Final Technical Report

Hassocks Surface Water Management Plan

Prepared for

West Sussex County Council

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Contents

SECTION 1

Acronyms and Abbreviations

Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
FCRM	Flood and Coastal Erosion Risk Management
FCRM GiA	Flood and Coastal Erosion Risk Management Grant in Aid
GIS	Geographic Information System (ArcGIS used in this study)
LFRMS	Local Flood Risk Management Strategy
MSDC	Mid Sussex District Council
OM	Outcome Measure
SFRA	Strategic Flood Risk Assessment
SWMP	Surface Water Management Plan
WSCC	West Sussex County Council

Introduction

1.1 Project context

This Surface Water Management Plan (SWMP) has been undertaken as part of a commission to develop SWMPs for seven areas of West Sussex which have a history of significant flooding from surface water, groundwater and drainage systems. The seven study areas were:

- Billingshurst;
- Easebourne;
- Hassocks;
- Lancing;
- Manhood Peninsula;
- Upper Lavant Valley, and;
- West Chichester, including Fishbourne and Parklands.

These areas were selected as part of West Sussex County Council's (WSCC) response to the severe flooding in the summer of 2012, known as Operation Watershed[1], although it is recognised that many of these have suffered flooding on multiple occasions.

A SWMP is described as a framework through which local partners with a responsibility for surface water and drainage in their area work together to understand the causes of surface water flooding and agree the most cost effective way of managing that risk. The purpose is to make sustainable surface water management decisions that are evidence based, risk based, future proofed and inclusive of stakeholder views. Managing surface water flooding requires a range of partners, organisations and individuals to work together. The roles and responsibilities for those involved in helping to manage surface water flooding are described in Appendix A.

1.2 Background to Hassocks SWMP

Hassocks is a small town within Mid Sussex District Council area, with an estimated population of 7,667, based on the 2011 census[2]. There are several watercourses flowing through the urban area, the most notable of which is known locally as Herring Stream, and the majority of the other watercourses ultimately drain into this watercourse. Flooding has been a long standing issue within the catchment, the primary cause of which is overtopping of the watercourses at key pinch points within the catchment. WSCC commissioned the Hassocks SWMP to identify the critical areas at risk and develop capital and maintenance options to reduce the risk of flooding from surface water and ordinary watercourse interactions where possible.

1.2.1 Objectives

The objectives of the Hassocks SWMP are to:

- evaluate the causes and severity of historical flooding within the catchment;
- understand the flooding from the ordinary watercourses, and;
- identify potential improvement works to reduce flood risk to local communities

[1] For more information on Operation Watershed see: http://www.westsussex.gov.uk/default.aspx?page=36724

[2] http://www.ukcensusdata.com/hassocks-e05007685#sthash.PKaR7FlA.dpbs

1.2.2 Scope

The scope for this SWMP was established during the early part of the overall project programme through discussions with WSCC, an initial assessment of available data, and early establishment of the flooding issues and mechanisms. It should be noted that the scope of work broadly follows the Surface Water Management Plan (SWMP) Technical Guidance published by Defra in 2010, ensuring the work is aligned with national best practice. The SWMP Technical Guidance describes a four step process, as outlined in Figure 1-1.

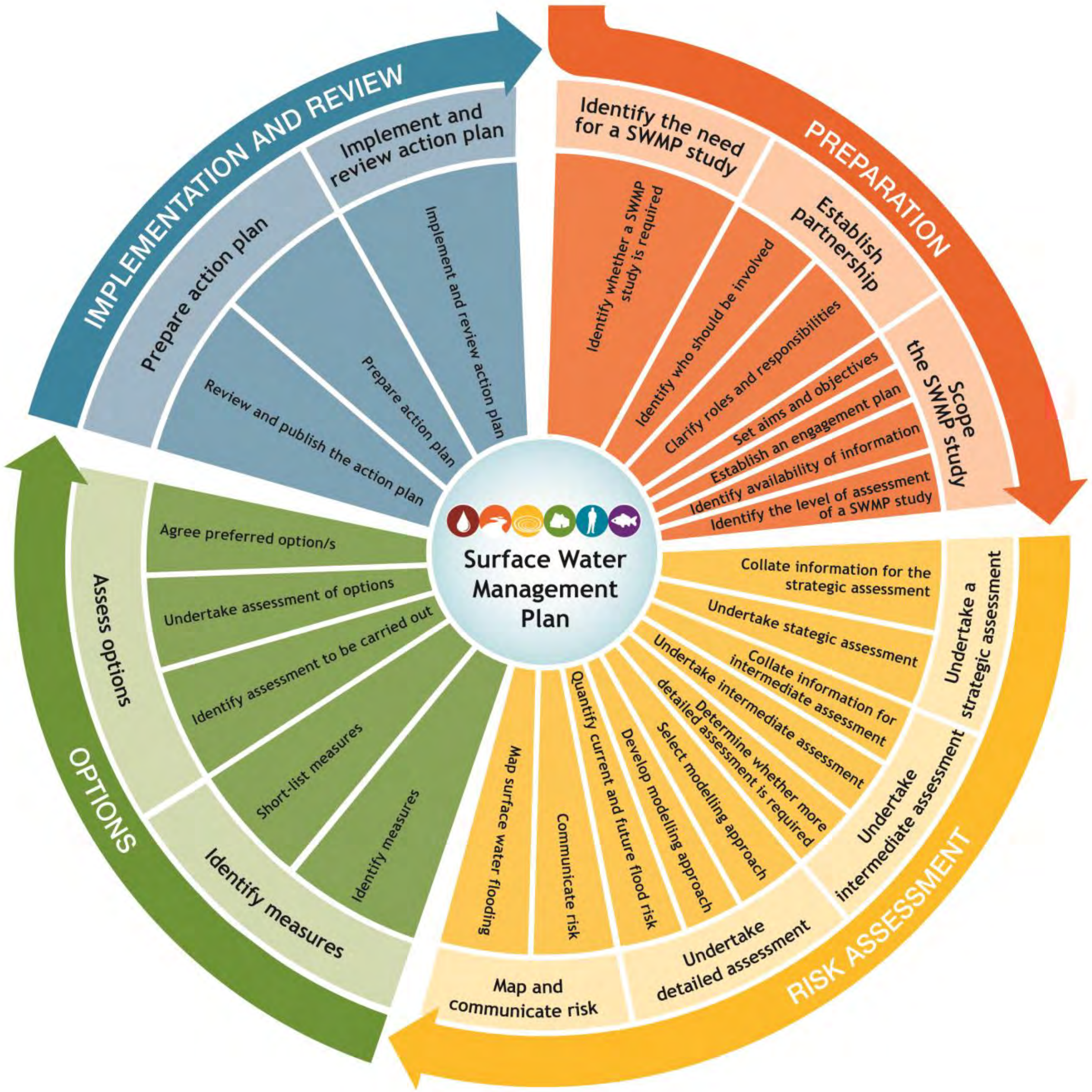

Figure 1-1 SWMP Process

Stage 1 – Data collection and review

Stage 1 consisted of data collection, compilation, and review. This included obtaining and compiling third party data (from Mid Sussex District Council, Southern Water, EA, and parish council), as well as WSCC. All data were reviewed, and previous reports were analysed to gain full understanding and appreciation of the issues. A review of the existing watercourse model of the catchment was also undertaken to assess its suitability for use as part of the SWMP.

Stage 2 – Evaluate historical flooding within the catchment

Anecdotal and photographic evidence of flood events from WSCC were examined in order to build up a more detailed picture of where the flooding issues were prevalent within Hassocks, and the likely causes. During this stage a site walkover was undertaken to evaluate the catchment, and as part of this site visit a meeting with a representative with the parish council was held to understand the historic flooding.

Stage 3 – Understand flood risk in the catchment

Using the available watercourse model of the Hassocks catchment an understanding of the probability and consequences of flooding within the catchment was developed for the current day scenario, and included an assessment of the effects of blockages to key culverts in the catchment. During this stage an assessment was undertaken of the predicted damages to properties, to support the appraisal of mitigation measures.

Stage 4 – Identify measures to reduce flood risk

During this stage suitable measures to reduce flood risk were identified. Options included different scales of capital works, and improving the maintenance of the network to enable water to flow more freely through the system and thus reduce flood risk. For all options a conceptual drawing and provisional cost estimate were provided.

1.2.3 Study area

Broadly, the study area consists of the whole of Hassocks urban area, to the point where the Herring Stream flows away from the urban area. The SWMP has focussed on areas of greatest flood risk within Hassocks. A map of the study area is shown in Appendix B.

1.2.4 Key stakeholders

For each of the SWMPs a stakeholder engagement strategy was prepared which identified who to engage with, when, and how. Stakeholder engagement is an important part of the overall approach to the development of the SWMP and is integral to the agreed methodology for the study as a whole. The approach aimed to ensure that professional stakeholders, landowners, parish councils and other relevant groups would be given an opportunity to help shape the study. Engagement, in different forms, has been undertaken throughout the study to:

- ensure the study is robust and that the data used to underpin it are as accurate as possible;
- ensure that best use is made of local knowledge and that the analysis of flood risk matches local experience;
- ensure the study addresses the key problems that are of most concern to the local community;
- generate greater understanding about, and support for, the way in which local flooding will be managed, and;
- help to encourage stakeholders and the general public to take actions to help protect themselves against flooding.

The key stakeholders identified for this SWMP are:

- West Sussex County Council as the Lead Local Flood Authority and Highways Authority;
- Mid Sussex District Council;
- the Environment Agency, and;
- Hassocks Parish Council.

The engagement activities undertaken during the Hassocks SWMP are described in Table 1-1.

Table 1-1 Engagement activities for Hassocks SWMP

Activity	Purpose/Detail	Timescale
Initial meeting with WSCC	To agree the scope of the work	January 2015
Technical discussions with WSCC	To understand the function of the highways drainage system	Throughout study
Technical discussions with Mid Sussex District Council	To understand the catchment, flooding history, and potentially suitable mitigation measures	Throughout study
Technical discussions with Environment Agency Staff	To understand the data available for the catchment	January 2015
Site visit and meeting with Hassocks Parish Council	To understand the catchment and local flooding issues	June 2015
Discussions with Adur and Ouse Rivers Trust	To discuss their ongoing work with respect to natural catchment management in Hassocks	February 2016

SECTION 2

Review of existing data, studies and actions

2.1 Data collected for the SWMP

A summary and analysis of the data received for the Hassocks SWMP is provided in Table 2-1. It includes a summary of data quality issues.

Table 2-1 Data received for Hassocks SWMP

Dataset	Data received from	Comments	Data Quality Issues
Common data received across all study areas			
Bedrock and Superficial Geology	British Geological Society	Maps of the bedrock and superficial geology	-
Digital Terrain Model (DTM)	EA	This is a model of the ground surface, used by the Environment Agency for its national surface water mapping	The data is a composite of LiDAR and NextMap. The NextMap has a much lower accuracy which makes it less reliable as a data source
Flooded Properties Register (DG5)	Southern Water	This is the register held by Southern Water of flooded properties which are the result of hydraulic capacity issues in the public sewer network	-
Flood Map for Planning	EA	National fluvial flood map provided by the EA	Only shows flooding from watercourses where the upstream catchment is >3km^2
Flood Map for Surface Water	EA	National surface water flood mapping provided by the EA for the 1 in 30 year, 1 in 100 year and 1 in 1000 year rainfall probability events	This is the most comprehensive surface water mapping available, but given the mapping is at a national scale there are a number of generic assumptions which may not be locally relevant
Groundwater Susceptibility Mapping	WSCC	A groundwater flood risk map provided by WSCC, dividing areas into low, moderate and high groundwater flood risk	
Highway drainage data	WSCC	Details of the public highway network	This dataset only contains the location of highway gullies, but does not include details of the pipework
Historic Flood Outlines	EA	Recorded flood outlines from fluvial flooding collated by the EA	
Historic flooded properties	WSCC	A point dataset showing the location of flooded properties	Known limitations, as there are many properties which are known to have flooded but are not

			recorded on this dataset. The data goes back to 2012
Historic flooded roads	WSCC	A point dataset showing the location of flooded roads	Known limitations, as there are many roads which are known to have flooded but are not recorded on this dataset. The data goes back to 2012
June 2012 Flood Investigation	WSCC	Investigation into June/July 2012 flooding incidents across West Sussex	-
Local Flood Risk Management Strategy	WSCC	A statutory document produced by WSCC as part of their responsibility as LLFA	-
National Receptor Dataset	EA	Provides location and details of residential and non-residential properties, and critical infrastructure	-
Operation Watershed details	WSCC	Details of the schemes completed or ongoing as part of Operation Watershed	-
Public sewer network data	Southern Water	Location, connectivity and details of the public sewer network	Asset details of the surface water sewer system are generally of poorer quality than for the foul or combined system
River network	EA	Location of watercourses	This is a national dataset and there are some assumptions about the routes of watercourses, especially where watercourses go into culverted sections
Data received bespoke to Hassocks SWMP			
Assets owned by Mid Sussex District Council	Mid Sussex District Council (MSDC)	Details of asset data owned by MSDC, and the survey specification for the summer 2015 surveys	-
Damian Way Balancing Pond	MSDC	Data on the Damian Way Balancing Pond, constructed in 2002	-
Details of historic flooding	MSDC and local residents	Photos and reports of historic flooding in the catchment	-
1D/2D flood model	EA	Model and associated reports undertaken by the Environment Agency in 2014	-
Operation Watershed bids	WSCC	Details of Operation Watershed bids in Hassocks	-
Rainfall data	EA	Rainfall data for a range of rain gauges from 2013-2015	

2.2 Existing studies or investigations

2.2.1 Local Flood Risk Management Strategy

Under the Flood and Water Management Act (2010) WSCC is required to develop, maintain, apply and monitor a Local Flood Risk Management Strategy (LFRMS) for the county. The LFRMS sets out: WSCC's objectives for managing flood risk from surface water, ordinary watercourses and groundwater; an understanding of the current level of flood risk; roles and responsibilities of organisations; and the actions required to manage flood risk from surface water, ordinary watercourses and groundwater. The LFRMS has identified that over 100,000 properties are in areas susceptible to flood risk within the county.

Analysis of flood risk in the Local Flood Risk Management Strategy has identified 53 "wet spots" in West Sussex. These are areas that have an increased risk of flooding compared to the rest of the county. They include areas at risk from river and sea flooding as identified by the latest Environment Agency flood mapping. Historic events and previous flooding issues have been taken into account and have contributed to the West Sussex wet spot list. Hassocks has been identified as one of these areas.

Table 2-2 Properties susceptible to surface water flooding in Hassocks

Wet Spots	**Area**	**1** **Surface Water Flood Risk* (no. of properties)**	**2** **River and Sea Flood Risk* (no of properties)**	**3** **Combined Flood Risk* (no. of properties)**	**4** **TOTAL (no. of properties)**
		*** property only within surface water risk map**	*** property only within river/sea risk map**	*** property within both surface & river/sea water risk maps**	
Hassocks	Mid Sussex District	525	105	**55**	**685**

2.2.2 Strategic Flood Risk Assessment

At the time of writing this report Mid Sussex District Council was preparing their draft Level 1 Strategic Flood Risk Assessment (SFRA). The draft SFRA is available in http://www.midsussex.gov.uk/media/DRAFT_SFRA_2015.pdf.

The SFRA provides an overview of all sources of flood risk including fluvial, surface water, groundwater and sewer flooding.

Relevant extracts from the SFRA are provided in Table 2-3.

Table 2-3 Relevant extracts from the SFRA

Headline	**Extract from SFRA**
Flood risk	"Generally Mid Sussex is an area of low flood risk however there are areas affected by specific issues and careful management is necessary to ensure flood risk is not increased now or in the future. Analysis undertaken for the West Sussex Local Flood Risk Management Strategy identifies 'wet spots' where a limited number of properties are considered to be at risk. These are Burgess Hill, East Grinstead, Haywards Heath/Lindfield and Sayers Common (mostly surface water flood risk) and Copthorne **and Hassocks** (both surface water and fluvial flood risk)."

Groundwater flooding	Large parts of the district are underlain by aquifers, particularly the chalk aquifers in the southern part of the district and the sandstone aquifers in the High Weald area of the district. Parts of the district where these aquifers lie are also low-lying. This includes part of the southern area of the district, particularly Hassocks, Hurstpierpoint and Sayers Common. The majority of the district is considered to have medium potential for groundwater flooding. A small area of the district, the southernmost part within the National Park, is considered to have high potential and the settlements of Burgess Hill, Hassocks, Hurstpierpoint, Albourne and Sayers Common, as well as countryside areas to the west are considered to be in an area of low potential for groundwater flooding”
Catchment Flood Management Plan	“The Burgess Hill and Hassocks area is identified within the CFMP as being an ‘area of low, moderate or high flood risk where we are already managing the flood risk effectively but where we may need to take further actions to keep pace with climate change’ (CFMP Policy 4). The Plan also predicts that the number of properties in Burgess Hill and Hassocks at risk will increase from 13 to 250 by 2100.”
Flood history	Information was provided by local residents and from the local press. It included: • Flooding on Keymer Road in November 2008 due to blocked drains • Flooding on Parklands Road in February 2014, due to “surge of water in Herring Stream. Culvert under Downs View Road not large enough to handle very heavy rainfall.”
Works to alleviate flooding	Stream and bank clearance, and de-silting of culvert on Herring Stream

2.2.3 National surface water mapping

In December 2013 the Environment Agency produced and published updated national surface water mapping to identify areas which are naturally susceptible to surface water flooding. This mapping is based on a modelling approach which applies rainfall onto the surface and allows runoff to be routed depending on the natural topography of the land. The rainfall is factored to account for losses to the ground, and the presence of existing drainage systems which will capture some rainfall. The model was simulated for three rainfall probabilities to comply with the Flood Risk Regulations 2009 (1 in 30 year, 1 in 100 year, 1 in 1000 year).

The national surface water map can be accessed via the Environment Agency’s website: http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?topic=ufmfsw#x=357683&y=355134&scale=2. Figure 2-1 illustrates the surface water flood risk.

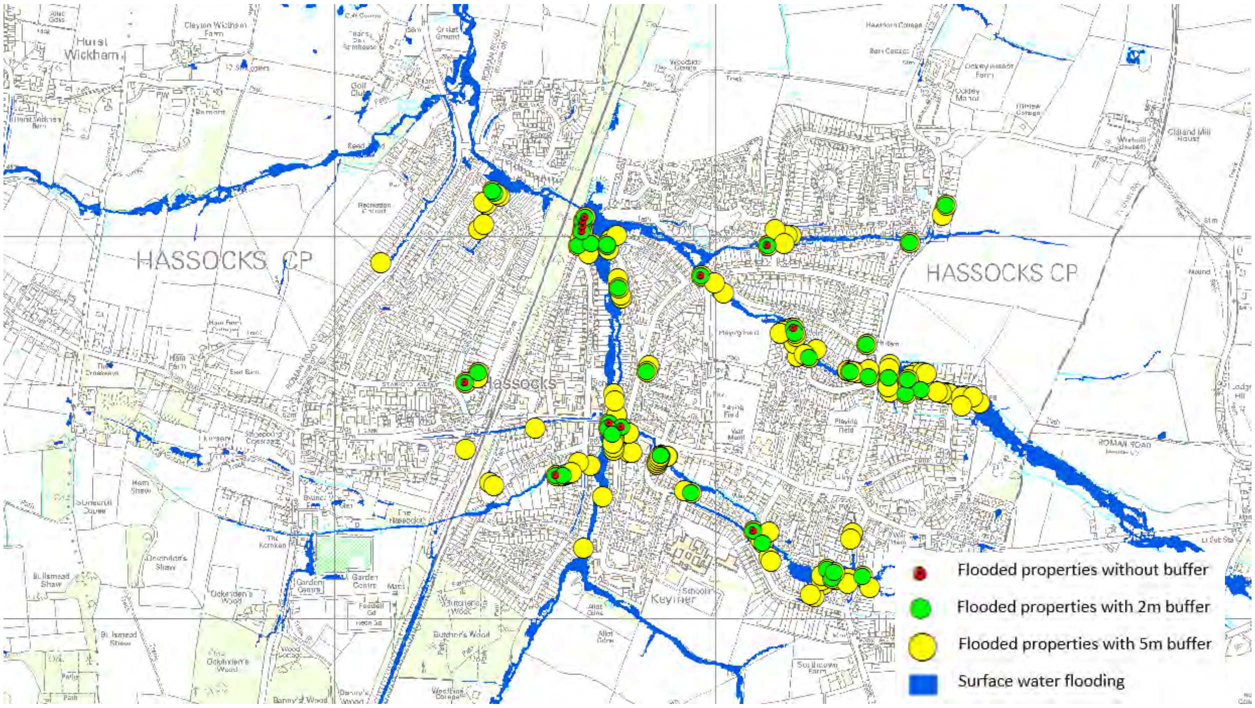

Figure 2-1 Properties at risk of surface water flooding for a 1 in 30 year rainfall event

2.2.4 Environment Agency modelling and mapping study in Hassocks

In 2014 the Environment Agency commissioned JBA Consulting to undertake a modelling and mapping study for the Herring Stream catchment, including other tributaries in Hassocks. The study area included the Herring Stream from its source to just north of Hassocks (east of Friar's Oak Cottages). It included the five tributaries of the Herring Stream including Mill Brook, the Ham Shaw Stream, the Keymer Stream, the Adastra Stream and the Hurst Wickham Stream.

The primary purpose of the study was to "produce a hydraulic model of the study area to model the channel and floodplain; and to produce a series of flood outlines for different Annual Exceedance Probability (AEP) events. These outlines will then be used to improve the demarcation of the Flood Map."[3]

The model was a 1D-2D linked hydraulic model using ISIS-TuFlow software and was run with the 50%, 20%, 10%, 5%, 3.33%, 2%, 1.33%, 1% and 0.1% AEP design flood events. In addition, the effects of climate change on the 1% AEP event were considered by increasing the flow by 20%. Sensitivity analysis was undertaken as part of the modelling and mapping including:

- changes in Manning's coefficients in channel and floodplains, as well as in the upstream and downstream boundary – water levels were insensitive to these changes, and;
- 80% blockage was represented at culverts in Damian Way, Spitalford Bridge and Lodge Lane – blockages on Damian Way and Spitalford Bridge did not significantly affect flood extents, whereas blockage of the Lodge Lane culvert did result in a significant increase in local flood extents.

For this SWMP a brief review of the hydraulics and hydrology of the 2014 model was undertaken to assess its suitability for use as a tool to support development of conceptual mitigation measures. The review of the hydraulics confirmed that the model is acceptable for the purpose it was designed for (to determine flood extents), but that if it were used to design mitigation options some improvements may be required. This SWMP is not considered a design project, and therefore the model has been accepted as a useful decision-supporting tool for this project. With respect to the hydrology the conclusion of the review is that the

[3] Environment Agency (2014), Hassocks Modelling & Mapping study (produced by JBA Consulting)

methods applied are appropriate, but some refinement could be made to the final design[4]. This should be taken forward if the model is to be used for design purposes.

2.2.5 Survey of MSDC drainage assets

In 2015 Mid Sussex District Council undertook a survey of trash screens, culverts and balancing ponds to assess their condition and identify any need for repairs. A summary of the key findings of the surveys in relation to Hassocks are shown in Table 2-4[5]. Further to the completed surveys Mid Sussex District Council has recently installed a new trash screen at Orion Car Park and has already taken the tree down and rebuilt the wall, as recommended by the survey.

[4] For example, by reconciling by the use of scaling factors to ensure hydrograph volume is correctly represented

[5] Mid Sussex District Council (2015), Asset Condition Survey Report (undertaken by JBA Consulting)

Table 2-4 Summary of asset surveys completed to date (December 2015)

Asset location and reference no.	Asset name and location	Condition Grade	Summary of key issues	Repair needs recommended in asset survey
Behind No. 36 Damian Way, asset no. 38	Trash Screen (A)	5	Asset in very poor condition, the screen is unstable and unsecured. Scour and outflanking of headwalls, leaving the wall weakened. Screen non-compliant with Environment Agency Trash and Security Screen Guide 2009.	• Signage outlining unstable structure (emergency) • Stabilise wingwalls, install connections between screen and wingwalls, develop a maintenance plan (urgent) • Monitor extent of corrosion, install scour protection (short-term) • Redesign and replace screen, installed safety harness anchor points, redesign and replace wingwalls (long-term)
	Land drain (B)	3	Asset in a fair condition, some dense vegetation at the southern section of the drain	• Develop debris and vegetation clearance plan (urgent)
East of Orion Car Park, asset no. 30	Trash screen (A)	3-5 (depending on component)	Asset is in very poor condition, multiple severe defects. Connection between trash screen and right wall bank almost completely disconnected, H&S issues associated with working platform, right wall bank in poor condition	• Investigate whether debris being removed, investigate cause of lean, investigate use of unknown opening (emergency)* • Replace horizontal bars with vertical bars, install additional support on screen, increase size of screen, fill fracture and level working platform, develop debris clearance plan, install guardrails/chain/gate and steps/ladder between platforms (urgent)* • Monitor corrosion and scour, remove tree and fill back section, monitor extent of crack and damage to waterproofing, redesign entire screen, replace
	Culvert inlet (B)	3	Asset in a fair condition, minor surface corrosion at the inlet	
	Culvert outlet (C)	2 / 3	Good condition as not major defects, apart from minor access problems and minor corrosion / cracking	

	Culvert outlet (D)	N/A	Asset not visible	headwall at point of fracture, monitor cracking and delamination (short-term)* • Place scour protection, consider filling section (long-term)
	Culvert outlet (E)	2	Asset in a fair condition, minor surface corrosion at the inlet	
Adjacent to no. 33 Lodge Lane, asset no. 74	Trash screen	2	Good condition with 2 minor defects: overgrown access to structure, during periods of high flow wingwalls may not be effective in directing water to the culvert	• Develop vegetation clearance plan (urgent) • Consider extension to wingwalls (short-term)
Adjacent to no.59 Lodge Lane, asset no. 109	Trash screen	2-3	Asset in a good condition. Access for maintenance is poor. The screen is too steep and does not conform to EA guidance. Accumulation of silt and debris causing up to 15% siltation	• Investigate whether screen is being cleared as per MSDC asset management plan (emergency) • Install lockable gate and working platform, remove silt, decrease angle of screen, install suitable working platform (urgent) • Develop silt removal plan, monitor outflanking of left bank wall, replaced damaged panel on right bank (short-term) • Extend wingwall (long-term)

* = Completed in April 2016

2.2.6 CCTV of Orion car park culvert

A CCTV survey of the culvert originating in Orion car park was undertaken in January 2016. Defects have been identified at points along the length, and the salient points from the CCTV survey have been noted below.

- The main line consists of a large corrugated steel pipe arch culvert[6], and is therefore expected to carry the majority of the flow. There are sections where the pipe is deformed, resulting in cross sectional area loss and some defective connections. Other minor issues such as cracks and debris were observed. Some of the line was also not surveyed, therefore the condition of this is assumed to be similar. Repair is likely to be required to this pipe as it is not conveying flow for its full cross sectional area, which will worsen over time as the deformities become more severe.
- The larger branch line consists of a 750mm diameter concrete pipe with a number of issues. As this is a concrete pipe, the deformities are less severe than on the main line, however there are a number of cracks and defective gully connections. It is operating close to its intended capacity but has issues which should be addressed in ongoing maintenance.
- The smaller branch line consists of a 650mm concrete pipe. In addition to cracks and defective connections, it has more issues than the other branch line as there are holes in the sewer and up to 20% cross sectional area loss. As above, these issues do not necessarily require immediate repair but should be addressed in ongoing maintenance.

Overall, the system is operating at slightly less than its intended capacity but with no major immediate blockages or collapses. There was some deformation observed in the main culvert, which will worsen over time. The defective connections to the culvert should be investigated to check whether localised flooding is occurring due to individual gullies not providing adequate drainage.

2.3 Actions to alleviate flooding

2.3.1 Damian Way balancing pond

Following flooding in the year 2000 Mid Sussex District Council constructed a balancing pond east of Damian Way to attenuate runoff during rainfall events. The balancing pond was designed with a proposed storage capacity of 5800 m^3, and since the completion of the balancing pond it is understood there has not been any further property flooding within Damian Way. When the balancing pond was constructed a series of design storms were assessed to estimate the overflow from the balancing pond under different rainfall circumstances. The results showed that during a:

- 1 in 25 year storm the lagoon will retain the volume with no overflow over the weir, storing 4951 m^3;
- 1 in 50 year storm show that the lagoon will overflow during 2 hour peak storm by 58 l/s over the weir, and;.
- 1 in 100 year storm results show that the lagoon will overflow during the 1hr, 2hr, 3hr and 4hr storm by maximum of 73 l/s over the weir which occurs during 120 min storm and rain 46 mm/hour.

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[6] This is estimated to be 1650 x 1015 initially, based on Mid Sussex District Council (1989), Orion Culverts, Hassocks. The same report notes that the main line becomes a 1475 x 900, before becoming a 1220mm circular culvert.

Figure 2-2 Damian way balancing pond during a storm event in November 2002

2.3.2 West Sussex County Council actions

Following the major flooding across West Sussex in June 2012 WSCC has undertaken many capital and maintenance improvements across the county. In Hassocks WSCC undertook repair works to gullies and culverts following the 2012 flooding. Furthermore, WSCC has an annual gully cleaning programme, whereby all gullies are surveyed and emptied depending on silt levels on the gully pot. This ensures the highway drainage network is well maintained and functioning.

2.3.3 Orion Car Park trash screen

Following the survey undertaken by Mid Sussex District Council in 2015 of trash screens, culverts and balancing ponds, actions have been taken to address some of the proposed remediation works. A new trash screen has been designed and installed at Orion Car Park in 2016 to address the defects identified at the trash screen. Figure 2-3 shows before and after comparisons of the trash screen. This demonstrates the ongoing work of Mid Sussex District Council to address any defects noted in the asset survey.

Figure 2-3 Orion Car Park trash screen in June 2015 (before – left) and April 2016 (after works completed – right)

2.3.4 Operation Watershed actions

Three Operation Watershed bids were successfully submitted to WSCC by Hassocks Amenity Association in March 2015 for minor works within Hassocks. These have now been completed and included:

- investigation into the cause of flooding in residential properties along the Herring Stream and commercial properties near Spitalford Bridge, including further investigations on riparian ditches in the area likely to impacts on the flow of water (application no. 2178);
- provision and placement of a new manhole cover in the footway of Lodge Lane to improve access to the existing culvert (application no. 2179), and;
- CCTV survey of the main culvert under Lodge Lane / Dale Avenue to detect any defects or blockages, and to remedy any blockages through jetting of pipes and cleaning of gullies application no, 2180).

The effect of these measures on flood risk is not known at this stage.

SECTION 3
Catchment characteristics

3.1 Catchment boundary

To determine the catchment boundary analysis was conducted using an ArcGIS Hydrology Tool. It was based on LiDAR data with cell size of 2m. The original DEM (Digital Elevation Model) was processed to fill the small holes and used further to define the flow direction, by working out the steepest downslope neighbour, and flow accumulation, by calculating the accumulated flow into each cell, enabling a catchment boundary to be created.

The catchment boundary is illustrated in Figure 3-1 and shows three main subcatchments in the study area that feed the Herring stream to the north west of Hassocks. The catchment covers an area of approximately 12 km^2.The built up area of Hassocks is part of a larger catchment where all the surface water converges to the Herring Stream, which is one of the main tributaries of the river Adur.

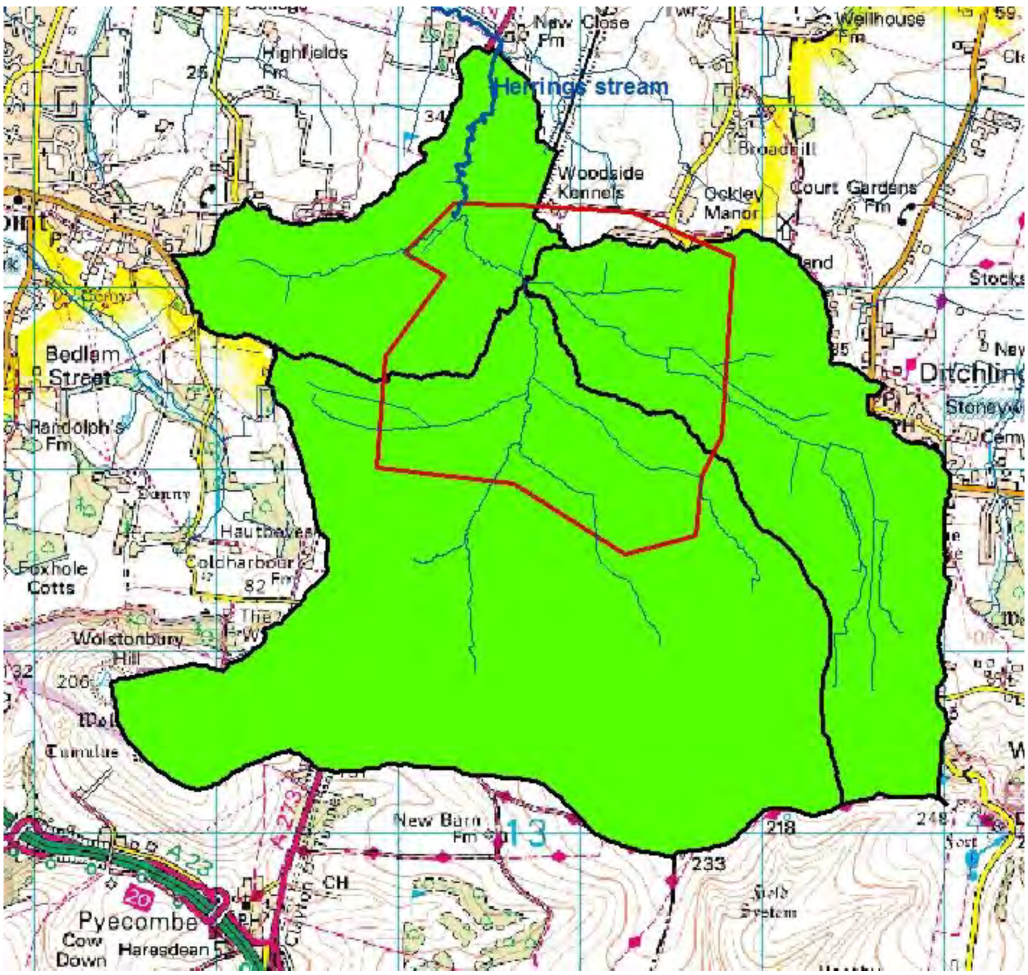

Figure 3-1 Catchment boundary for Hassocks SWMP (red line is the study boundary)

3.2 General description of catchment

Flood risk in Hassocks is dominated by fluvial flooding from the Herring Stream and associated tributaries. The Herring Stream emerges south of Hassocks and flows in a predominantly northern direction through the town. There are numerous tributaries joining the Herring Stream upstream or near Spitalford Bridge, including:

- a watercourse which flows from the south of Hassocks and joins the Herring Stream southwest of Parklands Road (point A on Figure 3-2);
- a watercourse which enters the urban area near Lodge Lane and flows in a generally north-westerly direction towards Spitalford Bridge (point B on Figure 3-2), and;
- a watercourse which emerges from the west of the catchment, past South Downs Nurseries and under the railway before joining the Herring Stream near Clayton Avenue (point C on Figure 3-2).

Downstream of Spitalford Bridge the Herring Stream continues to flow northwards in gardens between Kings Drive and Chancellors Park before flowing under the railway at the end of Woodlands Road. Before flowing under the railway a further tributary flows into the Herring Stream, which emerges from Damian Way and Ockley Lane (known as the Adastra Stream, point D on Figure 3-2). A map of the main watercourse through Hassocks is shown in Figure 3-2.

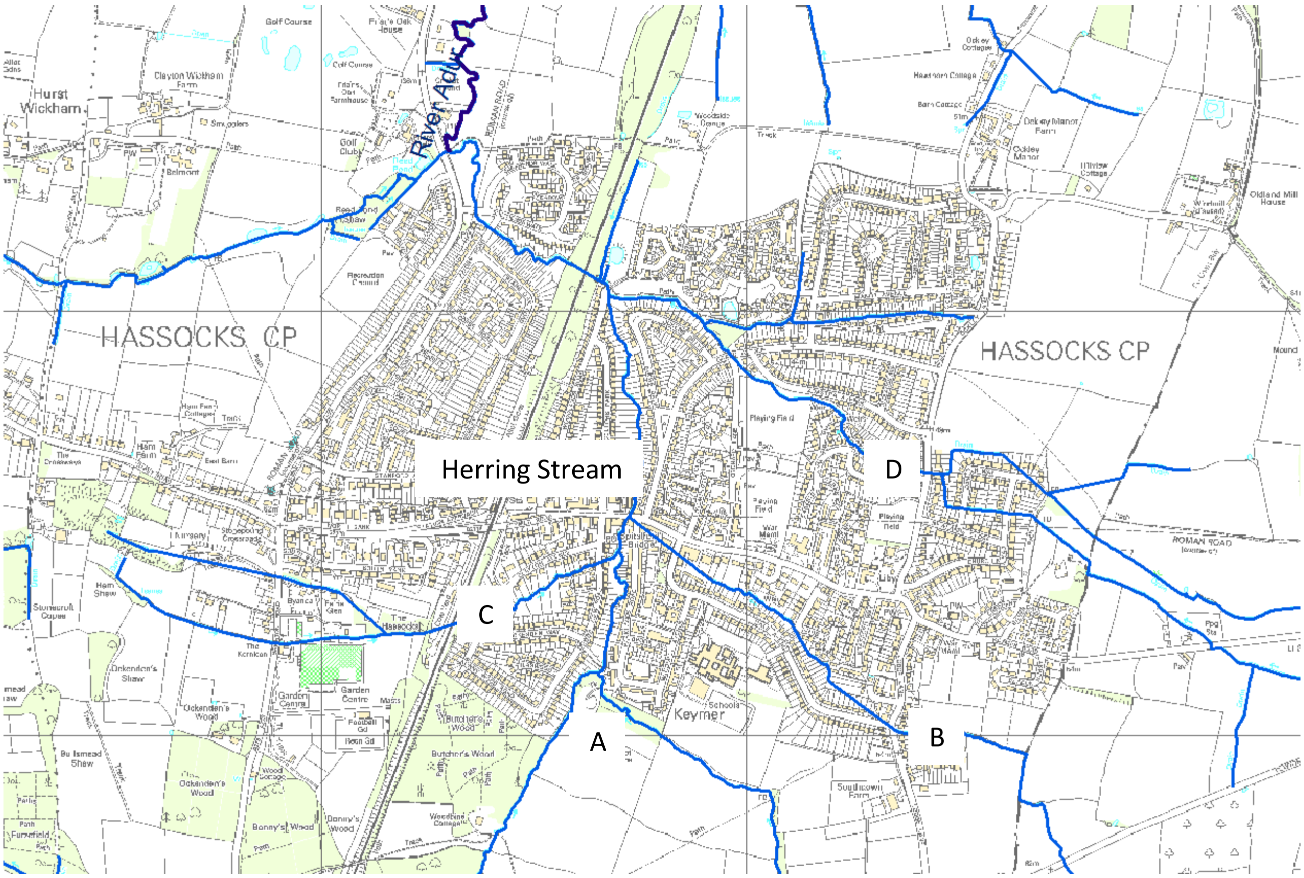

Figure 3-2 Watercourses in Hassocks

Within the urban environment surface water runoff drains predominantly via local highway drainage, discharging to the various watercourses and streams within Hassocks. Whilst data does exist for the highway manholes and gullies there is limited information on the pipe network. As the majority of flood risk in Hassocks is from the watercourses and streams no further data was collected on the highway drainage network for the SWMP.

3.3 Rainfall

There are two rain gauges situated in the Hassocks area and both provide daily rainfall data. Details of the gauges are shown in Table 3-1.

Table 3-1 Rain gauges situated in the Hassocks area

Gauge Name	NGR	Data provided start	Data provided end	Data Interval
Hurstpierpoint College	TQ1224028623	01.01.2013	31.08.2015	Daily observer
Hassocks Daily observer	TQ3138016100	01.01.2013	31.08.2015	Daily observer

At the Hassocks rain gauge the total rainfall depth in 2013 was 815mm and in 2014 it was 956mm. Over the period of data provided there were significant rainfall events on 10th February 2013 (34mm in a single day), 23rd December 2013 (31.6mm in a single day), and 12th October 2014 (32.9mm in a single day).

A summary of the Hassocks rain gauge from 1st January 2013 to 31st August 2015 is shown in Figure 3-3.

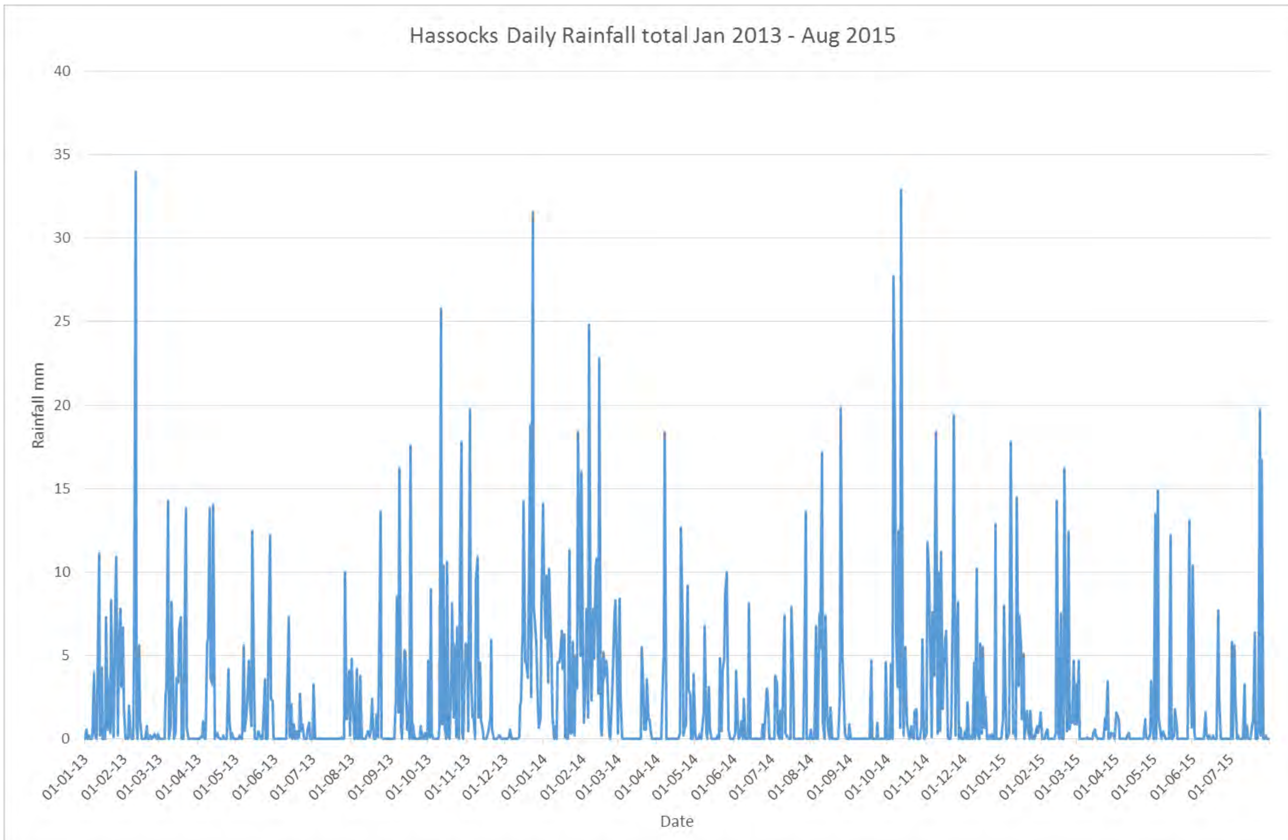

Figure 3-3 Hassocks daily rainfall

Further data on historic rainfall which has resulted in documented flooding within the catchment is described in Section 4.1.

3.4 Geology and hydrogeology

This section of the report focusses on the potential implications of the geology and hydrogeology on groundwater flooding in the catchment. A detailed summary of the geology and hydrogeology is provided in Appendix C.

Based on the hydrogeological characteristics of the study area, the potential risk of flooding direct from groundwater sources beneath Hassocks is primarily related to the potential upward movement and emergence (at the surface) of groundwater from the Folkestone Formation and Lower Greensand Group strata.

Although there is borehole evidence that groundwater levels in these strata may be at relatively shallow depths (c.5-6 m below surface) it is unclear whether this represents the true “water table” of an unconfined aquifer or whether these levels represent a water level from a confined or semi confined aquifer. Under these latter conditions, whilst boreholes that intercept groundwater at depth beneath a confining or semi confining layer allow groundwater (under pressure) to rise within the borehole, elsewhere any upward leakage of groundwater will be limited.

A lack of current groundwater monitoring data is such that it is difficult to draw firm conclusions regarding groundwater flood risk from the Lower Greensand strata, however as there is no consistent record or evidence that this type groundwater flooding has occurred in the past, the overall risk of flooding from emergent groundwater is considered to be low.

There is one report of flooding in Hassocks which has been attributed to groundwater. At this location a cellar was flooded to a depth of circa 50mm during December 2013/ January 2014. The property owner reported that this was the second occurrence within a year. The circumstances of this flooding incident are somewhat anomalous as there are around 6 other adjacent (neighbouring) properties that also have cellar accommodation, but which have not reported flooding. There are no watercourses in the immediate vicinity, so it is difficult to attribute the flooding (in this property) to fluvial/ surface water. The property is located west of the mapped area of superficial (Head) deposits and it is quite close (within 130m) to the site of the Old Gravel Pit so it is possible that coarser deposits within the Head provide a source of groundwater flooding. It is understood that when Mid Sussex District Council constructed the storm water balancing pond on the Adastra stream east of Damian Way, groundwater was struck at a shallow level preventing deeper construction. This pond also appears to be located within the mapped Head deposits, providing further evidence of shallow groundwater within these superficial materials. The “pond” is only about 420m from the flooded property. However, the topography of the area makes it difficult to envisage a direct link between these apparent groundwater bodies. Whilst within the valley of the Adastra stream groundwater (in the Head deposits) may be recharged directly by the stream, recharge of groundwater near the affected property may be more localized (e.g. from direct rainfall). Further information is really needed to understand any groundwater flooding mechanism that affects this property.

3.5 Environmental characteristics

This section includes a summary of the key baseline environmental characteristics (see Table 3-2) and details the findings of a preliminary desk-based study, against which the environmental effects of the drainage and surface water management strategy for Hassocks can be assessed. An environmental overview plan is provided in Appendix G.

Table 3-2 Environmental characteristics and issues in Hassocks

Baseline	Environmental Issues
Local Community	
• The study area encompasses the built up area of Hassocks including the Keymer area. • The population of Hassocks was 7,667 in 2011 (Office for National Statistics, 2011 Census). • The presence of the South Downs National Park to the immediate south, Hassocks Gate toll gate and retained	• Direct effects of flooding on the population and properties within flood risk areas, including businesses and visitors to Hassocks. • Quality of life is affected by flooding.

Baseline	Environmental Issues
heritage from over 100 years ago attracts tourists to the area, assisted by good access from London and Brighton. It is estimated that around £200 million was spent on trip expenditure during visits to the Mid Sussex District, which Hassocks is a part of, in 2005, supporting approximately 5,900 full time jobs (Tourism South East, 2006). • The population of Hassocks has increased by 9% from 2001 – 2011 (Office for National Statistics, 2011 Census). • Small areas to the west, north and east of Hassocks are safeguarded for development. • The Hassocks golf course and station goods yard are under proposals to be re-developed.	• Population growth is increasing development pressure on land and within the flood plain. • Development land could exacerbate flood risk and increase surface run-off if developed. • Opportunities exist for improved recreational provision and sustainable travel links in conjunction with flood risk management.
Material Assets	
• The A273 runs north-south to the west of the study area. This is the main road north or south from Hassocks. • The B2116 runs east-west, in the southern half of the study area. This is the main route east or west from Hassocks. • A main rail line runs north-south roughly parallel to the A273. This runs through the middle of Hassocks, splitting the village into two halves. The B2116 provides the only road bridge to cross the rail line. Hassocks Station is roughly in the middle of the village along this line. The line provides direct services to Brighton, Gatwick and London. • Keymer Road (B2116), Downs View Road (West Sussex Gazette, 2014) and Parklands Road (Mid Sussex Times, 2014) are prone to flooding during heavy rain. The rail line is also prone to flooding but not in the study area. This has disrupted rail services in and out of Hassocks in the past (BBC, 2000). • Other minor roads are interspersed throughout the study area, mostly associated with urban and residential areas.	• Flood risk to existing, critical and transport infrastructure. • New development will need to be appropriately located in terms of flood risk from all sources of flooding.
Biodiversity, Flora and Fauna	
• There are no international designated nature conservation sites within the study area.	• Potential for negative or positive effects on national and local conservation sites and terrestrial, fresh water habitats. • Need to ensure that measures do not adversely affect the flow, frequency or

Baseline	Environmental Issues
• The nearest Site of Special Scientific Interest (SSSI) is Wolstonbury Hill, 1.25km south-west of Hassocks. • The Brighton and Lewes Downs Biosphere Reserve borders the southern and eastern study boundaries. The Biosphere Reserve consists mainly of farmland, but also chalk downland, city and marine environments that provide linked habitats for many species that the reserve conserves (Brighton & Lewes Downs Biosphere, 2015). • Keymer Site of Nature Conservation Importance (SNCI) is located within the study area to the west of the Keymer neighbourhood of Hassocks. The status is given to non-designated sites that are important for wildlife conservation. • The Herring Stream flows through Hassocks and is used by migratory fish and as spawning grounds for sea trout (OART, 2014). The stream has the capacity to support fish and was previously stocked with bream, roach, dace and chub in 1997 (EA, 1997). However in 2005, a discharge from a sewage treatment works owned by Southern Water killed many fish in the stream (Mid Sussex Times, 2006). • There are known rare, notable and/or protected species within the study area in terrestrial, riverine and aquatic environments. In particular, in the agricultural east of the study area, there is potential for protected species. Such species may be sensitive to changes in hydrology, flood regime and water quality. • Details of Tree Preservation Orders (TPO) will need to be confirmed with Mid Sussex District Council prior to implementation of any SWMP measures. Where possible, the detailed design of a scheme should seek to avoid the loss of and damage to trees, particularly those protected by TPOs. However, where works to a tree designated by a TPO are required, this will need to be consented by the local planning authority.	duration of flooding to water-dependent habitats, particularly those within designated sites. • Need to ensure that any works on watercourses are compliant with the Water Framework Directive (WFD) regarding fish passage as well as water quality and geomorphology. • Potential requirement for Habitat Regulations Assessment (HRA) in accordance with the Conservation of Habitats and Species Regulations 2010 due to presence of international conservation sites. • Potential requirement for SSSI assent from Natural England for any works affecting a SSSI under the Wildlife and Countryside Act 1981 (as amended).
Soil, Geology and Geomorphology	
• The majority of the bedrock of Hassocks is of Lower Greensand Group consisting of mainly sands and sandstones (varying from well-sorted fine-grained to poorly sorted medium- to coarse-grained) with silts and clays in some intervals (BGS, 2015 – Geology of Britain Viewer).	• Flood risk affects soil quality which affects other environmental receptors. • Geology can influence the extent and likelihood of an area to flooding and/or the suitability of some types of

Baseline	Environmental Issues
• A small area of bedrock under Hassocks is the Folkestone Formation comprising of medium- and coarse-grained, well-sorted cross-bedded sands and weakly cemented sandstones (BGS, 2015 – Geology of Britain Viewer). • An even smaller area of bedrock under Hassocks is the Gault Formation comprising of Pale to dark grey or blue-grey clay or mudstone, glauconitic in part, with a sandy base. Discrete bands of phosphatic nodules (commonly preserving fossils), some pyrite and calcareous nodules (BGS, 2015 – Geology of Britain Viewer). • There are no historic landfills or active landfills within the study area. The nearest historic landfill is approximately 600m from the study boundary (EA, 2015a). • Flooding from the Herring Stream and Pookbourne Stream, in addition to limited capacity of the drainage system and increased surface run-off in Hassocks has caused flooding in the village centre of Hassocks. The Environment Agency (EA) has a Flood Risk Management System in place for the Pookbourne Stream to reduce flooding in Hassocks (EA, 2015b). • The entirety of the study area is classed as Grade 3 (good to moderate quality for crop production) (Natural England, 2010).	Sustainable Urban Drainage System (SUDS) options.
Water	
• The Herring Stream enters south of the study area, flowing north-west under the rail line. On the other side of the rail line, the streams flows north, through the centre of the village. There are a number of tributaries to Herring Stream that flow into the stream in Hassocks. • There are roughly 4 un-named ponds within the study area and other ponds close to the study area, mostly associated with the Hassocks Golf Course to the north-west of the study boundary. • The study area is subject to flooding from the drainage system being overloaded by surface run-off and stream flooding. • The entire study area is within a surface water Nitrate Vulnerable Zone (NVZ) (www.magic.org.uk, 2015). • There are no water abstraction licences registered within the study area. The nearest borders the southern	• Direct and indirect effects on water resources, both surface and ground water, which could affect their chemical and ecological status as required by the WFD. • Potential requirement for a preliminary WFD Assessment.

Baseline	Environmental Issues
boundary outside the study area. This abstraction is for ground and surface water used for agriculture (EA, 2015c).	
Historic Environment	
• There are 8 Grade II Listed Buildings within the study area. All but one are within the Hassocks Conservation Area (CA) (www.magic.org.uk, 2015). • There are no Scheduled Monuments or Registered Parks and Gardens within the study area or the surrounding areas (www.magic.org.uk, 2015). • Keymer CA is located in the south-east of the study area, in the Keymer neighbourhood of Hassocks. The conservation area consists of 7 listed buildings, which are the only ones within the built up are of Hassocks. Most of the buildings in the Conservation Area are over 100 years old (Mid Sussex District Council, 2005). • There are likely to be non-designated sites and Historic Environment Records (HER) sites of importance within the study area, particularly in and around the CA, and their details should be obtained in advance of project implementation, where appropriate and dependent on the nature of the works. • There is buried and unrecorded archaeological potential within the study area, particularly in and around the CA.	• Potential to reduce flood risk to archaeological assets and their setting. • Potential for impacts on the character of the historic landscape, archaeological assets and their setting. • Potential opportunities to improve heritage assets in conjunction with delivering action plans.
Landscape	
• There are no designations for landscape within or around the study area. • The study area is within the Low Weald (121) National Character Area (NCA). The NCA is described as a broad, low-lying clay vale which largely wraps around the northern, western and southern edges of the High Weald. It is predominantly agricultural, supporting mainly pastoral farming, with horticulture and some arable on lighter soils in the east, and has many densely wooded areas with a high proportion of ancient woodland. Around 23 percent of the area is identified as greenbelt land (Natural England, 2013). • The vast majority of the study area is the built up area of Hassocks. As such, this is classed as a built up area in the West Sussex Landscape Character Assessment, and therefore is not included in any of the Character Areas for the County (WSCC, 2015).	• Existing landscape, rural and visual resources currently under pressure from increase in development to support a growing population. • Flood risk management measures may present opportunities to protect and enhance the existing landscape.

SECTION 4

Flooding history

4.1 Location and dates of historic flooding

Figure 4-1 summarises the main location of historic flooding in Hassocks, based on mapping provided by Mid Sussex District Council. This was supplemented by anecdotal and photographic evidence provided by Mid Sussex District Council and the Parish Council at a meeting in June 2015. The most significant flooding in the catchment occurred in October/November 2000, January 2003, 2008, June 2012, and February 2014, although flooding has occurred at other times in the catchment.

Figure 4-1 Summary of historic flooding in Hassocks (extracted from Mid Sussex District Council historic flood events parish map)

4.1.1 October and November 2000

Following the severe flooding in October and November 2000 Mid Sussex District Council produced a paper describing the impacts of the event across Mid Sussex. Properties were flooded in Hassocks in both October and November. The report prepared by Mid Sussex District Council identifies that 165mm mm of rainfall fell over a 4 ½ week period, with the most intense rainfall occurring on 12th October and 29th October. Whilst the November rainfall events were individually less significant than those in October, saturated ground in the catchment meant flooding was more significant in November because the buffering capacity of the chalk downs to the south was fully utilised due to antecedent events. This effect is described in greater detail in 5.1.

The Mid Sussex District Council report of flooding during this period identifies that 44 properties (residential and commercial) were directly flooded in Hassocks, whilst a further 300 were affected with flood water in the vicinity of their property. Key locations that were affected by flooding were:

1. Brighton Road and near to South Downs Nurseries where 2 properties flooded following severe blockage of the railway culvert. This blockage has now been cleared and a trash screen installed. Since this work no further flooding has been experienced.
2. Properties and gardens were flooded on Parklands Road and on the High Street where shops and properties were also flooded. According to the Mid Sussex District Council report problems in this area were exacerbated by a fallen tree in the Herring Stream, immediately upstream of Spitalford Bridge.
3. Lodge Lane, where properties were threatened by internal flooding, due to overtopping of the culvert under Lodge Lane.
4. Damian Way, Ockley Lane and Church Mead where 10 properties were flooded internally and more than 20 were affected by flooding near their property. Flooding was caused by the capacity of the culverts underneath Damian Way being exceeded and runoff from the upstream land. Since the 2000 flooding Mid Sussex District Council have constricted an upstream balancing pond (see Section 2.3.1), and there is not believed to have been any property flooding since then.

The Mid Sussex District Council report identified the rainfall depths for certain storm events during this flooding period, using data from the Haywards Heath rain gauge. This has enabled us to determine the storm return period of some of the largest individual storm events during October and November 2000, using the catchment rainfall frequency curve as specified in FEH. The rainfall frequency curve is constructed from DDF (Depth-Duration-Frequency) curve and presented on the FEH CD-ROM 3. This analysis is shown in Table 4-1. This shows that the largest individual storm event was on 29th October, where the storm return period was between 23-33 years. It should be noted that due to the wet antecedent conditions during the October period the storm return period is likely to be under-estimated for all the analysis illustrated in Table 4-1. This may particularly be the case for the November storm events, where the storm return period from this analysis is relatively low, but may have caused disproportionate flooding because runoff from the upstream catchment would be much more significant than would normally be the case where antecedent conditions were dry.

Table 4-1 Storm return period analysis from October and November 2000 flooding[7]

Date	Rainfall depth (mm) (and duration [hrs])	Storm return period	Source
10th Oct 2000	60mm (24hrs)	8-12 years	Mid Sussex District Council report on October and November 2000 flooding
11th Oct 2000	40mm (24hrs)	2-3 years	
12th Oct 2000	35mm (3hrs)	11-13 years	
29th Oct 2000	54mm (6hrs)	23-33 years	
1st Nov 2000	20mm (3hrs)	2 years	
5th Nov 2000	16mm (1hr)	3 years	

The October and November 2000 flooding was the most significant with respect to property flooding in recent memory.[8] Since 2000 there have been numerous other occasions where properties have either been directly flooded, or had flood water within the vicinity of their property.

4.1.2 January 2003

In January 2003 further flooding across the catchment was recorded, although the exact number of properties was not documented. Flooding was less severe than in October and November 2000. According to the Environment Agency[9] the January 2003 event had a storm return period of 1.2 years[10], but the Environment Agency also noted that:

"The rainfall return period estimate seems fairly low and therefore there may be other factors that exacerbated flooding within Hassocks. This could be due to localised blockages and insufficient capacity in the drainage network. It could also be due to potentially wet antecedent conditions before the rainfall event which would therefore mean that direct runoff to the Herring Stream would have been more likely"

An example of the flooding in 2003 is shown in Figure 4-2, which illustrates exceedance from the Lodge Lane culvert.

[7] Not clear from Mid Sussex report which rain gauge was used to determine the rainfall depths over the storm event period. To estimate the storm return period we have used DDF curves from the FEH CD-Rom for Hassocks and Hurstpierpoint, which are known rain gauges close to Hassocks village

[8] Flooding in 1993 also caused property flooding across Mid Sussex

[9] Environment Agency (2014), Hassocks Modelling & Mapping study (produced by JBA Consulting)

[10] Based on the rain gauge at Plumpton

Figure 4-2 Flooding at the Lodge Lane culvert in 2003

4.1.3 June 2012

In June 2012 an extreme rainfall event caused widespread flooding across large parts of West Sussex. Across West Sussex over 800 properties were flooded, in some parts of the county the storm return period was considered to be a 1 in 200 year event on 11th June. The worst affected areas were to the south of the county in Manhood Peninsula, Bognor Regis, Littlehampton and Worthing[11]. However, there was also flooding further north in the county, including in Hassocks. It is not clear from anecdotal records where flooding occurred in Hassocks, but the documented storm return period was 9.4 years, based on a total rainfall depth of 54.2mm over 12.5 hours[12]. Indeed flows at the Herring Stream flow gauge were 1.66 m^3/s, the highest recorded.

4.1.4 January and February 2014

The most recent flooding in Hassocks was in January and February 2014, with the most significant individual flooding incidents occurring on 14th February 2014. There was significant antecedent rainfall in the preceding 6 weeks, with nearly 250mm rainfall recorded at the Hassocks rain gauge from 1st January – 13th February 2014. On 14th February 2014 nearly 23mm of rainfall was recorded at the Hassocks daily rain gauge. This rainfall event caused flooding at key locations including Lodge Lane, Keymer Road, Parklands Road, Downs View Road and High Street. A photograph looking towards Spitalford Bridge is shown in Figure 4-3, and demonstrates the high water level in the Herring Stream during this period. It is unclear if any properties flooded internally, but photographic evidence provided for this project indicates several properties that had floodwater within their gardens.

[11] West Sussex County Council (2012), Report on June 2012 Flood Event

[12] Environment Agency (2014), Hassocks Modelling & Mapping study (produced by JBA Consulting)

Figure 4-3 Herring Stream at Spitalford Bridge (February 2014)

SECTION 5

Summary of watercourses and flood risk in Hassocks

The majority of flood risk in Hassocks is from ordinary watercourses in the catchment. This SWMP has therefore focussed on addressing flood risk from ordinary watercourses. The Environment Agency model has been used as the basis of understanding flood risk, in combination with site visits and discussions with stakeholders. Using a combination of evidence from the hydraulic model, site visits, and discussion with stakeholders, this section of the report summarises the key flood risk issues in Hassocks, and the damages associated with this flood risk. The description of flood risk in Section 5.1 has been divided up into the key watercourses and flood risk areas in Hassocks.

With respect to the hydraulic modelling used to develop a better understanding of flood risk in the catchment two baseline modelling scenarios have been completed:

1. 80% blockages at Spitalford Bridge, Lodge Lane and Damian Way have been simulated to understand how flood risk changes depending on the condition of these assets[13], and;
2. all culverts and channels assumed to be free flowing with no blockages[14].

5.1 Description of flood risk

Upstream of Hassocks urban area the geology is highly permeable Chalk, which forms an important source of groundwater and also contributes flows to the watercourses through Hassocks via a series of springs. Springs emerge from the Chalk at Clayton and at Whitelands Farm which flow northward and form the primary sources of the headwaters of the Herring Stream. Keymer Stream also appears to be fed by groundwater from the Chalk. A further spring emerges near Park Barn Farm (NGR 532444, 114114). This also flows northward, toward the west side of Ditchling, before flowing west through Keymer and then through the housing estate around Damian Way. This watercourse is known as the Adastra Stream.

Flood risk in the catchment is heavily influenced by antecedent conditions because of the response of this Chalk catchment. Typically in Chalk catchments much of the rainfall is infiltrated into the Chalk, resulting in a low proportion of rainfall generating direct and rapid runoff to watercourses. However, during periods where single (or multiple) heavy rainfall events occur following a long wet period the buffering capacity of the Chalk is utilised. As a result the buffering effect of Chalk becomes less prominent and a more direct response to rainfall occurs in the catchment. This results in greater peak runoff entering the watercourses, causing higher river levels and flooding in Hassocks. The most significant property flooding in Hassocks in 2000 and 2014 (for example) occurred following a wet antecedent period, which had utilised the buffering capacity of the Chalk.

Extracts from a report prepared by Mid Sussex District Council following the October and November 2000 flooding confirms this:

"The chalk downs acted as a sponge. Consequently, when the water holding capacity of the sponge had been reached, runoff to the north was very heavy, even from relatively minor bouts of rainfall."

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[13] This represents a Do Nothing scenario, which effectively represents ceasing of all maintenance activities and therefore assets deteriorate and become blocked

[14] This represents the baseline (or Do Minimum) scenario, which effectively represents flood risk in Hassocks assuming that all drainage channels and culverts and flowing freely.

"Serious flooding also occurred on Monday 6 November. Although the amount of rainfall was less than 9 to 12 October, the ground had not recovered from the saturation of the two previous storms and the runoff effect was immediate."[15]

5.1.1 Herring Stream and Ham Stream

The source of the Herring Stream is south of Hassocks, with the catchment boundary near Foxhole Farm off Spring Lane. From its source it flows northwards, through Lag Wood and Butcher's Wood before flowing behind properties at the southern end of Downs View Road. At a footbridge near the children's playing area off Parklands Road the Herring Stream is joined by one its tributaries (the Mill Brook), where it immediately flows through a large twin culvert, which is shown in Figure 5-1. At the time of the site visit in June 2015 the Herring Stream was flowing freely.

Figure 5-1 Culvert under footbridge on Herring Stream

Downstream of this footbridge the Herring Stream flows through the gardens to the rear of properties on Parklands Road and Downs View Road. A further tributary (the Ham Brook) joins the Herring Stream near 11 Downs View Road. The Ham Stream flows from west of the railway near Brighton Road.

Downstream of this the Herring Stream continues to flow northwards where it flows under the Keymer Road/High Street at Spitalford Bridge. Spitalford Bridge is a large arch bridge structure opening has a cross-sectional area of 2.74 m^2 with a flood relief culvert that is approximately 800mm in diameter[16]. The Keymer Stream, which arrives from Lodge Lane and Dale Avenue, joins the Herring Stream via three large outlets, one of which is upstream of the bridge (750mm circular culvert) and the remaining two are downstream of the bridge (600mm and 1220mm circular culverts). Downstream of Spitalford Bridge the Herring Stream flows northwards to the rear of properties on Kings Drive, where it is joined by the Adastra Stream near the end of Woodsland Road, before flowing west under the railway line in an arch culvert with an opening that

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15 Mid Sussex District Council (2001), Flooding in Mid Sussex – October and November 2000 (CE&DPES) (Item DT 46 2000/01)

16 The cross-sectional area of the bridge has been taken from Auto-Cad drawings

is 3.4m wide and 3.6m high. Once under the railway the Herring Stream flows in a north-westerly direction to the rear of properties on Friars Oak Road, before flowing outside of the urban area.

There are three main hotspots of flood risk along the Herring Stream and Ham Brook which are discussed in turn below.

First, at the confluence of the Herring Stream and Ham Brook several properties and gardens are at risk of flooding during relatively frequent rainfall events (e.g. 1 in 2 year storm return period). This is because the culvert under Downs View Road has insufficient capacity to convey flows resulting in overtopping and garden flooding to some properties in the area. During heavier rainfall events (e.g. 1 in 20 year storm return period) further properties and garages to the west of Downs View Road are at risk of flooding due to backing up and overtopping of the Ham Brook. Under much more extreme rainfall conditions backing up at Spitalford Bridge contributes to flooding at this confluence.

Secondly, Spitalford Bridge acts as a constriction to flow down the Herring Stream. Based on the ISIS-TuFLOW model the culvert under Spitalford Bridge can convey approximately 5.5 m^3/s[17]. When flows back up at Spitalford Bridge properties and shops on Parklands Road and High Street/Keymer Road are at risk of flooding. Historic flooding at this location has been exacerbated by blockages due to fallen trees. Maintaining as much flow through this system as possible is critical to reducing the risk of flooding at this location. The hydraulic modelling shows that a significant blockage of Spitalford Bridge would cause property and highway flooding during a 1 in 2 year storm return period.

Thirdly, further downstream on the Herring Stream, gardens near the junction of Kings Drive and Queens Drive are at risk near the confluence of the Herring Stream and Adastra Stream. Based on the model predictions flooding would be restricted to gardens at this location, until a rainfall event between a 1 in 200 and 1 in 1000 year storm return period. It is worth noting that there is a Southern Water foul sewer which crosses the Herring Stream on Woodsland Road. During the February 2014 flooding in Hassocks this foul sewer was acting as a barrier and debris was being caught by the sewer crossing, which caused backing up of water in the Herring Stream. Mid Sussex District Council estimate that water levels were up to 500mm high upstream than downstream as a result[18].

5.1.2 Keymer Stream

The Keymer Stream originates south of the B2112 (New Road), where it flows in a north-easterly direction towards Lodge Lane. The stream enters a rectangular box culvert near no.59 Lodge Lane. The culvert turns sharply north under Lodge Lane before emerging in a short open section near no. 20 Lodge Lane. The stream then flows in a general westerly direction in a mixture of open and culverted sections before emerging as a predominantly open channel near Highlands Close. It then flows through a 950mm diameter circular culvert under Highlands Close. It continues to flow in a westerly direction to the rear of properties on Dale Avenue before entering a large culverted section at the eastern end of Orion Car Park. Initially the culvert is a single arched culvert, measuring 1650 x 1015mm[19], but subsequently becomes two and then three separate culverts before flowing into the Herring Stream via three outfalls (a 750mm outfall south of Spitalford Bridge and 600mm and 1220mm outfalls north of the Bridge) [20]. The culvert arrangement is illustrated in Figure 5-2.

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[17] This capacity is calculated from the rating curve in the flood model.

[18] Fiona Bishop, Mid Sussex District Council, *pers. comm.*

[19] Based on information from CCTV survey of this culvert, dated January 2016, and Mid Sussex District Council (1989), Orion Culverts Hassocks

[20] The ISIS-TuFLOW model represents this complex culvert structure in a simplistic manner. It represents the culvert as a single culvert, and may therefore underestimate the full carrying capacity of this culvert. This may result in slightly overestimated flood extents. Should the flood model be used for further design purposes the culvert would need to be modelled more accurately in accordance with site surveys and CCTV data

The estimated flow capacity (assuming no blockage) of the main culverts on the Keymer Stream has been estimated from the ISIS-TuFLOW model, and are illustrated in

. This indicates that without blockages the culvert under 59 Lodge Lane should have sufficient carrying capacity up to the 1 in 50 year return period. Further downstream the culvert entrance at Orion car park is liable to overtopping during more frequent return periods. The work already carried out by Mid Sussex District Council to improve the trash screen at this location should improve the flows through the culvert inlet.

Table 5-1 Culvert capacities on Keymer Stream culverts

Location of culvert	Culvert dimensions	Flow capacity	Return period at which culvert capacity likely to be exceeded[21]
Near no. 59 Lodge Lane	1.1 x 0.6m box culvert	1.1 m^3/s	1:50 year return period
Under Highlands Close	0.95 m circular culvert	2 m^3/s	>1:100 year return period
Culvert entrance at Orion Car Park	Estimated to be 1.65 x 1.015m (Cross-sectional area is 1.2 m^2)	0.85 m^3/s	1:20 year return period

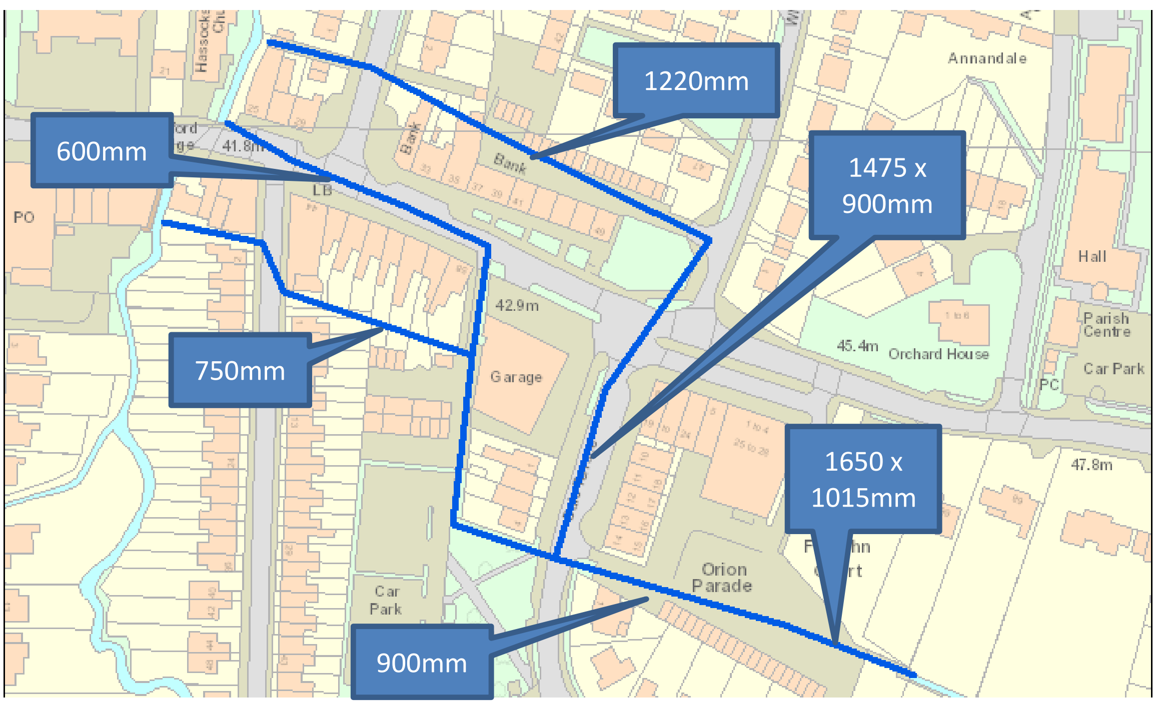

Figure 5-2 Culvert layout of Keymer Stream from Orion Car Park to outfalls into the Herring Stream

There are two primary locations of flood risk from the Keymer Stream, which are discussed in turn below.

1. Properties near the junction of Lodge Lane and Dale Avenue are at risk of flooding when the capacity of the Lodge Lane culvert is exceeded, causing flooding onto the highway which subsequently affects properties. Although the capacity of the Lodge Lane culvert is reasonable (up

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[21] Assuming the culverts are free flowing without blockages or siltation

to a 1:50 year storm return period), anecdotal evidence from historic flooding would indicate that water exceeds the capacity of this culvert more frequently, possibly due to blockages in the culvert. Indeed, the model simulation which assumed an 80% blockage at this culvert indicates that multiple properties would be at risk of flooding, even during a 1 in 2 year storm return period. During the January 2003 flooding in Hassocks the Lodge Lane culvert was exceeded which resulted in properties being close to flooding internally, and the storm return period analysis (as outlined in Section 4.1.2) indicated that storm may have been as little as a 1 in 1.2 year event[22]. The asset inspection survey at this culvert observed silt accumulation of 15% and noted that access for maintenance at this location is poor. This evidence would suggest that regular flooding may occur due to siltation or blockages at the culvert inlet, and that during more extreme events the culvert capacity will be exceeded.

2. Commercial and residential properties near the confluence of Keymer Stream and Herring Stream are at risk of flooding during storm return periods in excess of 1 in 20 (assuming no blockages at Spitalford Bridge). This is due to overtopping of the culvert in Orion Car Park, and backing up of flows at Spitalford Bridge.

5.1.3 Adastra Stream

The Adastra Stream is initially two watercourses at its source (near Ditchling), until they come together immediately east of Ockley Lane. The northern watercourse flows into a 600mm culvert behind no. 38 Damian Way, and flows north-west before emerging into an open ditch to the north of Damian Way. Between Damian Way and Ockley Lane the ditch meanders to flow in a southerly direction to join the other watercourse which emerges to the south of Damian Way. Surveys carried out by Mid Sussex District Council have indicated that the culvert inlet (trash screen) is in poor condition and requires works to remediate the inlet structure.

Figure 5-3 Culvert inlet behind no. 38 Damian Way

[22] Refer to Section 4.1.2 for relevant caveats with this analysis.

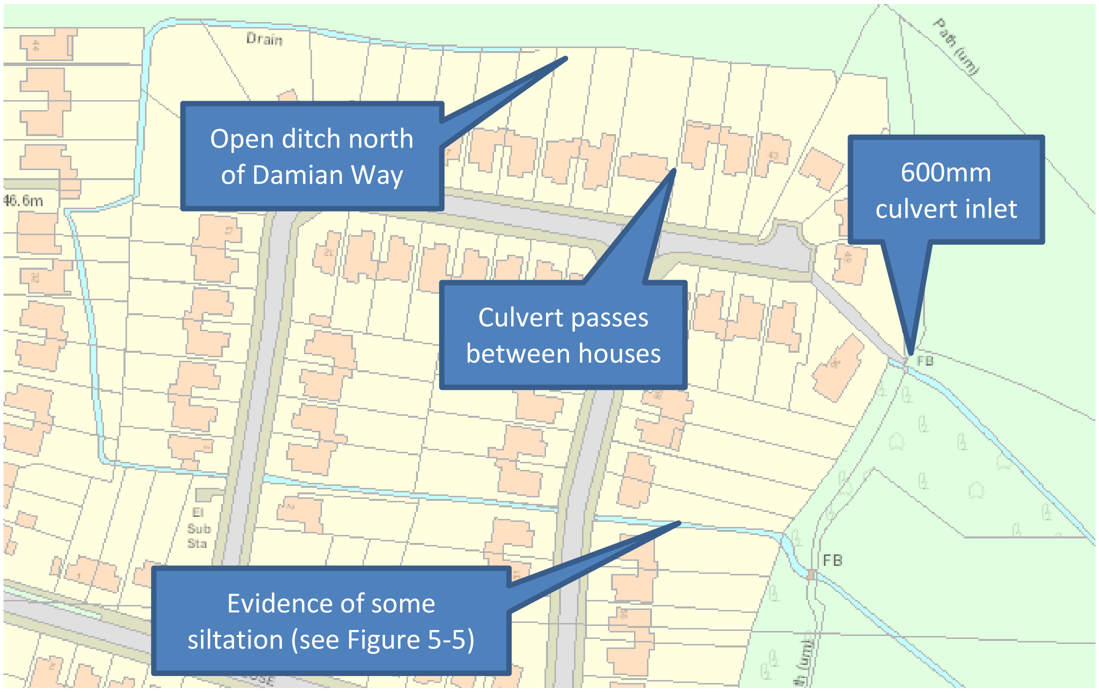

Figure 5-4 Layout of Adastra Stream on Damian Way

The second channel flows in various open and culvert sections (NB: culvert sections are estimated to be 1200mm diameter). During the site visit in June 2015 there was some evidence of siltation and stagnant flows in the open sections to the east of Damian Way, as shown in Figure 5-5.

Figure 5-5 Southern watercourse on Damian Way

At Ockley Lane the Adastra Stream passes through a culvert (estimated at 1500 x 1500), before flowing in a north-westerly direction behind properties on The Quadrant, along the northern edge of the playing field, to the north of Queens Drive, before converging with the Herring Stream.

As noted in Section 2.3.1, following flooding in 2001 in Damian Way Mid Sussex District Council constructed a balancing pond east of Damian Way to attenuate runoff during rainfall events. The balancing pond was designed with a proposed storage capacity of 5800 m^3. This balancing pond has alleviated flood risk significantly in this area. During rainfall events greater than a 1 in 30 year annual probability the flood model predicts shallow residual flooding in Damian Way, as the balancing pond overtops.

Along the remainder of Adastra Stream the floodplain is very narrow and unlikely to cause any property flooding, even during extreme flooding events. The exception to this is the potential risk of garden/property flooding near the confluence of the Adastra Stream and Herring Stream, near Queens Drive.

Options to mitigate flooding

6.1 Introduction

The approach to the development and appraisal of suitable mitigation measures is based around the concept described in Figure 6-1. This concept defines different flood risk management approaches dependent on the rainfall event within a catchment. For 'everyday rainfall' the drainage system and watercourses should function as designed to limit the impact of flooding. Conversely during an extreme rainfall event it is recognised that drainage systems and any other flood risk infrastructure will be completely overwhelmed and therefore emergency response is the most appropriate management technique to reduce the impacts of flooding.

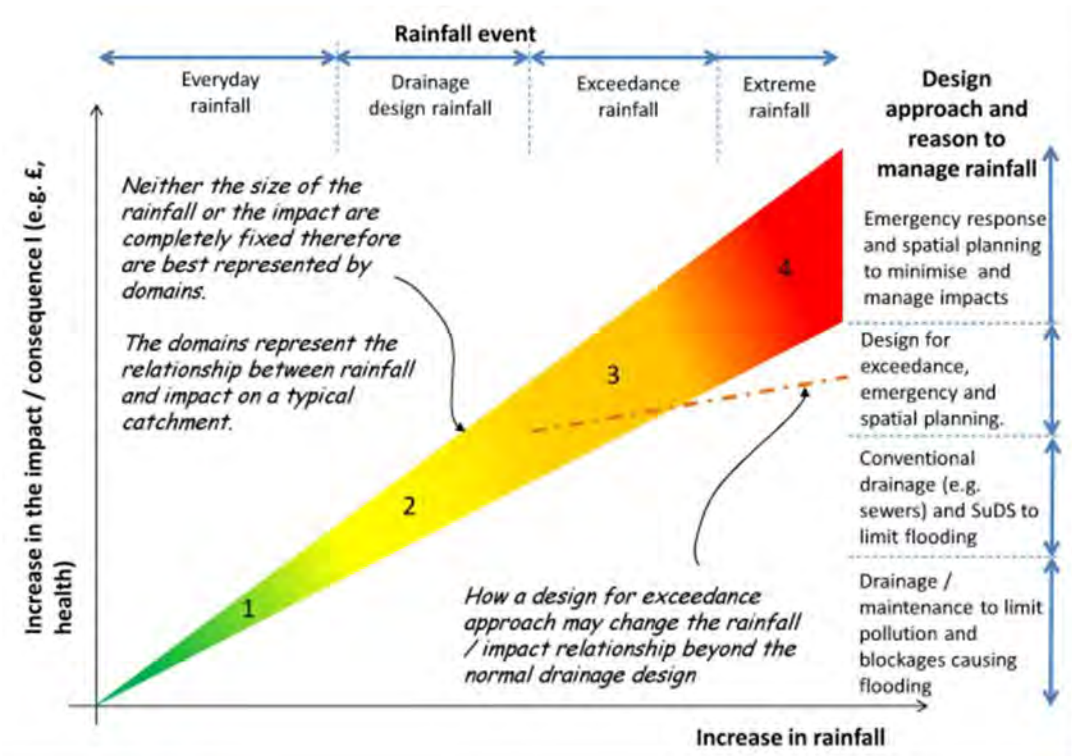

Figure 6-1 Flood risk management concept applied in Hassocks (taken from CIRIA's Designing for Exceedance guidance[23])

6.2 Initial measures considered

A range of potential options to alleviate flooding in Hassocks were initially considered. At this stage thinking was not constrained by funding routes and a range of structural and non-structural measures were considered which may have a range of costs and benefits associated with them. The measures initially considered, including whether they have been taken forward to options appraisal are outlined in Table 6-1. Options that were taken forward for further consideration were tested conceptually in the flood model.

23 Digman, C.J., Ashley, R.M., Hargreaves, P. and Gill, E. (2014a) Managing urban flooding from heavy rainfall - Encouraging the uptake of designing for exceedance – recommendations and summary, CIRIA, C738a.

Table 6-1 Long list of options considered

Type of measure	Outline description	Taken forward?	Justification
Do Nothing	Cease maintenance activities and take no further action	Yes	This must be taken forward as it forms the Do Nothing option required under the FCRM Appraisal Guidance[24]
Maintenance of structures	Continue maintenance of watercourses and structures, and enhance the structures where identified by Mid Sussex's asset survey. Improvements to culvert which runs through Orion car park, as identified in January 2016 CCTV survey	Yes	Important option to consider the benefits of maintenance and upgrades to existing structures. This forms the Do Minimum option required under the FCRM Appraisal Guidance[25]
Sustainable Drainage Systems	Use of rainwater harvesting, green roofs, downpipe disconnection, swales etc, to reduce surface water runoff from the urban area	No	Flooding in this catchment primarily originates from the watercourses, which receive the majority of their flow from the upstream rural catchment. Therefore measures which tackle urban surface water runoff are unlikely to be effective
Storage	Create storage upstream of Lodge Lane and Herring Stream, through formalised online / offline attenuation areas	Yes	Reducing peak flows through Hassocks will have a significant impact on flood risk to properties and infrastructure
Upstream land management	Reduce the peak flow rates through Hassocks by attenuating flows in the upstream (rural) parts of the catchment, through channel widening and natural catchment management (e.g. woody debris)	Yes	As above, plus upstream land management will have wider environmental benefits
Flood defence walls	Constructing flood defence walls along watercourses to improve the standard of protection	No	Technically infeasible due to access limitations for most of the watercourses. Prohibitive cost because of the access and construction issues
Channel deepening / widening	Widening and deepening of watercourses through Hassocks	No	Channel widening and deepening may undermine some of the structures in the catchment (e.g. Spitalford Bridge), and is likely to increase downstream flood risk

24 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/481768/LIT_4909.pdf

25 *Ibid.*

Improve conveyance (widespread)	Upsize culverts and bridge structures to improve conveyance through Hassocks	No	The number and complexity of structures (e.g. Spitalford Bridge, Network Rail culvert, culvert under Orion Car Park) make this option technically infeasible, and cost prohibitive. Furthermore, it will not be possible to do this without increasing downstream flood risk
Improve conveyance (localised)	Upsize selected culverts (e.g. under Lodge Lane) in the catchment to reduce flood risk in key hotspots	No	This will increase downstream flood risk. For example, if the Lodge Lane culvert were upsized it would exacerbate flood risk at the Orion Car Park culvert inlet.
Property level protection	Offer property level protection to properties at risk of internal flooding	Yes	This is a viable option for affected properties, subject to property level survey (which is outside of this commission)

6.3 Short-listed measures

6.3.1 Do Nothing

In this scenario it has been assumed that culverts on Damian Way, Lodge Lane and Spitalford Bridge are 80% blocked. In reality, should maintenance cease other culverts and structures would also fall into disrepair and the flood risk may in fact be greater than modelled for the SWMP. This should be explored if a business case needs to be prepared to justify Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GiA) funding.

6.3.2 Do Minimum

This scenario should also be considered, in accordance with the FCRM appraisal guidance. For the purposes of the Do Minimum scenario the assumptions are:

- all culverts are free of blockage and siltation, through regular maintenance[26], and;
- the improvement works to the Damian Way and Lodge Lane trash screens (as recommended in the Mid Sussex asset survey) are completed.

6.3.3 Option 1. Upstream land management

This option considers more natural catchment management, by working with nature to slow the peak rate of runoff from the upstream catchment in the Herring Stream. This could involve, for example, constructing low level bunds to hold back surface runoff, afforestation, or restoring woody debris in streams. Within the Hassocks catchment, the purpose would be to undertake localised interventions in the watercourses in the upstream part of the catchment, possibly through the use of woody debris.

Without further site investigation it is not possible to confirm the viability of this approach, predict its success, or consider the exact locations where natural catchment management may be most appropriate. Appendix D demonstrates some indicative drawings and plans for this approach on the Herring Stream, which involve channel widening. In order to achieve the same level of benefit as option 2 (storage), this approach would need to hold back (through localised storage) a similar volume of water during flooding conditions in the catchment. Whilst it is harder to predict the success of such an approach, recent evidence from the winter 2015/16 floods has provided positive evidence about the benefits of natural catchment management.[27]

In addition, the Ouse and Adur Rivers Trust has been working with the local community to identify the possibility of implementing natural catchment management within the Herring Stream catchment and has identified further opportunities and locations for localised intervention. The plans presented in this report, coupled with the work undertaken by the Ouse and Adur Rivers Trust provides a good foundation for adopting this approach should it prove the preferred option.

6.3.4 Option 2. Storage

Under this scenario upstream storage has been provided to alleviate flooding on Lodge Lane, and protect properties affected by the Herring Stream.

[26] In accordance with Mid Sussex's asset maintenance schedule

[27] For a good example, see the Pickering project, http://www.forestry.gov.uk/fr/slowingtheflow

With respect to the storage upstream of Lodge Lane a potential initial location has been identified to the east of Park Avenue (subject to landowner engagement and agreement, which has not been pursued as part of the SWMP). It is proposed that online storage is created at this location by widening the channel, to create a two stage flood channel. Offline storage has been discounted because of the topography in this part of the catchment. Two storage scenarios have been assessed at this location:

A. This option involves forming a two-stage channel and allows a 10 year return flow through the system. Any event above this is to be stored within this section of the channel. The required volume of storage to lessen flooding to Lodge Lane properties is 4700 m^3. This requires a plan area of 4500m^2 and the model indicated a significant reduction in flood risk to properties on Lodge Lane.

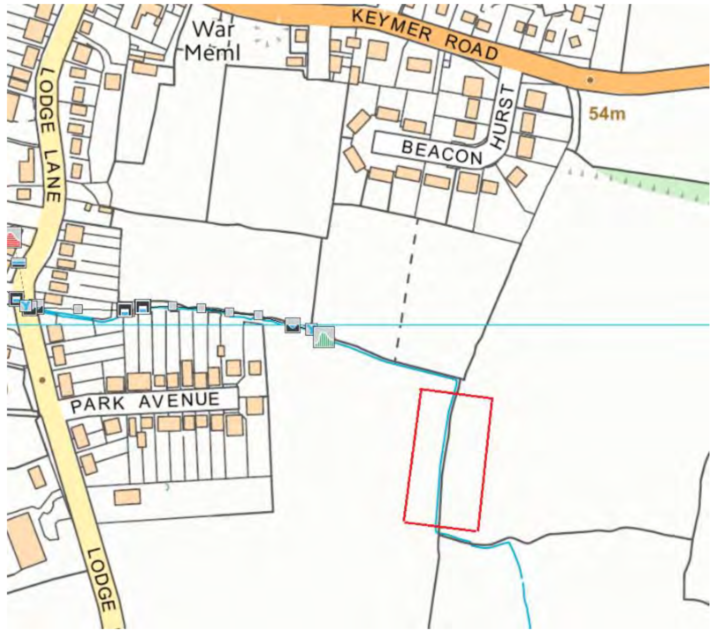

Figure 6-2 Approximate location suitable for online storage near Lodge Lane

B. This option similarly involves constructing a larger two-stage channel but alleviates flooding along the whole of the Keymer Stream including the culvert originating in Orion car park, which is forecast to flood under a 1 in 20 year return period (assuming it is free flowing). The required volume of storage to obtain this is 6500m^3 and to achieve this requires excavation over a plan area of 6300m^2. This option was modelled and was effective at relieving flooding downstream near Spitalford Bridge, and to Lodge Lane properties.

On the Herring Stream it is proposed to create an offline storage area near to the confluence of the two watercourses at the rear of Parklands Road (as illustrated in Figure 6-3).

The concept at this stage is to lower the right bank of the Herring Stream to allow it to naturally fill during flood conditions. Based on modelling undertaken for the SWMP it has been identified that the total volume of storage at this location should be in the region of 1500 m^3, with an associated plan area of 1600 m^2. Based on the modelled flood outputs this significantly reduces flood risk downstream near Spitalford Bridge.

A description of some of the key risks and issues associated with these storage areas has been provided in Table 6-2.

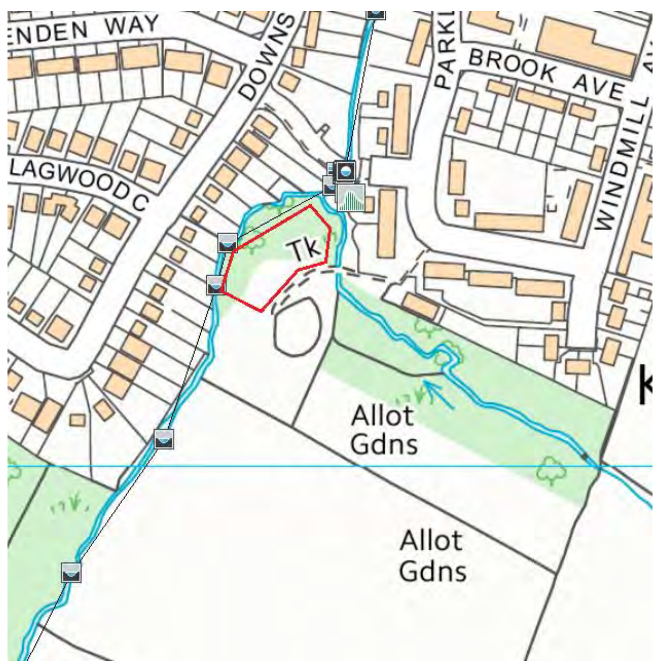

Figure 6-3 Approximate location for offline storage on Herring Stream

6.3.5 Option 3. Property level protection

Property level protection can include a range of measures at the household scale including; installation of flood doors, replacement of insulation with close cell insulation (followed by re-pointing with water resistant mortar), provision of air vent covers, or installation of flood gates, for example. Under this option all properties which are at Very Significant risk[28] under the Do Nothing scenario are assumed to be suitable for property level protection. This equates to 35 properties.

No property surveys have been undertaken for the SWMP, so it is not possible to assess which properties may be suitable for property level protection measures. For the purposes of the SWMP it has been assumed that all properties could be fitted with some property level protection measures.

[28] Greater than 1 in 20 chance of flooding in any given year

Table 6-2 High level appraisal of key issues associated with different options

Name of option	Access issues	Services issues	Proximity to buildings	Existing land use / ownership	Potential for inlet/outlet	Geotechnical risks	Other
Option 1 – Upstream land management	Access would be challenging as interventions would be spread across larger geographic areas.	Unknown	Upstream management would be distant from buildings	Unknown	Inlets / outlets would be through natural means (e.g. woody debris)	Unlikely	Less certainty about success, and harder to predict effectiveness
Option 2 – Storage upstream of Lodge Lane	Access may prove to be difficult. Area lies behind houses – Obtain access off New Road through field approx. 250m to site	Unknown	Nearest buildings are houses approximately 130m away from site	Unknown	Storage is to be online. Widen channel by 39m on both sides for 90m length of stream Offline storage not favourable	Mainly fine/coarse soil and sandstone Support needed for excavation Location of water table	Involves cutting down many trees
Option 2 – Storage on Herring Stream	Access can be obtained through Parklands Rd – Path of road leads to site, c.85m off Parkland Ave	Unknown	Nearest buildings are houses c.50m away from site, which is intercepted by trees/woodland	Unknown	No need for inlet and outlet, idea is to lower bank levels and restrict flow at stream to fill up in pond	Unknown	Would involve cutting down some trees
Option 3 – Property Level Protection	Majority of flooding to properties adjacent to Herring Stream at the rear, access unknown	N/A	N/A	Individual private householders	N/A	N/A	Potential low uptake of measures

6.4 Costs and benefits of measures

6.4.1 Costs

A summary of the costs of proposed measures is provided in Table 6-3, with further information provided in Appendix D. Costs have been prepared using information from SPONS costing books, engineering judgement, and experience of cost estimates prepared for other SWMPs for WSCC. For all costs a 20% uplift has been added for overhead and preliminaries and a further 8.25% added for the contractor fee. In addition, a 30% contingency has been applied because at this stage there are several risk items which could increase the overall fee estimate, including findings from the topographic survey, soil sampling, or consultation.

For option 1 (natural catchment management) and option 2 (storage) a £50,000 allocation has been estimated for the detailed design, enhancements of existing modelling, preparation of business case, additional topographic survey, and consultation. No allowance has been made at this stage for land acquisition. Finally, it should be noted that all material is assumed to be disposed of via landfill, rather than re-used on site. This is a conservative estimate at this stage, but there are likely to be opportunities to reduce the scheme costs by re-using some material on site, depending on its suitability.

Table 6-3 Cost estimate of options

Option ID	Features	Costs	Notes
Do Minimum	Clearance and de-silting of culverts / bridges (Damian Way, Lodge Lane, Orion Car Park, Spitalford Bridge) Improvement works to the Orion Car Park trash screen are completed Improvement works to the Damian Way and Lodge Lane trash screens are completed. Improvements to 1220mm culvert originating in Orion car park, based on defects identified in CCTV survey	Construction (improvement works to culverts and trash screen) = £50,000 Annual maintenance[29] = £2,000	Construction cost estimates: • £20,000 for Orion Car Park trash screen, based on discussions with MSDC • £30,000 for pipe rehabilitation on limited section of main length of culvert which originates in Orion Car Park[30] • £10,000 for improvements to Damian Way trash screen (assumed)
Option 1A	Herring Stream – Natural Catchment management	Appraisal and Design = £50,000 Construction = £734,000	

[29] Assuming clearance 12 times per annum

[30] Based on cured in place pipe lining for a 40m length of the 1220mm culvert which is more severely deformed (>20% deformation). More details provided here: http://www.ukstt.org.uk/trenchless-technology/lining-techniques/cured-in-place-pipe-lining-cipp. Should further length require rehabilitation or replacement this could significantly increase the costs

	approach[31] to achieve net storage of 1,500 m^3 Lodge Lane – 4,700 m^3 storage in catchment	Annual maintenance = £2,000[32]	
Option 1B	Herring Stream – Natural Catchment management approach to achieve net storage of 1,500 m^3 Lodge Lane – 6,500 m^3 storage in catchment	Appraisal and Design = £50,000 Construction = £925,000 Annual maintenance = £2,000	
Option 2A	Herring Stream – Online storage of 1,500 m^3 Lodge Lane – 4,700 m^3 storage in catchment	Appraisal and Design = £50,000 Construction = £615,000 Annual maintenance = £2,000	
Option 2B	Herring Stream – Online storage of 1,500 m^3 Lodge Lane – 6,500 m^3 storage in catchment	Appraisal and Design = £50,000 Construction = £806,000 Annual maintenance = £2,000	
Option 3	Property level protection of 35 properties	Appraisal and Design = £35,000 Construction = £157,500 No maintenance, but replacement every 20 years	Appraisal and design assumed to be £1,000 per property. Construction assumed to be £4,500 per property[33]

6.4.2 Benefits

To estimate the annual average damages (AAD) from the two baseline simulations outlined in Section 5.1 the following approach has been undertaken:

- merge the National Receptor Dataset (NRD) and OS MasterMap data to create a single building layer for flood damage calculation;
- buffer the buildings layer by 2m to account for sensitivities in the model grid resolution[34];

31 This is difficult to cost because there is less experience in delivering this type of flood risk management infrastructure. Furthermore the exact nature of the works has yet to be scoped out

32 Plus £25,000 every 10 years for inspection and improvement works

33 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/290837/scho0711buak-e-e.pdf

34 As the model resolution is 2m flood water can be 2m from a property in the model, but in reality that property could be at risk of internal flooding. A 2m buffer removes the risk of not accounting for properties which may flood

- calculate the maximum and average depth of flood water within the 2m buffered building layer for the full suite of storm return periods (1 in 2, 5, 10, 20, 30, 50, 75, 100, 200) for the two baseline modelling simulations;
- calculate the storm return period at which each residential and commercial property is likely to start flooding;
- using the maximum depth at the property boundary use the Multi-Coloured Manual to estimate the damage at each property for each storm return period (this is subsequently converted to an Annualised Average Damage);
- calculate other losses suitable at this stage of the analysis, which include damage to vehicles, social and health impacts (intangibles), and emergency services costs, using information from the Multi-Coloured Manual, and;
- apply discounting over a 100 year appraisal period to give the Present Value (PV) damages expected within each hotspot area[35].

In calculating the AAD several assumptions have been made, which are noted below.

- The onset of flooding at any given property was taken when flood depths within the 2m buffer surrounding the building exceeded 150mm.
- Residential properties were assumed to be flooded internally when the depth of flood water was greater than 150mm[36]. Without undertaking a threshold survey of each property this threshold is relatively conservative.
- For a full appraisal to support an application for Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GiA) further damages could be considered, including (but not limited to) damage to highway or other transport/utility infrastructure, risk to life and environmental costs and benefits. Furthermore climate change assessment would need to be undertaken which was not carried out for the initial SWMP appraisal.

The results of the benefits appraisal are provided in Table 6-4, and shown illustratively on flood risk maps provided in Appendix F. The Do Nothing damages are more than £9m over the 100 year appraisal period, with 33 properties predicted to be at risk for a flood event with an annual chance of flooding of 5% or greater. However, for the Do Minimum scenario, total damages over a 100 year period reduce to £2.46 million. This is a reduction of more than £7 million, which shows the sensitivity of the catchment to blockages at key locations. Furthermore the numbers of properties with an annual chance of flooding of 5% or greater reduces from 33 to 9. These results demonstrate the vital importance of continued maintenance at culvert inlets to mitigate flood risk.

With both the storage options in place Present Value damages reduce by a further £1.2-£1.4 million, depending on the volume of upstream storage provided within the Lodge Lane catchment. Whilst there is only a modest reduction in Present Value damages compared to the Do Minimum scenario, the numbers of properties at risk of flooding continues to reduce with the options in place, especially for properties with an annual chance of flooding of 1.3% or greater (1 in 75 year storm event). The number of properties with an annual chance of flooding of 1.3% or greater reduces by nearly half to two-thirds, depending on the preferred volume of upstream storage.

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[35] Discounting is a technique used to compare the costs and benefits that occur in different time periods. It is based on the principle that, generally, people prefer to receive benefits now rather than later and all costs and benefits should be discounted in the analysis. The SWMP has used the standard Green Book methodology for discounting: 3.5 per cent for 0-30 years, 3.0 per cent for 31-75 years, and 2.5 per cent for 76-125 years into the future.

[36] This is required to estimate the Outcome Measure 2 benefits for Flood and Coastal Erosion Risk Management Grant in Aid applications.

Property Level Protection is a viable alternative within Hassocks, although the benefit is calculated differently to the storage options, based on guidance from the Environment Agency[37], which recommends that the duration of benefits should be 20 years "unless there is robust evidence that the individual measures concerned are expected to deliver benefits for a longer period." Furthermore the Environment Agency guidance recommends that total benefits should be estimated at £30,000 per property. In this case it has been assumed that Property Level Protection could be applied to all 33 properties with an annual chance of flooding of 5% of greater under the Do Nothing scenario, which gives total benefits of £990,000.

[37] Environment Agency (2013), Flood Defence Grant in Aid 2013/14 allocation process, Medium Term Plan Guidance and Template

Table 6-4 Damages and properties flooded associated with baseline scenarios

Criteria	Do Nothing Scenario	Do Minimum Scenario	Option 1A / 2A[38]	Option 1B / 2B	Option 3
Annualised Average Damage	£189,000	£61,300	£37,271	£11,857	-
Present Value Damage over 100 years	£9.73 million	£2.46 million	£1.20 million	£1.06 million	-
Present Value Benefits over 100 years (compared to Do Nothing)	-	£7.27 million	£8.53 million	£8.67 million	£0.99 million (over a 20 year period, which is the assumed life of the PLP)
Residential properties at Very Significant probability of flooding (annual chance of flooding 5% or greater)	33	9	4	4	0 (assuming property level protection can effectively be applied to all 33 properties at risk under Do Nothing scenario
Residential properties at Significant probability of flooding (annual chance of flooding greater than 1.3% but less than 5%)	43	33	19	11	43
Residential properties at Moderate probability of flooding (greater than 0.5% but less than or equal to 1.3%)	49	55[39]	52	46	49

[38] Option 1A/2A and 1B/2B have the same benefit, because they are a different engineering option to achieve the same net benefit in terms of reduction in properties flooded

[39] This needs further investigation into why this is greater than the Do Nothing scenario

6.4.3 Outcome measures and funding

This section considers the potential funding available to implement the proposed options outlined in the SWMP (options 1-3). It does not consider potential funding of ongoing maintenance of trash screens or watercourses within the catchment, which should be undertaken by riparian owners or the relevant local authority, by agreement.

The most significant source of funding for flood risk management in England is Flood and Coastal Erosion Risk Management Grant-in-Aid (FCRM GiA). This is provided by Defra and administered by the Environment Agency, although funding approvals are also subject to the consent of the relevant Regional Flood and Coastal Committee (RFCC).

To be eligible for FCRM GiA a flood risk management scheme must deliver against defined 'Outcome Measures', which are used to calculate how much funding a scheme will receive. There are four categories of 'Outcome Measures'. These are listed below, alongside the payment rate associated with each outcome:

- OM1 - All benefits arising as a result of the investment, less those valued under the other outcome measures (payment rate of 5.56p per £1 of qualifying whole life benefit).
- OM2 - Households moved from one category of flood risk to a lower category (payment rates are 45p per £1 qualifying whole life benefit for 20% most deprived households, 30p per £1 whole life benefit for 21-40% most deprived households, and 20p per £1 for 60% least deprived households).
- OM3 - Households better protected against coastal erosion (payment rate same as OM2).
- OM4 - Statutory environmental obligations met through flood and coastal erosion risk management

The maximum amount of FCRM GiA funding available for each project will be based on the value of qualifying benefits under Outcome Measures 1, 2 and 3, plus the number of environmental outcomes achieved under Outcome Measure 4, each multiplied by the relevant payment rate. The total is then divided by the whole life costs of the project and expressed as a percentage score; the 'PF Score'. This is shown in Figure 6-4.

Eligible **£ FDGiA** = **H** + **B** + **E**

H = value of qualifying **Household benefits** x payment rate

B = value of **other whole-life Benefits** x payment rate

E = no. of **Environmental outcomes** x payment rates

PF Score % = Eligible **£ FDGiA** / **Project whole life costs**

Figure 6-4 Calculating eligible FCRM GiA (NB: FDGiA is now known as FCRM GiA)

The benefits, costs and associated partnership funding scores for each option are presented in Table 6-5. The results of this analysis demonstrate that the partnership funding score ranges from 57% to 76%, and therefore for all options additional funding or cost efficiencies will need to be found to secure FCRM GiA funding. It is likely that cost efficiencies can be found from the preliminary cost estimates which have been prepared for the SWMP.

Option 3, which assumes Property Level Protection is implemented for all properties with an annual chance of flooding of 5% of greater under the Do Nothing scenario, has the smallest funding requirement, but the duration of benefits for this investment is only 20 years, compared to the assumed 60 years for the land management and storage options. Furthermore, whilst Property Level Protection reduces flood risk to individual properties it does not reduce the wider effects of flood water in urban environments, such as vehicle damages or risks to life.

The storage options (options 1 and 2) are highly cost beneficial to implement, compared to the Do Nothing scenario. From the high level costing undertaken for the SWMP option 2A appears to be the most attractive of the storage options, which involves a single offline balancing pond on the Herring Stream and a smaller online balancing pond east of Lodge Lane. The costs of natural catchment management (option 1A or 1B) are highly uncertain because there is less evidence about the delivery costs of these approaches, and the exact locations and nature of interventions has not been determined.

Table 6-5 Summary of benefits, costs and partnership funding score for options

Criteria	Options				
	1A	**1B**	**2A**	**2B**	**3**
Benefit: Cost Ratio	9.2:1	7.8:1	10.7:1	8.7:1	5.5:1
Present Value Benefit	£7,990k	£8,114k	£7,990k	£8,114k	£990k
Present Value Costs	£860k	£944k	£746k	£930k	£182k
Duration of benefit[40]	60	60	60	60	20
Partnership Funding Score	66%	57%	76%	63%	60%
Third party funding / cost savings required to secure FCRM GiA	£260k	£410k	£155k	£302k	£72k

There will be a need to secure additional funding to deliver one of these options, irrespective of the preferred option. Some of the possible sources of funding could include[41]:

- Regional Flood and Coastal Committee;
- funding from West Sussex County Council and/or Mid Sussex District Council;
- Water Framework Directive funding where interventions could be used to meet the River Basin Management Plan;
- funding through the New Environmental Land Management Scheme (NELMS)[42], or;
- one off grants by Defra – there is no certainty of Defra funding but in the last 5 years Defra have provided one off grants for River Restoration Funding[43] or Catchment Restoration Funding[44], and similar funding may be available in the future.

40 Assumed to be 60 years for storage options, based on typical asset life cycle before major re-investment required

41 For further information on potential funding sources refer to Defra (2012), Partnership funding and collaborative delivery of local flood risk management: a practical resource for LLFAs (FD2643)

42 https://www.gov.uk/government/news/new-environmental-scheme-for-farmers-to-prioritise-biodiversity

43 http://www.land-water.co.uk/2012/02/defra-confirms-28m-funding-for-river-restoration-projects/

44 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/248857/pb14032-catchment-restoration-fund-report.pdf

6.5 Environmental constraints

A summary of the environmental constraints and benefits in relation to the proposed options based on a preliminary desk-based study is provided in Appendix G. This has not identified any absolute environmental constraints, but there are important design considerations to be incorporated depending on the preferred options taken forward in Hassocks.

6.6 Action plan and next steps

The SWMP Technical Guidance states that:

"The final stages of the SWMP study will be to collate the information from the first three phases into a study document, and where appropriate, to prepare an action plan (i.e. the SWMP) for implementing the preferred structural and non-structural option(s). The action plan must be based on the evidence base collated as part of the SWMP study. Contents and format for the action plan will vary depending on local circumstances, but should outline the preferred option, the actions required by each partner and stakeholder, who will pay for the actions, and the timetable for implementation."

Therefore in Table 6-6 a list of the actions and next steps to progress the proposed measures in this SWMP has been provided. It clearly identifies the actions, responsibilities and timescales for implementation. The actions are in sequential order to ensure the most urgent and important actions are undertaken first.

Table 6-6 Action Plan for Hassocks

Action	Responsibility	Timescale for action
Undertake consultation on report with Mid Sussex District Council and Hassocks Parish Council	WSCC	Summer / Autumn 2016
Implement emergency and urgent works identified by Mid Sussex's asset and CCTV survey (Orion Car Park trash screen, culverts and Damian Way trash screen)	Mid Sussex District Council	End 2016
Maintain watercourses	Riparian Owners	As required under the Land Drainage Act 1991
Continue maintenance of structures	Mid Sussex District Council	In accordance with Mid Sussex District Council asset management plan
Undertake engagement with landowners about implementing natural catchment management approach or online/offline storage	WSCC / Adur and Ouse Rivers Trust	Autumn 2016
Undertake further topographic survey within channels to support design of upstream measures	WSCC / Mid Sussex District Council	Autumn 2016
Based on engagement and topographic survey undertake detailed design of options. This will include enhancing the hydraulic model to make it suitable for design purposes. The hydraulic model should also be suitable for fully testing all proposed options. Further economic appraisal of options should be undertaken at this stage to maximise opportunities to secure FCRM GiA	WSCC / Mid Sussex District Council	Spring 2017

Securing funding for the preferred option, using a combination of sources considered in Section 6.4.3.	WSCC / Mid Sussex District Council	Spring 2017
Implement preferred option	WSCC / Mid Sussex District Council	TBC, depending on preferred option, engagement and funding

Appendix A Roles and responsibilities

1. Roles and Responsibilities

Appendix B Study boundary

1. Hassocks Study Boundary

Appendix C Geology and hydrogeology

1. Hassocks Geology and Hydrogeology Tech Note
2. Hassocks Bedrock Geology
3. Hassocks Superficial Geology

Appendix D Conceptual drawings and costs

1. 488929.10.01-01 (Overview)
2. 488929.10.01-02 (Herring Stream)
3. 488929.10.01-03 (Lodge Lane)
4. 488929.10.01-04 (Details)
5. Lodge Lane Initial Cost Estimates
6. Herring Stream Initial Cost Estimates

Appendix E Partnership funding calculators

1. Hassocks PF Calculator - Option 1A
2. Hassocks PF Calculator - Option 1B
3. Hassocks PF Calculator - Option 2A
4. Hassocks PF Calculator - Option 2B
5. Hassocks PF Calculator - Option 3

Appendix F Flood mapping outputs

1. Flood Mapping.zip

Appendix G Environmental constraints

1. Hassocks Environmental Constraints Plan
2. Hassocks Options Environmental Constraints