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Redbourne, North Lincolnshire

Flood Mitigation Options Report

R50358T140Y002/A

August 2012

Submitted by Pell Frischmann

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EXECUTIVE SUMMARY

- The report has been prepared in conjunction with the Redbourne Flood Evaluation Report, R50358T140Y001A.

- The Flood Evaluation Report identified that part of the study area floods during the 1 in 75 year flow event. Furthermore, two culverts in the study area flood during the 1 in 75 year flow event.

- PF were requested to produce options to mitigate the flood risk in Redbourne by offering a Standard of Protection (SoP), designed to accommodate the 1 in 100 year rainfall event; 1 in 75 year flow event.

- Five possible options have been identified to help reduce the flood risk in Redbourne.

- The proposal for Option 1 is to upgrade the existing Pollution Pond located upstream adjacent to the A15.

- The proposal for Option 2 is to investigate upstream storage as a method of holding back peak flood flow.

- Option 3 comprises regrading Beck Lane and the car park to enable flood waters to flow towards the car park rather than flood the properties around the beck.

- The proposal for Option 4 is to insert a buried pipe into the field at the downstream end of Redbourne. The pipe will act as an overflow pipe and will intercept flows during heavy rainfall events which will reduce flood levels on the main channel.

  This will remove the bend on the beck where the channel turns 90 degrees to flow in a northerly direction immediately west of Emmerson House.

- The proposal for Option 5 is to provide Property Level Flood Mitigation (PLFM) products to the nine houses affected by flooding in this area.

1. INTRODUCTION

Pell Frischmann (PF) has been appointed by North Lincolnshire Council (NLC) to undertake a Flood Evaluation Report and Options Report for the village of Redbourne in North Lincolnshire. This report represents Phase Two of the scheme and summarises the options proposed at Redbourne to address flood issues identified in the Flood Evaluation Report, R50358T140Y001A. This report should be read in conjunction with the Flood Evaluation Report.

2. SITE LOCATION

Redbourne is a small rural village located 17 km south east of Scunthorpe in North Lincolnshire and 4 km east of Kirkton in Lindsey as illustrated in Figure 1.

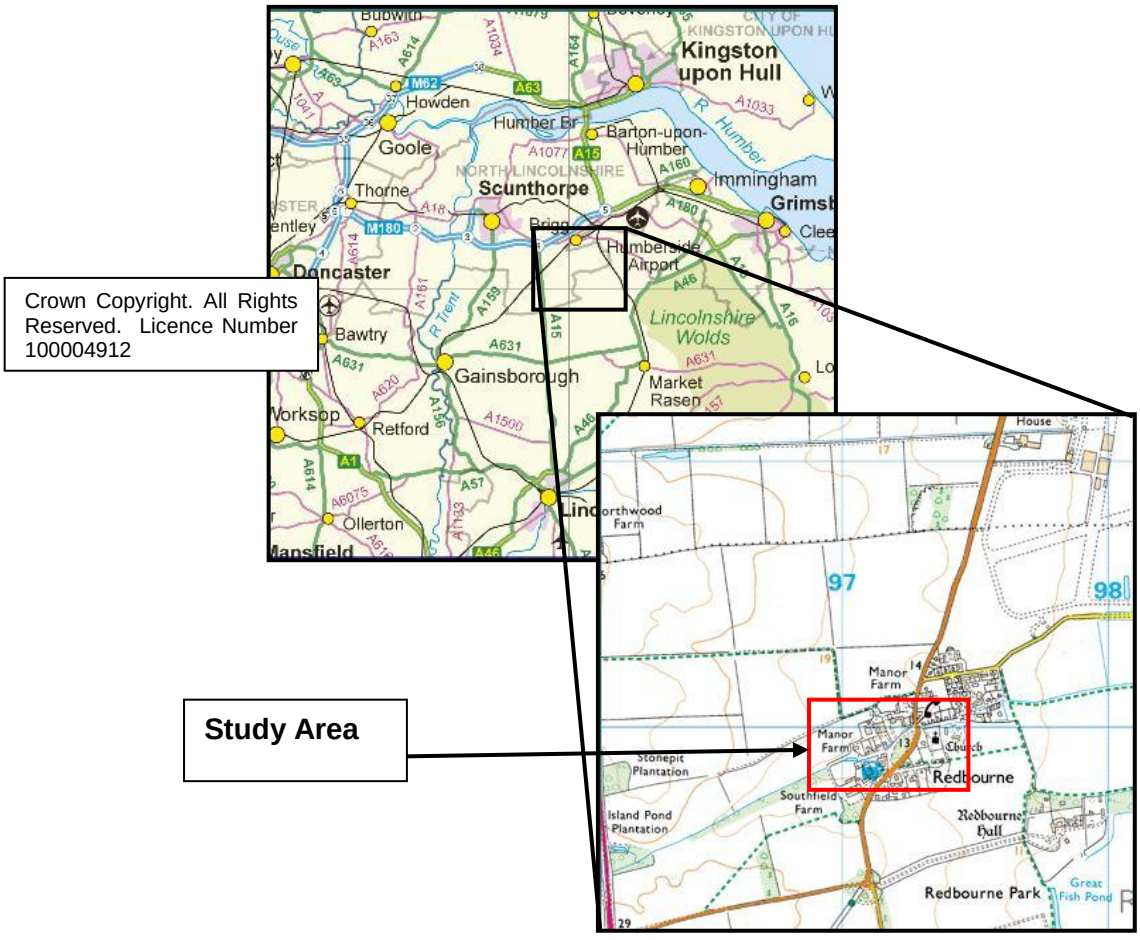


Figure 1 – Maps Showing Location Of The Site

An aerial photograph of the study area is illustrated in Figure 2 below. It also identifies the route of the beck through the village.

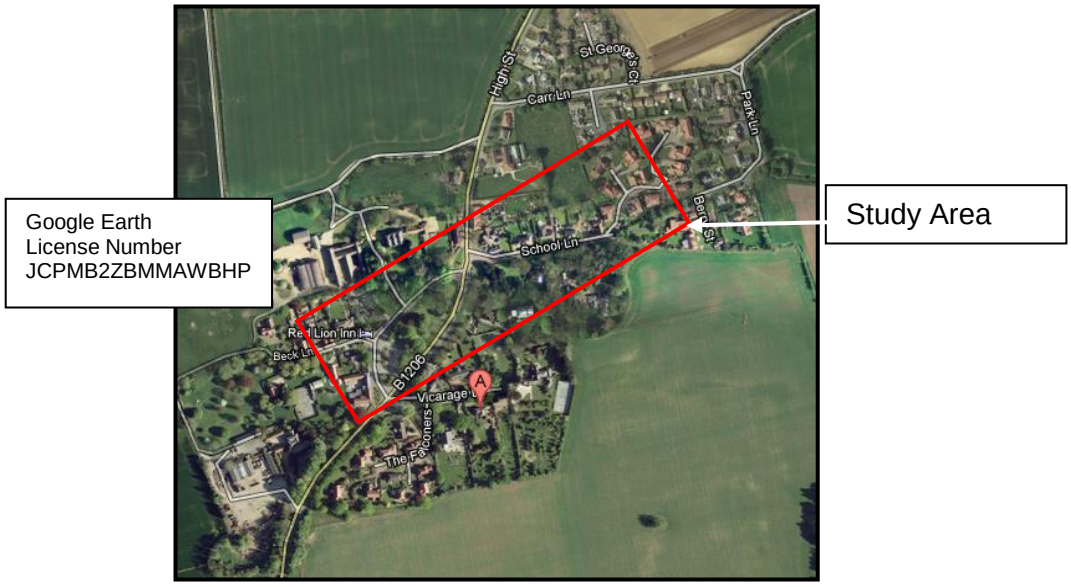


Figure 2 – Aerial Photograph Of The Site

3. BACKGROUND INFORMATION

3.1 FLOOD EVALUATION REPORT

The Flood Evaluation Report identified the following conclusions and recommendations regarding flood issues at Redbourne:

- Flooding in Redbourne has been assessed against historic records and local knowledge as well as via hydrological assessment and hydraulic modelling.

- It has been identified that in the past the village beck has overtopped its banks and culverts have surcharged. The NLC Multi Agency Flood Plan indicated that nine properties within the study area were affected by flooding during June 2007.

- Parts of the village are identified as being located in Flood Zone 2 and Flood Zone 3 of the Environment Agency Flood Map. As a result the village is assessed as being at medium and high risk of flooding. The main risk of flooding is from the beck which flows through the village.

- The beck is heavily culverted throughout the village and is diverted by ninety degrees at the east of School Lane which constricts the flow. The beck now flows to the north of Emmerson House and Thewall Cottage towards Park Lane. Previously, the beck continued its path eastwards to an agricultural field, to the south of the houses at School Lane and Park Lane.

- A hydraulic model was created based on a topographical channel survey of the village beck undertaken by Clugstons. Hydrological assessments were

carried out using the Flood Estimation Handbook to estimate the design flow (1 in 75 year flow) on the beck.

- The results of the modelling indicated that the area around Emmerson House, located to the east of School Lane, is at risk of flooding during the 1 in 75 year flow event. In addition, the model identified that nine culverts within the study area are at capacity during this event.

- A sensitivity analysis of the model was carried out and indicated that when the Manning's coefficient was increased, a larger area was flooded. In addition, one of the culverts flooded when the Manning's coefficient, a measure of channel roughness, was increased indicating the model is sensitive to changes in channel roughness and that maintenance of the channel will have a positive impact on reducing flood risk.

- The model was considered against the 2007 event, which corresponds to at least a 1 in 200 year storm event. The results identified that Beck Lane and the area around Emmerson House to the east of School Lane flooded, which corresponds with the anecdotal information. Generally, the results of the calibration indicate that the model underestimates the 2007 flood in Redbourne; however, it is difficult to reproduce a historic event as exact conditions cannot be replicated.

- The model indicates that no houses are at risk of flooding from the 1 in 75 year flow event however three houses are within 1 cm of being flooded during the 1 in 140 year flow event. It has been reported during the 2007 actual flood event nine houses were flooded.

3.2 MEETING WITH DAVID HARRISON

A meeting between Peter Melville-Shreeve (PM) from PF and David Harrison (DH) from NLC took place on 20.02.12, following the issue of the Flood Evaluation Report. The following points were noted at that meeting.

- DH would like to investigate the option of a buried pipe downstream of Redbourne to determine whether it would reduce the number of houses at risk from flooding. DH is concerned that this solution would not benefit upstream and if not, it would potentially give the wrong impression to the community that the flooding problem is solved.
- PM stated the report could investigate dropping the level of Beck Lane to route flood water away from the properties and towards the car park area which could be used as a flood storage area.
- PM stated that a Property Level Flood Mitigation Scheme could be put forward as an option.

3.3 CULVERTING IN REDBOURNE

It is clear that culverts present a constraint on the flow in the beck and modelling indicates that culverts will surcharge during return period events

larger than the 1 in 75 year flow. However due to the nature of the catchment, fluvial exceedence flows can typically re-enter the watercourse downstream of each culvert. As a result, it is considered that in relation to the 1 in 75 year flow, the presence of the culverts within the village is not a major factor contributing to flood risk within the village.

4. DESIGN CRITERIA

4.1 FLOW EVENT

The 1 in 75 year flow event was established as the design standard as stated by NLC in the design brief.

4.2 CLIMATE CHANGE

The impact of climate change was not considered in this report.

5. OPTIONS

A series of options are considered to reduce flooding. None are mutually exclusive and a suitable combination can be considered. The following options have been reviewed for this report and detailed below;

Option 1 Upgrade Pollution Pond Upstream
Option 2 Upstream Storage
Option 3 Regrade Beck Lane and Car Park
Option 4 Reinstate Ditch Downstream
Option 5 Property Level Flood Mitigation

5.1 OPTION 1

The proposal for Option 1 comprises considering opportunities to attenuate flows before they enter Redbourne. One Option considered was to upgrade the pollution pond located approximately 950 m upstream of Redbourne adjacent to the A15 as illustrated in Plate 1 below.

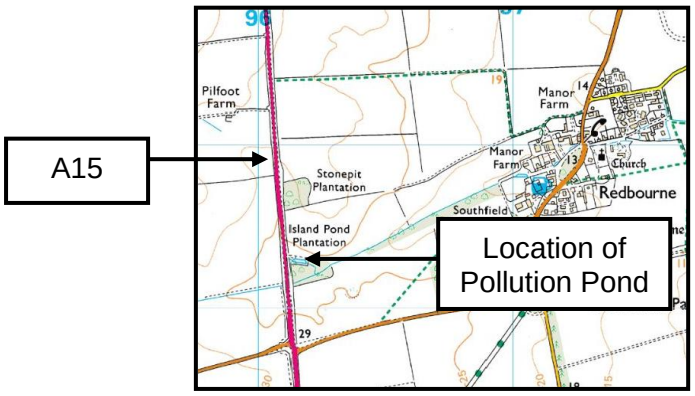


Figure 1 – Location of Pollution Pond

Figure 2 – Pollution Pond

A meeting with David Harrison, North Lincolnshire Council was held in February 2012. DH stated that the pollution pond works effectively and there is little scope to enlarge the pond due to spatial constraints in the immediate vicinity. A site visit to assess the pollution control pond confirms DH's statement and upgrading this pond has been discounted at this stage.

5.2 OPTION 2

The proposal for Option 2 is to incorporate an area of flood storage in agricultural land upstream of the village. By providing an area for flood storage it is envisaged that during heavy rainfall, water levels downstream will be lowered. However, a disadvantage of this method is that agricultural land would potentially need to be purchased from the local farmer. This option could provide wildlife benefits by providing an area of habitat and amenity benefits to the local community. The volume required to keep the 1 in 75 year flow in bank would be approximately 404 m^3. A calculation sheet is included in Appendix A.

It should be noted that the exact location of this flood storage area cannot be located until consultation with NLC and landowners has taken place.

5.3 OPTION 3

The proposal for Option 3 comprises regrading the levels of Beck Lane and the entrance to the pub car park to enable flood water to pond in the car park area rather than flooding the properties on Beck Lane.

The existing levels on Beck Lane prevent flood water entering the car park area and redirect the water towards the low lying area in front of Willow Cottage and Pond Cottages as illustrated in Figure 3 below.

Figure 3 – Existing Topography on Beck Lane

It is proposed that Beck Lane is regraded by reducing the finished road level below the existing threshold levels of the nearby properties. Existing levels are illustrated below in Table 1.

Property	Threshold Level (mAOD)
Willow Cottage	14.02
Boxmoor House	14.51
Pond Cottage 1	14.04
Pond Cottage 2	13.06

Table 1 – Existing Levels of Properties at Beck Lane

It is proposed that Beck Lane should be regraded to 100 mm below the threshold level of Willow Cottage (14.02 - 0.10 = 13.92 mAOD) which constitutes the lowest level of the nearby properties. This should enable the flood waters to be routed towards the car park which will act as an informal flood storage area. This will help prevent flood water flowing towards the properties highlighted in Table 1. The Clugstons topographic survey drawing 3112_001 indicates that the highest level on Beck Lane is 14.16 mAOD and therefore Beck Lane would need to be lowered by approximately 240 mm. Figure 4 indicates the flood mechanisms which would take place if the road at Beck Lane was regraded.

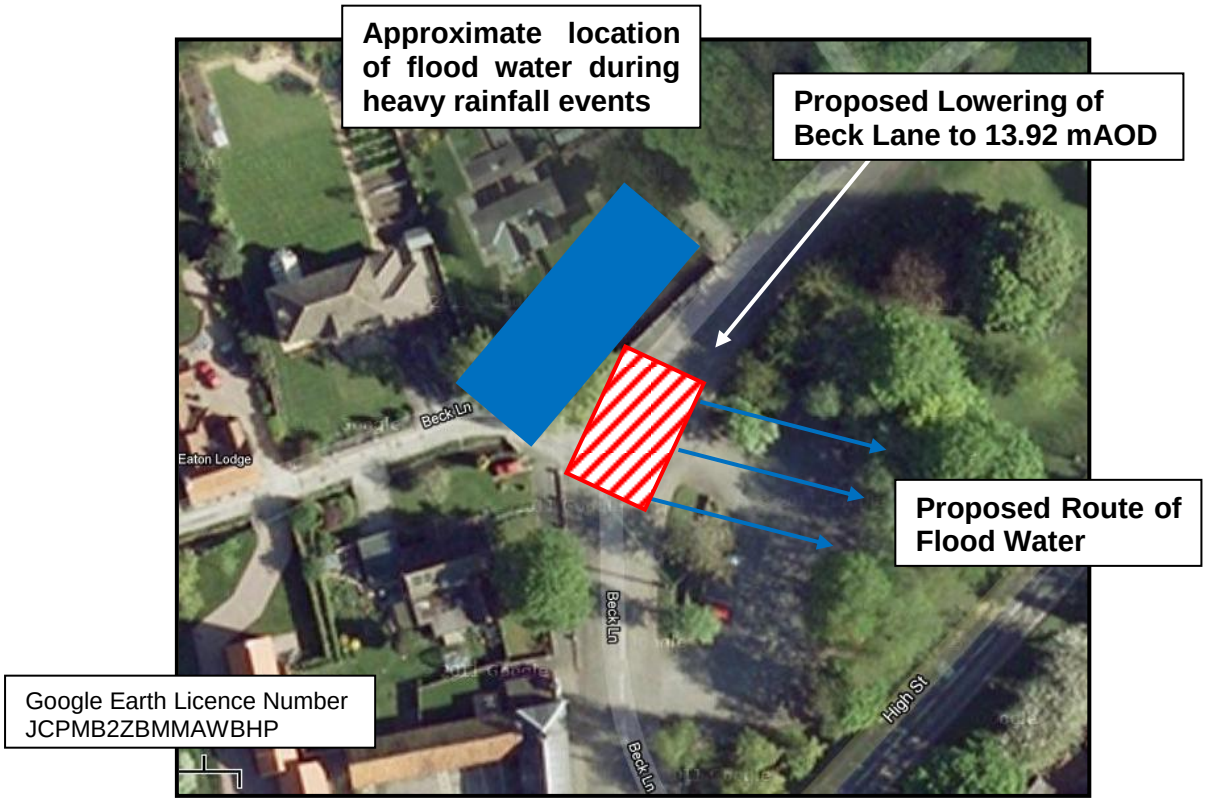


Figure 4 - Proposed Flood Mechanisms After Regrading of Beck Lane

This option would require consultation with the local Highway Authority in order to determine the existing road build up. It is anticipated there are services in the area as the topographical survey undertaken by Clugstons drawing number 3112_001 identifies several cover levels. As a result, a services search will be required to determine the exact location of services in the area. It should be noted that levels will need to be tied into the existing levels. Figure 5 below illustrates the car park which could be used to store water during flood events with appropriate gradients set.

Figure 5 – Car Park At Beck Lane

It is likely that this solution can provide significant benefit to mitigate flooding in the western part of Redbourne. A detailed 2D model should be undertaken to permit the detailed design of this option to be developed. Consultation with landowners (including the pub landlord) would be appropriate before this option is considered further. Appropriate signage 'designating' the car park as an area at high risk of flooding would also be prudent. If desirable, the car park could be regraded or reprofiled subject to detailed design.

The detailed design of the regrading of Beck Lane would reduce the risk of flooding elsewhere for example the property situated between Vicarage Lane and High Street (B1206). If this option is taken forward, it is recommended that the topographic survey is extended to include the levels on Beck Lane, the car park and the threshold level of properties on Beck Lane for consideration of the detailed design phase.

5.4 OPTION 4

The proposal for Option 4 comprises creating an overflow pipe which will divert excess flows via a weir from the main channel of the beck into the pipe. The pipe will flow eastwards, along what is thought to be the original course of the beck, and will rejoin the main channel at the end of Park Lane. A schematic of Option 4 is illustrated in Figure 6 below.

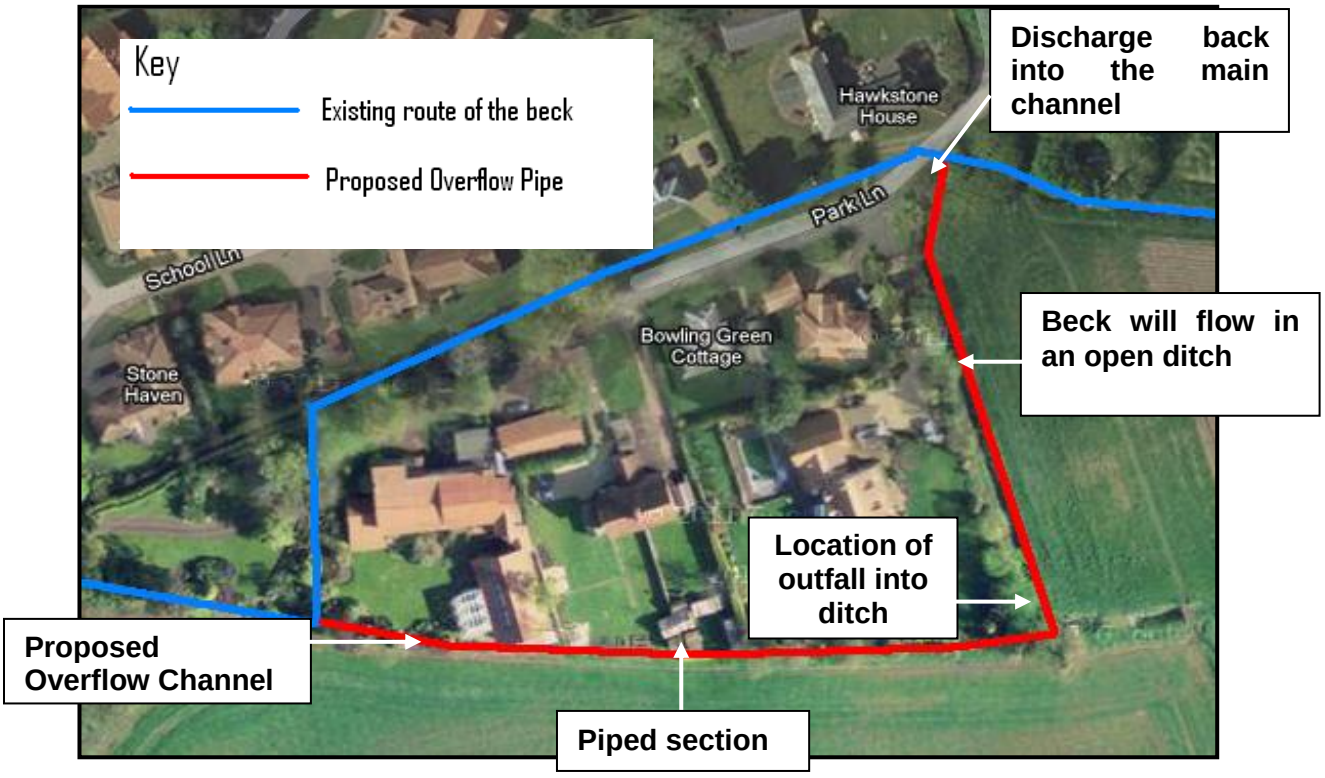


Figure 6 – Aerial Photograph Illustrating The Proposed Option 4

It is proposed that the watercourse will be conveyed in a pipe (or an open channel) which will be situated in agricultural land to the east of the village as highlighted in Figure 6. The pipe will then outfall to a ditch as indicated in Figure 6 above.

In order to determine the size of the proposed pipe, hydraulic modelling has been undertaken using HEC-RAS.

5.4.1 Results of Modelling 450 mm Pipe

HEC-RAS was used to determine how much flow the 450 mm pipe could convey during heavy rainfall events. The model indicates that a 450 mm diameter pipe would convey a maximum of 0.3 m^3/s. The output table has been included in Appendix B.

It is recommended that a 450 mm pipe is sufficient to convey the 1 in 75 year flow from the village beck. However it may be desirable to install a larger pipe network subject to detailed design constraints.

5.4.2 Capacity of the Main Channel

To determine the capacity of the existing channel through Redbourne, a range of flows were routed down the main channel of the model. The results indicate that a flow 0.42 m^3/s causes flooding at Cross Section 71. This is considered to be the bank capacity at this cross section.

5.5 OPTION 5

The proposal for Option 5 is to provide Property Level Flood Mitigation Products (PLFM) products to the houses affected by flooding in the study area.

In 2011-12, the Environment Agency awarded £2 million to local councils to provide PLFM products to homes, which had recently been affected by flooding. The maximum spend for each property is £4, 250, which includes administration and survey costs. The guidance document[1] states the expected life-span of these measures is deemed to be around 10 years.

A range of products are available which can reduce the risk of flood waters entering properties. Flood mitigation products include flood guards which can extend to 600 mm in height and can be fitted to doors to prevent the entry of flood water. The flood guards can be stored and placed in situ during receipt of flood warning / periods of heavy rainfall. In addition, flood proof doors can also be purchased.

Air brick covers can be used to reduce the entry of flood water via air bricks. Non return valves can be used to prevent the back up of surface water and foul

[1] Guidance for household-level flood protection schemes – February 2011 (Version 2)

water into the house. They are normally fitted inside manhole surrounding the property. Properties are generally surveyed by flood management engineers to determine which products would be best suited and to provide a bill of quantities which the contractor uses to procure and install the products. In addition, the final products are inspected by a flood management engineer to verify their suitability and approve each installation. Flood mitigation products have the BSI Kitemark PAS 1188-1:2009 quality standard which means they have been suitability tested and are recognised by the Environment Agency and local authorities.

A number of contractors in the UK supply these mitigation products therefore prices are generally competitive. Approximate costs for each product are indicated in Table 2 below.

Product	Average Estimated Cost (£) (Excluding VAT)
Flood guard (depending on size)	450 - 800
Air brick cover (dependent on size)	50 - 110
Non return valve	90 - 180

Table 2 – Indicative Prices of Property Level Flood Mitigation Products

6. OUTLINE COST BENEFIT ANALYSIS

NLC requested that the benefits of Option 2, Option 3 and Option 4 should be investigated numerically and if not, subjectively as well as the potential of using options in combination.

Option 2, Option 3 and Option 4 are detailed in Table 3 below. It should be noted that Option 1 has been discounted, as detailed in Section 5.1.

Mitigation Option	Benefit
1 – Upgrade pollution pond upstream	N/A
2 - Upstream Storage	9 properties
3 – Regrade Beck Lane and car park	3 properties
4 – Overflow pipe downstream of Redbourne	2 properties
Combination of Options 3 and 4	5 properties
5 – Property Level Flood Mitigation	9 properties

Table 3 – Benefits of Mitigation Options

It is considered that Option 2 would nullify the need for Options 3 and 4 as Option 2 benefits the entire village. If Option 3 and 4 were carried out jointly, flood risk would be reduced at 5 properties.

7. SUMMARY AND RECOMMENDATIONS

- This Flood Mitigation Options Report has been prepared following the Flood Evaluation Report.

- A total of five Options have been put forward to reduce the risk of flooding to properties in Redbourne.

- Option 1 has been discounted as NLC stated that the pollution pond at the A15 works effectively and spatial constraints mean there is little scope for creating a larger pond.

- Option 2 comprises upstream attenuation within agricultural land. Initial calculations indicate that volumes of storage would need to be approximately 404 m^3.

- Option 3 comprises regrading the level of Beck Lane and the car park in order to route flood waters towards the car park. This would require determination of the existing road build up, services and consultation with the Highway Authority and local landowners prior to detailed modelling.

- Option 4 entails creating an overflow pipe to reroute flows during periods of heavy rainfall. This option would reroute flows to the east of Redbourne to reduce flooding in the eastern section of the village.

- Option 5 includes the provision of PLFM measures to each of the nine properties which were affected in the 2007 flood.

8. KEY ASSUMPTIONS

The Options presented in this report are based on the following key assumptions:

- The hydraulic model and topography survey are accurate.
- The Flood Estimation Hydrograph is accurate.
- There is no sedimentation or blockages, leaves or debris, in any of the culverts.
- The riparian owners are maintaining the banks of the beck and will continue to do so.
- The boundary conditions within the hydraulic model were based on Critical Depth boundary conditions.
- The hydraulic model was based on steady flow analysis which represents a conservative estimation of flow volume. Due to the nature of the study area it is likely that an unsteady flow simulation would be less accurate and therefore little benefit would be derived from it.
- There is agricultural land available upstream of Redbourne which can potentially be used as a flood storage pond.

9. LIMITATIONS AND UNCERTAINTIES

This report has been prepared by Pell Frischmann with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client.

The information reviewed should not be considered exhaustive and has been accepted in good faith as providing true representative data with respect to site conditions. Should additional information become available that may influence the opinions expressed in this report, Pell Frischmann reserves the right to review such information and, if warranted, to alter the opinions accordingly.

The report conclusions and recommendations do not preclude the existence of other site conditions which could not reasonably have been revealed at the time of writing.

In addition, this report has been prepared solely for the use of the client, and may not be relied upon by other parties without written consent from Pell Frischmann.

Pell Frischmann disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

APPENDIX A

CALCULATION OF UPSTREAM FLOOD STORAGE VOLUME

Pell Frischmann

Project/Calc No. E50358T140/C001

Sheet No. 1

CALCULATIONS

Project: E50358T140 Redbourne

Date: 10.7.12

Subject: Calculating Upstream Storage Volumes

By: HM Chkd: SG

Ref.

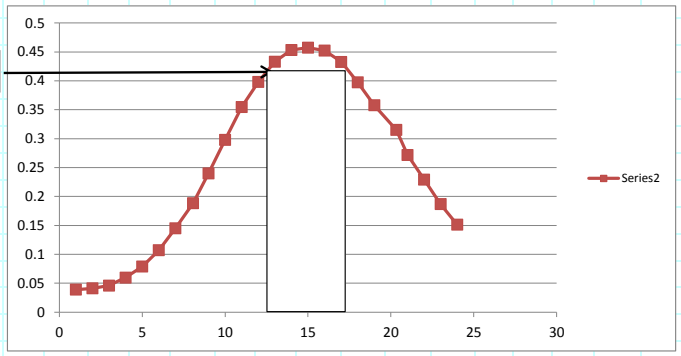
Output

Aim

Using the Flood Estimation Handbook (FEH) hydrograph, calculate the amount of flood storage required to reduce the flood levels within Redbourne to 'bankfull' stage

The FEH hydrograph for the Redbourne is indicated below

Q max =0.42 m³/s



Q_{max} is the maximum amount of flow the existing beck can convey without flooding

Q_{max} is 0.42 m^3/s

Methodology

The Trapezium Rule was used to estimate the area under the above curve between the x values corresponding to y= Qmax.

see sheet 2

Area Under Curve is approximately = $\frac{1}{2}h[(y_0 + y_n) + 2(y_1 + y_2 + \ldots + y_{n-1})]$

The values are given in the table below

Time (hrs)	13	14	15	16	17
y	0.43	0.45	0.46	0.45	0.43

h = 1 hr = 60 x 60 s = 3600 s

Area Under Curve = 1/2 x 3600 x [(0.43+ 0.43)+ 2(0.45+ 0.46+ 0.45)]

Area Under Curve = **6444 m^3**

Area of Rectangle = length x height

length = 17 - 13 = 4

height = 0.42 ie Q max

= 4 * 0.42 = 1.68 hours

1 hr = 60 x 60 secs = 3600 secs

= 1.68 * 3600

= 6048 m^3

Total Flood Volume = 6444 - 6040

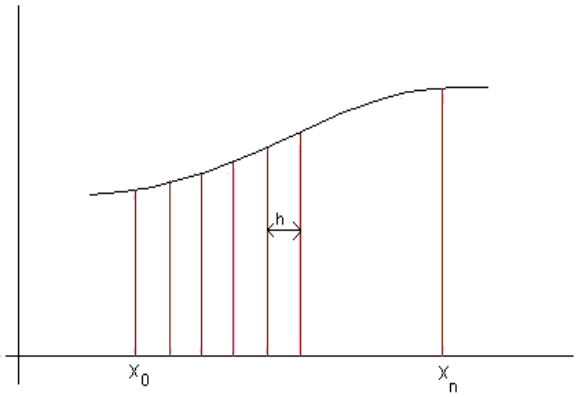
= 404 m^3

Ref.

Output

The Trapezium Rule was used to estimate the area under the above curve between the x values corresponding to y= Qmax.

The Trapezium Rule is as follows:



If we want to find the area under a curve between the points x_0 and x_n, we divide this interval up into smaller intervals, each of which has length h (see diagram above).

Then we find that:

$$\int_{x_0}^{x_n} f(x)\,dx = \frac{1}{2}h[(y_0 + y_n) + 2(y_1 + y_2 + \ldots + y_{n-1})]$$

where $y_0 = f(x_0)$ and $y_1 = f(x_1)$ etc

APPENDIX B

OVERFLOW PIPE CAPACITY ANALYSIS

Option 3 – Overflow Ditch

450 mm pipe

Output table showing main channel, overflow ditch and downstream of overflow ditch 450 mm can convey 0.3 m^3/s

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Ch
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Main_pool	Redbourne	26	PF 1	0.01	9.87	10.39	9.91	10.39	0.000002	0.01	0.67	1.38	0.0
Main_pool	Redbourne	25.5		Culvert									
Main_pool	Redbourne	25	PF 1	0.01	10.35	10.38	10.38	10.39	0.083042	0.47	0.02	1.25	1.1
Main_pool	Redbourne	24	PF 1	0.01	9.90	10.16	9.99	10.16	0.000180	0.08	0.12	0.80	0.0
Main_pool	Redbourne	23.5		Culvert									
Main_pool	Redbourne	23	PF 1	0.01	10.05	10.16		10.16	0.000936	0.13	0.08	1.13	0.1
Main_pool	Redbourne	22	PF 1	0.01	10.11	10.15		10.16	0.009839	0.27	0.04	1.02	0.4
Main_pool	Redbourne	21	PF 1	0.01	9.89	9.96		9.97	0.014274	0.37	0.03	0.55	0.5
Main_pool	Redbourne	20	PF 1	0.01	9.83	9.95		9.95	0.001796	0.17	0.06	0.92	0.2
Main_pool	Redbourne	19	PF 1	0.01	9.81	9.92		9.92	0.002437	0.18	0.05	0.90	0.2
Main_pool	Redbourne	18	PF 1	0.01	9.81	9.91		9.91	0.001991	0.17	0.06	1.01	0.2
Main_pool	Redbourne	17	PF 1	0.01	9.80	9.85	9.85	9.87	0.069738	0.56	0.02	0.69	1.1
Main_pool	Redbourne	16.5		Culvert									
Main_pool	Redbourne	16	PF 1	0.01	9.57	9.66		9.66	0.019687	0.41	0.02	0.57	0.6
Main_pool	Redbourne	15	PF 1	0.01	9.42	9.55	9.50	9.55	0.004082	0.24	0.04	0.65	0.3
Main_pool	Redbourne	14.5		Culvert									
Main_pool	Redbourne	14	PF 1	0.01	9.47	9.55		9.55	0.004215	0.22	0.05	0.88	0.3
Main_pool	Redbourne	13	PF 1	0.01	9.31	9.37	9.37	9.38	0.055551	0.53	0.02	0.68	1.0
Main_pool	Redbourne	12	PF 1	0.01	9.16	9.28	9.22	9.28	0.001273	0.14	0.07	1.11	0.1
Main_pool	Redbourne	11.5		Culvert									
Main_pool	Redbourne	11	PF 1	0.01	8.95	9.28		9.28	0.000015	0.03	0.31	1.44	0.0
Main_pool	Redbourne	10	PF 1	0.01	8.80	9.28		9.28	0.000002	0.01	0.74	2.93	0.0
Main_pool	Redbourne	9	PF 1	0.01	8.79	9.28		9.28	0.000000	0.00	3.39	9.07	0.0
ditch 2	ditch 20	30.5	PF 1	0.30	10.35	10.93	10.51	10.93	0.000017	0.06	5.08	24.16	0.0
ditch 2	ditch 20	30.45		Culvert									
ditch 2	ditch 20	30.4	PF 1	0.30	9.50	9.79	9.79	9.87	0.019041	1.21	0.25	1.69	1.0
ditch 2	ditch 20	30.3	PF 1	0.30	9.45	9.75	9.75	9.83	0.019215	1.23	0.24	1.62	1.0