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# Glossary of Terms

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<th>Definition</th>
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<tr>
<td>Address point data (ADD2)</td>
<td>Geographic point data supplied by Ordnance Survey describing both the property type and function.</td>
</tr>
<tr>
<td>Aerial Reduction Factor</td>
<td>This is the ratio between the average rainfall intensity for a set duration and return period over a given area, and includes the intensity of the same duration and period at a set point.</td>
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<tr>
<td>ASCII File</td>
<td>File format commonly used to store ground elevation data.</td>
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<tr>
<td>Catchment</td>
<td>Area of land where associated rainfall drains to one point, usually a river or body of water.</td>
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<tr>
<td>DEFRA</td>
<td>Department for Environment, Food and Rural Affairs</td>
</tr>
<tr>
<td>Diffusion wave equation</td>
<td>Used by Flood Risk Mapper to calculate how flow travels across the simulation grid. Equation is obtained by neglecting the acceleration terms in the 2D shallow water equations.</td>
</tr>
<tr>
<td>Digital Terrain Model (DTM)</td>
<td>A digital representation of ground surface topography or terrain feature code file</td>
</tr>
<tr>
<td>Used by Flood Risk Mapper to convert the MasterMap data into different surface types. The file controls the sampling of the MasterMap data to help ensure flood paths between buildings are represented.</td>
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<tr>
<td>FEH catchment descriptors</td>
<td>Various headings for information relating to a specific catchment as specified within the Flood Estimation Handbook</td>
</tr>
<tr>
<td>Flood Profile File</td>
<td>Describes how the inflows to Flood Risk Mapper changes with time.</td>
</tr>
<tr>
<td>Flow Profile ID</td>
<td>Reference number allows different flow profiles to be used in a single simulation.</td>
</tr>
<tr>
<td>Geo-Referenced</td>
<td>Process of allocating a geographic attributes to data that allows it to be displayed on a map/GIS.</td>
</tr>
<tr>
<td>Grid Resolution</td>
<td>Size of simulation grid, which can vary between 0.5m and 10m. The resolution influences the accuracy of the result and speed of the simulation.</td>
</tr>
<tr>
<td>Hydrograph</td>
<td>Graph describing how a flow rate changes with time.</td>
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<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>ITN</td>
<td>Integrated Transport Network is supplied by Ordnance Survey and is a geographic data set that describes the type and category of all roads in the UK.</td>
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<tr>
<td>Manning’s Coefficient</td>
<td>Represents the frictional resistance of water passing over the surface of an open channel.</td>
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<tr>
<td>Manning’s formula</td>
<td>Formula used to calculate open channel flow or free-surface driven flow.</td>
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<tr>
<td>MasterMap</td>
<td>Geographic dataset contains over 450 million individual features that represent objects such as buildings, fields, fences and letter boxes, as well as intangible objects such as county boundaries.</td>
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<tr>
<td>Medium Super Output Areas (MSOA)</td>
<td>Unit of geography used in the UK for statistical analysis and contains an average population of 7200</td>
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<tr>
<td>Surface water Flooding</td>
<td>Flooding caused by a period of heavy rainfall resulting in water collecting on the ground and not being able to drain away.</td>
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<tr>
<td>Rainfall Hyetographs</td>
<td>A hyetograph is a graphical representation of the distribution of rainfall over time.</td>
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<tr>
<td>Return Period</td>
<td>A measurement of the rarity of a flood / storm / rainfall event, defined as the average interval in years between occurrences of floods that exceed it.</td>
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<tr>
<td>Surface type number.</td>
<td>Used to describe the different surfaces use by Flood Risk Mapper to apply different elevation, infiltration and roughness characteristics across the simulation are.</td>
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<tr>
<td>TOID</td>
<td>Unique reference number allocated to each MasterMap topographic, ITN and Address2 item.</td>
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<tr>
<td>Topography</td>
<td>Graphic representation of the surface features of a place or region on a map, indicating their relative positions and elevations.</td>
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1 Introduction

1.1 Project Background
Under the Flood and Water Management Act 2010 and the Flood Risk Regulations 2009, local authorities have new responsibilities for a leadership role in local flood risk management, of which the production of Surface Water Management Plans (SWMP) will form a key part.

1.2 Assessment Level
Defra’s SWMP Guidance (March 2010) outlines three levels of assessment for SWMPs (strategic, intermediate or detailed).

1.2.1 Strategic Assessment
The strategic assessment should be based on existing information including records of past flooding and the EA mapping of areas at risk of surface water flooding.

There is good evidence that the residential areas of Bournemouth are subject to repeated flooding, the last of which occurred in 2008. This indicates a significant flood risk.

The first generation EA surface water flood map identified approximately 4000 residential properties at risk of flooding in a storm with a probability of occurrence of 1:200 years. This map is shown in Appendix A.

Due to the flood risks identified from the EA mapping backed up with knowledge of past flooding, Defra assessed that Bournemouth Borough Council (BBC) should carry out a more detailed SWMP and so awarded a grant of £75,000 for this work. The scope of this project is to carry out a more detailed intermediate level assessment of the flood risk.

1.2.2 Intermediate Assessment
An intermediate assessment enables a greater understanding of localised surface water flooding. The intermediate assessment should identify the nature and sources of the flooding, and the frequency and severity of flooding. The intermediate assessment should also calculate the damage cost and monetised risk from flooding and identify potential mitigation measures so that a cost benefit case can be made for further action.

BBC has commissioned Mouchel to undertake this intermediate level assessment for the entire Borough.

1.2.3 Detailed Assessment
Following from this project there will be a need to work with the Environment Agency (EA) and Wessex Water (WW) and other stakeholders to carry out detailed assessments of the highest risk areas to design and implement mitigation measures.
1.3 Technical Approach

The EA flood maps were produced using a bare earth model (this means the model excludes features such as vegetation, buildings, bridges, etc.) to look at the flooding on a borough wide strategic level to identify the areas with significant flood risk. The modelling ignores the contribution of piped drainage systems to managing flood risk and so may tend to provide a conservative estimate of the flood risk. It reports the number of properties likely to flood in a storm with a probability of 1:200 years but does not define the damage cost or monetary risk of flooding.

This study provides more detail than the initial EA study.

The SWMP Guidance is not prescriptive as to how the intermediate assessment is carried out. Objectives for the work have been agreed in advance with BBC to support the outcomes and decisions to be made.

The current water company drainage model was not available for this project and so a broad scale modelling approach was used to produce flood maps and to identify areas at risk of flooding. This is described in Section 2.

Mouchel has produced flood maps for 6 return periods and has calculated the potential flood damage cost due to these events. These have been integrated to an Expected Annual Damage cost for all areas of the borough.

The areas at highest risk have then been identified and potential mitigation measures have been assessed for these areas.

As a part of our baseline assessment of surface water flooding we have taken information from the Level 1 Strategic Flood Risk Assessment (February 2008, Halcrow) and The Dorset Stour Catchment Flood Management Plan (December 2009, EA).

The flood maps produced as part of this study have been compared with the EA flood maps to ensure that there are no major anomalies in terms of identification of flood risk.

The output of this assessment can be used to influence future capital investment, drainage maintenance, public engagement and understanding, land-use planning, emergency planning and future developments.

1.4 Future work

This study also identifies the areas to be carried forward for a more detailed assessment of mitigation measures. These more detailed assessments will require the use of the water company drainage model and it is hoped that this will be made available.
2 Modelling Process: Technical Report

A variety of different modelling approaches are available for surface water flooding, each of which has different advantages and disadvantages. The following section is a Non-Technical Summary of the BBC SWMP modelling approach. More technical detail can be found in Appendix C.

For this project Flood Risk Mapper (FRM) has been utilised for its effectiveness in delivering useful borough wide results facilitating further decision making. FRM is an ‘in-house’ software tool developed by Mouchel in which rainfall is applied directly to a surface and is routed overland to predict surface water flow pathways and locations where water will pond. The presence of underground drainage has been accounted for by adjusting the amount of water assumed to soak into the ground (infiltration).

2.1 Data Collection and Processing

The SWMP required data to be collected that reflects the topography, environmental characteristics and information on the historic flooding that has occurred in the catchment. This information was then used to generate and validate the surface water flood pathways and ultimately to quantify the initial surface water flooding risk for the catchment.

2.1.1 Data Collection

The data sets collected from BBC and processed for this study include:

- Digital Terrain Model – Bare earth DTM was collected, which has had all the buildings removed;
- Ordnance Survey MasterMap Data – ‘Intelligent mapping’ used to both generate the flood paths and quantify their impact;
- Address point data (ADD2) – Used to quantify the impact of the flood pathways and calculate risk;
- Rainfall Hyetographs – FEH was used to generate the rainfall profiles to be assessed in the study;
- Soil maps – Use to determine the soil infiltration rates;
- Environment Agency surface water flood maps – The maps were generated by the Environment Agency using a 5m resolution DTM, with no account for urban features, for a 1 in 200 year, 300 minute duration storm event;
- Historic Flood Incident data – Information relating to flooding events that have previously occurred in the catchment;
- Gully data – Geographic layer showing the gully locations across the catchment; and
- Super Output Areas (SOA) – Geographic layer used in the UK for statistical analysis. There are two different levels; Medium - containing an average
population of 7,200, and Low with an average population of 1500. SOAs were created with the intention that they would not be subject to frequent boundary changes. This makes SOAs more suitable than other geographic units (such as wards) because they are less likely to be altered, and thus SOAs are more suitable for use in change over time analysis.

2.1.2 Data Processing

Digital Terrain Model (DTM)

The initial data sets were obtained from Bournemouth County Council. The files provide the basis for the elevation grid that will be used in the model to determine the ground levels. The DTM files were loaded together with the Address Point (ADD2) boundary to ensure coverage of the entire area and that the watersheds impacting on the catchment were accounted for. The screen shot below shows the Bournemouth DTM data with the ADD2 boundary overlaid.

![Figure 1: Digital Terrain Model with Address Point boundary of Bournemouth](image)

The area was checked to ensure all bridges had been removed from the DTM. This was done by following any main roads and railways to ensure no bridges were still present. By doing this check it ensures the ground data is represented as accurately as possible, giving a true reflection of reality within the model, i.e. water will find the lowest path to take, which will always be under a bridge as opposed to over it. Any bridges that were present were edited to give the level of the average of the ground beneath it. Generally most of the bridges were removed from the DTM.

The initial model simulations identified a number of natural dams/embankments within the DTM data which caused significant depth of flooding, which are unrealistic. In reality, culverts or other drainage systems are present to transfer water from one side of the embankment to another. To improve the accuracy of the model both
upstream and downstream at these points it was decided to remove these natural dams/embankments by modifying the DTM data.

The modified data was saved and exported out of Global Mapper as an ASCII file on a 2.5m grid. The 2.5m resolution was initially tested using FRM, but following the completion of trial model runs, it became apparent that it would consume a considerable amount of time to run the model on this grid resolution. The decision was taken to run the models on a slightly coarser 5m grid, which would decrease running times, but would still provide indications of where flows are likely to accumulate.

MasterMap

The MasterMap data was changed from the compressed format into a seamless MapInfo table. The seamless tiles allow large areas of MasterMap data to be viewed. The information is used to increase the accuracy of the flood pathways generated by FRM and to quantify their impact. The address point information has been combined with the MasterMap data to enable the buildings functions to be identified.

Surface Grid Generation

The urban environment is represented in FRM through the use of a surface grid. This describes a type of surface (e.g. road, building, watercourse, open land, verge, etc.) by allocating a surface number.

To give a more accurate representation of the overland flow through the urban environment FRM internally modifies the ground levels of each grid square to
represent the obstruction caused by buildings and the channelling effect of roads. Grids within road objects are lowered by 100 mm to represent the gutter levels and grids within buildings are raised. Initially buildings were raised by 5 m to represent a typical building height but this was found to sometime trap unfeasibly large depths of flow behind large buildings and so this method was modified to raise buildings by only 300 mm. For large depths of flooding therefore the building does allow flow to pass – as it would by finding flow paths through building openings.

For buildings this adjustment is done for each individual grid based on the ground level of the grid cell rather than by defining a notional building level that is common across the building area.

This level adjustments are only done for the calculations within Flood Risk Mapper and this adjusted level is not reported as the ground level of the grid.

If two or more surface numbers are within an individual grid square, then the one with the highest surface number is assigned to the grid. This means that where there is an open flood path between buildings then the grid level will not be raised even though parts of the cell are within buildings. This enables flood paths between buildings to be represented as shown below.

![Figure 3: Surface Grid to assign surface type and corresponding infiltration](image)

As noted above, the grid resolution was reduced from 2.5m to 5m. In theory this could result in less detail being provided for the buildings, which would affect the flood pathway accuracy. However the process has been controlled to ensure that the level of accuracy is replicated from the 2.5 to the 5m resolution.

A final modification to the surface grids was required to optimise the simulation times for the pathway simulations. The pathway simulations were completed on 2.5km grid squares and the reasoning for this is explained in the Pathway Modelling section (Section 3.3).

### 2.2 Source Modelling

The source modelling determines the locations where flows enter onto the surface and the flow characteristics. For surface water flood modelling, this consists of flow
points that represent rainfall and how it changes with time. This section of the methodology sets out how the flooding location and rainfall profiles have been generated for Bournemouth’s surface water modelling

2.2.1 Flooding Locations
The surface water modelling works by introducing rainfall on to each 5m grid square and this has been achieved by importing the surface grid into FRM and changing its attributes to include; coordinates of each flooding location, flood flow rate and associated hydrograph reference.

The flooding locations file has then been divided up into 2.5km grid squares that cover the entire catchment. This approach was taken as current computer hardware constraints limit the size of the surface water modelling simulations that are possible. This issue is discussed further in the ‘Pathway Modelling’ section (Section 3.3).

2.2.2 Rainfall Profiles
The change of rainfall intensity with time was represented in the simulation through the use of a Flood Profile file. The Flood Profile table provides FRM with information in regard to each rainstorm event. An example of what the Flood Profile file may look like can be seen in Table 1 for the 100 year, 30 minute rainstorm event.
### Table 1: Example flood profile for the 100 year, 30 minute rainstorm event

Flood profiles have been generated using InfoWorks CS software and based on the Flood Estimation Handbook (FEH) catchment descriptors for the Bourne Stream catchment, which are shown by the outline area in Figure 4 below. The rainfall profiles were modified slightly to minimise the number of points on the hydrograph used by Flood Risk Mapper, which significantly influences the run times. The modifications maintained the overall flood depth and peak intensity for each event.
Next the hyetographs were converted into a hydrograph by multiplying the rainfall intensity by the cross-sectional area of each grid square, which is 25m$^2$, to give a flow rate from each unit area in m$^2$ per second. A climate change factor has been incorporated, (from Table B.2, Planning Policy Statement 25: Development and Flood Risk, Communities and Local Government, March 2010) in the rainfall events by increasing the intensities (effectively the volume of rain falling) by 20%.

Rainfall profiles were initially developed for storms with a 1% annual probability of exceedance (1 in 100 year return period) with the following durations; 15, 30, 60, 120, 360 and 720 minutes to determine the critical duration for the catchment. The rainfall profiles for these events are shown in Figure 5.
It is recognised that the critical duration would vary for:

- different areas of the catchment due to topography;
- time of concentration and upstream surface characteristics; and
- different duration events, which would potentially flood different properties.

Shorter high intensity events will lead to greater impact on those properties within the catchment flood channels, compared to longer duration events with low intensity that impact on properties located within topographic depressions.

The 1 in 100 year storm for the centre of Bournemouth was simulated for a range of durations to determine the ‘worst case’ duration in terms of number of properties flooded. This used initial assumptions about how water levels were compared with property thresholds and so the absolute numbers of properties are different from the final results but the relative numbers for different durations are valid.

The results are shown on the Figure 6 in terms of property flooding and can be summarised as:

1) The 15 minute storm duration led to the highest total number of properties with a low depth of flooding (less than 150mm, so below the assumed property threshold). This would normally be classified as external flooding but would be counted as internal flooding if the water entered through airbricks to the space below a suspended floor.

Figure 5: 1 in 100 year rainfall profiles for several storm durations
2) The 720 minute storm duration led to the highest number of properties flooded with flood depth over 450mm.

**Figure 6: Variation of building flooding with storm duration**

The depths shown in Figure 6 are depths above ground level outside the building so include both internal and external flooding. Depths greater than 150 mm indicate internal flooding.

The relatively flat line shown in Figure 6 for most of the flooding depths made it difficult to choose a definitive critical duration. It was therefore decided to use the critical duration identified by BBC from the model of the sewerage system, which was 120 minutes.

The identification of a single storm duration for the model allowed the profiles for the 10, 20, 30, 50, 100 & 200 year return periods to be generated from InfoWorks using the FEH parameters. The rainfall profiles are shown in Figure 7.
No aerial reduction factor was included within the rainfall events as the primary need was to identify localised flood areas and not flooding where there is a large upstream catchment area. Therefore it is anticipated that the results obtained are likely to be conservative and will need to be refined further during the detailed assessment stage.

Critical duration assessment was completed with the buildings represented as roof levels 5m above the surrounding ground level. This has subsequently been changed to 0.3m to more accurately reflect the fact that properties will flood at some point as the water level rises and hence no longer be a complete barrier to flow. This change will reduce the number of properties with a flood depth greater than 450mm for the longer duration events.

2.3 Pathway Modelling

The purpose of the pathway modelling was to represent how flood water travels across the surface. The output of this process was a set of mapping layers representing the flood path and describing the characteristics of the flood path, including depth and time to flood.

To prevent the flood pathways being simulated outside each simulation grid square and subsequently extending the simulation times unnecessarily, the surface grid for a 10m strip around the edge of each square was assigned a high infiltration rate. This allowed the flows to stop at the edge of the grid square and did not unnecessarily extend the simulation times by travelling beyond the 2.5km grid square being considered.
2.3.1 Methodology

The pathway modelling was completed using Mouchel’s Flood Risk Mapper (FRM) software, which is a 2 dimensional surface routing software application. The flow routing process in the software accounts for the local ground levels, as well as local surface characteristics such as surface roughness and infiltration characteristics. Flow is simulated travelling across the surface using a two dimensional diffusion wave equation which is obtained by neglecting the acceleration terms in the 2D shallow water equations, which simplifies the calculation and makes it faster to calculate. The down side to this approach is the inability to calculate velocity with a high degree of accuracy.

2.3.2 Application

The application of FRM for surface water modelling purposes is constrained by the capability of current computer hardware. These constraints led to the model using a grid resolution of 5m and a simulation grid of 2.5km x 2.5km. The study area has been divided into 20 x 2.5km x 2.5km squares and the grid layout has been generated to enable FRM to simulate flows travelling down a catchment as much as possible. The grid layout for the Bournemouth surface water model is shown in the Figure 9. Each square is simulated separately and the flood water is allowed to fall off the edge.
To account for any local flow characteristics at the edge of each square, the grids have been regenerated with an offset of 1.25km in both an easterly and northerly direction. The new squares are shown below and simulated to produce a new set of flood paths. The flood paths from both sets of squares are then aggregated together using the maximum flood depth for each individual flood cell. This approach allows a surface water model to be generated for a large area without extended computer simulation times. This approach will not generally represent any watercourse flows where the upstream catchment exceeds 2.5 km in length, but it likely that any such flow paths would exist as water courses and therefore would be modelled using conventional 1 dimensional modelling techniques.
Figure 9: Regenerated surface water flow grid to incorporate an offset of 1.25km

A further simulation area was completed to account for an historic flooding problem, associated with the Winton Catchment that crosses a number of the grid squares. The extent of this third simulation area is shown in red on the Figure below.

Figure 10: Historic flooding location represented with the predefined grid square for Winton Catchment
2.3.3 Flood Map
The output from the pathway modelling was a flood map with a geographic dataset containing the flooding information for each grid square. A series of flood maps have been produce for return period of 1 in 10, 20, 30, 50, 100 & 200 year return period for critical duration (120 min) storm, and are included in Appendix B.

![Flood Map](image1.png)

**Figure 11: Visual example of the flood paths developed by FRM**

2.4 Receptor Modelling
The receptor modelling process is required to map the flood pathway data onto the properties in the catchment to give predicted flood depth for each return period against each MasterMap property. This information is then used in the next step to calculate the flood damage cost and flood risk.

2.4.1 Methodology
There is considerable uncertainty involved in the receptor modelling as there was no information on the actual threshold levels of the properties, hence this needed to be inferred from the surrounding ground levels. The method can be updated with actual threshold levels where these are available and it may be appropriate to carry out some surveys in critical areas to establish this as part of future detailed assessments.

The receptor modelling is carried out in MapInfo using queries to correlate the property location with the depth of flooding in the flood paths. The steps are:

- Infer threshold levels for all buildings;
- Prepare “building envelope” objects;
- Find the maximum water level within the “building envelope”; and
• Compare water level with threshold level to give flood depth.

Inferred Threshold Level
The OS MasterMap seamless table is used to identify all properties. The current application has only looked at buildings but it is possible to use the same method to identify flood depths on roads or other features.

A table is created containing the following information for each building object in OS MasterMap:
• Unique building reference (MasterMap TOID field);
• Area of building;
• Maximum ground level within the building from the DTM; and
• Threshold level assumed to be 150 mm above the maximum ground level, but this can be over-ridden with survey data.

Building Envelope
As described in the earlier section, the flow routing in FRM forces the flow to pass around buildings to represent the obstruction that they cause. If only the flood depths within the building itself were assessed there is a risk that no flooding would be shown even though there was flooding immediately adjacent to it. A set of temporary map objects have therefore been produced, representing the buildings with an extra buffer of 2 m all around them so that flooding immediately outside the building is also accounted for.

Find Maximum Water Level
For each return period in turn the maximum flood level within each building envelope object is searched for and stored in a results table.

Where a flood path element has a water depth of less than 10 mm this is ignored, as this is unlikely to have any impact on adjacent properties.

Calculate Flood Depth
For each building the flood depth is calculated as the maximum flood level minus the building threshold. Flood levels are recorded to 150 mm below floor level so that the minor flood damage costs for external flooding can be calculated.

The outputs from the receptor modelling allow the depth of flooding immediately outside of each property to be quantified for the different return periods, as shown in Figure 12.
2.5 Risk Quantification

This section of the report describes how the predicted flood depths from the different return periods is used to calculate the overall financial risk, and then aggregate this to geographic areas. This enables the highest risk sites to be targeted and further surveys and modelling to be prioritised based on greatest risk.

2.5.1 Definition of flood impact

Internal and external property flooding are the only impacts considered by the risk assessment, but the outputs from the flood pathway modelling allow other impacts (e.g. Highway, open land, etc) to be considered if required. Internal property flooding is defined as when the maximum depth at the property is above the threshold. External flooding is a flood depth greater than 10mm occurring outside a building but below the threshold.

2.5.2 Value of flood impact

The conversion of the flood depth into damage costs for each property was based on the ‘The Benefits of Flood and Coastal Risk Management (FCRM): A Handbook of Assessment Techniques (Flood Hazard Research Centre, 2005)’. The depth damage curves contained in this document require the threshold level of the properties to be determined. This has been assumed to be 150mm.

The information in the FCRM Handbook has been used to define depth/damage curves for the following property types:

- **Object Type: Building**
  - **Property type: Dwelling**
    - Surface water FD – 10yr: 0mm
    - Surface water FD – 30yr: 50mm
    - Surface water FD – 50yr: 100mm
    - Surface water FD – 100yr: 170mm
The actual depth/damage curves for the above property types are shown on Figure 13.

Figure 13. FCRM Depth/ Damage curves for different property types that were used to calculate the overall pluvial flood impact.

2.5.3 Flood risk quantification
The damage costs are calculated for each property for each return period of 1 in 10, 20, 30, 50, 100 & 200. The values for the different return periods are then integrated into a single Expected Annual Damage (EAD) value using the method illustrated below by a fictional example for a large commercial site. The return periods are first expressed as probabilities (the inverse of return period).
<table>
<thead>
<tr>
<th>Return period</th>
<th>Probability</th>
<th>Damage cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in 5 year</td>
<td>0.200</td>
<td>£1,000</td>
</tr>
<tr>
<td>1 in 7 year</td>
<td>0.143</td>
<td>£15,000</td>
</tr>
<tr>
<td>1 in 10 year</td>
<td>0.100</td>
<td>£50,000</td>
</tr>
<tr>
<td>1 in 25 year</td>
<td>0.040</td>
<td>£450,000</td>
</tr>
<tr>
<td>1 in 30 year</td>
<td>0.033</td>
<td>£600,000</td>
</tr>
<tr>
<td>1 in 50 year</td>
<td>0.020</td>
<td>£699,000</td>
</tr>
<tr>
<td>1 in 75 year</td>
<td>0.013</td>
<td>£765,000</td>
</tr>
<tr>
<td>1 in 100 year</td>
<td>0.010</td>
<td>£900,000</td>
</tr>
<tr>
<td>1 in 200 year</td>
<td>0.005</td>
<td>£1,350,000</td>
</tr>
</tbody>
</table>

Table 2: Illustrative example flood damage costs for a large commercial site

The graph depicting damage cost against probability is shown in Figure 14. It can be seen that the line of the graph approaches but never reaches zero with either axis and tails off to infinity. At very low probabilities (high return periods) there is a large damage cost but the probability tends to zero. At high probabilities (low return periods) the damage also tends to zero. The total Expected Annual Damage cost (EAD) is given by the area under the graph. It should be noted that the EAD is sometimes referred to as the Average Annual Damage (AAD) but this is a misnomer as it is not strictly an average but rather an integral.

![Figure 14: Illustrative example envelope of flood damage costs]

The EAD is calculated as shown in the table below for this illustrative example.
<table>
<thead>
<tr>
<th>Probability</th>
<th>Damage cost</th>
<th>Calculation (Based on Range of Damage Cost)</th>
<th>EAD value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td>£1 000</td>
<td>(0.2 – 0.143) * (15k + 1k) /2</td>
<td>£456</td>
</tr>
<tr>
<td>0.143</td>
<td>£15 000</td>
<td>(0.143 - 0.1) * (50k + 15k) /2</td>
<td>£1 398</td>
</tr>
<tr>
<td>0.10</td>
<td>£50 000</td>
<td>(0.1 - 0.004) * (450k + 50k) /2</td>
<td>£15 000</td>
</tr>
<tr>
<td>0.04</td>
<td>£450 000</td>
<td>(0.04 – 0.033) * (600k + 450k) /2</td>
<td>£3 675</td>
</tr>
<tr>
<td>0.033</td>
<td>£600 000</td>
<td>(0.033 – 0.02) * (699k + 600k) /2</td>
<td>£8 444</td>
</tr>
<tr>
<td>0.02</td>
<td>£699 000</td>
<td>(0.02 – 0.013) * (765k+ 699k) /2</td>
<td>£5 124</td>
</tr>
<tr>
<td>0.013</td>
<td>£765 000</td>
<td>(0.013 – 0.01) * (900k + 765k) /2</td>
<td>£2 498</td>
</tr>
<tr>
<td>0.01</td>
<td>£900 000</td>
<td>(0.01 – 0.005) * (1 350k + 900k) /2</td>
<td>£5 625</td>
</tr>
<tr>
<td>0.005</td>
<td>£1 350 000</td>
<td>Total</td>
<td>£42 219</td>
</tr>
</tbody>
</table>

*Table 3: Illustrative example of calculation of expected annual damage (risk)*
3 Results

3.1 Number of flooded properties
The results from the study have been expressed as the number of properties predicted to suffer internal flooding (water level greater than assumed building threshold). The results from different return period storm events are shown in Table 4. This shows only residential properties excluding stand alone garages.

<table>
<thead>
<tr>
<th>Return period</th>
<th>Internal flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>732</td>
</tr>
<tr>
<td>20</td>
<td>1078</td>
</tr>
<tr>
<td>30</td>
<td>1297</td>
</tr>
<tr>
<td>50</td>
<td>1809</td>
</tr>
<tr>
<td>100</td>
<td>2311</td>
</tr>
<tr>
<td>200</td>
<td>3261</td>
</tr>
</tbody>
</table>

Table 4. Number of residential properties flooding for different return periods

The first generation EA surface water flood maps predict 4100 properties would flood in Bournemouth in a 200 year event. We are showing significantly fewer properties than the EA figure. The Mouchel approach is more accurate than the EA approach in several ways. Some of these would tend to increase the number of properties identified as suffering from flooding but these are outweighed by other differences tending to reduce the number.

3.1.1 Factors tending to increase flood numbers

- The EA maps assumed that properties had a 300 mm threshold to floor level whereas here we have assumed a more pessimistic 150 mm.

- We have used a critical storm duration of 120 minutes (2hrs) that is appropriate for the Bournemouth catchment whereas the EA model used a 6 hour duration storm that was considered critical as a national average.

3.1.2 Factors tending to reduce flood numbers

- The Mouchel modelling allows for the loss of flood water to the piped drainage system that was ignored in the EA mapping. This is the most significant factor.

- The model includes a representation of roads and buildings, which allow these urban features to influence the predicted flood routes. The EA model did not account for these features and used only a bare earth DTM model.

- Obstructions to flood flow that are relieved by bridges and culverts have been removed in the Mouchel modelling.
For the 30 year return period event the number of properties predicted to flood internally in the Mouchel modelling is higher than has been experienced in the catchment. The EA modelling did not define the number of properties flooded in these more frequent storms; but their methodology would have given an even greater overestimate. This overestimation of flooding in these medium probability events is likely to be due to an under estimation of the losses to the underground drainage system and to infiltration. We have intentionally made a ‘worst case’ assumption that poor maintenance of roof drainage leading to a capacity of 25mm/hr compared to the British Standard for gutter design requiring 50mm/hr. The ground infiltration rates represent saturated soils rather than dry summer conditions. These factors will have much less impact for the larger storms (1:100 and 1:200 probabilities) as the losses to drainage and infiltration are less significant in these events.

We consider that this overestimation of property flooding in medium probability events is acceptable as this modelling is acting as a screening process to identify areas of high risk. Consideration of worst case conditions will ensure no potential flooding location is missed.

We have also looked at the number of all types of properties flooded internally for the 30 year event. This is shown in Table 5.

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-category</th>
<th>Number flooded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Dwellings</td>
<td>1297</td>
</tr>
<tr>
<td>Commercial</td>
<td>Retail</td>
<td>61</td>
</tr>
<tr>
<td>Parent Shell</td>
<td>Property Shell</td>
<td>59</td>
</tr>
<tr>
<td>Residential</td>
<td>Garages</td>
<td>23</td>
</tr>
<tr>
<td>Commercial</td>
<td>Offices</td>
<td>8</td>
</tr>
<tr>
<td>Commercial</td>
<td>Leisure</td>
<td>6</td>
</tr>
<tr>
<td>Commercial</td>
<td>Community Services</td>
<td>2</td>
</tr>
<tr>
<td>Commercial</td>
<td>Education</td>
<td>2</td>
</tr>
<tr>
<td>Commercial</td>
<td>Industrial</td>
<td>2</td>
</tr>
<tr>
<td>Commercial</td>
<td>Hotels, Boarding and Guest Houses</td>
<td>1</td>
</tr>
<tr>
<td>Commercial</td>
<td>Medical</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 5. Number of all property types flooding for 30 year return period

3.2 Flood damage cost
The EAD has been calculated for individual properties and this has been aggregated to various geographic areas. The results for the whole catchment are shown in Figure 15.
In Figure 15, the area under the curve represents the EAD for the catchment and totals £4.37m. This represents the average damage, including direct, social and environmental costs that the catchment would suffer from flooding averaged over a long period of time.

Figure 16 shows the contribution that each event makes to the EAD (flood damage cost \times flood probability). This shows that the largest contribution to the expected annual damage is due to the high probability (frequent) storm events with the large rare events contributing less. This therefore suggests that interventions to reduce the risk are likely to be localised rather than catchment wide.

The results were aggregated to local census areas (lower statistical output areas) to help to target broad areas for detailed review. The results for all census areas are
shown on a colour coded map in Figure 17 showing the total EAD for all types of properties. The results for the top 20 census areas are listed in Table 6.

Figure 17 shows the total EAD for all census areas with the areas with the highest risk shown in dark pink and the lowest in green.

![Figure 17: Total EAD for each census area](image)

<table>
<thead>
<tr>
<th>Risk Rank</th>
<th>LSOA</th>
<th>EAD (£/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>All properties</td>
</tr>
<tr>
<td>1</td>
<td>E01015340</td>
<td>195 821</td>
</tr>
<tr>
<td>2</td>
<td>E01015339</td>
<td>166 342</td>
</tr>
<tr>
<td>3</td>
<td>E01015308</td>
<td>116 148</td>
</tr>
<tr>
<td>4</td>
<td>E01015303</td>
<td>113 063</td>
</tr>
<tr>
<td>5</td>
<td>E01015330</td>
<td>103 186</td>
</tr>
<tr>
<td>6</td>
<td>E01015328</td>
<td>95 360</td>
</tr>
<tr>
<td>7</td>
<td>E01015373</td>
<td>91 550</td>
</tr>
<tr>
<td>8</td>
<td>E01015338</td>
<td>90 566</td>
</tr>
<tr>
<td>9</td>
<td>E01015348</td>
<td>86 643</td>
</tr>
<tr>
<td>10</td>
<td>E01015375</td>
<td>82 840</td>
</tr>
<tr>
<td>11</td>
<td>E01015336</td>
<td>81 864</td>
</tr>
<tr>
<td>12</td>
<td>E01015334</td>
<td>73 359</td>
</tr>
<tr>
<td>13</td>
<td>E01015377</td>
<td>72 426</td>
</tr>
<tr>
<td>14</td>
<td>E01015282</td>
<td>72 267</td>
</tr>
<tr>
<td>15</td>
<td>E01015288</td>
<td>69 165</td>
</tr>
<tr>
<td>16</td>
<td>E01015342</td>
<td>65 924</td>
</tr>
<tr>
<td>17</td>
<td>E01015324</td>
<td>65 002</td>
</tr>
<tr>
<td>18</td>
<td>E01015315</td>
<td>61 454</td>
</tr>
</tbody>
</table>
In some areas a significant part of the risk cost is because of the flooding of non-residential properties including commercial property. As BCC is particularly concerned about the flooding of residential property we also show below the number of residential dwellings flooded in these same 20 high risk areas and the Expected Annual Damage counting only damage to residential dwellings.

Table 7: Numbers of dwellings flooding and EAD for dwellings only

It can be seen that for some of these areas the impact on residential property is actually quite low and it is the damage to non-residential property that means they are included in the top 20 risk ranking.

These 20 high risk areas are assessed in more detail in Section 4.

3.3 Validation

The capability to generate surface water flood maps is relatively new and the process applied using FRM is a simplification of a potentially complex process. This leads two issues for the users of the surface water flood paths.

<table>
<thead>
<tr>
<th>Rank</th>
<th>LSOA</th>
<th>Return period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E01015340</td>
<td>192 604</td>
</tr>
<tr>
<td>2</td>
<td>E01015339</td>
<td>49 899</td>
</tr>
<tr>
<td>3</td>
<td>E01015308</td>
<td>63 876</td>
</tr>
<tr>
<td>4</td>
<td>E01015303</td>
<td>47 341</td>
</tr>
<tr>
<td>5</td>
<td>E01015330</td>
<td>85 910</td>
</tr>
<tr>
<td>6</td>
<td>E01015283</td>
<td>17 916</td>
</tr>
<tr>
<td>7</td>
<td>E01015373</td>
<td>85 612</td>
</tr>
<tr>
<td>8</td>
<td>E01015338</td>
<td>6 707</td>
</tr>
<tr>
<td>9</td>
<td>E01015348</td>
<td>47 105</td>
</tr>
<tr>
<td>10</td>
<td>E01015375</td>
<td>36 956</td>
</tr>
<tr>
<td>11</td>
<td>E01015336</td>
<td>81 295</td>
</tr>
<tr>
<td>12</td>
<td>E01015334</td>
<td>71 000</td>
</tr>
<tr>
<td>13</td>
<td>E01015377</td>
<td>70 059</td>
</tr>
<tr>
<td>14</td>
<td>E01015282</td>
<td>2 688</td>
</tr>
<tr>
<td>15</td>
<td>E01015288</td>
<td>22 836</td>
</tr>
<tr>
<td>16</td>
<td>E01015342</td>
<td>65 435</td>
</tr>
<tr>
<td>17</td>
<td>E01015324</td>
<td>25 081</td>
</tr>
<tr>
<td>18</td>
<td>E01015315</td>
<td>60 241</td>
</tr>
<tr>
<td>19</td>
<td>E01015378</td>
<td>59 429</td>
</tr>
<tr>
<td>20</td>
<td>E01015322</td>
<td>48 301</td>
</tr>
</tbody>
</table>

Table 6: Top 20 census areas based on total EAD for all types of property
1) The need to understand how the surface water flood paths have been generated; and

2) How the outputs relate to reality, particularly the ability to represent historic events.

The outputs from the flood risk modelling have been compared against historical flooding information from BBC.

The Technical Report in Appendix C contains details of how the predicted flooding compares to historic events. In most of the locations looked at in detail there is good agreement that the flooding is in the right location; for one location the flooding is shown a few houses away from where the records show that it was reported.

The model has therefore been shown to have a good level of validation.

No model will ever predict all flooding 100% of the time due to the large number of flood sources and potentially complex mechanisms. This flood risk model identifies the areas susceptible to flooding and is suitable for targeting further investigation to reduce pluvial flood risk.

We have not been able to validate the model against historic events in excess of 1 in 50 years, as it appears there are no records of such events. However, a manual check of the 1 in 100 year event was carried out. The check included assessment of the LiDAR data against the 1 in 100 year flood outline to ascertain that the flow paths and the number of houses internally flooded appeared realistic. This proved to be the case, with the flood flow path following the contours and being blocked by properties.

We also included the previous historic events, to ascertain whether the areas that were modelled as flooding had been reported. This analysis proved that in many cases the areas we had determined as flooding had also been affected by historic events.

Please note, due to Appendix C containing data possibly covered under the Freedom of Information Act, it has been included as a restricted appendix.
4 Risk Areas

4.1 Mitigation Options
As defined by Defra, surface water flooding occurs where high rainfall events exceed the drainage capacity in an area. Such events can also lead to serious flooding of property and possessions where surface water flows and collects. Typically this type of flooding is very localised and happens very quickly after the rain has fallen, making it difficult to give any warning. It is most common in built up urban areas such as London or in this case Bournemouth, where there is little open ground to absorb rainfall.

Due to increasing development of urban spaces in Bournemouth, land has become increasingly impermeable and rainfall runs very quickly off these areas into drains and rivers. As the drainage system is already near capacity, the water is forced to ‘back up’ leading to localised surface water flooding.

The solutions may involve expanding the piped system, as there are relatively few watercourses and limited open spaces, which would have to be done in conjunction with Wessex Water. This is likely to be expensive and very disruptive; also there is no legal requirement for them to do so beyond the current 1 in 30 year design standard. Increased capacity of the pipe system will increase the discharge rate at the outfalls, which may increase erosion and the risk of downstream flooding. As such an engineered solution may be difficult to implement in practice.

The best approach to deal the surface water flooding problem is to implement a long term solution to control the water at or near the source. All the new development as well as the existing development, where possible, should be designed to mimic the greenfield runoff response at the source through the use of sustainable drainage and rainfall harvesting practices.

As mentioned in ‘The SUDS manual’ (CIRIA 2007), the goals of good site design should include:

- managing stormwater (quantity and quality) as close to source as possible;
- preventing potential damaging impacts rather than mitigating them; and
- where possible, using simple, non-structural methods for runoff management (that are often lower cost and lower maintenance than structural controls).

The use of good site design for storm water management can provide benefits including:

- reduced construction costs;
- increased property values;
- more open space;
- more pedestrian-friendly developments;
- more aesthetically pleasing and naturally attractive landscapes;
- integration of biodiversity and habitat provision; and
- availability of rainwater for reuse.

Bournemouth is a heavy developed area and there are very few water courses so most of the area is only drained by the Public sewerage system and in some places it is only a combined system. In most of the areas the flooding problems are endemic to urban development and may only be resolvable through the re-development of town centres and housing so that space can be made for water. But this is a long term approach and benefit may therefore take many years to be realised. This long term approach will also require the co-operation or enforcement with planners and developers.

### 4.2 Summary of Risk Areas

A summary of each risk area is presented in Table 8. The risk areas have been ranked not only based on the total damage cost caused by flooding but also considering the importance (i.e. hospital, school etc.). Detail of the assessment process is included in the Technical Report (Appendix C).

Table 8 summarises the model results for number of residential properties flooded for each of the modelled return periods. There may also be additional un-reported historical flooding incidents. It also shows the total Expected Annual Damage for the area.
### Risk Areas

Following the hydraulic modelling, 20 priority high risk areas were determined for further detailed assessment. The selection was based on the damages calculated, flooding history and discussion with BBC during the summer of 2010.

A map of the overall risk area has been presented in Figure D0 in Appendix D along with specific maps of the flood pathways and possible options to mitigate the 1 in 100 year surface water flood event.

<table>
<thead>
<tr>
<th>Risk Area Number</th>
<th>Risk Area Name</th>
<th>LSOA</th>
<th>EAD (£)</th>
<th>Return period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Castle Lane West</td>
<td>E01015340</td>
<td>195 821</td>
<td>35 42 51 72 76 103</td>
</tr>
<tr>
<td>2</td>
<td>East Way &amp; Castle Lane West</td>
<td>E01015339</td>
<td>166 342</td>
<td>14 15 18 23 34 54</td>
</tr>
<tr>
<td>3</td>
<td>Paddington Grove</td>
<td>E01015308</td>
<td>116 148</td>
<td>25 28 37 44 59 90</td>
</tr>
<tr>
<td>4</td>
<td>Northbourne</td>
<td>E01015303</td>
<td>113 063</td>
<td>10 18 24 33 50 97</td>
</tr>
<tr>
<td>5</td>
<td>Queen’s Park Avenue</td>
<td>E01015330</td>
<td>103 186</td>
<td>15 17 21 27 29 53</td>
</tr>
<tr>
<td>6</td>
<td>Old Christchurch Road &amp; Bournemouth Town Centre</td>
<td>E01015283</td>
<td>95 360</td>
<td>3 3 3 3 4 9</td>
</tr>
<tr>
<td>7</td>
<td>Green Road</td>
<td>E01015373</td>
<td>91 550</td>
<td>17 33 49 67 67 93</td>
</tr>
<tr>
<td>8</td>
<td>Throop Road</td>
<td>E01015338</td>
<td>90 566</td>
<td>0 0 1 3 4 6</td>
</tr>
<tr>
<td>9</td>
<td>Talbot Avenue and Glenferness Avenue</td>
<td>E01015348</td>
<td>86 643</td>
<td>6 18 18 23 27 40</td>
</tr>
<tr>
<td>10</td>
<td>Talbot Road</td>
<td>E01015375</td>
<td>82 840</td>
<td>8 10 13 16 16 31</td>
</tr>
<tr>
<td>11</td>
<td>Kings High School</td>
<td>E01015336</td>
<td>81 864</td>
<td>24 42 45 55 68 81</td>
</tr>
<tr>
<td>12</td>
<td>Howeth Road</td>
<td>E01015334</td>
<td>73 359</td>
<td>16 29 32 44 47 71</td>
</tr>
<tr>
<td>13</td>
<td>Redhill Road</td>
<td>E01015377</td>
<td>72 426</td>
<td>22 27 31 50 54 81</td>
</tr>
<tr>
<td>14</td>
<td>Sovereign Centre, Boscombe</td>
<td>E01015282</td>
<td>72 267</td>
<td>0 0 0 0 0 1</td>
</tr>
<tr>
<td>15</td>
<td>Area Surrounded by Wessex Way, Ashley Road, Christchurch Road and St Paul’s Road</td>
<td>E01015288</td>
<td>69 165</td>
<td>4 6 6 12 18 27</td>
</tr>
<tr>
<td>16</td>
<td>Queens Park Avenue</td>
<td>E01015342</td>
<td>65 924</td>
<td>9 10 11 17 18 41</td>
</tr>
<tr>
<td>17</td>
<td>The Avenue &amp; Redhill Park</td>
<td>E01015324</td>
<td>65 002</td>
<td>7 8 8 17 24 35</td>
</tr>
<tr>
<td>18</td>
<td>Harewood Avenue</td>
<td>E01015315</td>
<td>61 454</td>
<td>15 17 23 32 35 47</td>
</tr>
<tr>
<td>19</td>
<td>Charminster Road</td>
<td>E01015378</td>
<td>60 480</td>
<td>16 18 23 44 47 78</td>
</tr>
<tr>
<td>20</td>
<td>West Way &amp; Charminster Road</td>
<td>E01015322</td>
<td>57 191</td>
<td>19 22 25 28 31 52</td>
</tr>
</tbody>
</table>

Table 8. Summary of the risk areas showing number of properties affected for each return period

4.3 Risk Areas

Following the hydraulic modelling, 20 priority high risk areas were determined for further detailed assessment. The selection was based on the damages calculated, flooding history and discussion with BBC during the summer of 2010.

A map of the overall risk area has been presented in Figure D0 in Appendix D along with specific maps of the flood pathways and possible options to mitigate the 1 in 100 year surface water flood event.
Possible short term flood mitigation options have also been discussed in the following sections based on engineering judgement and local conditions. The options will need to be checked using the most up to date sewer network information in the next stage of the SWMP. For information, the areas have been assessed in numerical order and in relation to their proximity with each other. This may enable multiple flood risks to be mitigated with a single solution. The solutions mostly considered a combination of hard engineering (i.e. increasing pipe diameter, etc) and sustainable design like temporary attenuation, where applicable.

4.3.1 Risk Areas 1 & 8: Castle Lane West & Throop Road

The presence of the Royal Bournemouth General Hospital and properties at the Cooperdean Drive mean that the areas to the south are considered high risk. This is mainly due to the way the ground contours influence the flow from north of the Cooperdean Roundabout (Castle Lane West) down the Castle Lane East. It should be noted that the 1 in 100 year flood map does not indicate flooding within the hospital area (Figure D1 in Appendix D), but is ranked highly due to the restrictions in access during an extreme flood event and its vulnerability class.

The model also predicts flooding along the Cooperdean Drive, Wessex Way and along the Riverside Avenue. Flooding at the Cooperdean Drive and Wessex Way is caused by overland flow from the upstream catchment. The Riverside Avenue runs adjacent to a green open space that is designated as the River Stour flood plain, but not currently used for this purpose. As such any flood water can be accommodated in this area.

It is recommended that a storage pond be constructed at the north east corner of Queen’s Park Golf Course. Castle Lane East has an over capacity culvert, (anecdotal evidence by BBC), which can be used to convey the excess runoff water from the hospital area as well as from Wessex Way. It is assumed that there is an existing sewer running along and south of Sevenoaks Drive, as there is significant surface water flooding in the road, and no evidence of a watercourse in this area. Increasing the size of existing pipes may possibly mitigate flooding of this area.

A new connection pipe from Wessex Way to the existing culvert at Castle Lane East may also solve flooding issues in the upstream at-risk areas. Therefore, a combined solution is recommended considering all upstream areas. Another option could be installing a new pipe or increasing the existing pipe size along the Wessex Way all the way to the river downstream, but crossing the Cooperdean Roundabout may possibly be an issue.

This option will need to be checked using the up to date sewer network model in the next stage of the SWMP. It is possible, although this will need to be confirmed, that the proposed surface water flood mitigation options in this area may have a
beneficial impact to the flooding issues in the surrounding areas, specifically where flood water ponds and is restricted (i.e. Cooperdean Drive).

4.3.2  **Risk Area 2: East Way & Castle Lane West**
These areas are considered a high priority risk ranking due to the close proximity of the Bournemouth School for Girls and the Bishop of Winchester Comprehensive School (Figure D2 in **Appendix D**). The Castle Point Shopping Centre and Mallard Road Retail Park also increase the cost of damage estimation.

Landscaping or underground infiltration storage situated at the playing field of the Bournemouth School for Girls would allow temporary storage, potentially solving flooding problems within the school itself and the properties located in the corner of Castle Lane West and Uplands Road.

By increasing the existing pipe diameters along the Castle Lane West Road the system would gain additional capacity and conveyance. This solution may possibly solve flooding problems on either side of the road. This larger pipe would also be able to solve flooding problems at to the north west of Risk Area 1.

4.3.3  **Risk Area 3: Paddington Grove**
The majority of surface water flooding accumulates on the northern fringes of this area, with modelling predicting flooding mostly on the roads and gardens.

The property flooding in this area comprise of recently developed semi-detached and detached properties along with the Ringwood Road Industrial Estate and shopping complex. The average flood depth in this area is above the agreed 150mm flood depth, and as such the modelling has determined that large parts of this area will be internally flooded.

The flood map shows flooding between Englands Road and Meadows Way (Figure D3 in **Appendix D**). This part of Bournemouth is extensively developed, with minor green open spaces that could be utilised. As such, there are limited potential source control options in this area. Upgrading the existing surface water drainage system to accommodate additional storage during flood risk events and maintenance work may possibly resolve the flooding issue.

4.3.4  **Risk Area 4: Northbourne**
This is a recently developed area with a possibility of future development. The River Stour runs along the north west and north side of the area. It is assumed that surface runoff from the upstream area (Whitelegg Way, Wimbourne Road and New Road) is collected by the existing drainage network and discharged in the River Stour. There is an existing storage area with dam at the north end of Kinson Common, which is supposed to temporarily store the excess runoff from the upstream area (Risk Area 12). During the site visit the storage pond was found to be mostly silted up with sediment and debris and not able to provide the designed storage.
It is proposed to increase the size of the Kinson Common storage pond to provide sufficient storage to temporarily contain any additional surface water runoff during storm events. Currently BBC has an existing proposal to construct a reed bed storage option at the south corner of Kinson Common to treat and store runoff water from upstream (Risk Area 12). It may be possible to combine the schemes to provide a wider benefit that is more cost efficient.

A second option could be to increase the pipe size from Whitelegg Way along Wimbourne Road, Broadway, Kinson Road and New Road, delivering to a controlled discharge to the River Stour (see Figure D4 in Appendix D).

4.3.5 Risk Area 5 & 7: Queen’s Park Avenue and Green Road
The model predicts flooding along the natural stream route in this area. The downstream area of the stream path follows Queen’s Park Avenue and flooding affects all of the residential areas along this flow route to a greater or lesser degree. The existing Green Road storage tank at adjacent to the ‘Five Ways’ roundabout was originally designed for a 1 in 25 years return period storm. Whilst the storage tank does meet the original design, it is under capacity for storms that are greater than the 1 in 25 years return period.

Combining with the mitigation measure upstream (Risk Area 10 & 13) and downstream (Risk Areas 1, 8 & 16) options may offer a more cost effective optimised solution. The mitigation measure will involve increasing the size of the exiting pipe or installing a new pipe along Queen’s Park Avenue which will connect both upstream and downstream risk areas as well. In addition to that, increasing the size of the pipe at Maxwell Road is also recommended (Figure D5 in Appendix D).

4.3.6 Risk Area 6: Old Christchurch Road & Bournemouth Town Centre
This area has been selected as a priority site for mitigation of flood risk because of the magnitude of flooding and also for commercial value of the properties adjacent Old Church Street, Commercial Road, Bourne Avenue and the surrounding area (Figure D6 in Appendix D). The majority of predicted flooding occurs along either existing or historic watercourses.

There is an existing 2m diameter storage pipe beneath Old Christchurch Road, belonging to Wessex Water, which temporarily stores runoff water before discharging to the watercourse (The Bourne Stream). The discharge is controlled by means of a small diameter throttle pipe. One potential option could be to replace the throttle pipe with a 2m diameter pipe discharging directly to the existing downstream watercourse, then to the coast. The watercourse may not have enough capacity to take the additional amount of flow. In that case a new overflow pipe can be installed that will run parallel and follow the route of the existing watercourse and discharging directly to the sea.

4.3.7 Risk area 9: Talbot Avenue and Glenferness Avenue
The model is predicting flooding mostly on the roads and gardens in this area. However, there is significant flooding located at the Talbot Roundabout, which is a...
critical highway junction, and could have a direct impact on emergency access during a flood event.

There is an existing storage tank located at the Talbot Roundabout, which was not considered in the model due to lack of information. The flood map shows flooding on the Glenferness Avenue, Huntly Road and garden areas (Figure D7 in Appendix D). Maintenance work and/or increasing local road drainage pipe sizes may possibly resolve the flooding issue.

4.3.8 Risk Area 10, 13 & 19: Area surrounded by Talbot Road, Redhill Avenue and Charminster Road

Risk areas 10, 13 and 19 (Figure D8 in Appendix D) have been discussed in this section as these areas have similar issues with flooding and a combined mitigation measure may best serve these areas. This is a heavily built urban area with limited space for an above ground storage option. Talbot Road, Redhill Avenue and Charminster Road effectively define the extremities of this area. The predicted flood path runs through the middle of area 13 and 19 which seems to be a natural stream flow route.

As there is no available area to store flood water, upsizing the existing sewer network looks like the most suitable option. This would include upsizing the existing pipe along Wimbourne Road, Calvin Road and Pine Road to connect at Green Road. It is recommended that this option is considered alongside the flood risk in areas 5 and 7, which are located just downstream. Upsizing the pipe at Portland Road and Ripon Road may also be required for Risk Area 13. It is anticipated that these pipe capacity increases can link into the existing drainage systems that run alongside Queens Park Avenue.

4.3.9 Risk Areas 11 & 12: Kings High School and Howeth Road

The existing roads and houses have been developed over a natural stream flow path. During heavy storm events excess runoff water may tend to follow that path due to the topography and may cause flooding. There is evidence of historical flooding at the Columbia Road along the natural stream flow path which matches the model predicted flooding extent (Figure D9 in Appendix D).

BBC is currently working with Wessex Water to construct a storage tank in Priestly Road. As such, further assessment is recommended to review the possibility of using Kings High School play area for temporary storage.

A further natural and drainage storage and flow control solution could be included downstream of the Kings High School possibly reducing surface water flooding further, by staggering the outflow to the proposed Kinson Common storage area (Risk Area 3).

4.3.10 Risk Area 14: Sovereign Centre, Boscombe

The predicted flooding (Figure D10 in Appendix D) shows that flood risk is likely to impact the commercial centre and residential area around the Sovereign Centre, north of Boscombe. The A35 trunk road also runs east to west through this priority
area, and as such would be a major emergency and evacuation route. It is also likely that there will be a significant number of pedestrians in this area, should a surface water flood event occur during daylight hours.

Given that this area is heavily developed, there are limited amounts of source control flood storage locations to be identified. Possibly the most appropriate would be the Churchill Road Park to the north, or taking advantage of below ground storage at potential development sites, as and when they arise. Otherwise localised pipe upgrades and maintenance work may prove beneficial in reducing flood risk.

4.3.11 Risk Area 15: Area Surrounded by Wessex Way, Ashley Road, Christchurch Road and St Paul’s Road

Local flooding is assumed to be caused by insufficient drainage capacity and local topography. The model is predicting local flooding mostly near Northcote Road, Windham Road & Cleveland Road and Knoll Gardens (Figure D11 in Appendix D).

It may be possible that maintenance work on the existing drainage system and localised pipe size increases may solve the flooding problem in this area. Anecdotally, BBC have stated that there is a large surface water pipe running along the Kynveton Road. Increasing the pipe size at the Knoll Gardens to convey excess runoff to the large surface water pipe at the Kynveton Road should solve the flooding. However, topography may be an issue as the Knoll Gardens is at a much lower level than Kynveton Road. The difference in levels indicates that some form of pumped solution may be required.

4.3.12 Risk Area 16: Queens Park Avenue

The modelling has predicted that flooding mainly occurs in the southern and western fringes. Figure D12, in Appendix D, shows that there is significant surface water flooding to Queens Park Avenue along with the Bishop of Winchester School. These locations would either be major evacuation routes, or require evacuation themselves.

Whilst the boundaries of this area are susceptible to surface water flood risk, the centre has large areas of green open space. Ideally these open spaces would be utilised as source control flood storage that could reduce surface water flooding. However the ground levels suggest that this is not possible, unless below ground storage is used. Therefore we would recommend capacity increases for the existing drainage network on Queen’s Park Avenue.

4.3.13 Risk Area 17: The Avenue & Redhill Park

The surface water flooding follows the natural ground contours in this area, along the roads and moves to the east and west boundaries of this risk area, Figure D13, in Appendix D.

It is proposed that the potential option for this risk area would require upgrade to the existing drainage system. This would enable the surface water run off to be sorted further upstream of its likely discharge to the River Stour. Added to this pipe upgrading could be a potential storage area in Redhill Park. This would be an ‘offline’ storage option that would take discharge at a specified capacity level in the
drainage system. The excess run off would be allowed to accumulate over a period of time, then exit back into the drainage system when that has emptied, post event.

4.3.14 Risk Area 18: Harewood Avenue
Risk Areas 16 and 18 have been combined as there is the potential to utilise options across both to minimise surface water flood risk to a wider area. The predicted flooding (Figure D14 in Appendix D) follows existing low ground contours, flowing west to east, and accumulating at a number of infrastructure points (i.e. Harewood Avenue). These accumulation areas are mainly in green open spaces and could also be used for source control flood storage areas. Linking these with proposed drainage upgrades could reduce the flood risk impacts to the Castle Lane East.

4.3.15 Risk Area 20: West Way & Charminster Road
In this area the surface water flooding follows the ground contours towards Queens Park Avenue. Unfortunately this area is a heavily developed residential area, as shown in Figure D15, in Appendix D.

As such it is anticipated that the best option in this area would be to increase the capacity of the existing drainage system, to enable surface water run off to be caught and stored upstream of the drainage system at Queen’s Park Avenue and Green Road.
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5 Summary and Next Steps

5.1 Summary

In order to meet the requirements of the Surface Water Management Plan guidance (Defra, March 2010) BBC has commissioned a study to assess the borough wide surface water flood risk. The borough wide assessment used existing data provided BBC and other key partners, including the EA, who provided information in terms of perceived flood depths, flow paths and an indication of at-risk areas for surface water flooding.

Flood extents have been produced from the borough wide hydraulic modelling outputs. The modelling has taken into account the borough topography and the network of highways, residential and commercial areas, as well as building thresholds, to improve on the EA’s surface water mapping.

The flood outlines have enabled BBC to move beyond the information provided by the EA, as part of the country wide surface water flood risk mapping, and establish some priority flood risk areas that could be resolved with the implementation of mitigation options; these are a combination of improvements to the existing surface water drainage system, as well as storage and capacity improvements.

Feasibility outline options have been developed using consideration of local topography and engineering solutions. In all cases the option recommended needs further assessment to determine details such as specific dimensions, benefits and costs.

The Technical Report in Appendix C contains details of how the predicted flooding compares to historic events. In most of the locations looked at in detail there is good agreement that the flooding is in the right location; for one location the flooding is shown a few houses away from where the records show that it was reported.

The model has therefore been shown to have a good level of validation.

No model will ever predict all flooding 100% of the time due to the large number of flood sources and potentially complex mechanisms. This flood risk model identifies the areas susceptible to flooding and is suitable for targeting further investigation to reduce pluvial flood risk.

The model represents surface water flooding only, but there are many other factors which contribute to surface water flooding including hydraulic overload of the sewerage system and blockage of trash screens for culverted surface water systems. An assessment should be made of each asset and its associated failure modes to evaluate the size of risk posed.

It is recommended that detailed assessments are completed at the high risk locations identified by the surface water model to confirm the level of risk, identify the
route causes and develop outline mitigation measures. The following information from this surface water model should be considered as part of the detailed assessment:

- Source, scale and interaction of the flood routes. The flood paths from this study will allow the source of any flooding to be identified, plus how different high risk sites interact with each other;

- Initial understanding of risk in a given area and the elements contributing to the risk; and

- DTM that has been developed to remove the natural dams and embankments. Its use should be considered for any further hydraulic modelling.

5.2 Next Steps

BBC will be using the broadscale flood maps and feasibility outline options to determine where the necessary detailed assessments can be funded further, and to communicate flood risk, via the Bournemouth Borough Council website.

Release of this data is not intended to create ‘property or development blight’. The purpose of this work has been to identify surface water flood risk to enable BBC to effectively make long term planning and development decisions.

BBC will be working with their partners at Wessex Water and the EA to establish a wider framework of solution orientated planning decisions and collaborate to develop cost effective flood risk mitigation options.

Going forward it is recommended that the top priority sites are assessed to a detailed level to ensure that a cost effective solution can be established and taken forward. It may also be possible to realise the wider benefits of collating risk areas (i.e. Risk Areas 1, 2, 5, 7, 8 & 16 or Risk Areas 4, 11 & 12).
Appendices
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Appendix A – BBC Location & EA Flood Maps
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Appendix B – BBC SWMP Flood Maps
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Appendix C – Modelling Technical Report
Appendix D – Risk Areas & Option Maps
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