CRESSWICK / MIMRAM CLOSE

Whitwell

Technical Assessment Report to support Section 19 Flood Investigation

Project No: **0469**
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1 INTRODUCTION

1.1 TERMS OF REFERENCE

This Technical Assessment Report to support Section 19 Flood Investigation was commissioned by Hertfordshire County Council (HCC) to investigate flooding at Cresswick and Mimram Close, Whitwell, Hertfordshire (the site). The report contains a summary of an investigation into the flooding to identify the areas affected, the flooding mechanism(s), the relevant Risk Management Authorities (RMAs) and it also includes potential mitigation measures.

1.2 THE INVESTIGATING CONSULTANT

The study was conducted by NHTB Consultancy Limited. The team consisted of a team of professional civil engineers with extensive drainage experience and personal knowledge of the Hertfordshire area.

1.3 FLOOD & WATER MANAGEMENT ACT 2010 - DUTY TO INVESTIGATE

The study described in this report was commissioned by Hertfordshire County Council (HCC) in their role as the Lead Local Flood Authority (LLFA) , as defined in the Flood & Water Management Act 2010. The Act requires, as specified in Section 19, that the LLFA investigate a flood when they are aware of the event and to the extent it considers appropriate and relevant. Specifically it must investigate which Risk Management Authorities (RMAs) have functions and whether they have exercised, or propose to exercise, those functions in response to the flood. Where an investigation under the Act is conducted, the LLFA must publish the results of its investigation and inform relevant RMAs.

2 DETAILS OF THE SITE

2.1 SITE LOCATION

The area affected by flooding is shown in Figure 1 below. The area includes 1 residential property in Cresswick and 1 residential property in Mimram Close.

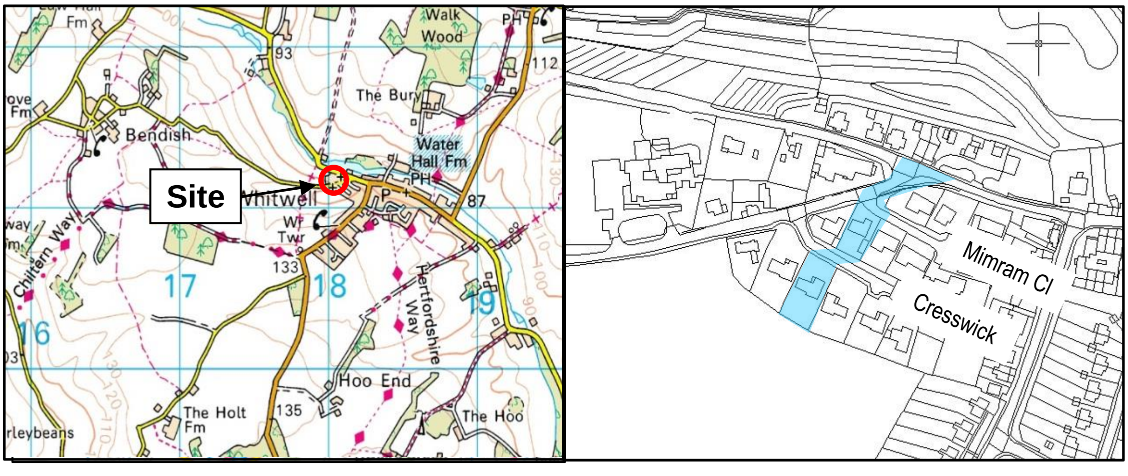


Figure 1: Site Location

2.2 SITE DESCRIPTION

The site is located to the western end of Whitwell adjacent to the junction of Bendish Lane and Lilley Bottom Road, which bisects the village. Lilley Bottom Road is a single lane country road connecting Whitwell to the village of Lilley Bottom to the east and toward Luton in the west. Cresswick and Mimram Close are located off Bendish Lane adjacent to its junction with Lilley Bottom Road.

The affected area lies within the small residential streets of Cresswick and Mimram Close. A natural valley exists running from the arable field to the west, down through the lowest lying areas of Cresswick and Mimram Close out onto Bendish Lane and onto Lilley Bottom Road. The affected properties in Cresswick and Mimram Close lie directly in this valley channel.

3 FLOODING EVENT IMPACTS – 7 February 2014

3.1 INTRODUCTION

The storm event of 7 February 2014 occurred in the early hours of the morning. There had been a prolonged period of unusually wet weather in the weeks preceding the storm and the ground was saturated when the storm commenced. The rainfall was unable to infiltrate into the ground and significant surface water runoff resulted. The procedure adopted for this study to assess the impact of the flooding was to conduct interviews with those affected directly by the flooding and to identify and record where the flood water came from and went to, the flooding mechanism.

3.2 FLOODING MECHANISM

3.2.1 Areas affected by flooding

The flooding occurred within the flow path of the natural valley runoff, as shown by the direction arrows in Figure 2 below; one property in Cresswick and one in Mimram Close. Two ponds were also formed, in the upper field and the field adjacent to Cresswick, in shallow depressions.

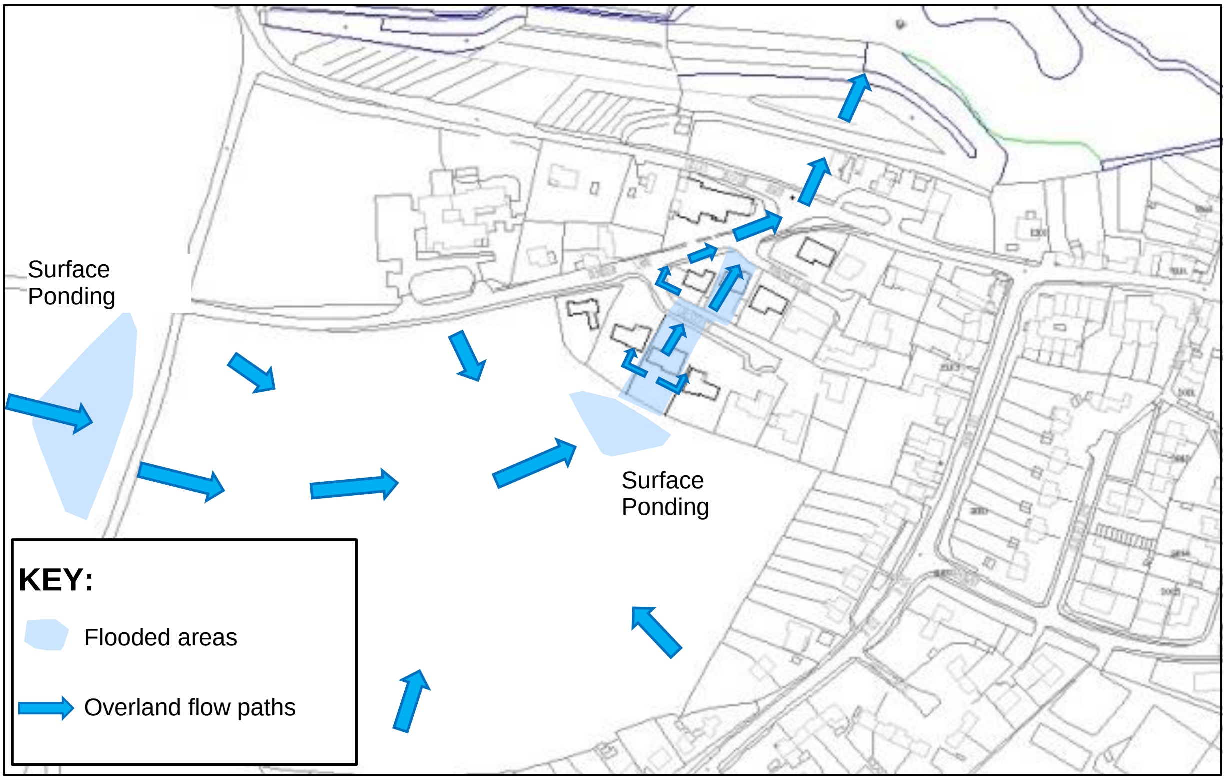


Figure 2: Flooding Mechanism - Overland Flow Paths

3.2.2 Overland Flow Paths

3.2.2.1 Cresswick

One property was flooded in Cresswick.

Water ponding at the bottom of the adjacent field at the rear of Cresswick overspilled and ran across the rear garden directly into the path of the property and entering it via the rear doors at ground level. Excess flood flows ran round both sides of the property onto Cresswick and then toward Mimram Close.

One property in Mimram Close

Overland flow from Cresswick entered the rear gardens of Mimram Close and Bendish Lane; the water pooled in the lower garden of the flooded property in Mimram Close and entered the house via an old dryer vent and the rear conservatory. Water built up in the rear garden to a depth of 0.5m. Water also built up in the rear garden next door in Bendish Lane; however only to a depth of 65mm and caused flooding internally to the garage only, and not the main property; due to the relative ground level being higher at this property by approximately 1m. The natural channel between the properties was effectively blocked by two solid wooden doors/gates providing side/garage access and caused the backup. The conservatory of the internally flooded property prevented flood flows from passing round the other side of the property. Flood flows also flowed around the opposite side of the adjacent property and out to the front garden.

The flows then continued down Mimram Close and into Bendish Lane and Lilley Bottom Road. The flows crossed Lilley Bottom Road and down past the garden centre opposite into the River Mimram.

The flooding of these properties was the result of a single flow path shedding runoff from the contributory catchment, as illustrated in Figure 3 below. The flows were effectively funnelled to the bottom of the natural valley of the catchment, immediately upstream of Cresswick. The flow regime was fairly simple with no other contributory factors to the runoff volume (for example, surface or foul water sewers, reservoirs etc.).

The flows in the catchment ponded at two locations; in the field upstream of the access track which separates it from the field below, which backs onto Cresswick. The pond eventually spilled over a low point in the track and across the field, where it ponded again behind the rear gardens in Cresswick, before spilling over and flooding Cresswick; see Figure 2 for locations of ponding areas. The contributory catchment is also completely permeable, and with minimal barrier to overland flow paths, i.e. minimal ability to "hold up" flows other than the two low spots where the ponds formed. These ponds were not particularly large and had little effect in mitigating the flows.

The threshold of the property that flooded in Cresswick lies approximately 0.8m below the level of the field at the rear. The garden ramps down from the field to the rear of the property. Flows pooled in the garden, inundating the private foul system and mixing with the surface runoff. The runoff entered the property flooding the entire ground floor and garage, as well as flowing around both sides, across Cresswick and into Mimram Close. Mimram Close is approximately 1.5m lower than Cresswick. Flows pooled at the rear of one of the property in Mimram Close and the other in Bendish Lane. Pooling at one property was in the region of 0.5m deep (according to the resident) in the rear garden. The pooling was exacerbated by the side access gates between the two properties being of solid wood preventing water escaping via its natural path. Flows could not escape around the other sides of the property due to the conservatory and garage blocking any route. Water flowed around the opposite side of the adjacent property. Water entered the one property flooding the entire ground floor. Water also entered the garage at the rear of the adjacent property but levels did not get high enough to breach the threshold; see Figure 3 and Table 1 below for details of flooded properties.

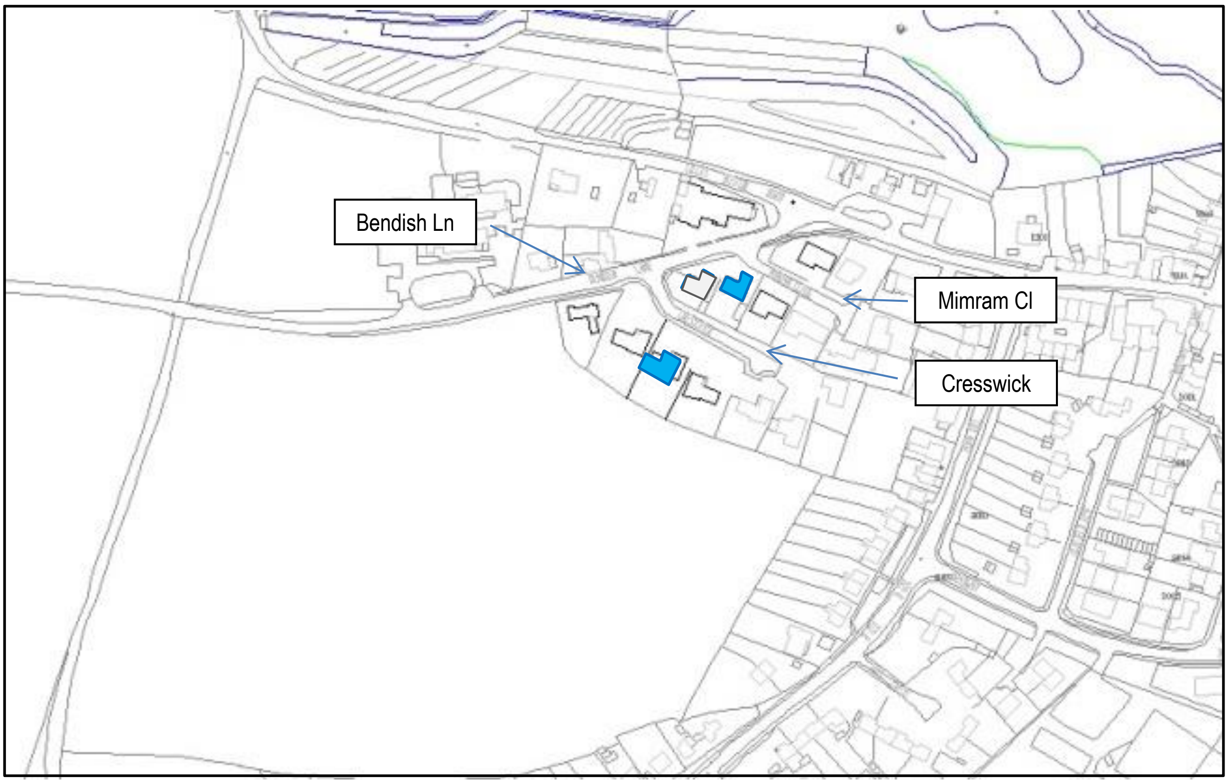


Figure 3: Flooded Properties

Property	Internal Flooding	External Flooding
Cresswick	Yes (through rear doors)	Yes
Mimram Close	Yes (Through rear door and dryer vent	Yes
Bendish Lane	No	Yes (incl. Garage)

Table 1: Flood Event Impact Summary

3.3 RELEVANT STAKEHOLDER ENGAGEMENT

3.3.1 Local Residents and Businesses.

Occupants of each property in the areas affected by the flooding were interviewed as part of this study. The interviews were conducted in person with the resident/occupant wherever possible or over the telephone, by email or by the interviewee completing a questionnaire and returning it through the post. The information gathered from the interview process included the following:

- Details of the flooding mechanism; where the water came from and where it went
- How the property was affected by the flooding including the depth of water inside and outside the property
- The impact of the flooding; damages and other tangible and indirect effects
- Photographic records
- Correspondence records

The interview information was recorded onto a standard questionnaire. The properties affected by flooding are shown in Figure 3 above. Interviews were conducted at all affected properties.

3.3.2 Hertfordshire County Council as Lead Local Flood Authority
Local residents in Cresswick and Mimram Close contacted the LLFA and this study has subsequently been commissioned.

3.3.3 Hertfordshire County Council as Highway Authority (Highway Drainage)
Residents of Cresswick, Mimram Close and Bendish Lane had not contacted the highways authority to request drain clearance, although mention was made in correspondence to Hertfordshire County Council of the drains and the question of their capacity.

3.3.4 Thames Water (Surface Water Sewers)
None of those affected by the flooding contacted Thames Water in connection with the flooding. NHTB Consultancy has not contacted Thames Water as there are no surface water or foul sewers which contributed to the runoff from the catchment. Any surface drainage had no effect on Cresswick flooding. The flow path of the floodwater passed adjacent to two road gullies in Cresswick, possibly accepting some of the flow but accounts of the flow path suggest they would have had minimal effect.

3.3.5 North Hertfordshire District Council (Ordinary Watercourses)
There are no ordinary watercourses in the vicinity of the site, nor within the catchment which could have any effect on the flow regime from the catchment, or to the flooded area from other directions.

3.3.6 Environment Agency (Main River Watercourses)
No Main Rivers affected the contributory catchment. However, it was prudent to check the river levels in the River Mimram to confirm whether the river could have had any impact on the flows and the backing up of floodwater.

According to the Environment Agency website, and the river flow data for the gauging station in Whitwell shows the historic high level. This was incidentally recorded on 7 February 2014, at a level of 0.27m. The height at which flooding form the river is possible is set at approximately 0.40m. It is clear that the river had sufficient capacity so as not to impact on any surface runoff into the river; see Figure 3a below for extract from the website:

Figure 3a: Main River Levels

3.4 FLOOD DAMAGE COSTS

The nature of the flooding had different effects on each affected property; some experienced internal flooding of varying depth and consequence whilst others suffered external flooding only.

As part of the interview process with those affected by the flooding, details were obtained of the financial implications of the flooding damage and these included those costs incurred by the resident/occupier and other costs that were the subject of an insurance settlement, or pending, insurance claim.

Costs provided by the affected residents are set out in Table 2 below.

Location	Insurance Claim Costs	Personal Costs
Bendish Lane (External Only)	N/A	Not Claimed
Mimram Close (Internal)	£60,200	None Claimed
Cresswick	£35,947.80	None Claimed

Table 2: Flood Damages - Costs Summary

The damage caused by the flooding to two properties in Cresswick and Mimram Close was extensive. Flood Depths were approximately 2 inches across the ground floor in Cresswick. Replacement of the entire ground floor contents and fittings/fixings (including kitchen and all in wall plasterboard/rendering) was required.

Flooding within Mimram Close was approximately 25mm deep across the entire ground floor. Flood damage wasn't as extensive (walls did not need attention, nor electrics, hence a relatively lower cost).

The resident with external flooding only in Bendish Lane suffered some minor flood damage to garage items but did not claim any costs to repair.

4 HISTORICAL FLOOD EVENTS

4.1 INTRODUCTION

During the flood survey interviews, the residents at Cresswick, Mimram Close and Bendish Lane were not aware of a flooding history at the site. One affected resident was aware of an historic flood event, similar to the 7 February event, occurring in 1968. This event apparently pre-dated the construction of the houses, so no properties were affected during this event. There are no other known flooding incidents in Whitwell from surface runoff.

4.2 FLOOD HISTORY

All of the residents confirmed that they had never been subjected to flooding from surface runoff before or since the properties were built. The key accounts for this confirmation were from two of the residents, who had lived in Whitwell for 29 and 21 years respectively.

5 CATCHMENT CHARACTERISTICS & EXISTING SURFACE WATER DRAINAGE INFRASTRUCTURE

5.1 INTRODUCTION

The catchment that drains to the area where flooding occurred measures approximately 69.2 ha. The catchment is shown in Figure 4 below and constitutes the only contributing area to the surface water flooding:

- Arable farmland to the west of the site

There is no surface water infrastructure, or areas of hardstanding, to contribute to the runoff

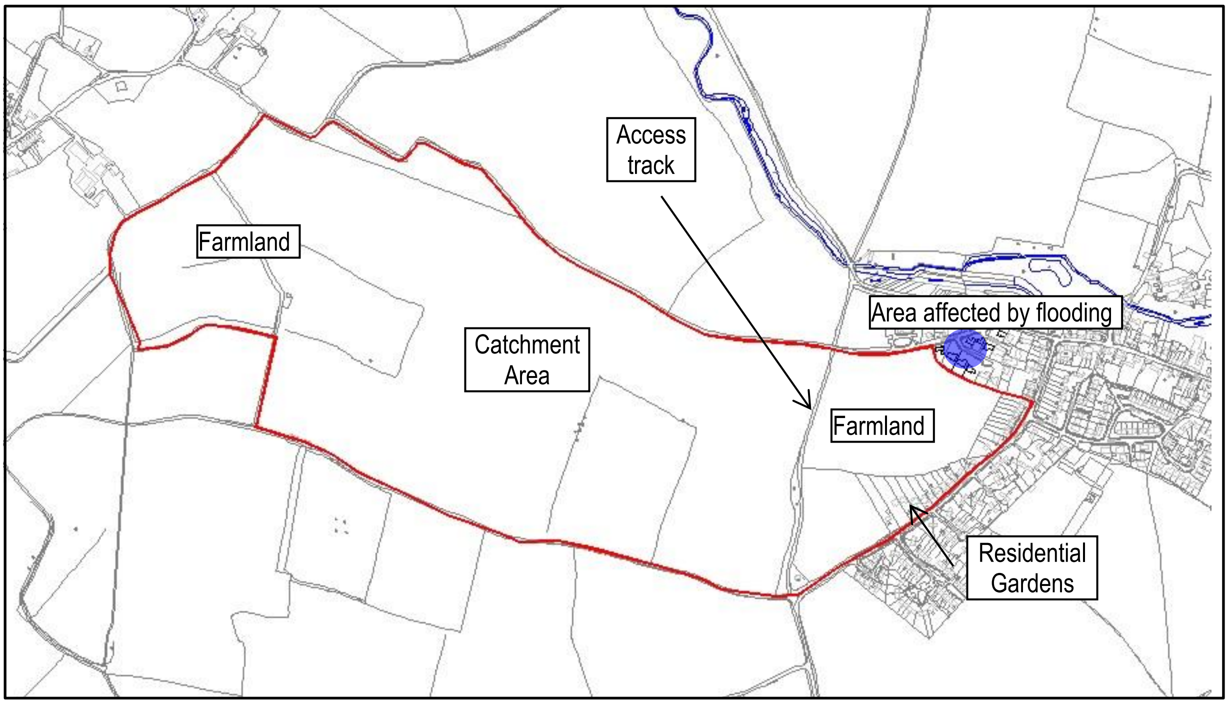


Figure 4: - Catchment Boundary

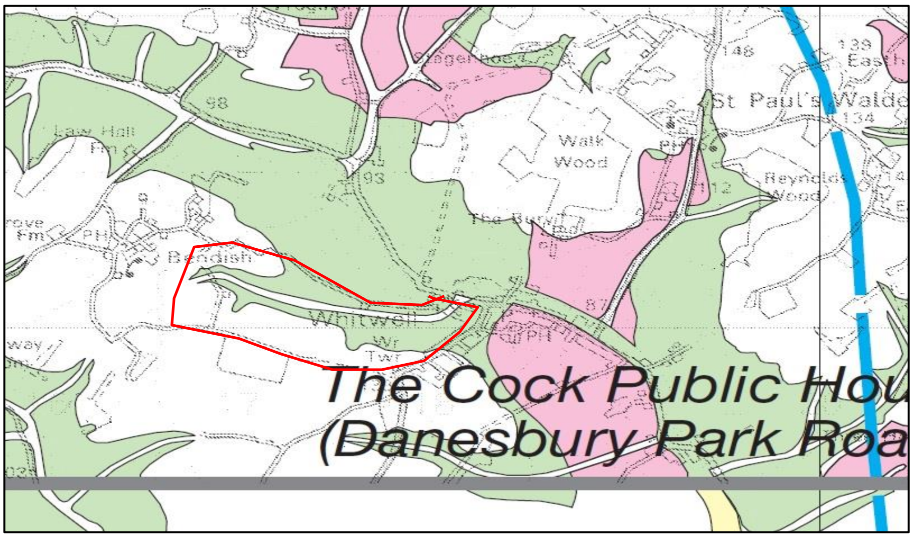
5.2 TOPOGRAPHY & GEOLOGY

5.2.1 The catchment is a relatively steeply sloping catchment, from a high point to the west at approximately 148m elevation to the lowest point in Lilley Bottom Road at the eastern boundary of the catchment, at an elevation of approximately 90m. The flooded properties in Cresswick and Mimram Close lie at approximately 93m and 91.5m elevation, respectively.

The land west of Cresswick is almost entirely arable farmland, with the single lane road of Bendish Lane denoting the northern boundary of the catchment. A treeline denotes the natural watershed along the western and southern catchment boundary. A small number, approximately 27, of rear gardens in Strathmore Rd at the south eastern boundary also drain in the catchment toward Cresswick. The entire catchment is funnelled into the field at the rear of Cresswick, with the low point of the field directly behind Cresswick.

5.2.2 A topographical survey was conducted of the principal elements of the catchment including those areas where major sources of surface water runoff resulted in overland flow and where flooding was experienced. This survey was conducted by NHTB Consultancy and utilised precision Total Station survey techniques supplemented by GPS measurements where appropriate. The survey data was used to identify and measure overland flow paths that were used subsequently in the hydrological analyses (refer to Chapter 6 below) and surface depressions where surface water runoff collected, either causing flooding of properties or where runoff was held before the locations affected by flooding.

5.2.3 The geology of the catchment is a combination of Glacial Sand and Gravel deposits and Chalk as shown in Figure 5 below. This would imply that the catchment is relatively free draining with high permeability.



Map produced from British Geological Society UK Map PDF.

Figure 5: Geology

Key:
Catchment boundary
Chalk bedrock
Sand and gravel deposits

5.3 LAND USE AND SURFACE WATER DRAINAGE ARRANGEMENTS

There are two principal surface water drainage systems within the catchment comprising mostly natural and a small area of man-made. Different bodies are responsible for each system. The different systems are shown in Figures 6.1 and 6.2 below.

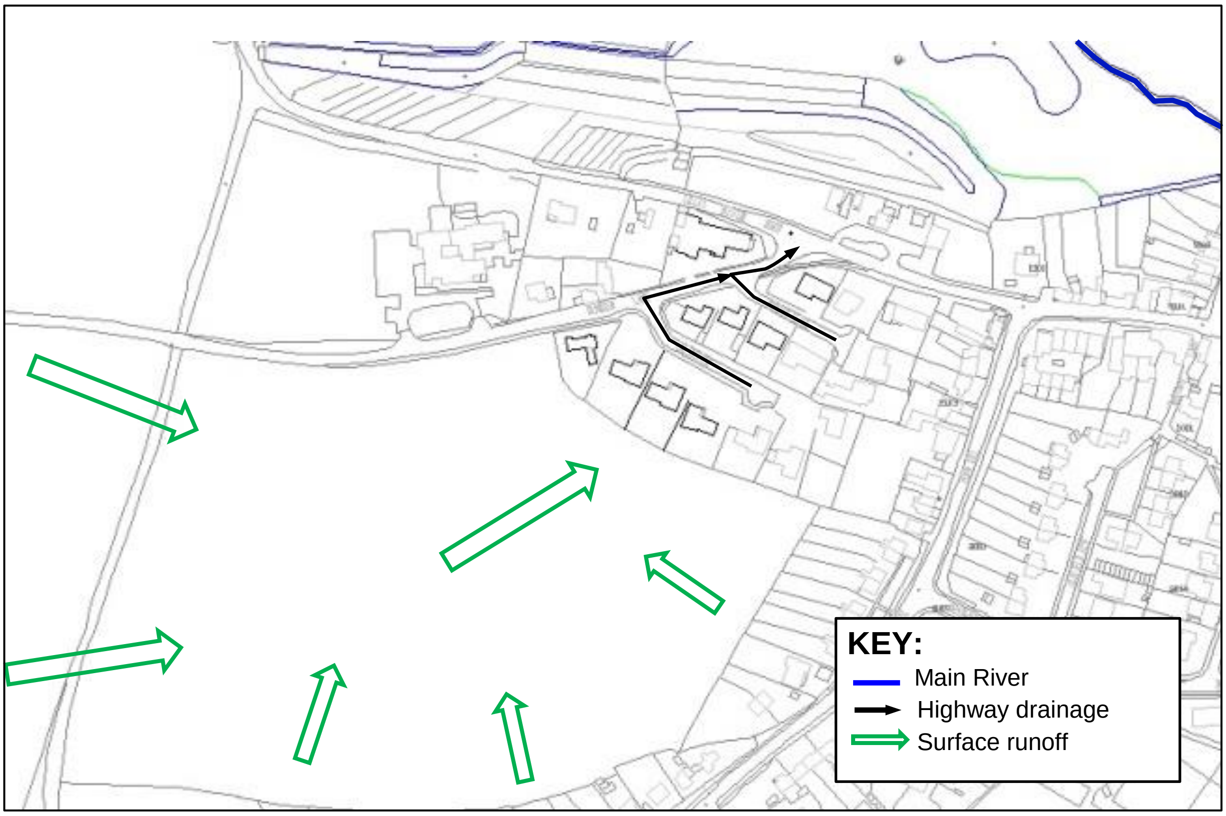


Figure 6.1: Surface Water Drainage Systems

5.3.1 Highway Drainage (Hertfordshire County Council as Highways Authority)
There is a highway drainage system serving Cresswick and Mimram Close, and a small section of Bendish Lane. A survey of the system was conducted as part of this study in October 2014 and the results of that survey are shown in Figure 6.2 below.
There are a few isolated road gullies evident in these roads and they appeared generally clear during our surveys on site, except for some silt in the bases. The manhole chambers were generally heavily silted and it was not possible to ascertain the outfall from the system due to the quantity of silt. It had been proposed by the residents that the drainage was blocked and would have made some difference to the flooding. This would not have affected properties in Cresswick in any case as it lies upstream of any man-made drainage. Gullies were unlikely to have significantly affected Mimram Close either. The gullies assist in conveying water off the road surface and towards the highway drainage system in Bendish Lane, but has limited size and are not at an ideal location to intercept the maximum quantity of surface flow. The initial flow path does not directly cross any gullies due to their location in Cresswick but would eventually flow into gullies as flows drain toward Bendish Lane. Mimram Close gullies will also accept some flows as it drains into Bendish Lane. Flood flows would likely not have been impacted enough before interception by the highway drains to prevent flooding.

In extreme storm conditions there can be a significant rate of surface water runoff from the farmland into Cresswick and Mimram Close.

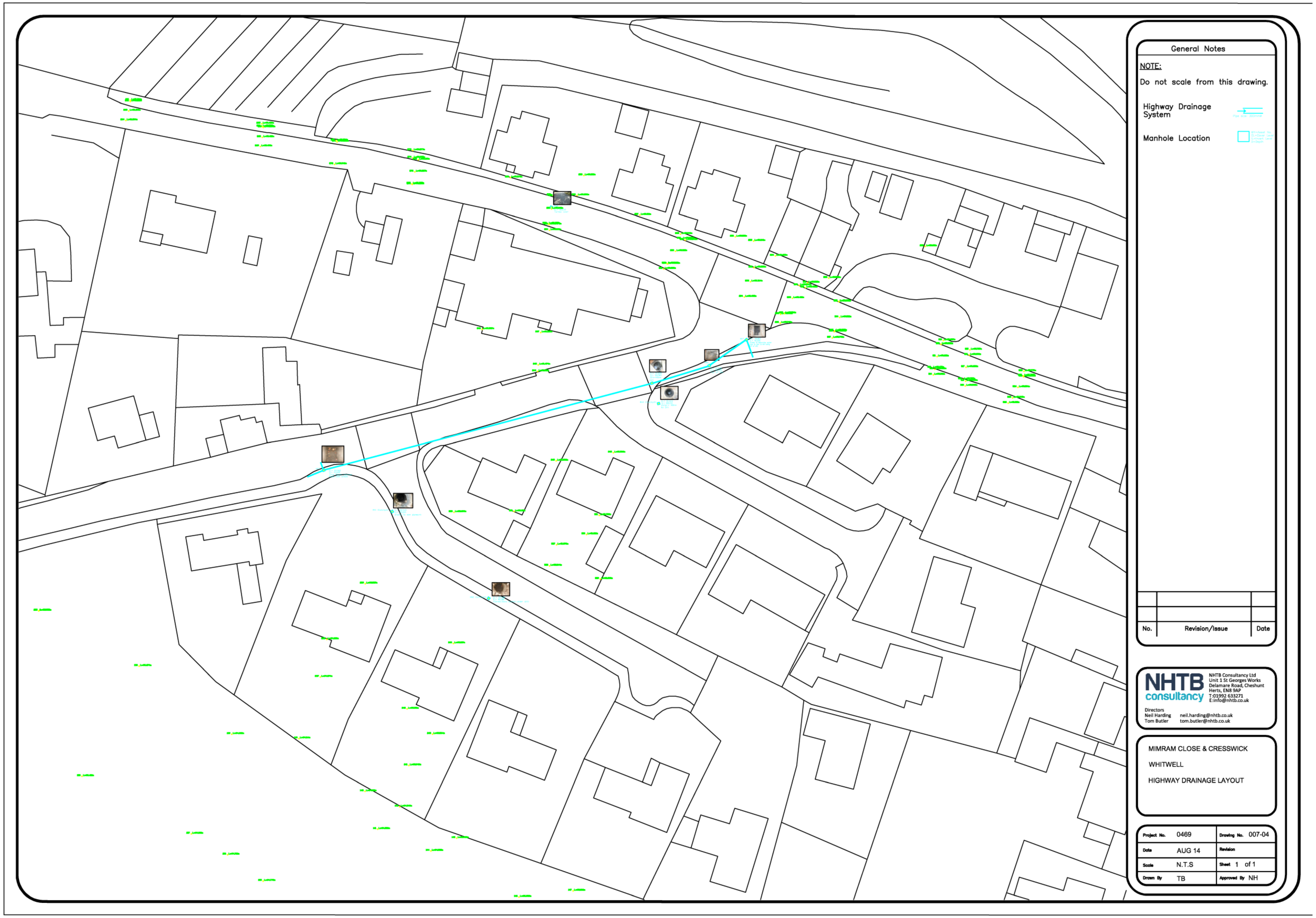


Figure 6.2: Highway Drainage System

5.3.2 Surface water sewerage (Thames Water)

5.3.2.1 There is no surface water sewerage network that could affect the flooding in Cresswick and Mimram Close.

5.3.3 Land Drainage

5.3.3.1 Field Drainage (Farmer)

Except for the rear gardens of the properties in Strathmore Road, the catchment to the west consists of cropped fields. The fields effectively form a natural valley profile aligned towards a natural low spot adjacent to the rear of Cresswick. The catchment is relatively steep with an average gradient of approximately 1:30 to 1:40. This would result in a relatively short time of concentration of runoff, especially considering the existing ground conditions at the time of this event.

5.3.3.2 Ordinary watercourses (North Hertfordshire District Council)

There are no Ordinary Watercourses within the catchment or that could affect the flooding.

All surface water runoff from the catchment ultimately drains into the River Mimram to the east of the catchment. The watercourse is classified as a Main River and therefore falls within the overall administration of the Environment Agency's land drainage powers. There is no formal point of discharge into the river; natural overland flow will drain the catchment.

6 HYDROLOGICAL ASSESSMENT

6.1 INTRODUCTION

As part of this investigation, an assessment was made of the rainfall conditions that precipitated the flooding. The assessment took into consideration the conditions prior to the flooding and including the catchment conditions and antecedent rainfall in the period leading up to the storm that caused the flooding. Other contributory factors that may have influenced the flood event were also investigated and are described below. The investigation sought to confirm the flooding mechanism and to quantify the various factors that combined to cause the flooding, putting each into relative perspective and scale with the others. The second part of this chapter describes the results of a hydrologic assessment that examined how the catchment and components of the drainage systems would respond to a range of statistical design storms under a range of antecedent conditions. The final part of this chapter makes reference to other recent flood risk assessments that have been conducted and how they compare to this investigation.

6.2 ASSESSMENT OF 7 FEBRUARY 2014 STORM EVENT

6.2.1 Rainfall data

Details of rainfall recorded at three permanent rain gauge sites, maintained by the Environment Agency, were obtained by the Lead Local Flood Authority for this investigation. The gauges were located at the following sites shown geographically in Figure 7 below:

Figure 7: Rain gauge locations

The measurements of rainfall were recorded as a total depth of rainfall over each successive 15 minute interval.

A brief summary of the rain recorded by the rain gauges is presented below in Table 3.

	Stevenage TBR	Whitwell STW TBR	Markyate STW TBR
Date/time	Depth of Rain (mm)	Depth of Rain (mm)	Depth of Rain (mm)
07/02/2014 00:15:00	0	0.1	0.2
07/02/2014 00:30:00	0	0.3	0.8
07/02/2014 00:45:00	0.2	0.7	1
07/02/2014 01:00:00	0.2	0.5	1
07/02/2014 01:15:00	0.2	0.5	0.4
07/02/2014 01:30:00	0.4	0.6	0.4
07/02/2014 01:45:00	0.4	0.3	0.2
07/02/2014 02:00:00	0.2	0.6	0.4
07/02/2014 02:15:00	0.4	1.3	1
07/02/2014 02:30:00	0.8	1.3	1.2
07/02/2014 02:45:00	1.2	1.9	1
07/02/2014 03:00:00	1.4	1.9	2.2
07/02/2014 03:15:00	2	1.9	1.6
07/02/2014 03:30:00	1.4	1.7	1.2
07/02/2014 03:45:00	3	1.5	1.2
07/02/2014 04:00:00	3.2	1.6	0.8
07/02/2014 04:15:00	1.8	0.9	0.8
07/02/2014 04:30:00	1.2	0.5	0.6
07/02/2014 04:45:00	0.8	0.7	0.4
07/02/2014 05:00:00	0.4	0.1	0
07/02/2014 05:15:00	0.4	0.1	0.2
	19.6mm	19mm	16.6mm

Table 3: Rainfall Summary (7 February 2014)

From examination of the data above the following details are evident:

(i) The storm commenced just after midnight on 6 February and continued for approximately four and a half hours

(ii) 19.0mm of rain was recorded at the Whitwell rain gauge (the nearest to Cresswick/Mimram Close) located at Whitwell Sewage Treatment Works (STW).

(iii) The storm was reasonably consistent in character as it moved across the catchment from west to east (Markyate to Stevenage) with approximately 15% variation in total depth of rainfall recorded between the three gauges. The maximum depth of rainfall recorded by the rain gauges was at Stevenage.

(iv) The rainfall intensity peaked in Whitwell at 1.9 mm in the 15 minute time period from 02:45am – this peak continued until 03:15am. This equates to an average intensity of 7.6mm/hr. The average intensity for the storm event as a whole was 4.2mm/hr (19.6mm over 4:30 hours).

The depth of rainfall recorded in Whitwell does not represent rainfall of unusually high intensity nor significant quantity. As an illustration the data in Table 4 below shows the average equivalent depths and intensities for design storms of a similar duration and increasing severity compared to the event of 7 February 2014. The rainfall characteristics compare very favourably with those of a theoretical storm of 1 in 1 year return probability.

Storm Return Period	Storm Duration	Average Rainfall Intensity	Rainfall Depth
7 February 2014	**270 mins**	**4.2 mm/hr**	**19.0mm**
1 in 1 year	270 mins	4.3 mm/hr	19.35mm
1 in 5 years	270 mins	6.6 mm/hr	29.7mm
1 in 10 years	270 mins	7.7 mm/hr	34.7mm
1 in 50 years	270 mins	11.0 mm/hr	49.5mm
1 in 100 years	270 mins	12.8 mm/hr	57.6mm

Table 4: Illustrative Design Rainfall Characteristics

Under normal conditions, a storm of 1 in 1 year return period would not be expected to create flooding conditions as witnessed on 7 February 2014 in Whitwell. Other contributory factors to the flooding are discussed below.

6.2.2 Catchment antecedent conditions

The period leading up to the flooding event was unusually wet and the ground was reported by the local residents as being saturated with two areas of ponding in the adjacent fields. An assessment of the rainfall recorded over the preceding 28 days is reported in Table 5 below.

	Stevenage TBR	Whitwell STW TBR	Markyate STW TBR
Date/time	**Depth of Rain (mm)**	**Depth of Rain (mm)**	**Depth of Rain (mm)**
11/01/2014	1	0.8	1.4
12/01/2014	2.4	2.9	3
13/01/2014	4.2	2.7	3.6
14/01/2014	1.4	1.8	2
15/01/2014	3.4	3.3	4
16/01/2014	8.2	10	4.6
17/01/2014	1	1.4	2
18/01/2014	2.4	1.7	1.2
19/01/2014	0.4	0.2	1.4
20/01/2014	0	0	0.2
21/01/2014	0.2	0.7	0.2
22/01/2014	6.2	8.2	6.4
23/01/2014	3.4	3.2	2.8
24/01/2014	4.4	5	5.6
25/01/2014	3.4	2.8	3.2
26/01/2014	5.8	7	8.2
27/01/2014	0.8	0.6	1.6
28/01/2014	2.4	3	1.4
29/01/2014	7.6	8.7	10
30/01/2014	4.2	3.3	2.6
31/01/2014	8.2	8.3	10
01/02/2014	5.8	7.4	6
02/02/2014	0	0	0
03/02/2014	0	0	0
04/02/2014	1.6	2.3	3.4
05/02/2014	8.2	9	13.8
06/02/2014	8.6	9.5	10
	100.9mm	**110.6mm**	**108.6mm**

Contains Environment Agency information © Environment Agency and database right

Table 5: Antecedent Rainfall Summary

The data above in Table 5 shows that there was almost 111mm of rain over the 26 days prior to the flooding event on 7 February 2014. This is considerably greater than the average that would be expected. The standard average annual rainfall (SAAR) for this part of the UK is 600mm which equates to a monthly average (January) of 60mm. The average rainfall data for January is shown in Figure 8 below. The amount recorded is typically 85% greater than the average and, more importantly there was 18.5 mm recorded in the 48 hours before the flood event. This rainfall would have resulted in the soil being saturated and the removal of any soil moisture deficit (SMD). The quantity of rainfall also resulted in the formation of ponding on the surface in small surface depressions. These two factors in combination would have created conditions conducive to a very high percentage runoff that in turn would have resulted in most of the rainfall that fell converting into surface water runoff. The typical percentage runoff that would be expected from a permeable surface from a theoretical design storm is approximately 35% (wetted). In comparison, the runoff from an impervious surface would be in the range of 95% (wetted).

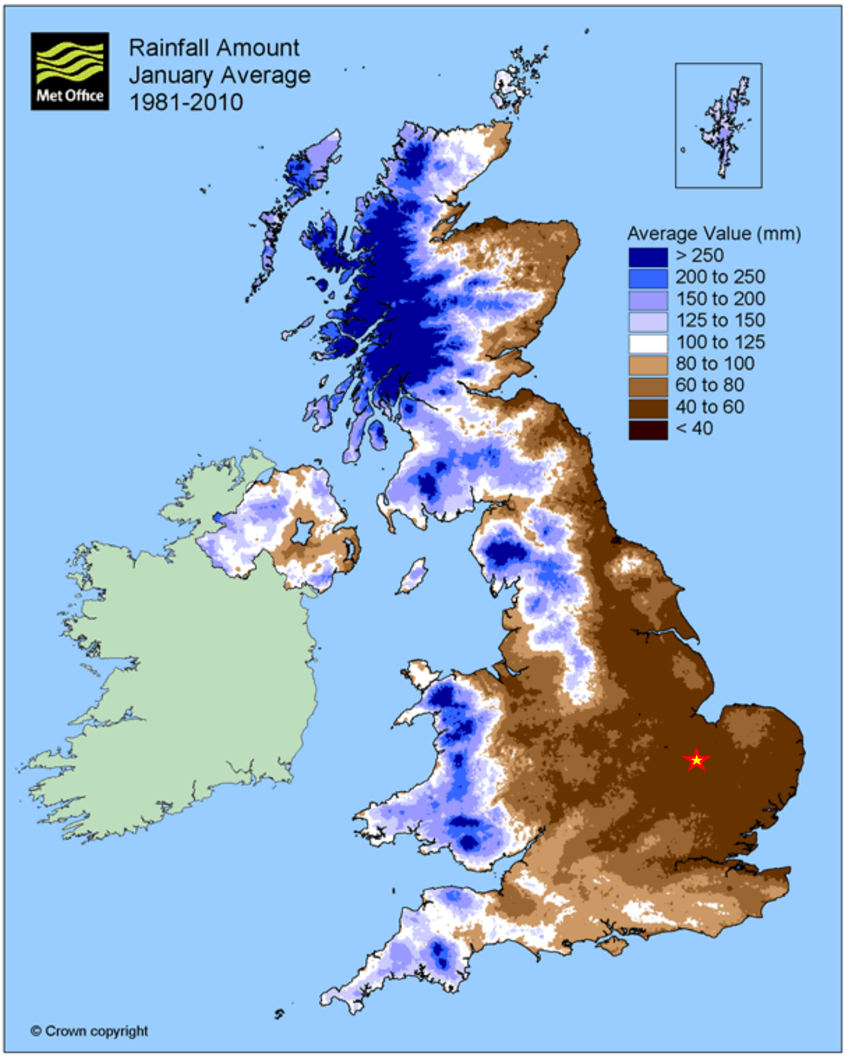


Figure 8: Average Monthly Rainfall Depth for January

6.2.3 Runoff assessment

A hydrological assessment was undertaken of the 7 February 2014 storm event to investigate how the catchment runoff converted into overland flows (refer to Figure 4), namely the farmland and small area of rear gardens. The analyses are included in Appendix A. The analyses included certain assumptions as summarised below:

(i) The catchment was saturated before and during the storm event

(ii) The highway drainage system provided negligible capacity and impact on drainage of runoff from Cresswick, Mimram Close and Bendish Lane - on the basis of the survey conducted in October 2014

(iii) The rainfall intensity profile during the storm was assumed to be an equivalent average intensity.

The analyses show that there was an excess of surface water runoff that could not be contained within the natural surface hollows in the large fields system in the catchment, and a peak discharge into Cresswick/Mimram Close with a calculated depth across the natural valley running through Cresswick, leading towards the flooded properties, of 58mm.

The total runoff from the event amounted to 11,979m^3.

6.2.4 Assessment of Existing Drainage Infrastructure

Highway Drainage

The existing highway drainage infrastructure is representative of that which is found in edge of town / rural areas. The gullies can become blocked easily by debris blown from the farmland to the south, straw from farm vehicles and by leaves off nearby trees and bushes. The effect of these conditions is that surface water runoff from the road, and any from adjacent ground (see below) will be conveyed along the road surface, being unable to enter the highway drainage pipes below ground. The fall along Cresswick will convey flows to the lowest point in the road outside Cresswick where there are no gullies in the initial path toward Mimram Close.

Normally highway drainage is designed for storm conditions that are less severe than the exceptional weather that occurred over the winter of 2013-14. The highway drainage system would not have been able to accommodate all of the surface water runoff from the extreme conditions experienced, even if each component part was operating to its optimum performance. As an illustration, the theoretical capacity of the highway drainage system in Bendish Lane, based on a 150mm diameter pipe at a gradient representative of the lower section of Bendish Lane (typically 1 in 40), is 28l/s. The typical rate of surface water flow on Bendish Lane is calculated as 303l/s (refer to Appendix A). The highway drainage system is able to convey approximately 9% of the storm runoff from the February 2014 event and the remaining flow would remain on the road surface.

6.3 IMPACT OF EXTREME STORM EVENTS

6.3.1 Rainfall criteria and catchment antecedent conditions

A simplified method of hydrological assessment was conducted as part of this investigation to ascertain the impact of design storms of increasing severity and the likely flooding and consequential damages that they would induce. In making the assessment, certain assumptions and simplifications were made as summarised below:

(i) The assessment was conducted on the basis of deriving the total volume of surface water runoff within separate principal sectors of the catchment, removing volumes that would be accommodated in any large surface depressions then calculation of the depth of flow in principal overland flow paths to derive depths of flow and the properties that would be expected to flood. Flood damages were calculated on the basis of typical higher-end insurance and privately funded repair costs obtained from the flooding interview data

(ii) Rainfall data and runoff volumes were derived from standard data profiles and processed by the ‘FLOOD2’ analysis software (Copyright Hertsmere Borough Council)

(iii) The duration of each design storm was set at 270 minutes to be equivalent to the flood event of 7 February 2014

(iv) The catchment was saturated prior to the storm and all rainfall was converted into surface water runoff

(v) No surface water runoff was conveyed by the highway drainage system and all runoff remained on the road surface based on the findings of the survey of the highway drainage.

6.3.2 Predicted flooding impact
Details of the hydrological analyses are contained in Appendix B. A general summary is provided below.

Four different scenarios were analysed using two design storm return periods; 1 in 10 year event and 1 in 100 year event. Each was analysed with a dry and a wet catchment before the storm. The following summary in Table 6 shows the calculated depth of flood water in the flow path through Cresswick and Mimram Close. The reported flood depths outside the flooded properties in the February event ranged from 200-300mm at Cresswick (at rear and in garage) and 0.5m in rear garden of Mimram Close which flooded internally. Depths were noted as 65mm in the rear garden of the adjacent property (below property threshold level of approximately 150mm). The flood depths within the flooded properties range from 25mm to 50mm. The following figures support those accounts and are indicative of the expected flood depths to be expected for more extreme storm events.

Storm	**Depth of flow across flow path**
1 in 10 year dry catchment	70mm
1 in 10 year wet catchment	90mm
1 in 100 year dry catchment	95mm
1 in 100 year wet catchment	120mm
7 February 2014	**58mm**

Table 6: Summary of Design Storm Hydrological Analyses

6.3.3 Predicted Flood Damages
The predicted depths of flood water for the 1 in 10 year and 1 in 100 year design storm conditions are all greater than that of the 7 February 2014 event and as a result it is to be expected that there would be a greater likelihood of more water entering inside properties. In the February 2014 event flooding entered 2 properties; in Cresswick and Mimram Close.

Both internally flooded properties suffered significant damages as a result. The third property in Bendish Lane was affected externally only with minimal damage in the garage.

For more extreme storm conditions it is projected that the internal flooding would affect all 3 properties, rather than just the initial two properties. Flooding would also be deeper with all three properties having water throughout the ground floor with considerable damage to fixtures and fittings, plaster and electrical wiring. The value of the insurance claim made for the property in Cresswick, as a result of the February event, (£35,947.80) was quite considerable, compared to the quoted claims from the other locations studied. The nature of the flooding and its path through the houses flooded the entire, large, ground floors. This cost, however, would have been higher had electrics been compromised. The costs incurred in Mimram Close were £60,200. It is anticipated that this cost would be reflected in the adjacent property in Bendish Lane during higher order storm events, typically of likely return period of 1 in 100 years and greater.

It is typical for the value of damage costs to rise only marginally with increase in flood depths above 25-50mm as most furniture, kitchen floor units, carpets and plaster are generally affected by the initial shallow depth of flooding and no further damage (replacement costs) is incurred by an increase in depth of water. There may be some exceptions to this general presumption however if high value electrical goods (televisions, audio equipment etc.) are affected as the flood water increases in depth. On this basis the damage costs for a 1 in 100 year event are considered to be at least 10% greater than those for a 1 in 10 year event.

In consideration of these factors we consider that the typical costs of damages for each residential property in Cresswick and Mimram Close are as shown below in Table 7.

Property Type	**Predicted Damage Costs**	
	1 in 10 years	**1 in 100 years**
Cresswick	£36,000 / property	£39,600 / property
Mimram Close	£60,000 / property	£66,000 / property

Table 7: Summary of Predicted Design Storm Flood Damages

6.4 FLOOD RISK ASSESSMENTS

6.4.1 Environment Agency Surface Water Maps

The results of the analysis undertaken by the Environment Agency are illustrated below in Figure 9. They show a reasonable correlation with the surface water runoff witnessed by local residents on 7 February 2014. The map indicates that surface water runoff from the catchment would flow eastwards to the low point behind Cresswick. The maps also show one area of ponding in the field adjacent to an access track, as reported by residents. It does not show the ponding area adjacent to Cresswick, which was also reported by residents.

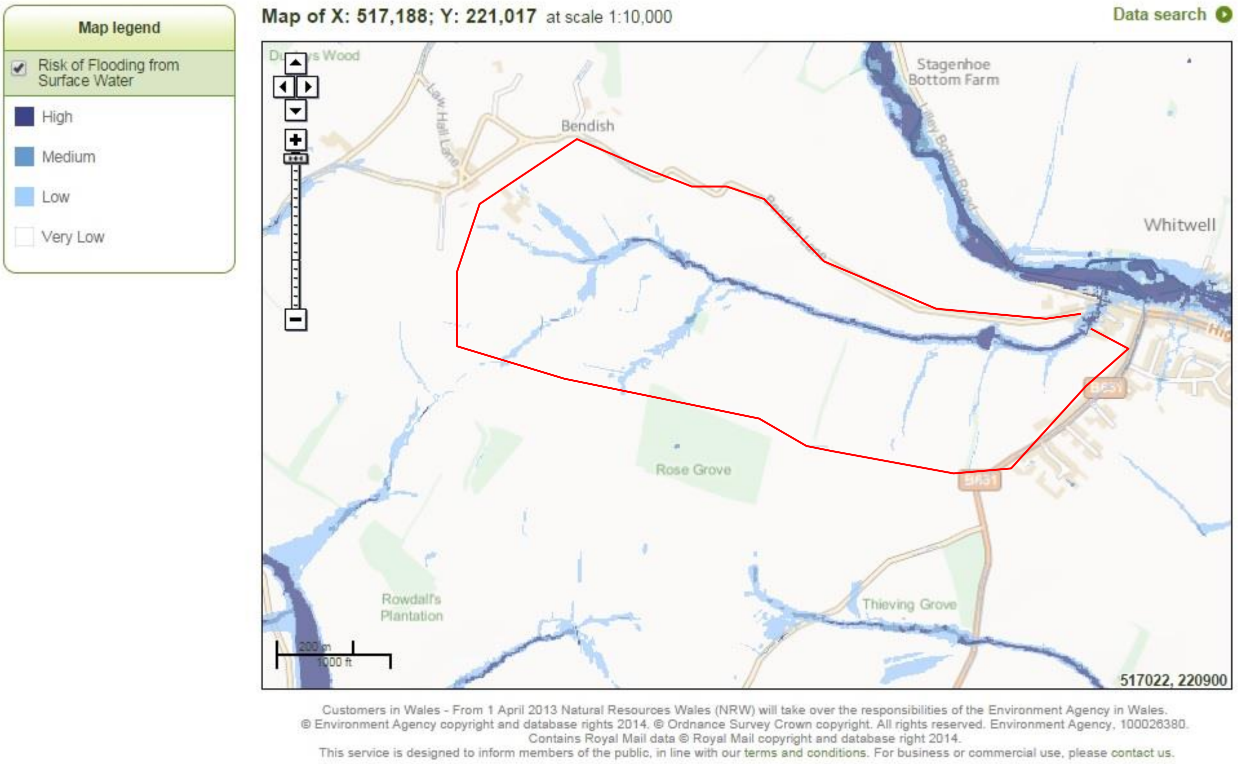


Figure 9: Environment Agency Surface Water Maps

6.4.2 North Hertfordshire District Council SFRA

According to the North Hertfordshire District Council Strategic Flood Risk Assessment, historic flooding occurred in Whitwell; as a result of Main River flooding, in 1947 – a result of heavy rainfall and snow melt, and again in 1996 – Main River flooding from heavy rainfall. No other historic flooding, other than the anecdotal evidence from residents, appears to have been recorded or reported.

7 FLOOD MITIGATION AND RESILIENCE OPTIONS

7.1 INTRODUCTION

There is suitable scope to provide mitigation to reduce flooding. The highways drainage has some scope to be improved, either by regular planned inspection and maintenance and/or by improvement to increase their hydraulic performance. This section provides a brief overview of the various options available. They can be implemented individually or in combination. The flood risk benefit of each is ranked in comparison with the others. A description is provided of the relative merits and issues associated with each option. Budget cost estimates are provided for the construction of the options. Further detailed assessment will be required to establish accurate cost estimates if any is to be progressed further. A drawing of the proposed mitigation options is located in Appendix C.

7.2 MAINTENANCE ENHANCEMENTS

7.2.1 Clean and CCTV Survey the highway drainage system

The existing highway drainage system has limited capacity and offers little protection against flooding. It is recommended that the entire system is cleaned using high pressure jetting, and a CCTV survey conducted to establish any serious structural defects that are inhibiting optimum hydraulic performance. A programme of routine inspection and reactive maintenance of gullies should be introduced. These actions should be implemented by Hertfordshire County Council Highways Department.

7.3 MITIGATION OPTIONS

The various mitigation options are summarised in the following Tables 8.1 to 8.4 on the following pages.

Ref:	**Description**
1	**Improvements to Highway Drainage - Surface Water Collection** There is suitable scope to improve the surface water collection and disposal capacity for runoff from the carriageway surface. Modern standards for highways that are to be considered for adoption by the highway authority would be a logical starting point as the basis for the criteria the drainage should meet. We strongly recommend that additional gullies are installed at a greater density required in the design standards to allow for the inevitable blockage of some gullies during extreme storm events.
	Advantages: Improved collection and disposal of surface water from the road surface Reduced likelihood of blockage to gullies
	Issues: Increased maintenance liability No benefit to Cresswick
	Budget Cost Estimate: £30,000

Table 8.1: Mitigation Option 1 - Improvements to Highway Drainage Surface Water Collection

Ref:	Description
2	**Improvements to Highway Drainage - Modify Carriageway Surface Profile and Edge Details** The major factor in the cause of the flooding to Mimram Close was the conveyance of surface water across the carriageway surface of Cresswick into the rear gardens of the properties that suffered from flooding. The opportunity exists to convey water off the road surface in Cresswick and direct it towards Bendish Lane, and into Lilley Bottom Road, thus avoiding it travelling over Cresswick and through the property in Mimram Close and alongside in Bendish Lane. Raised double height kerbs would be used to convey flows through a designated route down Bendish Lane into Lilley Bottom Road and down toward the cress beds and into the River Mimram. Raised bunds/speed tables would be placed across dropped kerbs and across part of Lilley Bottom Road to create a continuous conveyance channel during flood events, toward the Cress Beds
	Advantages: Significantly reduce risk of flooding to properties in Mimram Close/Bendish Lane. Minimal maintenance liability. Reduces risk of flooding to new properties opposite Bendish Lane which are in the current flow path.
	Issues: Does nothing to reduce risk of flooding to properties in Cresswick.
	Budget Cost Estimate: £100,000

Table 8.2: Mitigation Option 2 - Improvements to Highway Drainage, Modify Carriageway Surface Profile and Edge Details

Ref:	Description
3	**Improvements to Land Drainage Arrangements by Provision of Attenuation Storage Features** Provide a raised embankment in the field to the rear of Cresswick with a restricted outlet to drain into the gardens in Cresswick. This option would need to be implemented with elements of Option 4 below (channelling residual flow routes around the property).
	Advantages: Improved flood risk protection by attenuation of surface water runoff from a major part of the catchment Minimal maintenance liabilities
	Issues: Requires consent from the local landowners Maintenance liability for the flow controls Potential damages for loss of crops Embankment likely to be large to store all runoff.
	Budget Cost Estimate: £35,000

Table 8.3: Mitigation Option 3 – Improvements to Land Drainage by Provision of Attenuation Storage Features

Ref:	Description
4	**Flood Protection Measures to Individual Properties** Emergency protection measures are recommended to be fitted to each of the flood entry points at the properties that have been subject to flooding in Cresswick and Mimram Close. Ideally these should be automated devices that are activated by the presence of approaching flood water, alternatively they can be fittings that require installation by the residents in advance of anticipated severe storm conditions. The property in Cresswick has 2 double glazed rear sliding doors as well as a kitchen door so could benefit from an automated raising wall to encompass the entire rear of the property. Otherwise individual manual install barriers could also suffice. It may be appropriate to re-landscape the rear garden of the property in Cresswick to create a channel for flows around the property, around both sides, rather than install property flood barriers (or use in conjunction with one another). The property in Mimram Close with internal flooding has a single point of entry via a rear conservatory (currently being re-built) door which could also benefit from either automated or manual fitted barrier. The old dryer vent would be filled in to prevent future ingress of water. In addition, remove flow barriers at sides of properties and replace with flow sensitive alternatives (i.e. large wooden gates/fencing replaced with iron gates / open slatted fencing or raised fencing) to reduce backup effect / blockage. Grants are currently available from the local authority under certain conditions. The grant scheme is known as: Local Government “Flooding Recovery: Repair and Renew Grant Scheme” Advice can be found at the following web site (One property in Mimram Close has already applied for some funding through this route). *www.gov.uk/government/publications/flooding-recovery-households-and-businesses-applying-for-the-repair-and-renew-grant-scheme/flooding-recovery-households-and-businesses-applying-for-the-repair-and-renew-grant-scheme*
	Advantages: Protection to the inside of the properties.
	Issues: Requires consent from the local landowners Dependence upon sufficient grant and/or top-up or possible contribution from property owners Owner intervention required to install non-automatic flood barriers No protection to the gardens and driveways
	Budget Cost Estimate: £0 - £50,000

Table 8.4: Mitigation Option 4 - Flood Protection Measures to Individual Properties

7.4. BENEFIT:COST ASSESSMENT OF MITIGATION OPTIONS

The nature of the flood mechanism and disparity between the mitigation options in terms of the benefits they bring to different properties makes any direct correlation between the costs of mitigation and the value of benefits derived difficult. As an illustration of the mitigation measures that will achieve a significant, but not the maximum reduction in risk of flooding, comparisons of costs and benefits are presented below in Table 9. The costs and benefits are approximate and accurate figures should be developed as part of detailed development of options.

Mitigation Option	Costs	Properties Benefitted	Benefit Value			
			1 in 10 yr	Benefit: Cost	1 in 100 yr	Benefit: Cost
1	£30,000	Mimram Close (1 no.)	£60,000	2.0	£66,000	2.2
2	£100,000	Mimram Close (1 no.)	£60,000	0.6	£66,000	0.7
1,2 + 4	£180,000	Mimram Close (1 no.) Cresswick (1 no.)	£96,000	0.5	£105,600	0.6

Table 9: Benefit : Cost Comparison for Selected Mitigation Measures
Note – 1:100 yr event costs includes additional predicted flooding to a second property, located in Bendish Lane

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

8.1.1 A total of 3 properties were affected by the storm event of 7 February 2014. Two of the properties were flooded internally, with one with external garage flooding only.

8.1.2 The flooding was the result of excessive surface water runoff from a combination of rural and residential urbanised catchment. The surface water runoff resulted from an intense rainfall event over a period of approximately 4.5 hours onto ground that was saturated from a period of prolonged rainfall over 4 weeks prior to the flood.

8.1.3 The natural topography of the catchment funnelled surface water runoff towards the location where flooding occurred. Surface water runoff from an extensive and relatively steeply sloping rural catchment was conveyed through the rear garden of Cresswick, across Cresswick and into the rear gardens and properties of Mimram Close. Flood flows ran into Bendish Lane and into Lilley Bottom Road and across open land to the River Mimram.

8.1.4 Flooding to properties in Mimram Close was exacerbated by the side access to properties being effectively blocked by solid wooden gates. The adjacent side of one property was blocked by a conservatory which tied into the rear garage, closing off any flow routes. The residents of the affected properties in Mimram Close and Bendish Lane have removed these barriers, with one side gate replaced with an iron gate, and the double wooden driveway gates of the other removed altogether. This will ultimately help reduce any future flooding past the properties.

8.1.5 Highway drainage - responsibility of Hertfordshire County Council in its role as the Highway Authority
This system is likely in need of cleaning and CCTV survey to ensure optimum performance and structural integrity.
The system is also likely to have limited capacity to cope with an event of this type.

8.1.6 Flooding is predicted to occur for storm events of a return period of once in 10 years on a dry catchment or of once 1 in 1 year on a saturated catchment.

8.1.7 There is scope for introduction of mitigation measures to improve the current drainage systems and to reduce the risk of flooding from surface water runoff.

8.1.8 Multiple mitigation measures will need to be implemented, as Cresswick will not benefit from any highways improvements to route flood flows. Properties in Cresswick will need additional measures, such as flood barriers or re-landscaping to create a flow channel around the sides of the property.

8.2 RECOMMENDATIONS

8.2.1 Arrange for a programme of detailed investigation and cleaning of all of the existing drainage systems by the responsible Risk Management Authorities:

Highway Drainage: Hertfordshire County Council as the Highway Authority

8.2.2 Develop and implement a programme of planned inspection and maintenance for the existing drainage systems to ensure they operate at their optimum performance.

8.2.3 In addition to the investigation and maintenance measures stated above, implement a series of mitigation measures to reduce the risk of flooding from surface water runoff for severe storm events and, at the same time, improve drainage arrangements for less severe rainfall conditions. The optimum combination of mitigation measures should include all of the following:

Option 1 Improvements to Highway Drainage Surface Water Collection (HCC)
Option 2 Improvements to Highway Drainage, Modify Carriageway Surface Profile and Edge Details (HCC)
Option 3 Improvements to Land Drainage by Provision of Attenuation Storage Features (Land owners)
Option 4 Flood Protection Measures to Individual Properties (Property owners - potentially with assistance/contribution from RMAs).

8.2.4 Of these options there are three that are recommended to be progressed in tandem as a priority. Option 1, Option 2 and Option 4 will provide the most significant part of the potential benefit to the affected properties. Protection measures to affected properties (Option 4) has the potential opportunity of grant from North Herts District Council through the central government scheme (Indeed, one property in Mimram Close was aware of this grant and has applied for some funding already). If the flood barriers are initially installed in Option 4, it will avoid internal flooding until such time as other mitigation measures are implemented to reduce the overall risk of flooding.

The property that has applied for grant funding has also recently erected a new fence to the rear garden to prevent water from entering in the future. This potentially increases the risk to the adjacent property by diverting the majority of the runoff into this property. The raised kerbs and formal flow route would prevent water flowing into the garden in Mimram Close in any case, however, the adjacent property may need additional protection such as flood barriers to the rear door to mitigate any increased risk as a result of the new fence.

As mentioned above, Option 2 will ensure that any surface water runoff on Cresswick avoids coming into contact with properties in Mimram Close/Bendish Lane. The protection measures to Cresswick would not benefit from the impact of Option 2; its protection will be solely dependent upon Option 4, with either or both flood guard protection and a designated flow path around the house.

Option 3 is not recommended due to the potential size of the bund required to store the volume of runoff. Failure of the bund at capacity may increase risk to other properties or possibly risk to life from the flood surge.

APPENDIX A

Runoff Assessment of the storm of 7 February 2014

Saturated Catchment

NOTE: USE 1 IN 1 YEAR DESIGN STORM IN FLOOD2 (RAINFALL FIGURES CORRELATE CLOSELY TO A 1 IN 1 YEAR DESIGN STORM). STORM DURATION = 270 MINUTES

Catchment	Description	Area (ha)	Tc (mins)	Peak Discharge	Flow Channel		Depth of flow on Cresswick (m)	Total Volume of Runoff (m3)	In-catchment Storage (m3)	NET Volume of Runoff	Receptor For Runoff
				(assumes all contributory area is effectively impermeable due to saturation and runoff is equivalent to 5l/s/ha)			(using Manning formula)	(Ave rainfall intensity from a 1 in 1 year storm of 270 min duration. Input Tc = 54mins into FLOOD2. Ave i = 4.4mm/hr)			
2	Fields (SE)	60.5	72	302.5	Cresswick	W= 20m, Gradient = 1 in 30		11979	648	11331	Cresswick/Mimram Close
				0.3025			58mm				

http://www.calctool.org/CALC/eng/civil/manning

Slope of Ground			Channel Width	Flow Depth	CSA	Wetted Perimeter	Slope (3000mm over 84m = 1 in 30)	Q	
	30	0.03333333	4.8	0.05	0.24	4.9	0.033333	0.23	m3/s
			4.8	0.055	0.264	4.91	0.033333	0.27	m3/s
			4.8	0.058	0.2784	4.916	0.033333	0.3	m3/s
			4.8	0.06	0.288	4.92	0.033333	0.32	m3/s
			4.8	0.07	0.336	4.94	0.033333	0.41	m3/s
			4.8	0.08	0.384	4.96	0.033333	0.51	m3/s
			4.8	0.1	0.48	5	0.033333	0.73	m3/s

APPENDIX B

Runoff Assessment of Design Storms

1 in 10 year Saturated Catchment

NOTE: USE 1 IN 10 YEAR DESIGN STORM IN FLOOD2

Catchment	Description	Area (ha)	Adjusted Area	Tc (mins)	Peak Discharge	Flow Channel		Depth of flow on Cresswick in front of Flooded Houses (m)	Total Volume of Runoff (m3)	In-catchment Storage (m3)	NET Volume of Runoff	Receptor For Runoff
			(assumes 40% imp +60% perm@100% imp equiv)		(assumes all contributory area is effectively impermeable due to saturation and runoff is equivalent to 9l/s/ha) 1 in 10 year runoff is approx 90% greater than a 1 in 1 year so 5l/s/ha is increased to 9l/s/ha)			(using Manning formula)	(Ave rainfall intensity from a 1 in 10 year storm of 270 min duration. Input Tc = 54mins into FLOOD2. Ave i = 7.8mm/hr)			
2	Fields (SE)	69	69	72	621	Cresswick	W= 20m, Gradient = 1 in 30		24219	648	23571	Cresswick/Mimram Close
					0.621			90mm				

http://www.calctool.org/CALC/eng/civil/manning

Slope of Road			Channel Width	Flow Depth	CSA	Wetted Perimeter	Slope (3000mm over 84m = 1 in 30)	Q	
	30	0.033333							
			4.8	0.05	0.24	4.9	0.033333	0.23	m3/s
			4.8	0.055	0.264	4.91	0.033333	0.27	m3/s
			4.8	0.058	0.2784	4.916	0.033333	0.3	m3/s
			4.8	0.06	0.288	4.92	0.033333	0.32	m3/s
			4.8	0.07	0.336	4.94	0.033333	0.41	m3/s
			4.8	0.08	0.384	4.96	0.033333	0.51	m3/s
			4.8	0.09	0.432	4.98	0.033333	0.62	m3/s
			4.8	0.1	0.48	5	0.033333	0.73	m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s

Channel Width	Flow Depth	CSA	Wetted Perimeter	Slope	Q
4.8	0.1	0.48	5	0.033333	m3/s

1 in 100 year Saturated Catchment

NOTE: USE 1 IN 100 YEAR DESIGN STORM IN FLOOD2

Catchment	Description	Area (ha)	Adjusted Area (assumes 40% imp +60% perm@100% imp equiv)	Tc (mins)	Peak Discharge (assumes all contributory area is effectively impermeable due to saturation and runoff is equivalent to 15.7l/s/ha) 1 in 10 year runoff is approx 317% greater than a 1 in 1 year so 5l/s/ha is increased to 15.7l/s/ha)	Flow Channel		Depth of flow on Cresswick in front of Flooded Houses (m) (using Mann[illegible] formula)	Total Volume of Runoff (m3) (Ave rainfall intensity from a 1 in 10 year storm of 270 min duration. Input Tc = 54mins into FLOOD2. Ave i = 13.0mm/hr)	In-catchment Storage (m3)	NET Volume of Runoff	Receptor For Runoff
2	Fields (SE)	69	69	72	1083.3	Cresswick	W= 20m, Gradient = 1 in 30		40365	648	39717	Cresswick/Mimram Close
					1.0833			120mm				

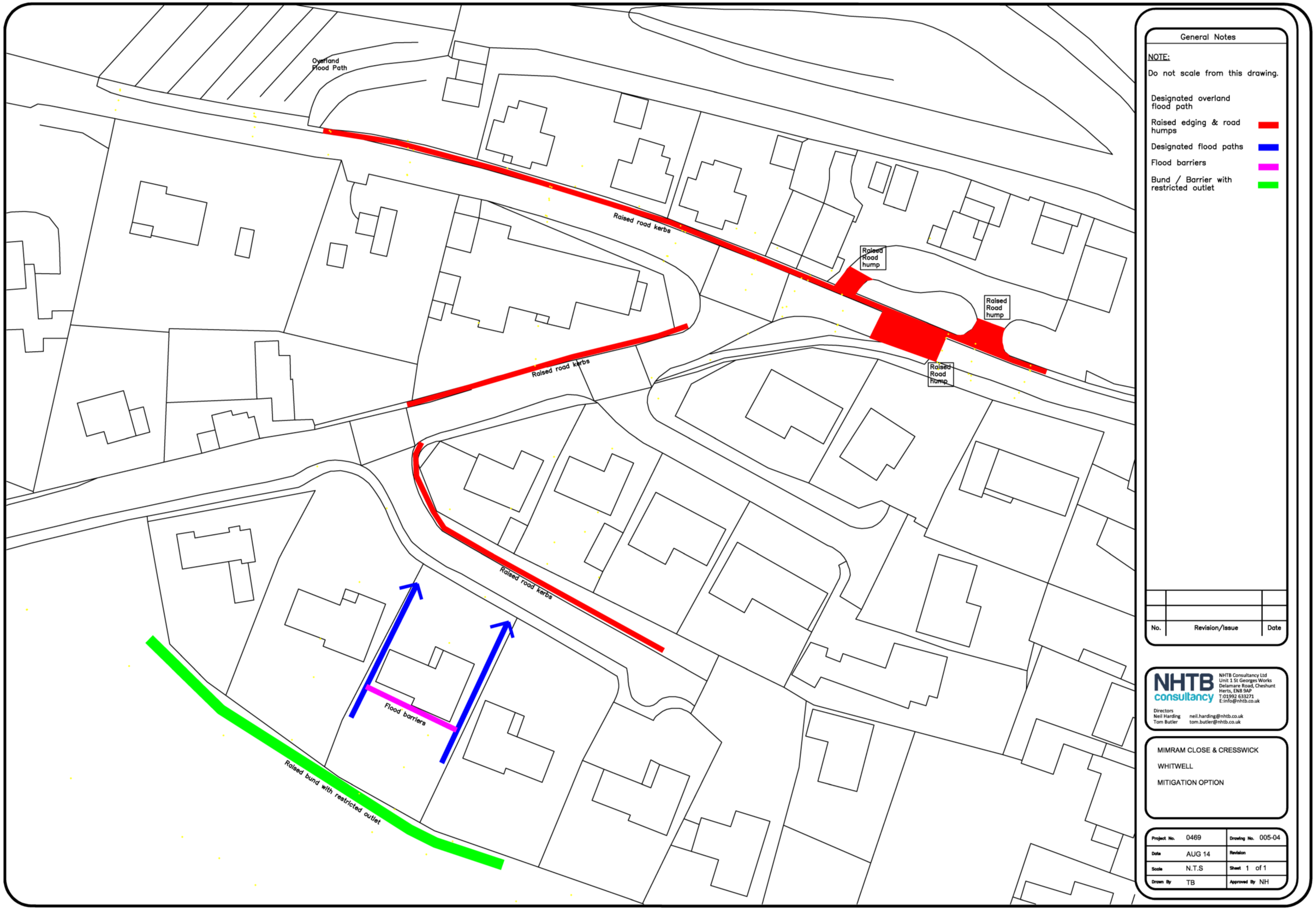
http://www.calctool.org/CALC/eng/civil/manning

Slope of Road			Channel Width	Flow Depth	CSA	Wetted Perimeter	Slope (3000mm over 84m = 1 in 30)	Q	
	30	0.03333333	4.8	0.05	0.24	4.9	0.033333	0.23	m3/s
			4.8	0.055	0.264	4.91	0.033333	0.27	m3/s
			4.8	0.058	0.2784	4.916	0.033333	0.3	m3/s
			4.8	0.06	0.288	4.92	0.033333	0.32	m3/s
			4.8	0.07	0.336	4.94	0.033333	0.41	m3/s
			4.8	0.08	0.384	4.96	0.033333	0.51	m3/s
			4.8	0.1	0.48	5	0.033333	0.73	m3/s
			4.8	0.11	0.528	5.02	0.033333	0.86	m3/s
			4.8	0.12	0.576	5.04	0.033333	0.99	m3/s
			4.8	0.13	0.624	5.06	0.033333	1.13	m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s
			4.8	0.1	0.48	5	0.033333		m3/s

4.8	0.1	0.48	5	0.033333	m3/s
4.8	0.1	0.48	5	0.033333	m3/s
4.8	0.1	0.48	5	0.033333	m3/s

APPENDIX C

Proposed Mitigation Measures



Overland Flood Path
Raised road kerbs
Raised Road hump
Raised Road hump
Raised Road hump
Raised road kerbs
Raised road kerbs
Flood barriers
Raised bund with restricted outlet
General Notes
NOTE:
Do not scale from this drawing.
Designated overland flood path
Raised edging & road humps
Designated flood paths
Flood barriers
Bund / Barrier with restricted outlet
No.
Revision/Issue
Date
NHTB consultancy
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MIMRAM CLOSE & CRESSWICK
WHITWELL
MITIGATION OPTION
Project No. 0469
Drawing No. 005-04
Date AUG 14
Revision
Scale N.T.S
Sheet 1 of 1
Drawn By TB
Approved By NH