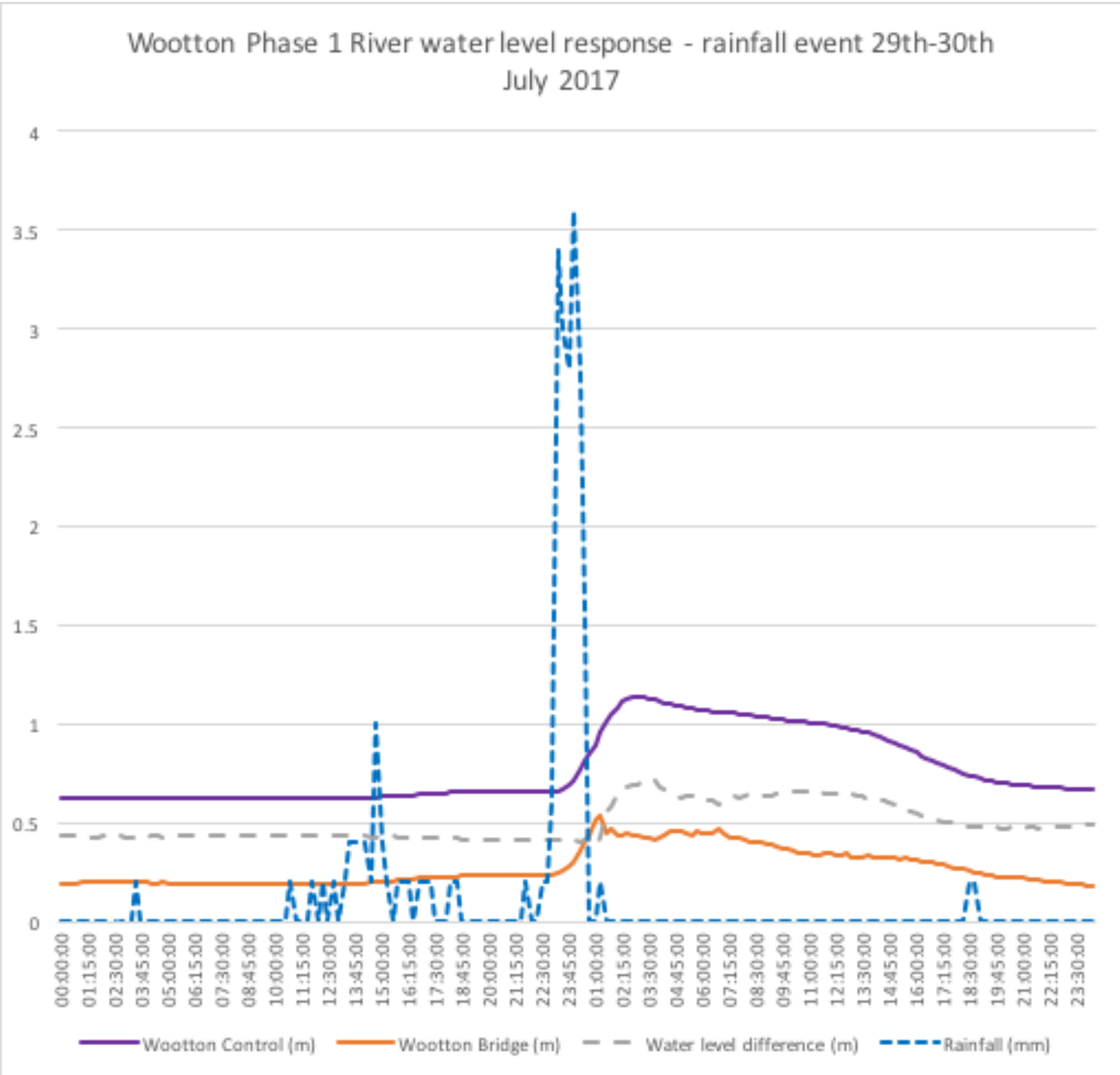
07:00:00
13:30:00
20:00:00
02:30:00
09:00:00
15:30:00
22:00:00
04:30:00
11:00:00
17:30:00
00:00:00
06:30:00
13:00:00
19:30:00
Time (10/06/2019 - 23/06/2019)

3.5.2 Timelapse Camera Footage – Wootton

Timelapse camera footage is available (Camera 2 – Phase 1 East) covering the rainfall event of 29/07/2017 which formed part of the data logger analysis detailed above. By this date, the Phase 1 restoration had already taken place in 2016 between the Control data logger and the Wootton Bridge data logger so a comparison of river level data and synchronised timelapse photographs show how the river visually responded to the rainfall event and in turn influenced the hydrographs. Figure 3.7 shows the water level response from the logger data capture relative to the rainfall event. The river response has already been described in detail in Section 3.5.1 but the timelapse camera images allow a visual analysis of how the river responded.

Figure 3.7: Wootton Phase 1 River level response – Rainfall event 29th-30th July, 2017



Prior to the rainfall event starting TLC footage in the morning at 06:58 shows the river at normal level still well within its banks.

Some small showers occurred between 10:00am and 18:45 and footage captured at 16:58 shows a very slight rise in river levels. The data logger upstream records a rise of 1cm and the downstream data logger a rise of 3cm.

The main peak of the rainfall event occurred overnight when it was not possible for the camera to capture visible images but the hydrographs show a rapid response to the heavy rain and the first clear image in the morning taken at 06:58, approximately 5 hours after the peak rainfall ceased shows the river flowing out of bank and actively engaging with the floodplain. The patterns in the hydrograph, where the distance between the upstream and downstream river levels graphs suddenly increases after the peak rainfall suggests that the has river started to overtop its banks and engage with the floodplain around 01:15 hours.

Two hours later the camera starts to capture the river levels starting to fall with river levels reducing 2cm upstream and 4cm downstream

Footage from 09:00 and 13:00 hours shows that river levels are still high but falling with more of the higher bankside features gradually being exposed. The patterns in the hydrograph still show that the river is engaging with the flood plain.

From 16:00 hours onwards the differences in the upstream and downstream river levels start to decrease and camera footage shows the river starting to fall back within its banks. The image at 19:00 was one of the last clear images captured before darkness fell.

Analysis of timelapse footage relative to various rainfall events suggest that following the Phase 1 restoration the river close to the timelapse camera starts to overtop when the upstream Wootton Control hydrograph records a level of around 1m.

3.5.3 Pondhead - Water Level Data Analysis

In order to make a close comparison between pre and post restoration water levels at Pondhead, the same two 13-day periods of high rainfall were used as at Wootton. The rainfall data between 18/07/2017 to 31/07/2017 was used in order to display water level change pre-restoration, and to display the effects of post-restoration 10/06/2019 to 23/06/2019 (Figure3.3). As with the Wootton analysis, two shorter heavy rainfall events were used over a three-day period to investigate more specific and isolated water level changes (Figure 3.10). Data loggers are placed at two locations at Pondhead, one at a control site upstream of the restoration work, and one downstream of the work (Figure 3.2); giving us the ability to compare hydrographs based on the length of restored river upstream of that logger.

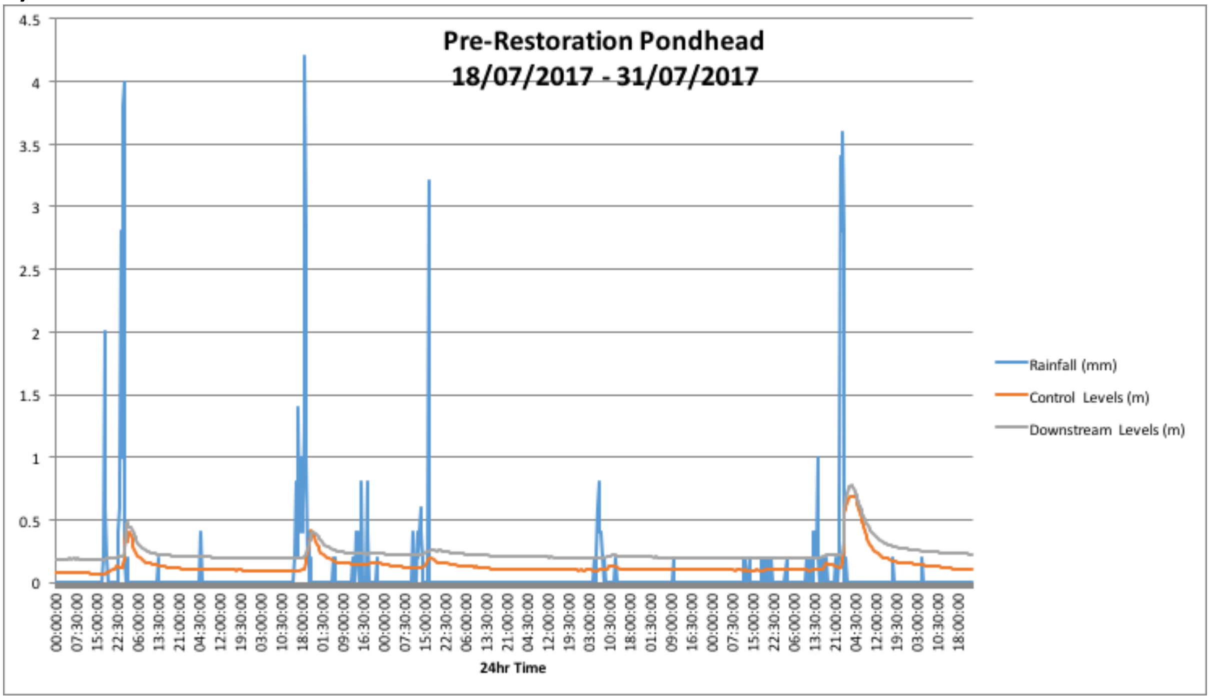
When analysing the water level hydrographs for rainfall events prior to the restoration work at Pondhead, it is clear that levels react quickly and closely to heavy rainfall events. Peak water levels can be seen to rise and fall particularly quickly in both the upstream and downstream hydrograph's, with very short lag times being displayed. After a peak in rainfall reaching 3.8mm on 29/07/2017, the Pondhead Control hydrograph (Figure 3.8) displays a rapid increase in water level, reaching a maximum of 0.69m, 4 hours after peak rainfall is recorded. The rate, at which the water level returns to its perceived base level, although slower than the increase, is also relatively fast. The Pondhead Downstream logger data displays water level changes which react closely to rainfall patterns however, increases do not seem to be as substantial and the time taken for the water level to decrease is slightly longer than the upstream location. The decrease curves are slightly longer and longer lasting further downstream; this mirrors the same pattern seen in Wootton's pre-restoration hydrographs.

Analysis of the 13 day rainfall event hydrographs after the restoration had been completed (see Figure 3.8), these changes are extenuated further; with increased lag time between peak rainfall and peak water level and also long drawn out decreases in water level once the peak has been reached. It is clear that as we move from the data logger at the upstream location to that further downstream we do not see the same changes as before. Before, water level peaks were less dramatic, lag times longer and the rivers water levels decreased at a slower rate when we moved downstream, for the post-restoration hydrographs, they almost follow an identical pattern in water level changes. There is near enough little difference between the hydrograph of the Pondhead Control and that of downstream site potentially due to restored floodplain connection.

It is difficult to accurately assess the base water level changes from before and after the restoration work using just the 13-day hydrographs; however, they can be used to make an overall analysis of the general differences the restoration work has potentially achieved. When comparing the pre and post restoration hydrographs, Pondhead control data logger displays an approximate increase in base water level of 0.05m. The downstream data logger site, on the other hand, displays an approximate 0.05m decrease in base water level after the restoration work has taken place. This follows a similar pattern to that of the Avon Water at Wootton with the upstream site showing signs of overall increased water level and downstream site the opposite. The fact that both the Pondhead and Wootton sites have displayed this pattern change after restoration work has taken place, strongly suggests that water retention and flow stabilisation has potentially been achieved as part of the HLS wetland restoration programme.

Figure 3.8: Hydrograph data relative to rainfall (13 day sequence)

a)



b)

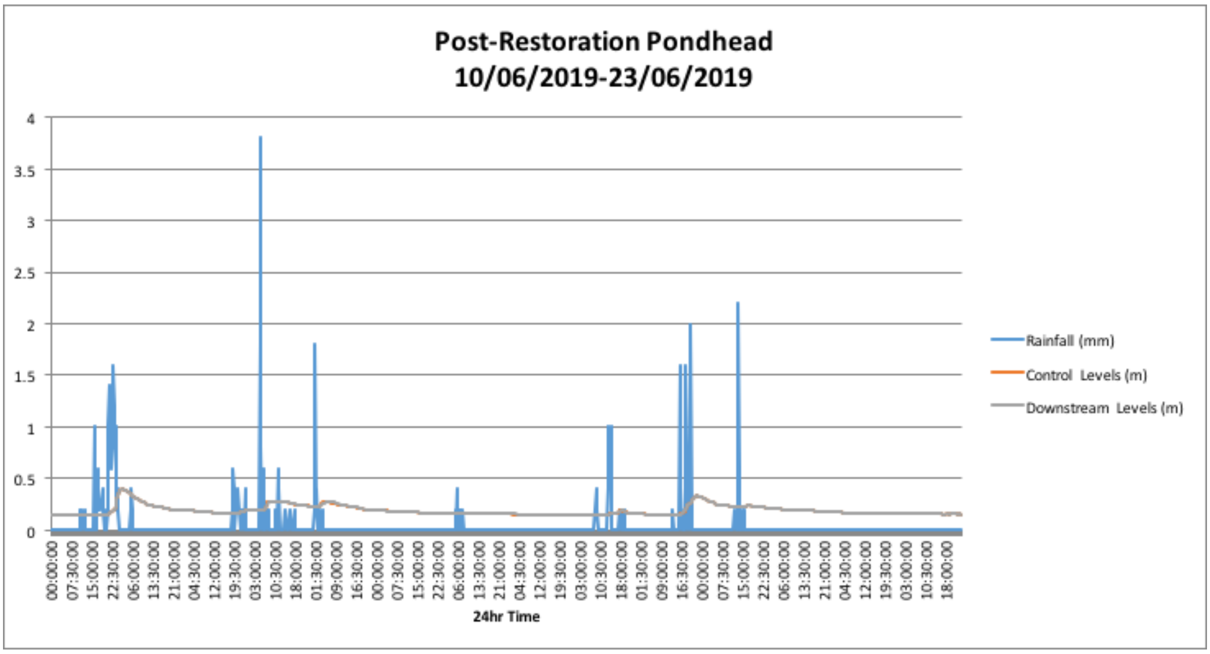
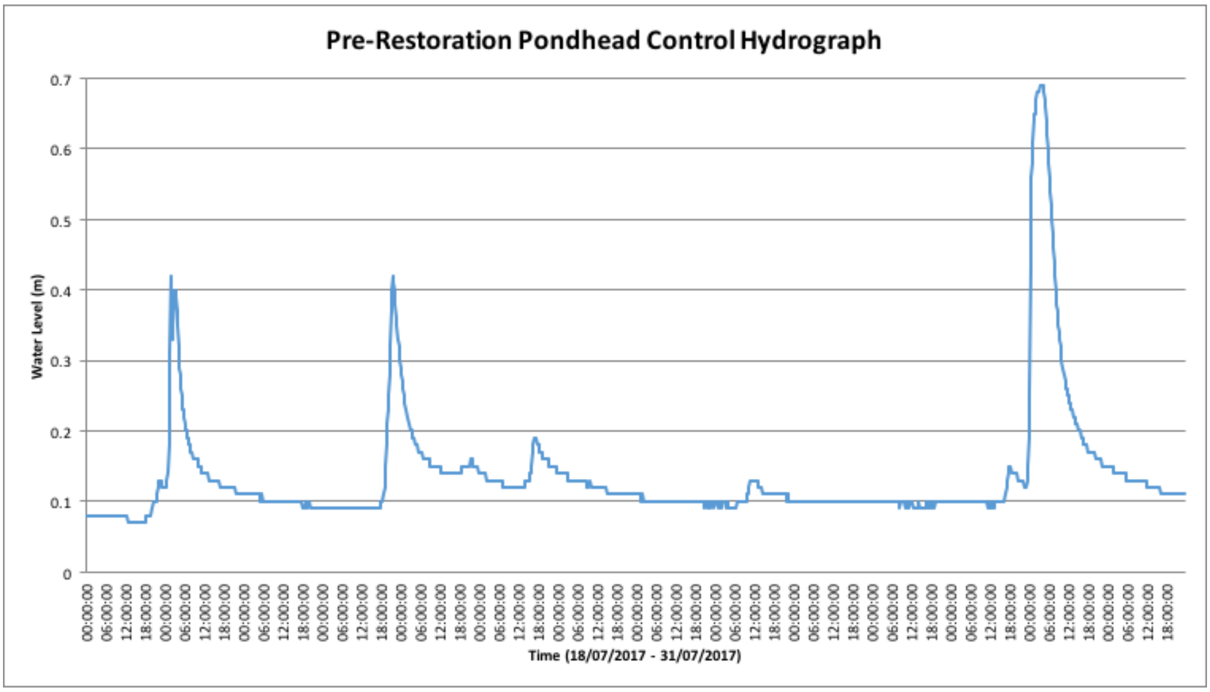


Figure 3.9: Individual station hydrographs



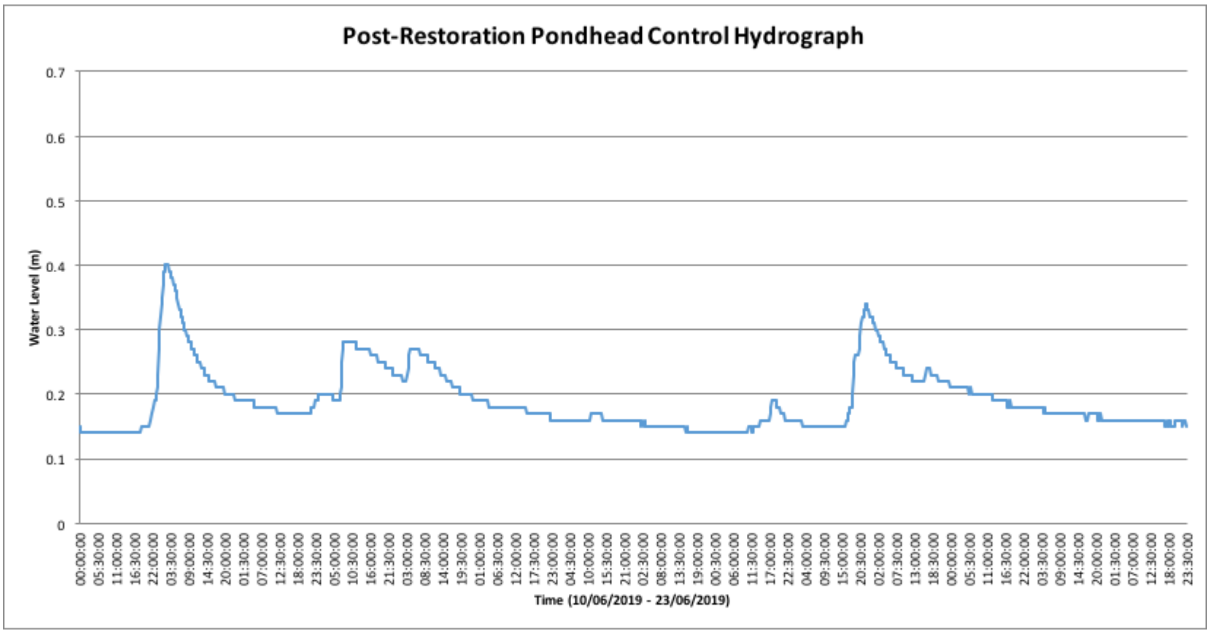
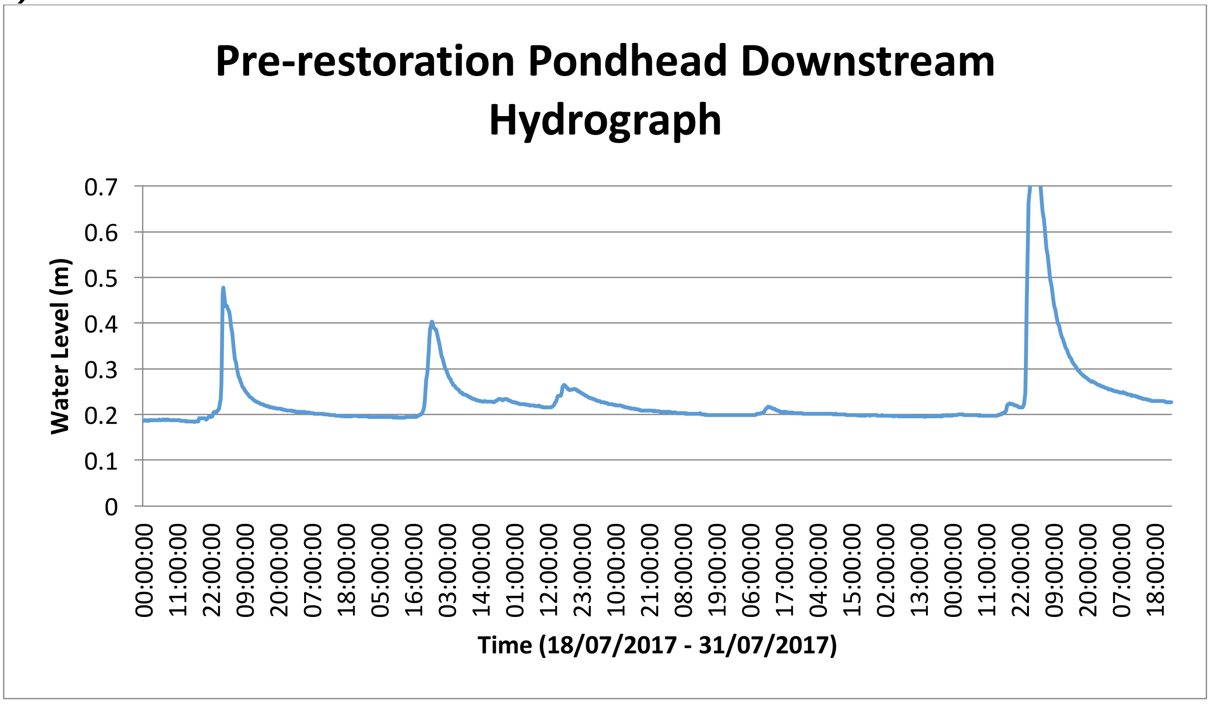
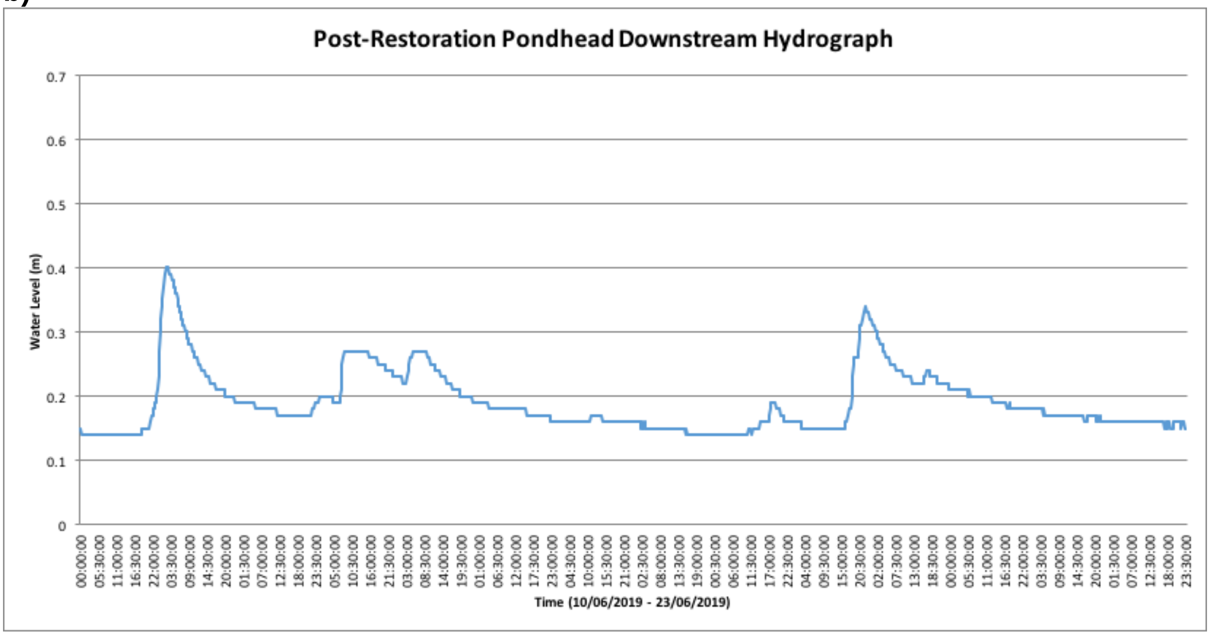


Figure 3.10: Hydrograph data relative to rainfall data (3 day sequence)

a)



b)



With the post restoration water level data from Pondhead it is possible to make direct comparisons between the hydrographs of the two data logger sites, based upon their different locations along the course of the river. It is clear that the post restoration water level hydrographs for the Pondhead Control data logger and Pondhead Downstream data logger (Figures 3.9, 3.10), follow an almost identical pattern. This does not follow the trend of the pre-restoration water levels hydrographs at Pondhead, which display more obviously reduced water level increases and a slower return rate to base water level when moving from the control to downstream data logger sites. Therefore, it can be presumed that the restoration work completed on the 0.7km stretch between the two data logger sites, has brought them to look increasingly similar.

Whilst concentrating specifically on the post-restoration rainfall event between 12th and 15th June 2019 and conducting a comparison of the length of time each site remains at its peak water level after heavy rainfall, it is clear that the stream at Pondhead follows a similar pattern to that found for the Avon Water at Wootton. Although it is only possible to compare the water level data from two loggers at Pondhead, it is evident that the downstream site remains at peak water level for a far longer duration than that of the upstream. The Pondhead Downstream site, with 0.7 km, of river restoration work having been undertaken upstream, remains at its peak water level of 0.27m for 7 hr 45mins. This far supersedes that of the Pondhead Control data logger site, which remains at its peak water level of 0.28m for 4hrs. This follows the same pattern of that of the Avon Water, at Wootton, after restoration and suggests that the restoration work completed successfully enables flow stabilisation and works as a form of natural flood management.

3.5.4 Timelapse Camera Footage – Pondhead

Pre-restoration

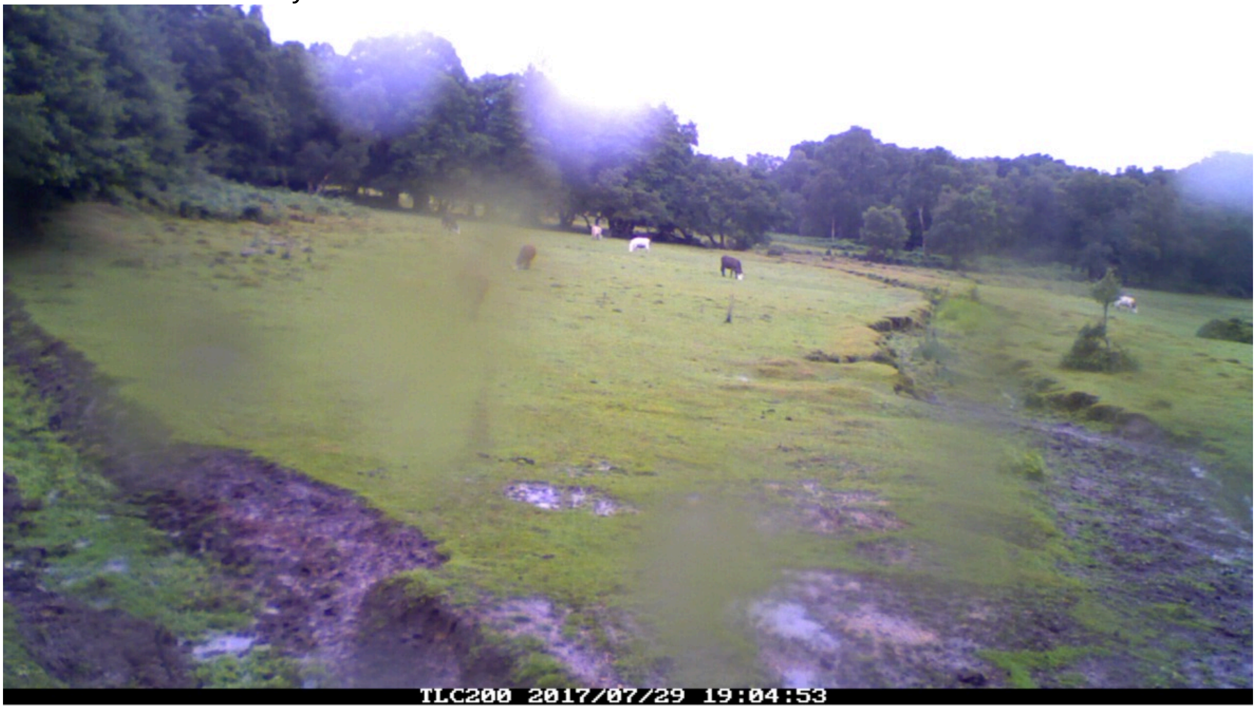
Timelapse camera footage for Pondhead is has been identified covering the rainfall event of 29th July,2017 to 30th July which is the event which gives the largest hydrograph peak from the period 18th to 31st July, 2017 and which formed part of the pre-restoration data logger analysis detailed above. The river response has already been described in detail in Section 3.5.3 but the timelapse camera images allow a visual analysis of how the river and drains across the site responded. Rainfall started around 10:45 hours on the 29th July and continued sporadically and with heavier, longer bursts through the day to the early hours (01:15am hours) on the 30th July with the peak in the hydrograph occurring around 01:30 hours.

Pre-restoration camera footage covering this event is available for Camera 1 – Link drain and Camera 3 – Confluence. However, no footage is available for Camera 2 (Edge of Inclosure Bank) as it disappeared at the end of June, 2017 or Camera 4 (Lyndhurst drain near farm boundary) as the camera was not in place at the time.

Footage for Camera 1 shows that there is absolutely no response within the dry link drains other than some puddles and wet ground as would naturally be expected during the entire rainfall event.

Footage for Camera 3 shows that there is little or no change to water levels within the channel during the day of the 29th July but by first light on the 30th July water levels have risen noticeably, potentially by several centimetres but the channel is still well within its banks.

Camera 1 Link drain by farm




TLC200 2017/07/30 04:16:15


TLC200 2017/07/30 07:06:13

Camera 3 - Confluence


TLC200 2017/07/30 05:25:58


TLC200 2017/07/30 07:05:56


TLC200 2017/07/30 10:05:57


TLC200 2017/07/30 12:05:57

Post restoration

Post restoration footage has been identified for the rainfall event of 10th/11th June, 2019 which is the event which gives the largest hydrograph peak for the period 10th to 23st June, 2019. Footage is available for Camera 1 (Link drains), Camera 3 (Confluence) and Camera 4 (Lyndhurst drain near farm boundary). The rain started sporadically on the 10th June at 10:45 with a few showers totalling 0.6mm before 12:30 hours. The rain began in earnest at 16:00 hours with 17.8mm falling over the next 9 hours until 1:00 hours in the early hours of 11th June, 2019 with the final shower delivering 0.8mm of rain between 5:30 and 6:00 hours.

Like the Pre-restoration event, the footage for Cameral 1 shows virtually no response within the dry link drains other than some standing water/puddles.

Camera 3 which shows the channel has undergone bed-level raising also shows a similar response to the pre-restoration event with the channel showing little response to the early part of the rainfall event with no significant change before nightfall of the 10th June. However, by first light at 03:29 in the morning water levels have risen to almost bank full and are stay up close to those levels until at least the afternoon.

Camera 4 again shows little response within the Lyndhurst to the rain during the 10th June but by first light on the 11th June at 04:04 levels are significantly higher than the previous evening although the water is still in bank at the bridge. Within a couple of hours at 06:04 hours water levels are starting to subside and continue to do so as shown in images for 09:04 and 12:04 hours. By 12:04 hours water levels only appear to be a few centimetres higher than the previous day.

Camera 1 – Link Drain


TLC200 2019/06/11 03:54:20


TLC200 2019/06/11 06:09:18

Camera 3 – Confluence


TLC200 2019/06/11 03:29:04


TLC200 2019/06/11 03:44:04


TLC200 2019/06/11 05:59:03


TLC200 2019/06/11 06:59:03


TLC200 2019/06/11 12:14:02

Camera 4 – Lyndhurst Drain


TLC200 2019/06/11 04:04:59


TLC200 2019/06/11 06:04:58

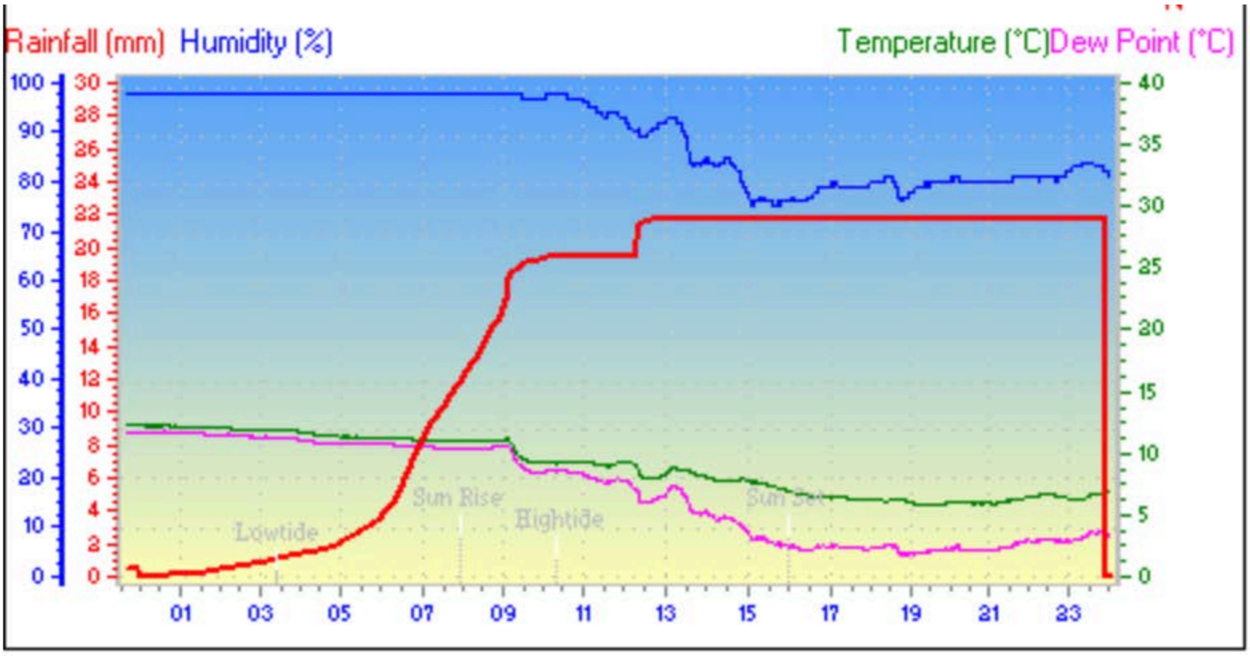

TLC200 2019/06/11 09:04:58


TLC200 2019/06/11 12:04:58

3.5.5 Analysis of timelapse camera footage across the New Forest streams

With multiple timelapse cameras in place at the same time on both unrestored and restored river sections it is possible to visually compare the difference in responses of these sections to the same rainfall event to determine how different rivers are interacting with their floodplain. An event on 7th December, 2018 recorded 21.8mm of rain falling at the Southampton Weather Station which is similar in size to the events documented above (Figure 3.11). On the 7th of December, 2018, timelapse cameras were active at Wootton (Phase 1 East, Sheepwash Lawn and downstream of Sheepwash Lawn), Pondhead and Millersford and visually record how the rivers and streams reacted.

Figure 3.11: Rainfall Event – 7th December, 2018



Source: Southampton Weather Station (on-line data)

Pondhead Camera 3 - Confluence


TLC200 2018/12/07 11:14:20

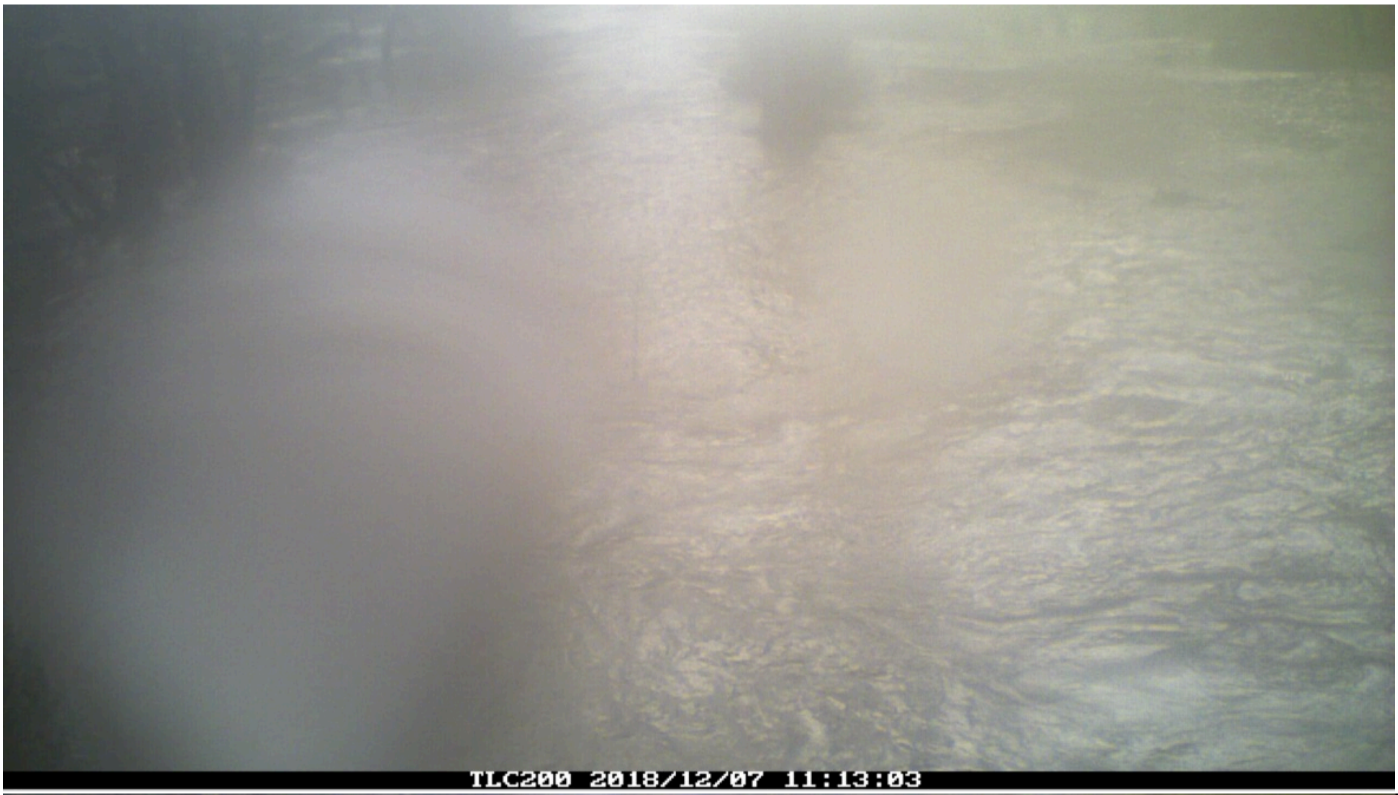

TLC200 2018/12/07 13:59:19

Millersford


TLC200 2018/12/07 11:26:41


TLC200 2018/12/06 15:08:54

Wootton Camera 2 (Phase 1 East - Between Wooton Control and Wootton Bridge)


TLC200 2018/12/07 11:13:03


TLC200 2018/12/07 11:58:03


TLC200 2018/12/07 12:58:03


TLC200 2018/12/08 09:55:50

Wootton Camera 3 – Sheepwash Lawn


TLC200 2018/12/07 12:27:56


TLC200 2018/12/08 07:55:45

Wootton Camera 4 Downstream from Sheepwash Lawn


TLC200 2018/12/07 14:23:58


TLC200 2018/12/07 15:38:58


TLC200 2018/12/08 07:41:41

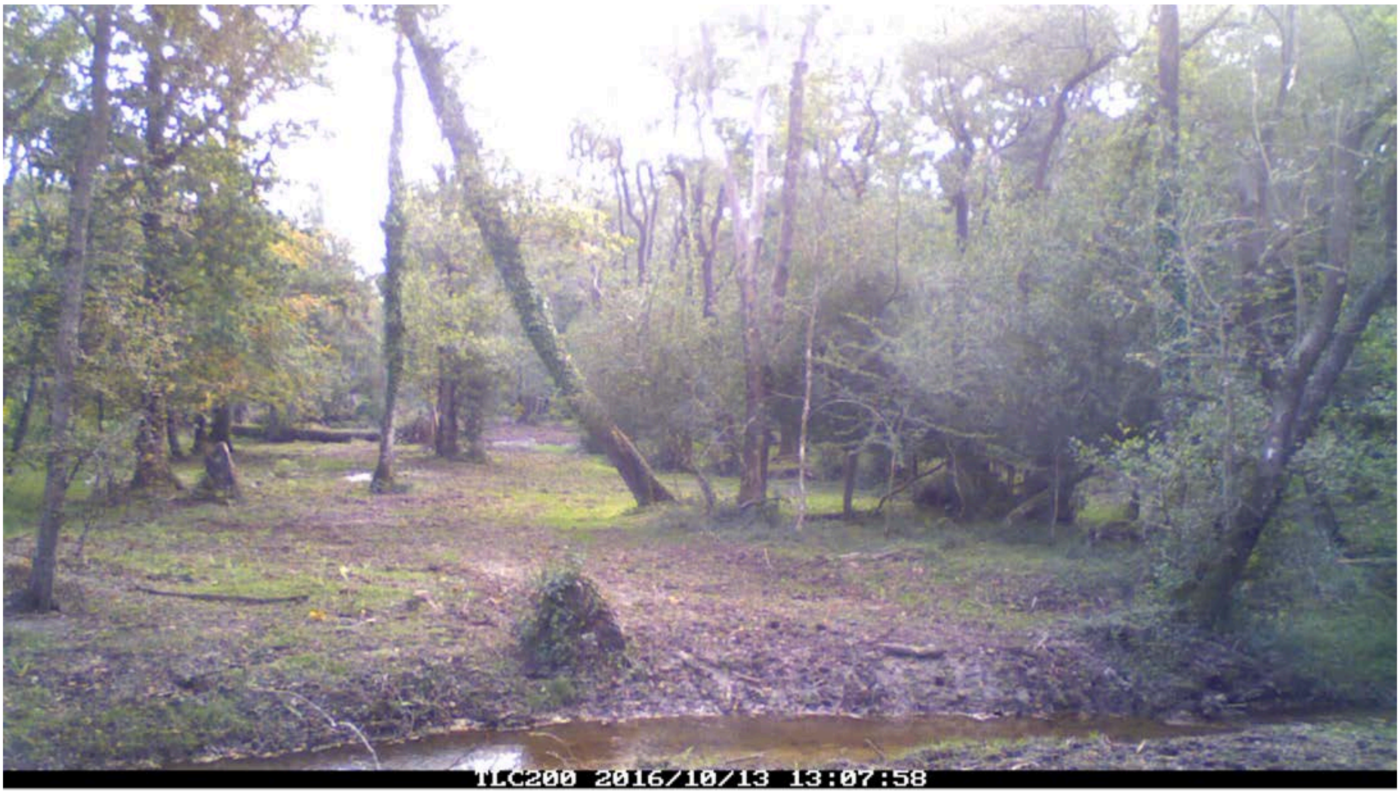
3.5.6 Wootton Phase 1 – Camera 1 (Same location as Wootton Camera 2 but facing the old infilled channel)

Analysis of timelapse camera footage has identified some interesting footage from Wootton Phase 1 when the camera was initially sited facing the straightened channel. The following images capture scenes from pre-restoration, restoration work in progress through to completion and the first significant flood and activation of the flood plain post restoration in the following weeks. The images capture the essence of what river restoration in the New Forest is trying to achieve.

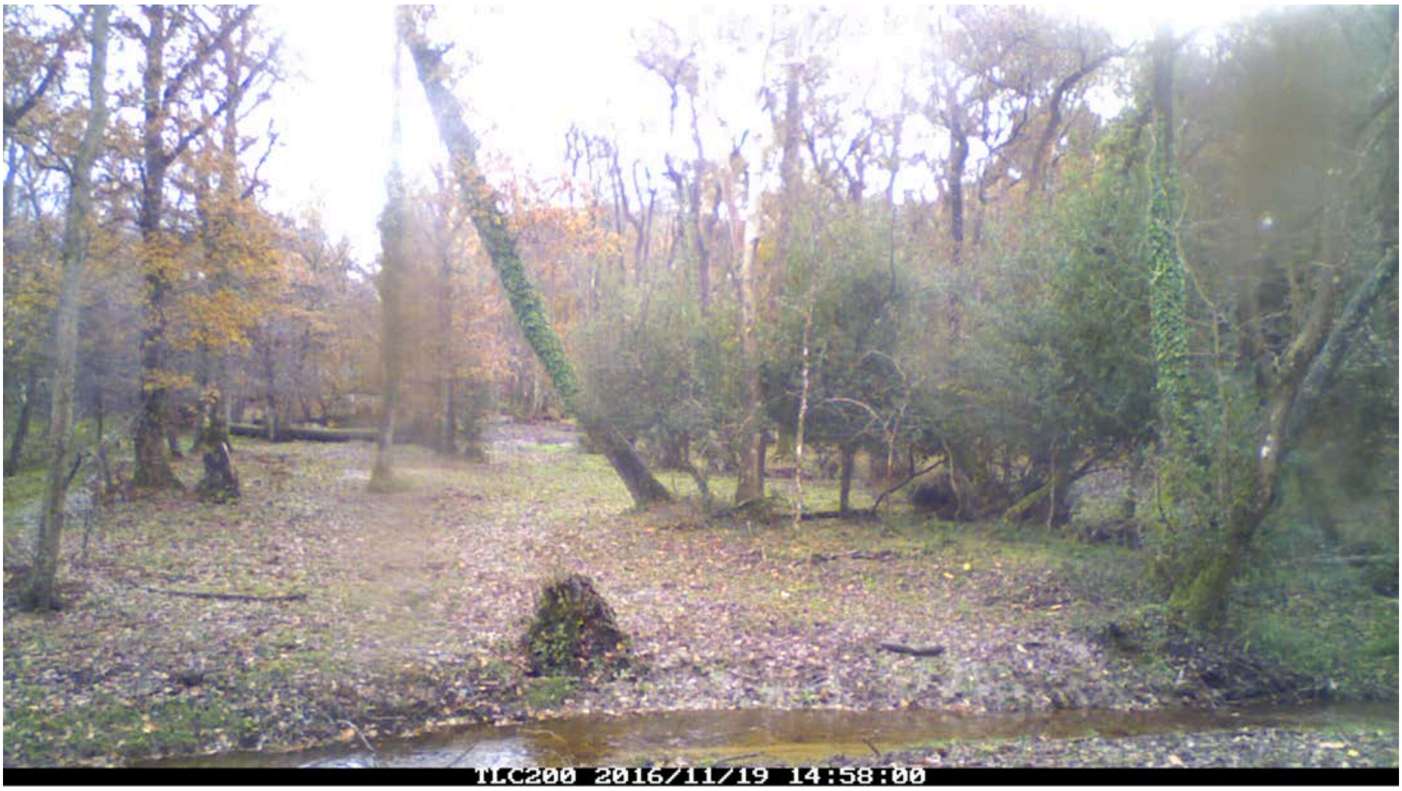

TLC200 2016/08/30 18:57:57


AlaskA
TLC200 2016/08/31 11:37:57


TLC200 2016/09/16 11:17:57


TLC200 2016/10/13 13:07:58


TLC200 2016/10/17 17:37:58


TLC200 2016/11/19 14:58:00


TLC200 2016/11/20 11:18:00


TLC200 2016/11/21 11:18:01


TLC200 2016/11/21 16:28:02


TLC200 2016/11/22 16:18:01

3.5.7 Latchmore Catchment – Amberwood and Studley Wood/Claypits

Cameras have recently been installed at unrestored sites at Amberslade and Studley Wood/Claypits. The following footage captures the behaviour of the stream at these sites during the same rainfall event of $10^{th}/11^{th}$ June,2019 analysed as part of the hydrograph logs for Pondhead post restoration.

Studley Wood/Claypits

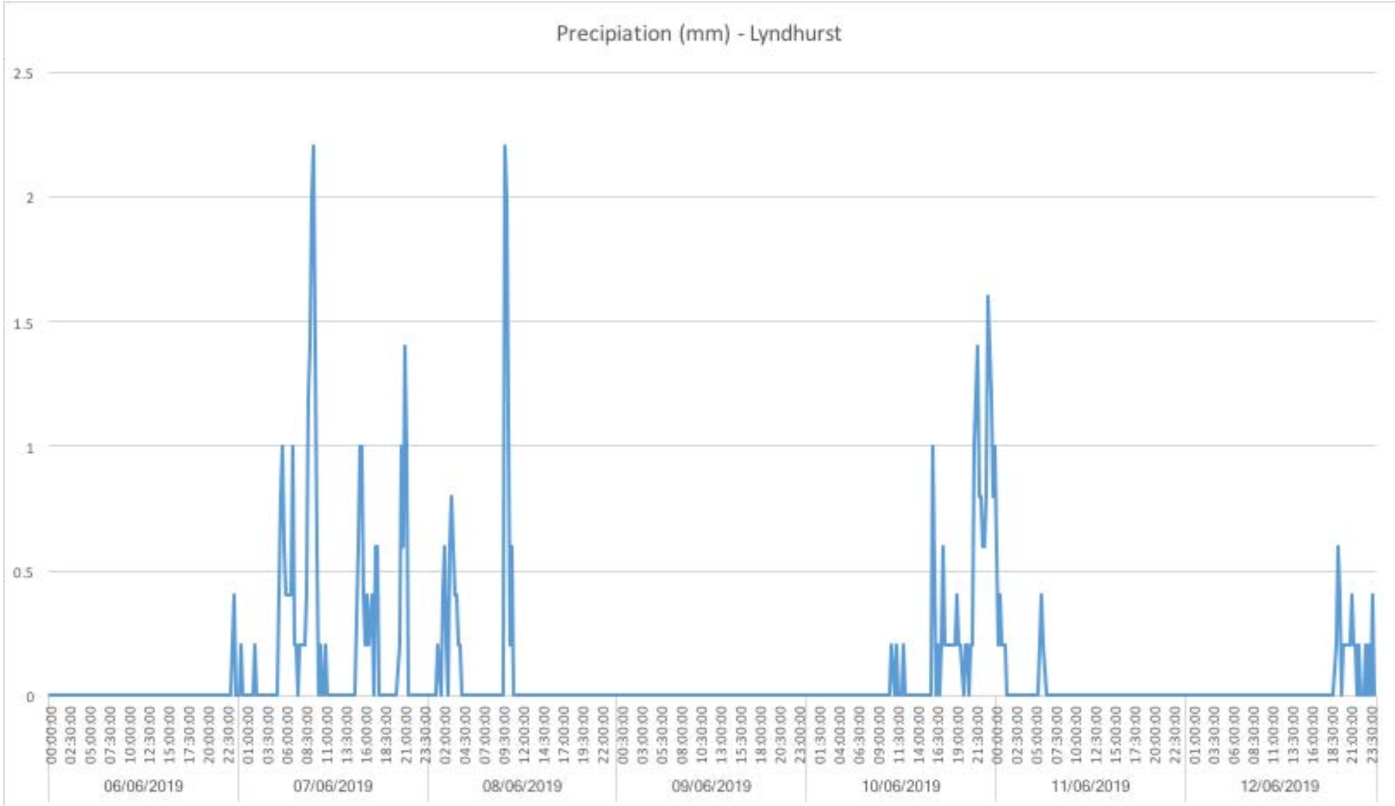
The camera footage for Studley Wood is not particularly clear but does show that water levels have risen overnight and water appears to be moving rapidly down the channel and flowing over a large nick point in the bottom left of the image. By the evening of the 11th June water levels appear to have subsided back to pre-event levels.


TLC200 2019/06/11 07:36:30


TLC200 2019/06/11 18:21:30

Amberwood

Figure 3.13 shows the rainfall recorded at the Environment Agency gauge at Lyndhurst After a dry spell at the end of May/beginning of June and the sequence of timelapse images show the response of the river.



The first image shows the river channel (Latchmore Brook) flowing through Amberwood.It appears to have a very low flow after a period of low rainfall with only with some residual pools remaining. An initial rainfall event started late on the 6th June with sustained rainfall started at around 05:00 hours on the 7th June, 2019 and by 09:00 hours timelapse images show the river starting to rise. Heavy showers over the next 24 hours keep the river levels sustained at similar levels but before the start of the next rainfall event the river level has settled (refer to Image - 14:14 hours 10th June). Rain continues overnight with the peak around 01:00 hours but continues until around 6:30 hours. Some of the first images of the morning (06:31hours 11th June) show river levels have significantly increased overnight although the river is still with bank. The levels stay high for the next 6 hours although they appear to start to drop around and by midday. By the 12th June levels are almost back to where they started prior to the rainfall event. The sequence of images relative to the rainfall patterns suggest that the river is flashy in nature and highly responsive to rainfall events with most of the energy confined to the channel.


TLC200 2019/06/06 11:49:45


TLC200 2019/06/07 09:16:02


TLC200 2019/06/07 11:46:01


TLC200 2019/06/10 14:14:51


TLC200 2019/06/10 19:29:51


TLC200 2019/06/11 06:31:16


TLC200 2019/06/11 08:31:14


TLC200 2019/06/11 12:31:14


TLC200 2019/06/11 18:31:16


TLC200 2019/06/12 12:22:36

3.6 Conclusions

Timelapse camera footage is extremely useful for showing the visual behaviour and response of rivers and when paired with water level log data scope exists for even greater, in-depth analysis of river behaviour and response. The timelapse footage is extensive and it has only been possible to use a few key events to highlight river behaviour as part of this evaluation. If greater time allowed and as more data becomes available through on-going monitoring even more in-depth analysis could be carried out.

Evaluation of both the timelapse data and the hydrometric data show that HLS river restoration projects have resulted in re-activation of the floodplain and appear to be slowing the flood peaks as evidenced for those rivers which have hydrometric monitoring data. This is particularly evident at Wootton. River restoration also appears to be having a positive effect at Pondhead as evidenced by changes in the hydrographs generated from the upstream and downstream water level loggers although visual activation of the floodplain is less evident from the views from the timelapse cameras.

The New Forest rivers are considered to be flashy in nature, quick to rise and fall, and this behaviour is clearly captured in the timelapse camera footage although each river and stream does have its own unique pattern in relation to catchment size, shape and surrounding land use.

Although not included in this report, thousands of photographs taken by FC staff and others at river restoration sites across the New Forest since the start of river restoration show photographic evidence of rivers that rarely/if ever flooded once they were straightened, flowing out of bank and once again interacting with floodplain.

Timelapse cameras sited on non-restored rivers such as at Millersford and Latchmore upstream at Amberslade/Claypits show little or no evidence of flooding out of bank during peak rainfall events compared to restored rivers elsewhere which are either clearly out of bank and/or hydrometric data is showing that restoration works are slowing the flow during the same rainfall events.

It can be concluded that the HLS Restoration Objective Traffic Light Status is **Green** with monitoring results suggesting that river restoration does appear to meeting its aims and objectives in terms of:

- Reconnecting the river channels with the flood plain and restoring floodplain morphology
- Slowing the flood peak and response times downstream