Technical note

Project:	Great Bedwyn	**To:**	Danny Everett, Wiltshire Council
Subject:	Flood Risk Management Feasibility Study	**From:**	Alison McKerrow , Mike Vaughan, Emily Craig
Date:	30 May 2014	**cc:**	Simon Burgess

1. Introduction

This study has been commissioned by Wiltshire Council (WC) to investigate options for mitigation of surface water flood risk to specified catchments.

This technical note provides an overview of the assessment undertaken to test the feasibility of providing flood risk management for the village of Great Bedwyn. This assessment is specifically the catchments west of the village, draining to Church Street. See Figure 2.1 below.

2. Background

Great Bedwyn is a small village in Wiltshire which has suffered surface water flooding in recent years; there are eight reported instances in the years 2000-2014, the most recent in January 2014. Initial investigations show there are four main catchments posing surface water flood risk to Great Bedwyn.

Of these, two areas have been investigated as recent flooding, and the Environment Agency flood maps, show these to pose greatest risk to properties. These are located at Lower Church Street (NGR SU 2755 6396) and Back Lane (NGR SU 2770 6442).

Figure 2.1 shows the Environment Agency Surface Water Flood map which identifies the flood water flow paths at the sites.

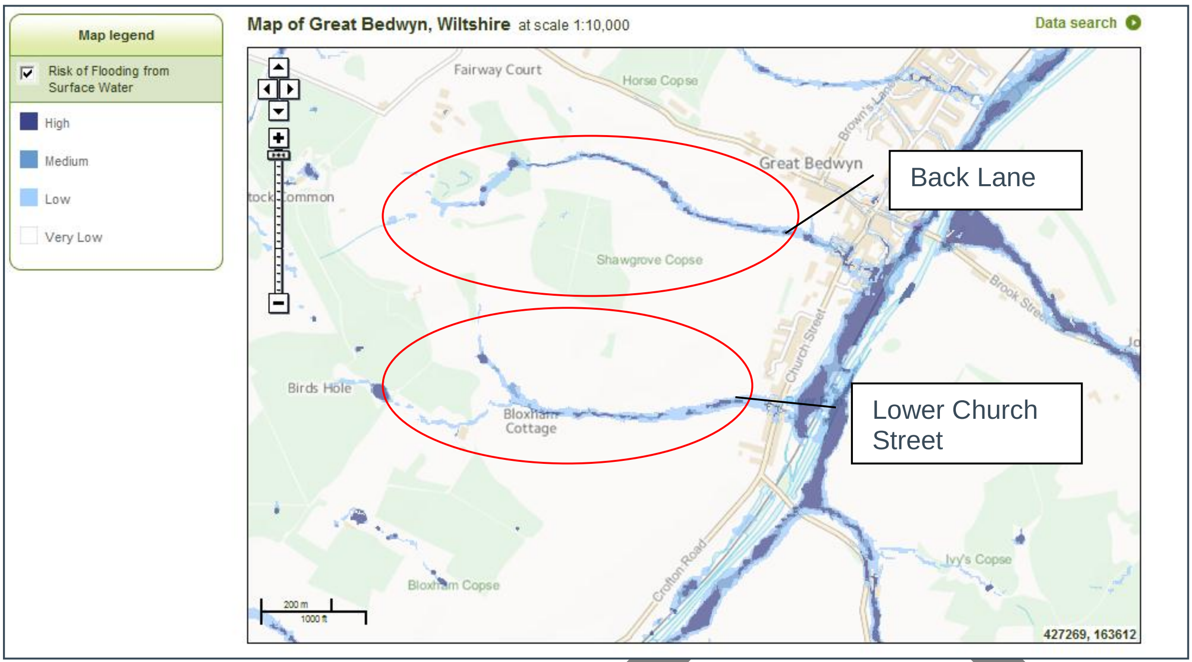

Figure 2.1 Environment Agency Surface Water Flood Map[1] .

3. Data Collection

The following data was obtained for use in this project:

- Composite 5m LIDAR supplied by Ordnance Survey
- Topographic survey commissioned in February 2014 and undertaken by *Infomap-Surveys and Mapping*
- Previous studies *–Aptec, River Engineering Consultancy- Great Bedwyn Drainage, Flood Risk Report March 2003*
- Network Rail- Great Bedwyn Site Report, March 2014 *(Ref: BHL, 66m56c-67m02c)*
- CCTV survey from 2012 was supplied by Wiltshire Council and reviewed
- Drainage Plans from WC - *DSNP226-D001A* to *DSNP226-D0013A*

A further source of information for this study has been consultations with the village Flood Working Group (FWG). The Group has been extremely helpful in providing anecdotal evidence from past events in addition to meeting with our staff on site and discussing various options for mitigation.

[1] http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?lang=_e&topic=ufmfsw&layer=0&x=427500&y=164500&scale=10&location=Great+Bedwyn%2c+Wiltshire#x=427311&y=164141&scale=11, seen at 06/03/2014, 13.03.

4. Hydrology

4.1. Catchment description

The two catchments investigated, which have given rise to flooding, are small in area, predominantly rural, consisting mainly of agricultural land. The urban area of Great Bedwyn village is situated at the lower reach of the catchments.

Figure 4.1 below indicates the sub catchment locations and size.

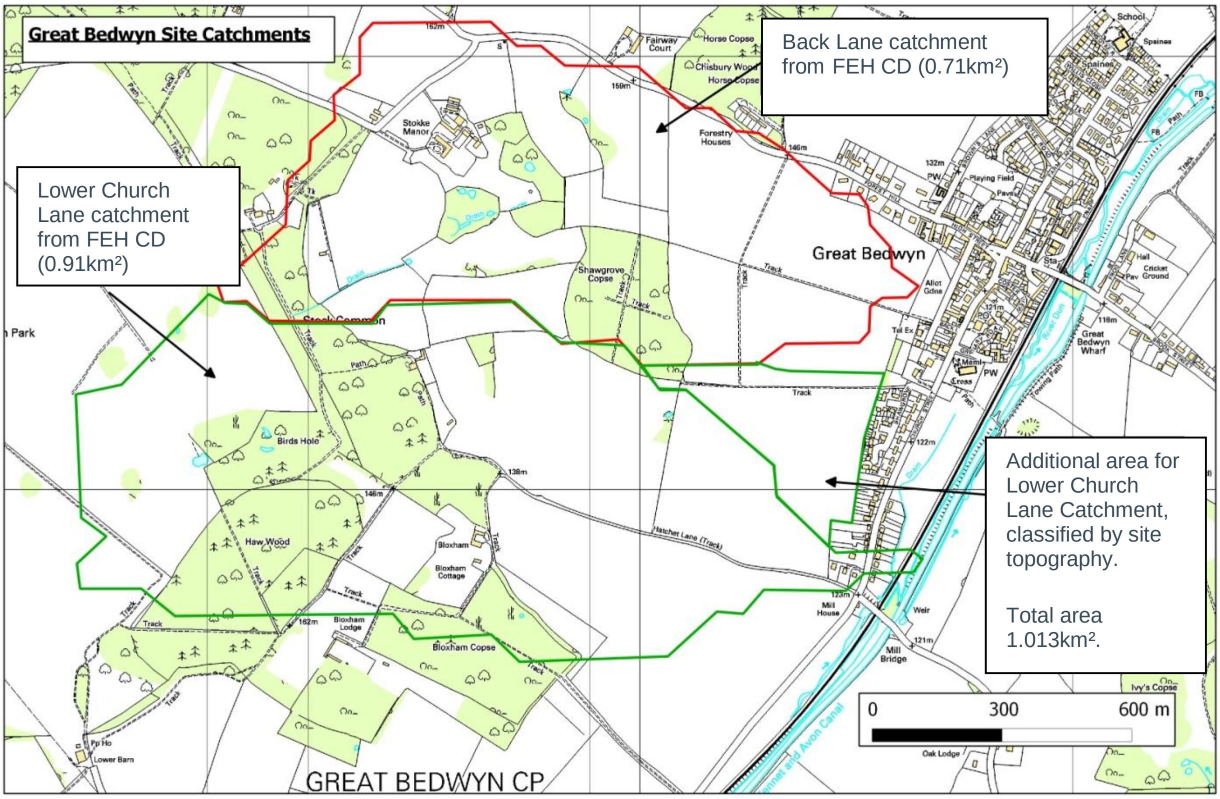

Figure 4.1 - Sub Catchments

4.1.1. Back Lane Catchment

The Back Lane catchment flows into an open channel, through the allotments at Back Lane, into a piped drainage network. This conveys the flows through the village, under the railway and into the River Dun.

Ground levels in the catchment vary from approximately 162mAOD at the upstream extents, to 124mAOD at the downstream. This fall occurs over approximately a 1.4km length, giving a typical slope of 1 in 37. The catchment area is 0.71km².

The underlying geology is Newhaven Chalk Formation. There are some small areas of London Clay in the upper reaches of the catchments.

There was no gauged flow data available for catchment.

The urban area of Great Bedwyn, contributing to the catchment was evaluated separately and represented as lateral inflows in the hydraulic model.

4.1.2. Lower Church Street Catchment

The Lower Church Street catchment collects in fields above the village and is conveyed as overland flows through properties and on to the road. Surface water flows via the Water Meadows, under the railway and into the River Dun.

This catchment, calculated from its entry point at the River Dun using the FEH CD, is an area of 0.9km². The Ordinance Survey mapping indicates an additional area of 0.103km ².

Ground levels in the Lower Church Street catchment vary from approximately 165mAOD at the upstream extents, to 118mAOD at the downstream. This fall occurs over approximately a 1.8km length and thus a typical slope of 1 in 38.

The underlying geology is Newhaven Chalk Formation. There are again some small areas of London Clay in the upper reaches of the catchments.

There was no gauged flow data available for catchment.

The impermeable urban areas have not been quantified within this catchment, as they are minimal in size and thus impact.

4.2. Approach

The methods applied to develop flow estimates were: Flood Estimation Handbook (FEH) Revitalised Flood Hydrograph (ReFH), FEH Statistical, FEH Greenfield runoff, ADAS and IH124.

The ReFH method was used to generate hydrographs.

In accordance with The National Planning Policy Framework (NPPF, 2012) Technical Guidance Note a 20% increase in fluvial flows should be applied to take account of climate change.

4.3. Flood Estimates

4.3.1. Peak Flow Assessment

The results from the assessment are shown in Table 4.1 & Table 4.2. Critical storm durations of 2.87 and 3.3 hours were calculated for peak flow, at Back lane and Lower Church Street catchment respectively, based on the equation in FEH (using SAAR and Tp).

Table 4.1 - Comparison of estimated flows (l/s) for the Back Lane catchment.

	Return Period (years)						
Method	**2**	**10**	**20**	**30**	**75**	**100**	**100CC**
REFH (l/s)	201.0	324.0	381.0	411.0	509.0	545.0	654.0
FEH Greenfield (l/s)	173.0	317.5	392.7	443.0	576.2	625.2	750.3
FEH Statistical (l/s)	173.1	308.7	N/A	417.5	530.4	571.3	628.4
ADAS (l/s)	14.2	26.2	32.4	20.7	26.2	32.4	36.5
IH124 (l/s)	11.3	20.8	27.4	29.0	37.8	41.0	49.2

Table 4.2 - Comparison of estimated flows (l/s) for the Lower Church Street catchment.

	Return Period (years)						
Method	**2**	**10**	**20**	**30**	**75**	**100**	**100CC**
REFH (l/s)	268.0	428.0	502.0	549.0	678.0	725.0	870.0
FEH Greenfield (l/s)	235.5	433.5	536.1	604.8	786.8	853.7	1,024.4
FEH Statistical (l/s)	235.5	419.9	N/A	568.0	721.6	777.1	854.9
ADAS (l/s)	21.6	31.4	39.7	49.1	55.4	78.2	93.9
IH124 (l/s)	15.6	28.7	37.7	40.0	52.0	56.5	67.8

4.3.2. Reconciliation of Flows

The FEH Greenfield runoff and statistical methods compared favourably with those estimates generated using the ReFH approach for the two catchments. These methods provided flows much larger than the ADAS and IH124 methods. Recent studies have bolstered confidence in the application of REFH method for small catchment hydrology, indicating that ReFH provides reliable results for catchments such as this.

The FEH Statistical estimates were evaluated using two separate statistical distributions. These compared well and generated similar results to the other FEH approaches.

The catchment descriptor based QMED estimate for the Back Lane Catchment was 173l/s. Taking a donor catchment refined this to 175l/s, suggesting the empirical QMED equation provides realistic estimates.

Research undertaken by CEH Wallingford in 2011 has suggested that the IH124 method often under estimates small catchment flow. The IH124 peak flows were tested in an Infoworks sewer network model (discussed in section 5.2), as inflow hydrographs. The model failed to replicate the flooding seen at Back Lane for return periods up to 1 in 100yrs. For this reason IH124 and ADAS flows, which employ basic hydrology, were deemed unsuitable for the catchments at Great Bedwyn, flooding has been experienced; 8 events in 14 years.

4.4. Design Flows

The REFH method was selected for peak design flows. The values are higher and thus more precautionary than the older ADAS and IH124 methods. The limited differences between the FEH methods for Great Bedwyn catchments provide confidence in the flow estimates.

The final design flows applied to the hydraulic model are displayed in Table 4.3.

Table 4.3 – Design peak flows from REFH method

Catchment	Return Period (years)						
	2	**10**	**20**	**30**	**75**	**100**	**100CC**
Back Lane Catchment (l/s)	201	324	381	411	509	545	654
Lower Church Street Catchment (l/s)	268	428	502	549	678	725	870

5. Assessment of flooding in the Back Lane catchment.

5.1. Understanding the problem

An overview of surface water flow routes from the catchment is shown in **Error! Reference source not found.** & Figure 5.1 below.

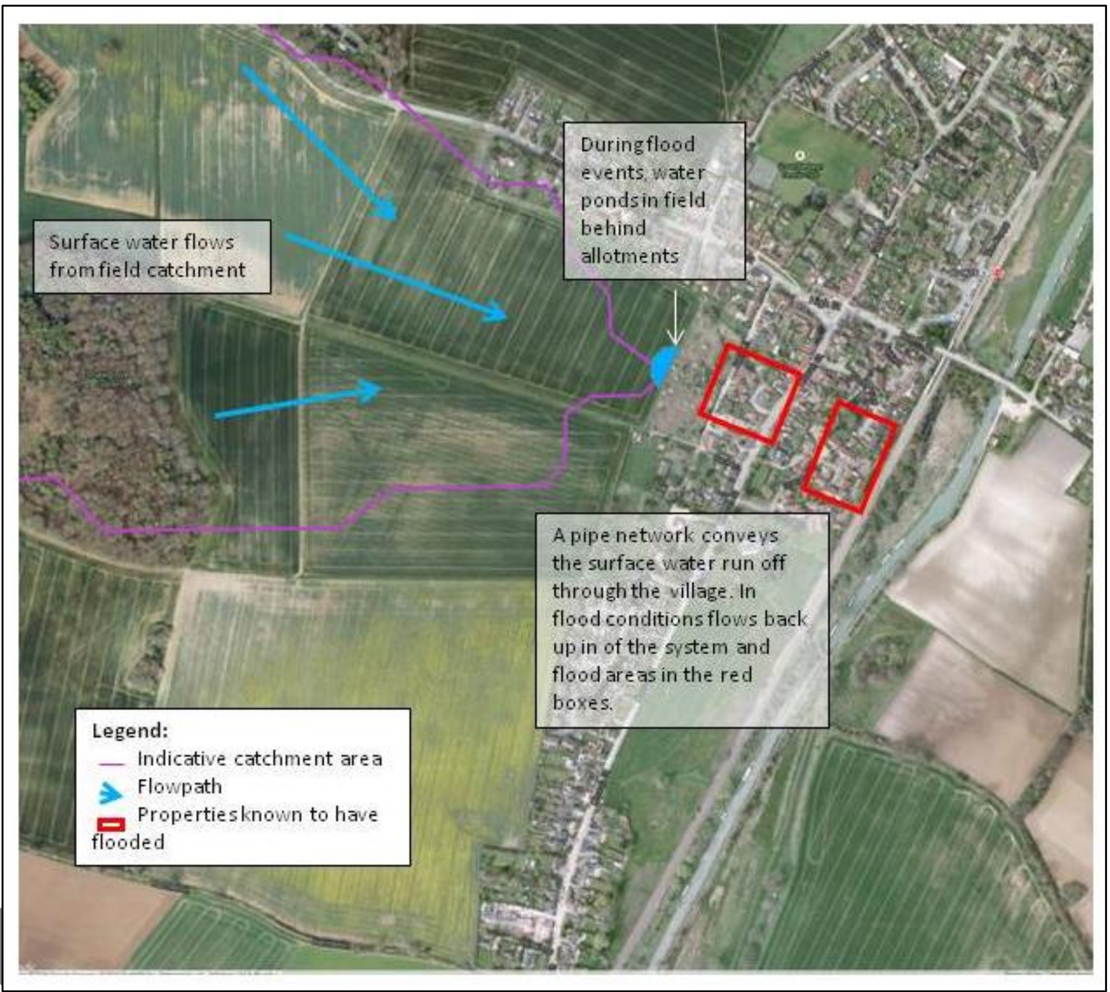

Figure 5.1 Overview of flooding in the North catchment.

Anecdotal evidence from the FWG, and residents who witnessed the January 2014 flooding event, imply that the Back Lane area flooded first, followed shortly after by Granary Road and Coster View.

Figure 5.2 shows the surface water pipe network, from Back Lane to the River Dun.

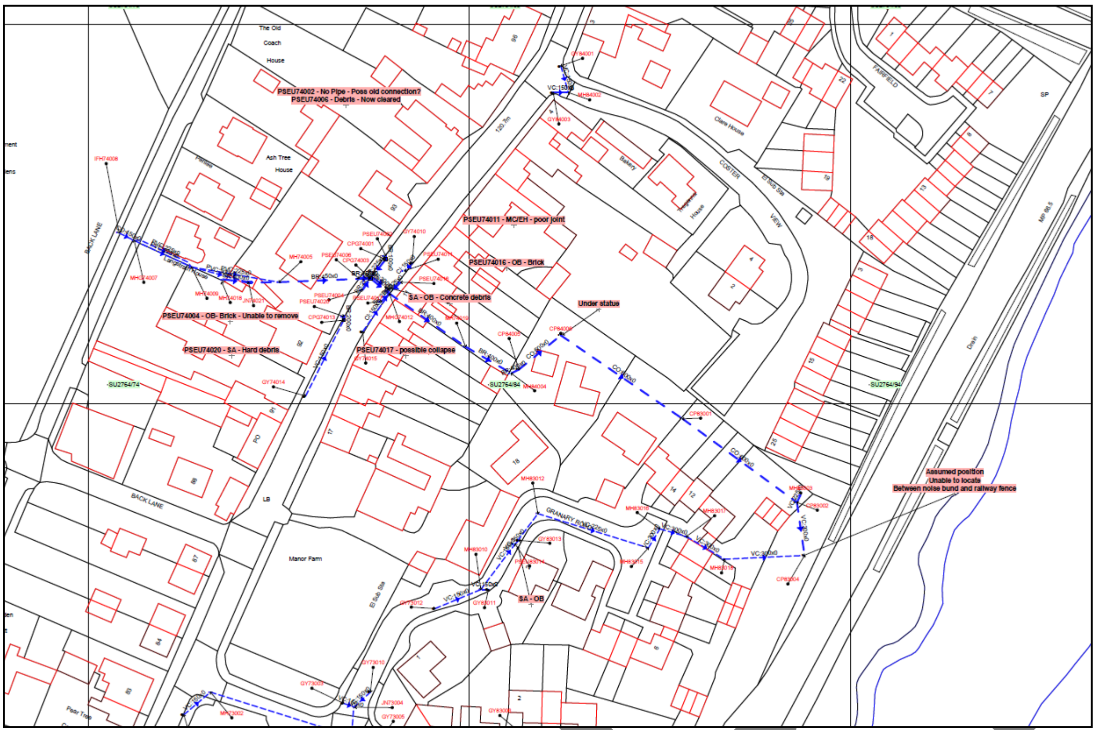

Figure 5.2 Pipe drainage network

The culvert location under the railway and the proximity of residential houses can be seen on Figure 5.3. The constriction downstream of the Network Rail culvert and the additional inflows from Coster View and Granary Road make this area susceptible to flood risk.

Figure 5.3 Railway line culvert and nearby flooding locations.

5.2. Hydraulic Modelling

Hydraulic modelling was undertaken to test options to alleviate flooding from the Back Lane catchment. A one dimensional hydraulic model of the study area was built with the Infoworks CS software, using LiDAR, pipe networks plans and best available data.

The following data was used to develop the model:

1) **Kennet District Council- Aptec, River Engineering Consultancy- Great Bedwyn Drainage, Flood Risk Report March 2003** – Pipe sections and invert levels down to Network Rail culvert
2) **Network Rail Survey, March 2014** - Pipe sections and invert levels from Network Rail Culvert to outfall – it should be noted that the invert levels were not provided, only depths from cover. The invert levels were derived using available ground level data (from topographic survey where available or LiDAR / OS contours)
3) **CCTV survey, Wiltshire Council, 2012** – condition of pipes
4) **Topo Survey by 'Infomap - Surveys and Mapping', February 2014** - The survey plan is shown in the appendix to this note.
5) **Composite 5m LIDAR supplied by Ordnance Survey**

The model was used as a tool to test options and whilst it remains uncalibrated, is of sufficient quality to evaluate solutions for this feasibility study.

5.2.1. Baseline Scenario

The baseline scenario describes the existing drainage case.

Model Schematisation

The extents of the hydraulic model are shown in Figure 5.4 below.

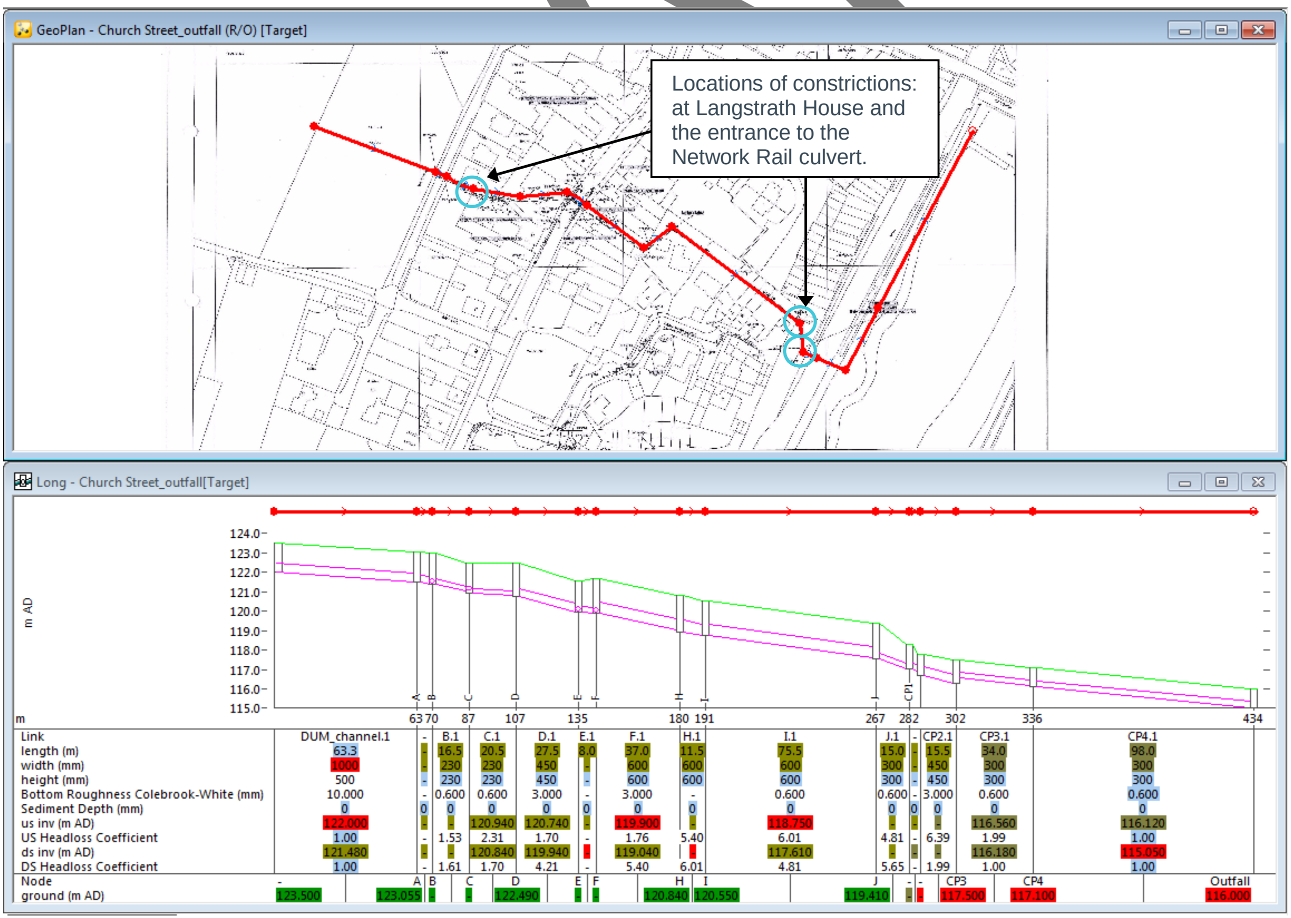

Figure 5.4 Hydraulic model extents

Impermeable / urban areas

Urban sub catchments were represented in Infoworks. It was assumed that the surface water sewer receives flows from all paved, roof, and permeable areas that are within 10m of a paved surface. The drainage plans indicate that there are no additional incoming branches to the main sewer line, except those from Granary Road and Coster View. An urban catchment map and table of inflows is included in the Appendix.

Model boundaries

The downstream boundary of the model is the outfall to the River Dun. Free discharge was assumed in the baseline model. Testing was undertaken to establish the sensitivity of this boundary condition. (See section 5.2.3).

Sensitivity to storm durations was carried out for each urban sub catchment to determine the critical duration (giving rise to the highest flows); this was found to be 30 minutes for all sub catchments. The flow from urban sub catchment 4 was the greatest at 128l/s in a 30minute, 30 year storm.

Catchment wide critical storm duration tests for flow and storage were undertaken as part of the hydraulic modelling. A critical duration of 2.7 hours in the Back Lane catchment was found for peak flow analysis from the hydrology.

Pipe roughness

The standard Colebrook White value use for surface water sewer modelling is 0.6. The standard value for brick sewers used was 3 and the smooth earth channel value was 60.

Model verification

No historic flood event data was available to verify the hydrological and hydraulic model. Great Bedwyn has experienced flooding 8 times in the last 14 years. The model predicts flooding in the village will occur between in 1 in 2 and 1 in 10yr storm event, which ties in with recent flooding. However, whilst validated, the model should not be used for the prediction of absolute flood levels, although it is suitable for predicting the difference in between scenarios.

5.2.2. Baseline Results

The key results from the model are summarised below.

Pipe Capacities

The calculated maximum capacity for each element of the pipe network is shown in Table 5.1 below. Modelling shows points of key constriction are pipes at Langstrath House (full bore capacity of 38 l/s), the railway culvert and noise bund, at the back of Granary Road and Coster View, full bore capacity of 173 l/s (see Figure 5.4 for these mapped locations).

Table 5.1 Estimated pipe capacity for a fully functioning pipe network

Location	Length (m)	Diameter (mm)	Gradient (m/m)	Full bore flow capacity (l/s)
Back Lane	7.0	375	0.009	185
Back Lane/ Langstrath House	16.5	230	0.022	82
	16.5	230	0.022	82
Langstrath House	20.5	230	0.005	38
The Old School Surgery	27.5	450	0.029	488
Church Street	8.0	300	0.005	69
Church Street Gardens	8.0	300	0.005	69
	37.0	600	0.023	933
Granary Road Gardens	11.5	600	0.016	862
Granary Road Gardens	75.5	600	0.015	846
Noise bund	15.0	300	0.035	208
Network Rail land	-	300	0.024	173
Network Rail land	15.5	450	0.026	465
Network Rail land	34.0	300	0.011	117
Network Rail land	98.0	300	0.011	116

The lowest downstream capacity available in the Networks Rail pipes is 117 l/s in comparison to upstream pipe capacity in excess of 500l/s between Church Street and Granary Road back gardens.

The maximum flow from the urban areas in a 30 year 30 minute duration storm was calculated to be 432l/s: this will surcharge the system, causing flooding and is an independent risk from that at longer storm durations where rural catchment runoff is the main cause. Flood volumes in the 30minute and longer durations are discussed in the flood volume section, below, with Table 5.2 and Table 5.3.

Flood Volumes

Infoworks calculates volumes of surcharged water at each model node which could rise through manholes and onto the ground surface. This provides an indication of the volume of water which may result in flooding at the given location. Return periods up to a 30yr event have been investigated. Events of a greater magnitude of than this have not been investigated.

30 minute storm duration

The results from the 30 minutes duration storms are shown below in Table 5.2 for only urban inflows (no rural catchment). The flooding shown in these return periods indicates that flooding will occur at return period events from 1 in 2 (with 2.1m³) and worsening for events greater than this. This is an important finding as it indicates that flooding will occur irrespective of the rural runoff entering the system at Back Lane indicating an insufficient sewer capacity for the village. Additional flows from the rural catchment will exacerbate flooding downstream.

Table 5.2 Flood volumes from the urban catchment critical duration of 30 minutes.

Location	Flood Volumes (m^3)			
	2 year	**10 year**	**20 year**	**30 year**
Entrance to open channel through the allotments	0.0	0.0	0.0	0.0
Back lane	0.0	0.0	0.0	0.0
Back lane	0.0	0.0	0.0	0.0
Langstrath	0.0	0.0	0.0	0.0
Surgery	0.0	0.0	0.0	0.0
Church Street/Granary Road gardens	0.0	0.0	0.0	0.0
Granary road - rear gardens	0.0	0.0	0.0	0.0
Noise Bund	0.0	3.9	18.0	29.8
Railway Margin	0.0	13.2	27.1	36.5
Between the tracks	0.2	11.5	21.6	29.1
Below the railway	1.9	22.2	36.5	45.7
Below the railway	0.0	3.4	6.5	8.7
Total	2.1	54.2	109.7	149.8

12 hour duration storm

Storm durations lasting 12 hours have been tested with a variety of return periods and are shown below in Table 5.3. The flood volumes are created from inflows from both the rural and urban catchment.

Flooding is evident at all tested return periods. Flooding is predicted at Back Lane and Langstrath House, as well as downstream at the noise bund and Network rail culvert. In a 1 in 30 year event flood volumes are predicted to daylight from all manholes with a total volume of 1927.2m³

When urban inflows were tested in isolation at duration of 12 hours no flooding was seen in the network. This indicates that if the whole rural catchment could be attenuated then flood risk could be eliminated for longer duration storms.

Table 5.3 Flood volumes from the rural and urban catchments critical duration of 720 minutes.

Location	Flood Volumes (m3)			
	2 year	**10 year**	**20 year**	**30 year**
Entrance to open channel through the allotments	0.0	87.8	173.5	231.4
Back lane	3.0	132.2	219.4	278.2
Back lane	2.3	126.2	212.5	270.5
Langstrath	11.2	126.0	206.0	258.9
Surgery	0.0	0.0	0.0	6.6
Church Street/Granary Road gardens	0.0	0.0	7.2	19.6
Granary road - rear gardens	0.0	1.7	17.2	37.9
Noise Bund	0.0	73.8	120.9	147.6
Railway Margin	3.6	113.0	154.5	178.8
Between the tracks	8.3	123.2	162.8	186.0
Below the railway	18.1	140.7	179.5	202.3
Below the railway	2.9	65.3	93.1	109.4
Total	49.4	989.9	1,546.6	1,927.2

5.2.3. Sensitivity testing

Sensitivity testing was carried out to understand the impacts of water levels in the receiving River Dun, and the condition of the sewer pipes, which were assumed to be clean and free flowing in the baseline tests.

Sensitivity to downstream water level

The pipe model was tested against different boundary conditions appertaining to the River Dun. The baseline assumption was for a free discharge from the final pipe. This was tested by raising the receiving water level to 1m above surrounding ground level, corresponding to a 1m depth of water on the floodplain at that location, or a raised water level of 118m AOD.

The model indicates that raised River Dun levels could increase the amount of flooding experience in Great Bedwyn by a notable proportion.

During the short, urban, storm, the volume of water predicted to surface rose from 150m^3 to 238m^3. This was seen to affect only those pipes currently predicted to flood, and not daylight water from any additional pipes. Furthermore, the impact of the river level is seen to reduce with distance upstream.

Table 5.4 Effect of river levels on volume of flooding from intense rainfall

Location	Free outfall (m^3)	Floodplain level +1m (m^3)	Difference (m^3)
Entrance to open channel through the allotments	0.0	0.0	0.0
Back lane	0.0	0.0	0.0
Back lane	0.0	0.0	0.0
Langstrath	0.0	0.0	0.0
Surgery	0.0	0.0	0.0
Church Street/Granary Road gardens	0.0	0.0	0.0
Granary road - rear gardens	0.0	0.0	0.0
Noise Bund	29.8	32.8	3.0
Railway Margin (CP1)	36.5	43.7	7.2
Between the tracks (CP2)	29.1	45.2	16.1
Below the railway (CP3)	45.7	66.6	20.9
Below the railway (CP4)	8.7	49.8	41.1
Total	149.8	238.1	88.3

For the longer, rural, rainfall, the volume predicted to surface rose from 1927m^3 to 2610m^3. All pipes were impacted by the rise in river level, although the impact of the river level is seen to reduce with distance upstream.

Table 5.5 Effect of river levels on volume of flooding from long duration rainfall

Location	Free outfall (m^3)	Floodplain level +1m (m^3)	Difference (m^3)
Entrance to open channel through the allotments	231.4	249.3	17.9
Back lane	278.2	296.5	18.3
Back lane	270.5	289.7	19.2
Langstrath	258.9	283.4	24.5
Surgery	6.6	39.8	33.2
Church Street/Granary Road gardens	19.6	74.5	54.9
Granary road - rear gardens	37.9	99	61.1
Noise Bund	147.6	213.4	65.8
Railway Margin (CP1)	178.8	261.3	82.5
Between the tracks (CP2)	186	279	93
Below the railway (CP3)	202.3	299	96.7
Below the railway (CP4)	109.4	226	116.6
Total	1,927.2	2,610.9	683.7

Given the sensitivity, it would be prudent to consider the installation of a non-return / flap value at the outlet from this system. This should be tested in the hydraulic model.

However it was found that the constriction on Network Rail land (CP3) caused by a 300mm diameter pipe (receiving flow from a 450mm pipe) and the misalignment of the pipe levels in the catch pit (as per Network Rail survey) has a greater impact. The flow backs up at this point in the system which impact further upstream than reached by that river's influence on the system. This pipe restriction is likely to result in flooding at Granary Lane and Coster View.

Sensitivity to Pipe roughness

To test the impact of roughness conditions in the system the model was reapplied using alternative Colebrook White values. To simplify the test, those pipes where the 0.6mm values were applied, were increased to 6mm, representing a deteriorated pipe with sediment and some obstructions.

The model indicates that raised pipe roughness could increase the amount of flooding experience in Great Bedwyn by a notable proportion, to a varying extent compared to river level.

During the short, urban, storm, the volume of water predicted to surface rose from 150m^3 to 185m^3. This was seen to affect only those pipes currently predicted to flood, and not daylight water from any additional pipes.

Table 5.6 Effect of roughness on volume of flooding from intense rainfall

Location	Baseline (m^3)	Rougher pipe test (m^3)	Difference (m^3)
Entrance to open channel through the allotments	0.0	0.0	0.0
Back lane	0.0	0.0	0.0
Back lane	0.0	0.0	0.0
Langstrath	0.0	0.0	0.0
Surgery	0.0	0.0	0.0
Church Street/Granary Road gardens	0.0	0.0	0.0
Granary road - rear gardens	0.0	0.0	0.0
Noise Bund	29.8	38.1	8.3
Railway Margin (CP1)	36.5	37.9	1.4
Between the tracks (CP2)	29.1	37.8	8.7
Below the railway (CP3)	45.7	58.6	12.9
Below the railway (CP4)	8.7	12.7	4.0
Total	149.8	185.1	35.3

For the longer, rural, rainfall, the volume predicted to surface rose from 1927m^3 to 2689m^3. All pipes were impacted by the rise in pipe roughness, although the pipes in the upper reaches were seen to be particularly sensitive.

Table 5.7 Effect of roughness on volume of flooding from long duration rainfall

Location	Baseline (m^3)	Rougher pipe test (m^3)	Difference (m^3)
Entrance to open channel through the allotments	231.4	369.8	138.4
Back lane	278.2	418.6	140.4
Back lane	270.5	409.7	139.2
Langstrath	258.9	380.6	121.7
Surgery	6.6	15.3	8.7
Church Street/Granary Road gardens	19.6	37.4	17.8
Granary road - rear gardens	37.9	61.6	23.7
Noise Bund	147.6	173.3	25.7
Railway Margin (CP1)	178.8	208.8	30
Between the tracks (CP2)	186	225.4	39.4
Below the railway (CP3)	202.3	246.1	43.8
Below the railway (CP4)	109.4	142.7	33.3
Total	1,927.2	2,689.3	762.1

It should be noted that the CCTV study, shows the pipes to be in good condition, free from sediment and obstruction and tree roots. As such, the baseline results are considered to reflect the current conditions. However, the sensitivity results do indicate that maintenance of the system would be required in order to maintain the level of flood risk and not exacerbate the situation.

5.3. Mitigation Options

The model was used to evaluate the performance of options for mitigation. These include upstream attenuation to reduce flows entering the system from the allotments, as well as upgrading the pipe network at various points. See Figure 5.5 for option summaries which are discussed below in more detail.

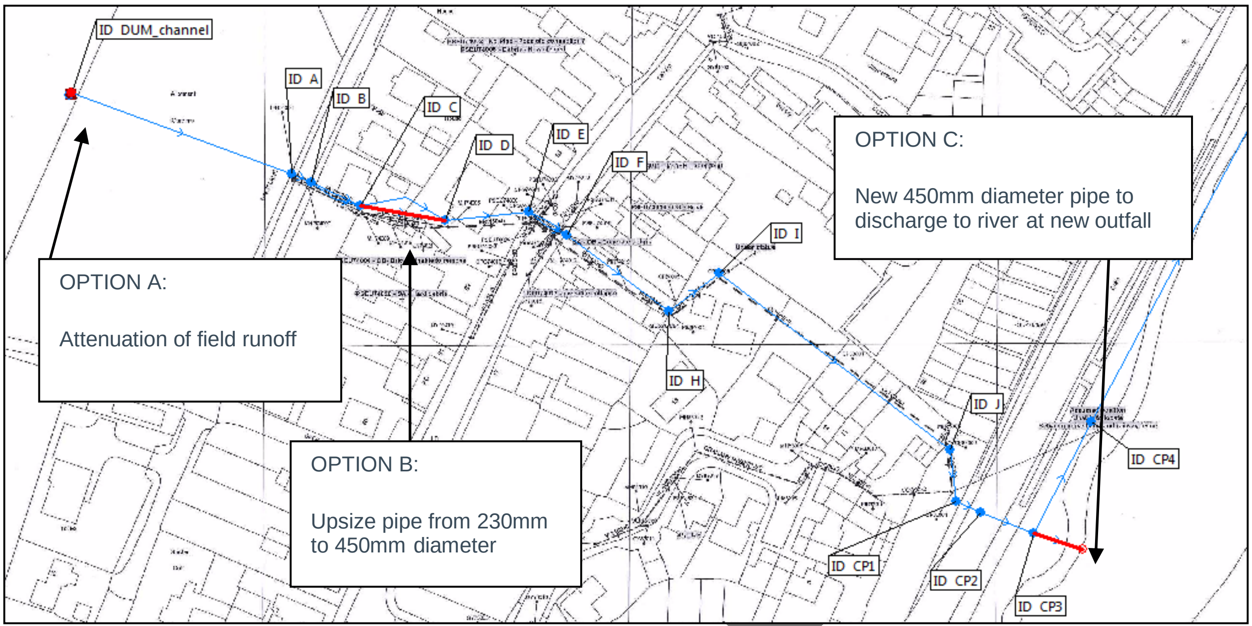

Figure 5.5 Mitigation options for system improvements

5.3.1. Option A – Upstream Storage

The rural topography has been examined for the availability of small sites in which to store surface water runoff and attenuate flows draining to the village. LiDAR, a ground survey and a site walk over with the FWG were used. Two locations were identified as potential locations for temporary flood storage during flood events, as shown in Figure 5.6 below.

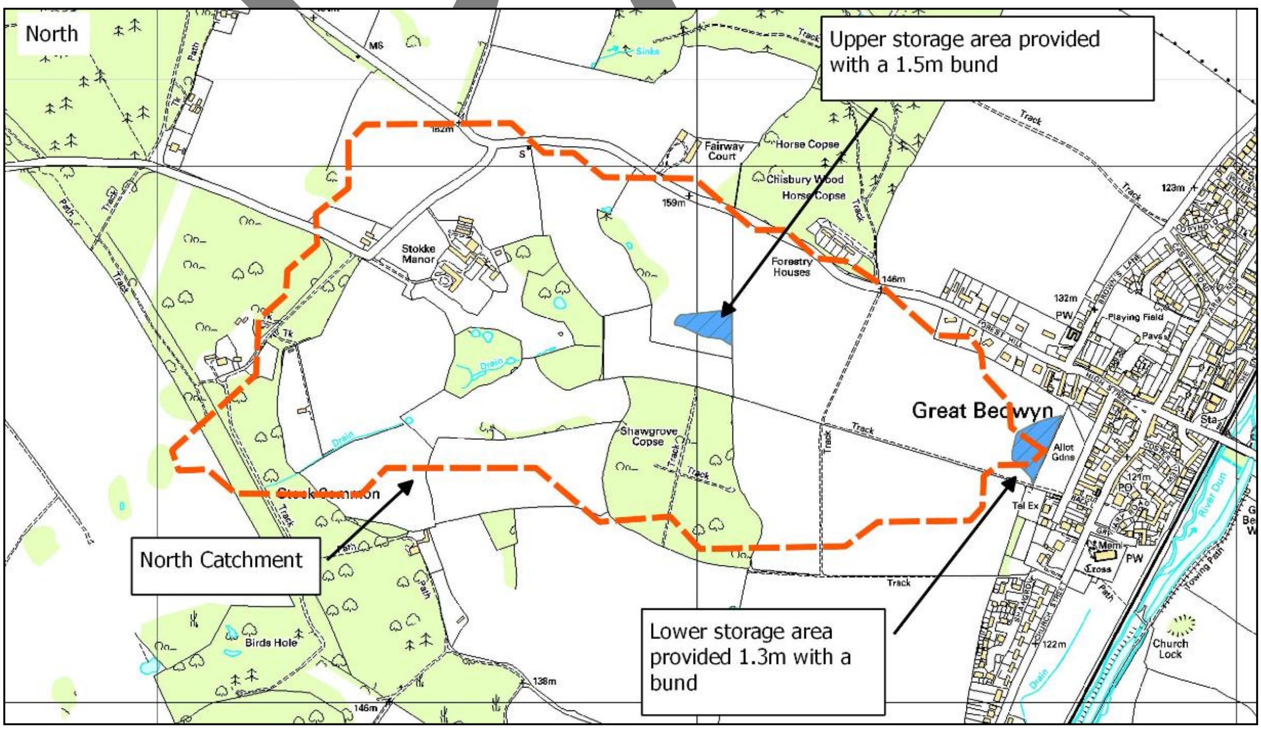

Figure 5.6 Identified areas for storage in the Back Lane catchment.

Both storage areas would require small earth bunds to retain water. A number of different height bunds (depth of water retained) have been examined, with varying lengths. Table 5.8 below provides details of the analyses.

Table 5.8 Storage options

Location	Max. Bund Height (m)	Area Submerged (m^2)	Volume Stored (m^3)
Upper storage area	0.5	1,275	456
	1	2,600	1,423
	1.5	4,075	3,091
Lower storage area	0.5	1,675	319
	1	4,125	1,749
	1.3	5,350	3,200

Construction of both minor storage areas could enable some 6,291m³ to be attenuated with 1.5m bunds. Consideration of available storage in a combined scheme is summarised in Table 5.9.

Table 5.9 Combined storage availability

		Lower Storage (m^3)			
		0m	**0.5m**	**1m**	**1.3m**
Upper Storage (m^3)	**0m**	0	319	1,749	3,200
	0.5m	456	775	2,205	3,656
	1m	1,423	1,741	3,171	4,623
	1.5m	3,091	3,410	4,840	6,291

It was considered that the upstream storage area would not provide sufficient benefit for the disruption to farmland and access issues posed by building in this area.

Storage would be enabled by restricting flows using a weir or orifice.

Storage fluctuation in relation to critical storm duration was investigated in the modelling process to identify, and consider the most stringent design conditions within each return period. The critical duration storm was found to be 12 hours.

The results of storage facilitated by a 250mm diameter orifice can be seen in Table 5.10 . Some flooding is predicted (6.9m³ and 25.1m³) on the Network Rail land area in the 1 in 20 and 1 in 30 year events. The flood volumes are minimal and not in the residential housing area during a 12 hour storm and could be caused by the urban catchment runoff (not mitigated by the storage area). For this event, a storage volume of 3867m³ is required, with a peak stored depth of approximately 1.5m.

Table 5.10 Flood volumes from option A critical duration of 720 minutes.

Location	Flood Volumes (m3)			
	2 year	**10 year**	**20 year**	**30 year**
Entrance to open channel through the allotments	0.0	0.0	0.0	0.0
Back lane	0.0	0.0	0.0	0.0
Back lane	0.0	0.0	0.0	0.0
Langstrath	0.0	0.0	0.0	0.0
Surgery	0.0	0.0	0.0	0.0
Church Street	0.0	0.0	0.0	0.0
Church Street/Granary Road gardens	0.0	0.0	0.0	0.0
Granary road - rear gardens	0.0	0.0	0.0	0.0
Noise Bund	0.0	0.0	0.0	0.0
Railway Margin (CP1)	0.0	0.0	0.0	2.4
Between the tracks (CP2)	0.0	0.0	1.3	6.1
Below the railway (CP3)	0.0	0.0	5.2	14.5
Below the railway (CP4)	0.0	0.0	0.4	2.1
Total	0.0	0.0	6.9	25.1

These results are directly comparable to those in Table 5.3 and show a significant reduction in flooding (1927m³ in the baseline to 25m³ at the 30 year event).

5.3.2. Option B - Upsizing network at Langstrath house

The baseline modelling highlights a severe constriction at the 275mm diameter pipe at Langstrath House. Upsizing the 275mm itself could prove very costly given it's alignment underneath properties but the option of twinning it with another 275mm has been explored to add capacity at this point. Alternatively the existing 275mm diameter could be abandoned and a new 450mm diameter laid along a new alignment.

Table 5.11 Flood volumes from option B- critical duration of 720 minutes.

Location	Flood Volumes (m3)			
	2 year	**10 year**	**20 year**	**30 year**
Entrance to open channel through the allotments	0.0	0.0	0.0	0.0
Back lane	0.0	2.0	49.8	92.8
Back lane	0.0	0.6	37.4	79.0
Langstrath	0.0	0.0	14.6	36.8
Surgery	0.0	0.0	3.0	14.9
Church Street	0.0	13.8	64.6	97.8
Church Street/Granary Road gardens	0.0	29.6	96	129.4
Granary road - rear gardens	0.0	51.7	119.7	153.3
Noise Bund	0.5	161.3	231.5	266.3
Railway Margin (CP1)	12.6	188.2	252.6	284.9
Between the tracks (CP2)	21.4	194	255.3	286.1
Below the railway (CP3)	37.9	210	270.2	300.5
Below the railway (CP4)	7.5	114.4	157	178.4
Total	79.9	965.6	1,551.7	1,920.2

There is a risk that this could move the flooding problem downstream. When compared with baseline flooding quantities (Table 5.3) the overall flood volumes are very similar with 1927.2m³ from the baseline predictions and 1920.2m³ from the option b upsized pipe. The flooding quantities in the upstream sections of pipe show reduced flood quantities. However, the flooding at Langstrath house and downstream of here to Church Street and Granary Road area, is increased quite considerably, 1711.6m³ in comparison to 888.2m³, a total difference of 823.4m³. Flooding here is also known to affect Coster View properties.

5.3.3. Option C - Relocate the railway culvert outlet

The baseline modelling shows that the outlet to the River Dun causes backing up in the system and cannot convey the necessary flows incoming from Granary Road and Coster View. To relieve this, the impact of discharging directly to the river has been considered rather than the current system which runs parallel to the railway for approximately 130m prior to discharge.

Table 5.12 Flood volumes from option C- critical duration of 720 minutes.

Location	Flood Volumes (m3)			
	2 year	**10 year**	**20 year**	**30 year**
Entrance to open channel through the allotments	0.0	87.7	165.3	215.7
Back lane	3	132.1	210.9	262
Back lane	2.3	126	202.8	252.6
Langstrath	11.2	124.3	188	229.2
Surgery	0.0	0.0	0.0	0.0
Church Street	0.0	0.0	0.0	0.0
Church Street/Granary Road gardens	0.0	0.0	0.0	0.0
Granary road - rear gardens	0.0	0.0	0.0	0.0
Noise Bund	0.0	0.0	0.0	0.1
Railway Margin (CP1)	0.0	0.0	0.0	0.0
Between the tracks (CP2)	0.0	0.0	0.0	0.0
Below the railway (CP3)	0.0	0.0	0.0	0.0
Below the railway (CP4)	0.0	0.0	0.0	0.0
Total	16.5	470.1	767.0	959.6

Table 5.12 above shows that the improved outlet almost eradicates the downstream flood risk flooding up to the constriction at Langstrath house (38 l/s); there is still day lighting in the manholes upstream of here. Total flood volumes are reduced to 959.6m³ from baseline 1927.2m³ in a 30 year return period.

Mitigation Results

The flooding for 30 year return period storm and mitigation options A to C can be seen in the below table. A critical duration storm of 12 hours, which required the greatest storage volumes, was applied for all tests.

Option A (storage) removes the flood risk to the back lane area by attenuating rural flows upstream. The downstream area of Network rail land still suffers flooding, albeit to a reduced level.

Option B (pipe) can now be discounted as it doesn't provide any marked improvement to the total flood volumes. Further to this there is a negative effect on the flood situation downstream increasing flood volumes and therefore the increasing risk to properties in this area.

Option C (outfall) removes downstream flood risk by relocating the current river outlet to a direct route with free flowing condition. Upstream flooding shows no improvement to that found in baseline predictions.

Neither option A, upstream flood attenuation, or option C, relocating the outlet to the River Dun, provide an all in one solution to flood risk in the village. The two locations of flooding Granary Road and Coster View area, and upstream at Back lane need separate mitigation options to remove flood risk entirely.

Table 5.13 Summary of residual flooding with scheme improvements

Location	Flood Volumes (m3)			
	Baseline	**Option A**	**Option B**	**Option C**
Entrance to open channel through the allotments	231.4	0.0	0.0	215.7
Back lane	278.2	0.0	92.8	262
Back lane	270.5	0.0	79	252.6
Langstrath	258.9	0.0	36.8	229.2
Surgery	0.0	0.0	14.9	0.0
Church Street	6.6	0.0	97.8	0.0
Church Street/Granary Road gardens	19.6	0.0	129.4	0.0
Granary road - rear gardens	37.9	0.0	153.3	0.0
Noise Bund	147.6	0.0	266.3	0.1
Railway Margin (CP1)	178.8	2.4	284.9	0.0
Between the tracks (CP2)	186	6.1	286.1	0.0
Below the railway (CP3)	202.3	14.5	300.5	0.0
Below the railway (CP4)	109.4	2.1	178.4	0.0
Total	1,927.2	25.1	1,920.2	959.6

6. Assessment of Flooding in the Lower Church Street Catchment

6.1. Understanding the Problem

Figure 6.1 below provides an overview of surface water flow routes for the Lower Church Street catchment.

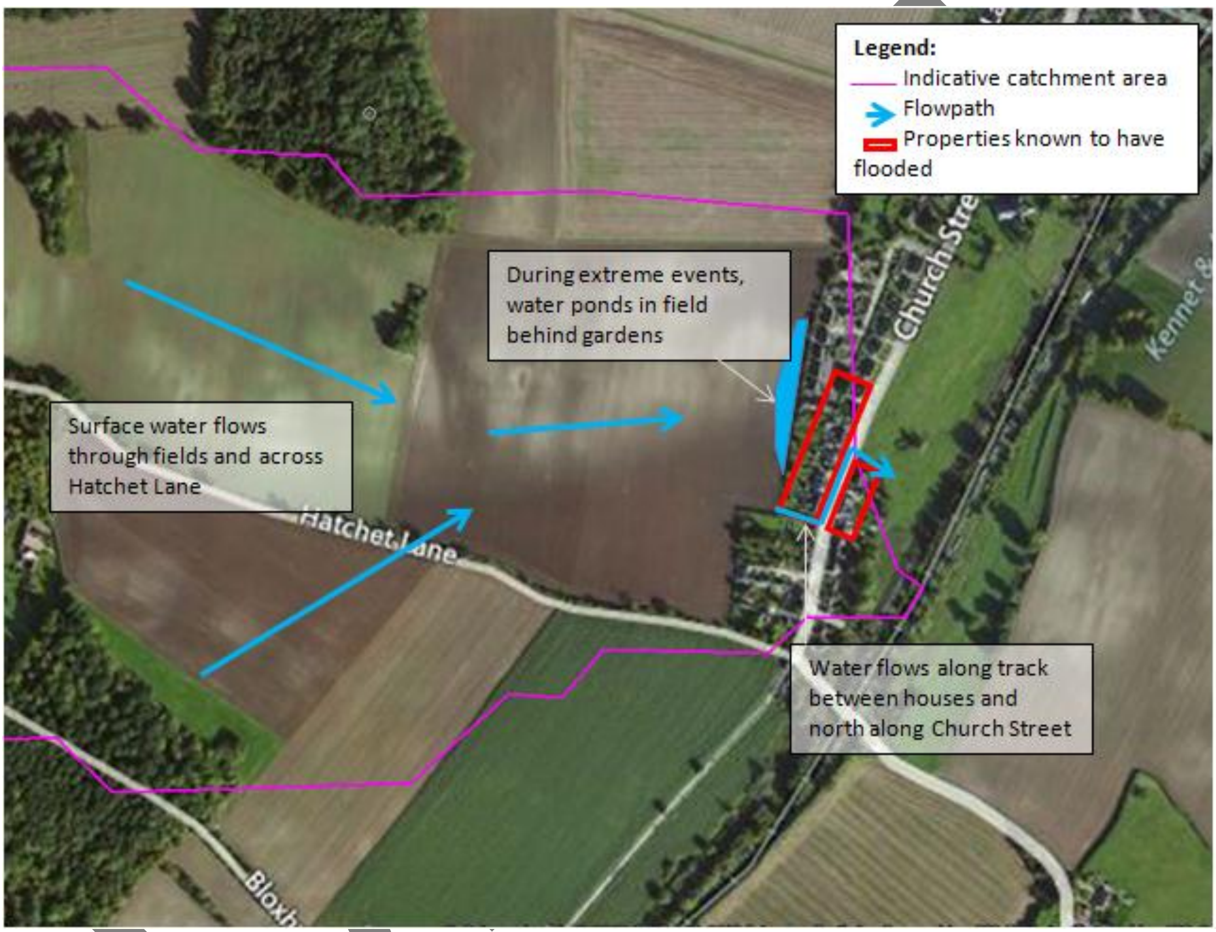

Figure 6.1 - Overview of Flooding in Southern Catchment

Previous flood events show that properties on the western side of Church Street are susceptible to flooding directly from runoff from the fields. While some ponding occurs behind the gardens, there is no formalised way to intercept the surface runoff above the properties and consequently several houses have experienced flooding through their properties as shown in Figure 6.3 below.

Figure 6.2 - Water flowing through properties and on to Church Street (January 2014)

Figure 6.3 - Photos of flooding of fields behind houses and water flowing down track on to Church Street

Properties on the eastern side of Church Street have experienced internal flooding from surface water flowing off the highway itself. In 2008 there was significant internal property flooding as Figure 6.4 below shows.

Figure 6.4 - 2008 flooding of No. 40 Church St.

Following flooding in 2008, WC lowered ground levels underneath the gate into the water meadows adjacent to No. 39 – this enabled surface water on Church Street to pass into the water meadows. From discussions with residents and the FWG, the properties on the east of Church Street (No's 39 - 42) have not flooded since this lowering was carrying out. It should be noted however that some residents have also raised walls in their front gardens to reduce the risk of water ingress, providing a raised defence.

Figure 6.5 - Gate into water meadows where ground levels have been lowered
(https://maps.google.co.uk 22.04.2014)

Drainage Plans obtained from WC show that there are two PVC surface water drains (100mm and 225mm dia) connecting Lower Church Street to the water meadow. See Figure 6.6 below. The connection of the 225mm pipe to the road / track has not been proven. Both drains outfall into an open ditch in the water meadows.

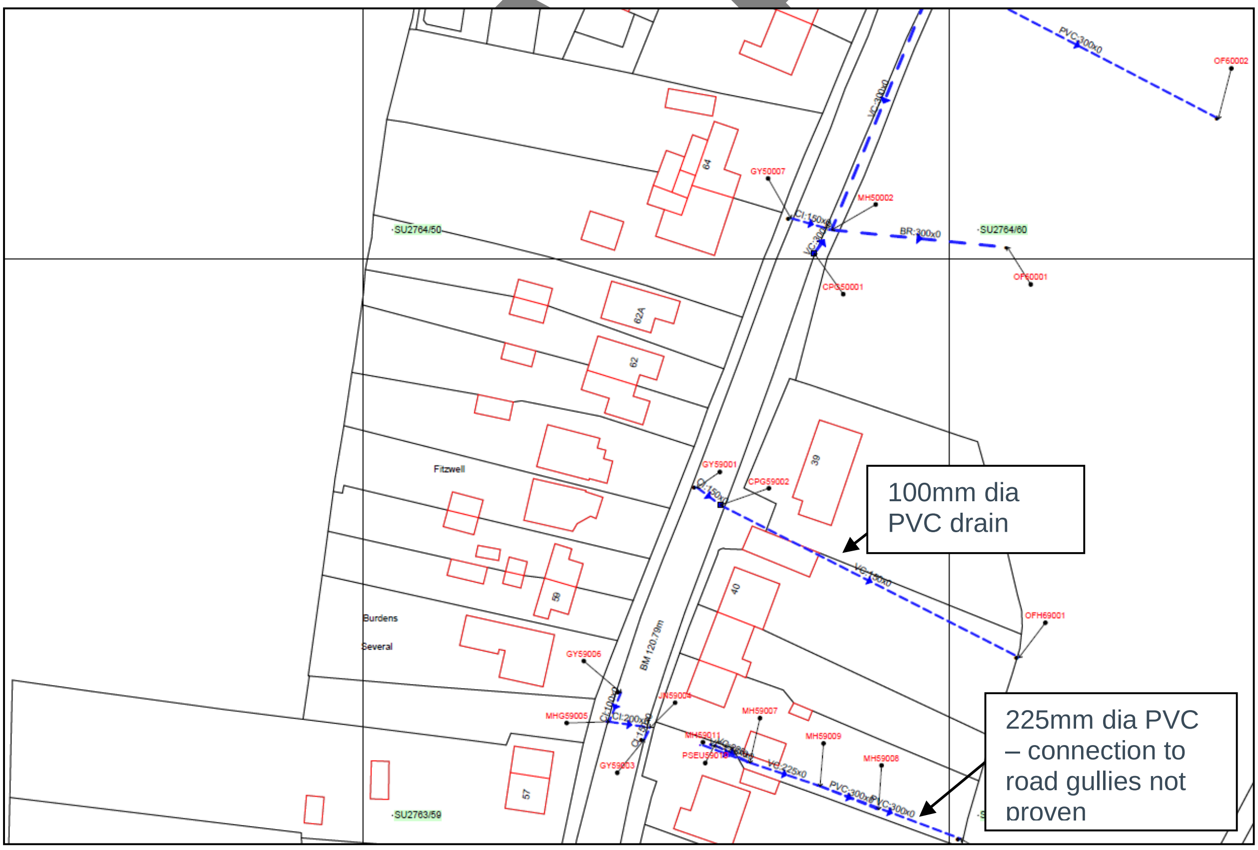

Figure 6.6 - Extract of drainage plan DSNP226/D007

6.2. Mitigation Options

Various options have been considered to manage the surface water from this catchment, these include: storage in the fields above Church Street, a new pipe system around the houses, and management of water on track / road surface.

Unlike with the Back Lane catchment, there is no (pipe) restriction on the system downstream of the fields. Below Church Street, the surface water currently discharges from the street, under the gate and into the water meadows whilst road gullies drain the surface water network to the same point. Mitigation has been considered to allow the water to pass from the fields upstream of Church Street to the meadows below in a controlled manner, reducing the risk to properties on the way.

6.2.1. Storage in Field

At bottom of field

The catchment drains to a location behind the properties shown in Figure 6.1. A small bund could be formed along the field boundary, to retain water, and once the level reaches that of the existing farm track it could convey flows towards Church St. During the flooding in early 2014, the local residents carried out minor earthworks to encourage the water to do just this; see Figure 8.7.

Figure 6.7 - Minor channel dug by local residents to convey water down track onto Church Street during 2014 flooding

The topography has been analysed using LiDAR, a topographic survey and a site walk over with the FWG. A 100m long bund of up to 0.7m in height behind the gardens, where the surface water naturally collects, could store approximately 400m^3 of water before reaching the level of the existing access track. Calculations suggest this equates to only 10 – 15 % of the runoff from a 1 in 2 year storm event. Consequently it is crucial that the exceedance flows from the storage area are conveyed in a controlled manner.

For budgeting purposes, a construction cost of £15 – 20k has been estimated for this 100m long bund.

Within Public Byway / track

The FWG suggested it may be feasible to store runoff within the Hatchett Lane byway, further up the catchment. A site visit and topographic survey was carried out to explore this suggestion. Investigations show that while there is a flatter section of the track, there is limited capacity to store water within the track itself - calculations suggest as little as 50m^3. Some localised bank and ground raising along the track could attenuate *some* water during a flood event, marginally reducing the flow continuing down towards Church Street. However the impact of this would be minimal.

6.2.2. Pipe system

Calculations indicate that to convey the 1 in 30yr peak flow within a pipe system, from the fields above Church Street to the water meadows, a 600mm diameter pipe would be required. This could be reduced to a 450mm diameter below the access track where the gradient is considerably steeper than along the road (1 in 23 gradient compared with 1 in 350 along road).

Were a piped system to be installed, an inlet with a trash screen would be recommended to reduce the likelihood of the system becoming blocked during a flood event providing both a debris screen and sediment trap. Some earthworks would also be required to allow the storage area to overflow / discharge into the pipe system.

Were this option to be taken forward, subject to landowner consent, the system could outfall into the water meadows through an outlet structure similar to those existing (as shown in Figure 8.8). For budgeting purposes, a construction cost of £25 – 40k has been estimated for this new pipe system.

Figure 6.8 - Existing Outfall into Water Meadows

6.2.3. Management of flow through track and on road

As outlined in CIRIA C635: *Designing for exceedance in urban drainage*, the conveyance capacity of existing flood pathways can be significantly influenced by relatively minor details such a kerb heights. By careful landscaping of the track adjacent to property “Burdens Several” and ~70m length of Church Street up to the field gate, the surface water could be conveyed above ground to the water meadows. Such landscaping and minor works would need to be carefully designed but could include some of the following features:

- A shallow ditch running the length of the access track. - Note track is approx. 4.5m wide so to retain access for farm vehicles it may be necessary for the ditch to be located in the centre of the track.
- Re profiling of the cross section of the access track to convey water across the width of the track with raised “bunds” either side adjacent to property boundaries (note that the ground naturally rises on both sides at the top but works would likely be required at the church street end).
- Minor road re-profiling - speed bump type raising
- Minor kerb adjustments to keep water within the road
- Minor modification to property garden boundaries

This mitigation would not prevent the flooding of the Church Street itself. It would however encourage water to pass in a more controlled manner from the fields above the street into the meadows below. It would not be at risk of blockage like a pipe system and could be sized to convey greater flows thus offering a higher standard of protection. For budgeting purposes, a construction cost of £20 – 30k has been estimated for these minor highways works.

7. Environmental Screening

A desk based study was carried out at each location identified for mitigation measures. Freely available information was reviewed to provide an overview of the current environmental baseline of each site. The desk based study included the use of:

- MAGIC website (http://magic.defra.gov.uk/);
- Joint Nature Conservation Committee's website;
- Environment Agency Flood Map (www. environment-agency.gov.uk);
- Bing aerial photography and Ordnance Survey mapping;
- Local Authority websites (www.wiltshire.gov.uk);
- Wiltshire and Swindon Historic Environment Record (www.wiltshire.gov.uk); and
- Local Conservation Groups websites.

Based on the information collected, recommendations for further environmental investigation and consultation have been proposed.

7.1. Environmental Baseline

- The site is located within North Wessex Downs Area of Outstanding Natural Beauty (AONB), which is a nationally important site designated for its unique and spectacular landscape that includes chalk down land, ancient woodland and chalk streams.
- At the northern limit of the proposed site is ancient and semi-natural deciduous woodland, which is a Biodiversity Action Plan (BAP) high priority habitat.
- The vegetation in the proposed location is scrub and grassland. Therefore the site has potential to support a variety of protected flora and fauna species such as reptiles, bats and nesting birds.
- The proposed site borders residential properties.
- There are public byways located near to the proposed works.
- The catchment drains in to the River Dun. The watercourse is of good potential ecological quality.
- There are thirty three listed buildings within 1km of the site. The Historic Environment Record (HER) provided on the Wiltshire Council (WC) website indicates that there is evidence of Iron Age remains at the site and therefore the area has potential to contain further buried remains.

7.2. Recommendations

- Due to the AONB designated area, the WC Planning team should be consulted on the proposed works and the need for any consents.
- The scale of the works is unknown at present and therefore, the WC Planning team should be consulted on whether the works are considered permitted development or would require planning permission. The fact that the site is located within an AONB may influence this decision.
- Due to the nature of the ground cover in the area (grassland, woodland and scrub) advice should be sought from the WC Ecologist as to the need for an Extended Phase 1 Habitat Survey of the area.
- Consideration needs to be given to the public and homeowners in the vicinity as well as to the potential impacts on access and public rights of way (PRoW). Temporary PRoW diversions/closures may be required.
- Potential cultural heritage constraints have been identified. Advice should be sought from the WC Archaeologist as to what mitigation is required and to confirm whether there are any further constraints for the project.
- Consideration should be given to how the works may impact on the Water Framework Directive objectives.

It should be noted that the above information is based on a high level review of readily available desk study information and therefore does not constitute a full environmental assessment.

8. Summary

- The study has investigated flooding in two catchments, along Church Street, in Great Bedwyn; these have been referred to as the Back Lane and Lower Church Street catchments.
- The investigations were informed by village FWG and local residents.
- Hydrology was undertaken using standard flood estimation techniques in accordance with best practice.
- A desk based environmental screening was carried out for the sites and recommendations for further environmental investigation and consultation have been proposed.

Back Lane Catchment

Back Lane catchment experiences flooding from two sources; the urban and rural catchments. The critical peak flow storm durations are 30 minutes and 3 hours respectively. The critical peak storage storm durations are 30 minutes and 720 hours respectively.

The rural catchment runs off the land north west of the village and runs down to the allotment area behind Back Lane. The flows inundate the pipe network upstream causing flooding in the allotments, Back Lane and Langstrath house.

Surface water runoff from the urban area feeds in to the system on Church Street and at the entrance of the railway culvert from Granary Road and Coster View. This causes further flooding downstream.

The outlet of the system on Network Rail land has an unusual layout which the model predicts will cause further constrictions and backing up of flow. The system is sensitive to raised water levels in the river Dun and pip roughness from sediment tree roots and the like.

Investigation undertaken:

- A one dimensional hydraulic model of the study area was built using Infoworks CS
- Results indicate the current standard of protection is approximately 1 in 2 years. Key restrictions in the pipe system were identified at Langstrath House and downstream of the railway culvert.
- Various mitigation options were tested showing the optimum solution to be a combination of upstream storage and reconfiguration of the outlet to the River Dun (downstream of the railway culvert) .Independently neither solution can completely remove the flood risk.

Lower Church Street Catchment

- Calculations suggest that a bund of up to 0.7m in height behind the houses of Lower Church Street could store approximately 400m^3 of water – approx. 10-15% of the runoff in a 1 in 2 year event.
- Calculations show that to convey the 1 in 30 year peak flow, a pipe of at least 600mm diameter would be required along Church Street.
- Minor modifications to the road and track adjacent to Burdens Several could be used to convey the water on the surface without the need for pipes / culverts.

9. Recommendations

North Catchment

- Options A, upstream storage is recommended to alleviate flooding at Back Lane, Granary Road and Coster View, with the construction of a bund behind the allotments to retain water levels of approximately 1.5m. A new outlet structure sized at 250mm diameter would be necessary to control the flows passed forward.

- Option C, rerouting the system outlet, could provide flood alleviation Granary Road and Coster View. Responsibility for the pipe system on Network Rails land needs to be identified for option C works. It is recommended to undertake river level monitoring and topographic survey to identify the practicality of a direct free flowing outlet at this point.

- Further conceptual design and economic viability should be investigated to progress this project.

- Further environmental investigations and consultations should be carried out prior to construction on these sites.

South catchment

- It is recommended that a small bund is designed and constructed along the field boundary behind the properties on lower Church Street.

- Flows from the storage area behind such a bund must be carefully managed to reduce the risk of flooding to houses along Lower Church Street. It is recommended that minor works to the track and road are designed and constructed to do this.

- The bund and highway works described above are estimated to cost a total of £35-50k to construct.

- Further environmental investigations and consultations should be carried out prior to construction on these sites.

10. Appendix A

Urban catchment Layout

Figure 10.1 Urban catchment layout map

Table 10.1 Predicted runoff from urban catchments

Sub-catchment	Maximum runoff (l/s) in a 30 year storm		
	30 min	360 min	1440 min
1	82	30	11
2	98	37	14
3	30	8	3
4	128	47	18
5	94	35	13
Total	**432**	**157**	**59**