Southern Staffordshire Surface Water Management Plan Phase 2

Stafford Town

Stafford Borough, Lichfield District, Tamworth Borough, South Staffordshire District, Cannock Chase District and Staffordshire County Councils
May 2011

Final Report

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ROYAL HASKONING

Stafford BOROUGH COUNCIL

Staffordshire County Council

raa Richard Allitt Associates Ltd CONSULTING ENGINEERS

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GLOSSARY

Annual Exceedence Probability (AEP)	The probability associated with a *return period* (T). An event of return period 50 years has an AEP of 1/T, 0.02 or 2%.
Antecedent Conditions	The pre-existing condition before a rain event (e.g. waterlogged soil)
Brownfield site	Any land or site that has been previously developed.
Catchment	The area contributing flow or *runoff* to a particular point on a watercourse.
Climate change	Long-term variations in global temperature and weather patterns both natural and as a result of human activity, primarily greenhouse gas emissions.
Culvert	Covered channel or pipe that forms a *watercourse* below ground level, or through a raised embankment.
Defra	UK Government department responsible for policy and regulations on the environment, food and rural affairs.
Development	The carrying out of building, engineering, mining or other operations in, on, over or under land or the making of any material change in the use of any buildings or other land.
Enmained	Watercourse designated as a *Main River*
Environment Agency	Government Agency charged with the protection of the environment.
Flood probability	The estimated likelihood of a flood of a given magnitude occurring or being exceeded in any specified time period.
Flood Map for Surface Water	Second edition national surface water flood mapping produced by the Environment Agency.
Flood risk	An expression of the combination of the *flood probability* and the magnitude of the potential consequences of the *flood event*.
Flood risk assessment	A study to assess the risk of a site or area flooding, and to assess the impact that any changes or development in the site or area will have on *flood risk*.
Flood Zones	Flood Zones are defined in Table D.1 of Planning Policy Statement (PPS) 25: Development and Flood Risk. They indicate land at risk by referring to the probability of flooding from river and sea, ignoring the presence of defences.

Fluvial Water	Water contained or flowing within a river or stream.
Greenfield	Previously undeveloped land.
InfoWorks	Modelling software used to simulate surface water and drainage networks in 2D.
LiDAR	Data set that provides a 3D image of the surface of the earth.
Local Planning Authority	Body responsible for planning and controlling development, through the planning system.
Main River	A watercourse designated on a statutory map of Main rivers, maintained by the Environment Agency.
Mitigation measure	A generic term used in this guide to refer to an element of *development* design which may be used to manage some *risk* to the *development*, or to avoid an increase in *risk* elsewhere.
Ordinary watercourse	A watercourse which is not a private drain and is not designated a *Main river*.
Outfall Height	Level at which a sewer or drain discharges into a watercourse.
Overland Flow	Water flowing over the surface of the land, originating from direct rainfall runoff or other drainage networks (e.g. watercourses or underground drainage) that have exceeded their capacity).
Return Period	The return period of a flood (T) is a measure of its rarity, defined as the average interval in years between occurrence of floods that exceed it.
Risk	The probability of an event occurring multiplied by the consequence of such an event.
Runoff	Water flow over the ground surface to the drainage system.
Surface Water	Water collected or flowing over the ground not contained within a watercourse. Usually results from heavy rainfall.
Sustainable Drainage Systems (SUDS)	A sequence of management practices and control structures, often referred to as SUDS, designed to drain surface water in a more sustainable manner. Typically, these techniques are used to attenuate rates of runoff from potential development sites.
Watercourse	Any natural or artificial channel that conveys surface water.

Water Cycle Strategy (WCS)	Provides a plan and programme of Water Services Infrastructure implementation. It is determined through an assessment of the environment and infrastructure capacity for: water supply; sewage disposal; flood risk management; and surface water drainage.
Watershed	Line depicting the area within which all surface water will drain into an area of interest, such as a town or village. For the assessment of surface water this boundary is defined from the topography.

ABBREVIATIONS

AAD	Average Annual Damages
AEP	Annual Exceedence Probability
AStSWF	Areas Susceptible to Surface Water Flooding
CSO	Combined Sewer Overflow
Defra	Department for Environment Flood and Rural Affairs
FEH	Flood Estimation Handbook
FMfSWF	Flood Map for Surface Water Flooding
GIS	Geographical Information System
LiDAR	Light Detecting and Ranging
MCM	Multi Coloured Manual
NPD	National Property Dataset
NVZ	Nitrate Vulnerable Zone
PFRA	Preliminary Flood Risk Assessment
STWL	Severn Trent Water Limited
SUDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan
WCS	Water Cycle Study
WFD	Water Framework Directive

EXECUTIVE SUMMARY

Introduction

In November 2009 Royal Haskoning was appointed by Stafford Borough, Lichfield District, Tamworth Borough, Cannock Chase District and South Staffordshire District Councils to produce a Phase 1 and Phase 2 Surface Water Management Plan (SWMP) and a Phase 1 and Phase 2: Scoping and Outline Water Cycle Study (WCS). This report relates to the production of the Phase 2 SWMP for Stafford Borough, relating specifically to Stafford town. It has been written with reference to Defra's latest SWMP guidance. The Phase 2 SWMP covers all the required elements of an Intermediate study and many of the elements of a Detailed study.

Modelling

An integrated model has been constructed for Stafford town using the latest Infoworks ICM (Integrated Catchment Modelling) software, covering the area contained within the watershed of the town. It has been constructed to include overland flow, fluvial flows affected by surface water and the underground drainage network (i.e. sewers), producing outputs of flood extent, depth and velocity for a variety of annual probabilities of flooding, including three climate change scenarios. This model is considered the best available tool to define surface water flooding, given the current data limitations (please see Section 3.2.6 for more information).

Verification of the modelling outputs has been undertaken using the historic flooding information identified as part of the Phase 1 SWMP and through comparison with the Environment Agency's Flood Map for Surface Water (FMfSW). Both forms of verification have provided a fairly good match with the Stafford model outputs. As the historical flooding points represent both fluvial and surface water flooding, some are not directly attributable to surface water flooding and therefore do not coincide with the surface water model outlines.

Quantification of Flood Risk

Average Annual Damages (AAD) have been calculated for both the current and future flood risk scenarios, using basic available information, accounting for damages to property, stress related impacts and emergency costs. Key potential sources of pollution damage to the environment have been identified as direct runoff into watercourses (from both rural and urban areas), surface water sewer outfalls and runoff from industrial estates. These have not been quantified within this assessment. Potential impacts of surface water flooding on critical infrastructure have also been identified.

Outputs

In addition to the model, mapping has been provided to the Steering Group in the form of Interactive PDFs to show:

- ✓ the extent of the modelled flooding for each return period (including the climate change scenarios);
- ✓ the predicted depth of flooding;
- ✓ the associated hazard; and
- ✓ the historical flood locations (from Phase 1) [1].

The following key surface water flooding issues and hotspots within the Stafford watershed have been identified, alongside key mitigation strategies and partnership actions:

Key Surface Water Flooding Issues for Stafford Town

1. Flooding across Stafford town originates from overland runoff originating both from rural areas upstream of the town and from within the urban area;
2. Limited impact has been identified from the sewer network within the town, correlating with the lack of historic sewer flooding records;
3. There is significant potential for interaction between surface water and fluvial flooding within the town. In particular, the backing up of fluvial flows along the surface water drainage network should be investigated further;
4. The M6, railway and major road embankments (both in operation and disused) act, in parts, as barriers to flow, resulting in inflated flood depth and hazard upstream. In some instances this may be reducing the flood risk to Stafford downstream, but once water has accumulated to a significant depth, this results in the flooding of the key access and egress routes;
5. Capacity exceedence is illustrated for many of the ordinary watercourses and smaller Main Rivers in the rural area;
6. Potential for surface water interactions with the canal network should be investigated further;
7. Some of the key access and egress routes are flooded in the higher probability flood events;
8. Flooding initiates during the 1 in 2 year flood event;
9. For the current situation, the flood event that generates the greatest annualised damages is the 5 year storm, which would therefore be the most cost beneficial to mitigate against;
10. The total AAD for the current situation is approximately £21.9m (>0.1m water depth), including an allowance for stress and emergency costs (significantly generated by the flooding of commercial properties);
11. The total AAD for the future flood scenarios (based on three flood probabilities) is approximately £36.8m (>0.1m water depth), indicating that climate change poses a significant increase to surface water flood risk in the City;
12. Surface water flood depths are generally low in all return periods, although increase to a maximum of 2.5m at residential property boundaries (0.9m for commercial properties) in the 1 in 200 year flood event;
13. Flood hazard within Stafford town is limited, although hazard is identified as 'significant' to 'extreme' in some areas of the watershed, parts of the M6 and the industrial estates to the east of the town;
14. Risk of pollution is closely linked to surface water flood risk and should be reduced to assist in meeting the WFD targets downstream (details of sources of pollution are provided in **Table 3.3**);
15. Critical infrastructure is at risk of surface water flooding, affecting care homes, fire stations, schools, telephone exchanges, sewage treatment works, waste management sites and electricity installations.

[1] These have been updated following publication of the Phase 1 SWMP - please see the Southern Staffordshire Phase 1 SWMP Addendum dated March 2011.

Key Mitigation Strategies for Stafford

1. Regular monitoring, clearance and maintenance of key drainage routes, including highways drains, Main River, Ordinary watercourses and culverts;
2. Investigation into the potential to increase certain culvert sizes or install additional culverts under road, railway and canal embankments;
3. Maintenance of watercourses to enable surface water to flow efficiently through the urban area;
4. Investigation of the potential to alter land management practices to reduce/slow surface water runoff from the surrounding countryside;
5. Investigation into the interactions between surface water runoff and the canal;
6. Investigation into interactions between the surface water drainage network and fluvial flooding;
7. Investigation into the potential to utilise the road network to route surface runoff between residential areas;
8. All information contained within this SWMP should be considered when site specific FRAs are undertaken for developments within this area;
9. Installation of SUDS in all new developments, with the aim to reduce runoff below Greenfield rate in the key drainage areas upstream of the town[2] (please see Section 4.3 of the Southern Staffordshire WCS for further information regarding individual SUDS techniques and STWL's guidance on surface water discharges and SUDS);
10. Retrofitting of SUDS in existing developments, where feasible;
11. Investigation of potential to install storage ponds/utilise the existing and naturally occurring storage areas to accommodate surface water runoff upstream of residential areas and flow constrictions, perhaps through dual use of parkland or playing fields;
12. Preparation of emergency plans to accommodate road closures and the evacuation of vulnerable populations from hazardous areas;
13. Maintenance of surface water sewer network for continued operation[3] and to allow effective CSO operation and minimise backing up of network below the design capacity (1 in 30 year flood event);
14. Promotion of Codes of Good Agricultural Practice and recognition of NVZ status to reduce pollution from direct runoff in rural areas;
15. Installation of pollutant filtering SUDS in industrial areas, especially to the east of the town;
16. Investigation into mitigation strategies to protect against the 1 in 5 year storm, potentially through local/ site specific Phase 3/4 SWMPs; and
17. Partnership working between organisations to implement the most beneficial and cost effective solutions (the main actions required from the key partners identified within this report are summarised in **Table 5.1** below - these require review, discussion and agreement as part of a Phase 3 SWMP, if undertaken).

[2] The Environment Agency advise this is set to an annual rate for all return periods. We recommend the Council discuss the most appropriate rate with the Environment Agency.

[3] Please note that surface water sewers do not require regular clearing and maintenance in the same way that foul/combined sewers may require maintenance due to the lack of solids and particulate matter within the flows. However, a number of standard activities are already undertaken by STWL to ensure they operate effectively.

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APPENDICES

1 INTRODUCTION

1.1 General Overview

In November 2009 Royal Haskoning was appointed by Stafford Borough, Lichfield District, Tamworth Borough, Cannock Chase District and South Staffordshire District Councils to produce a Phase 1 and Phase 2 Surface Water Management Plan (SWMP) and a Phase 1 and Phase 2: Scoping and Outline Water Cycle Study (WCS).

The Phase 1 and 2 WCS and Phase 1 SWMP reports were published in July 2010 and both reports covered a study areas consisting of all five Local Authority Boroughs/Districts. This report relates to the production of the Phase 2 SWMP for Stafford Borough, relating specifically to Stafford town. It has been written with reference to Defra's latest SWMP guidance[4].

1.2 Study Area

The Phase 1 SWMP covered the study area enclosed by the administrative boundaries of Stafford Borough, Lichfield District, Tamworth Borough, South Staffordshire District and Cannock Chase District, as outlined in red in **Figure 1.1** on the following page. The Phase 2 SWMP has focussed upon one settlement within each of the Local Authority boundaries: Lichfield City; Stafford town; Cannock town; Tamworth town; and Penkridge village. These locations have been selected from the Phase 1 SWMP using the following criteria:

1. High incidence of historical surface water flooding;
2. High number of houses located within the Environment Agency's Areas Susceptible to Surface Water Flooding (AStSWF) 'less than' flood zone[5]; and
3. A potential for future growth.

To provide a comprehensive assessment of surface water flooding within these settlements, the study area of each SWMP extends beyond the residential boundary to cover the geographical area, defined by topography, in which all surface water runoff flows towards the settlement (the watershed). The outlines study areas are outlined in green on **Figure 1.1** and a separate Phase 2 SWMP report has been produced for each watershed.

1.3 Scope of the SWMP

Defra's SWMP guidance states there are four main stages and a number of sub stages to producing a SWMP, interlinked into a linear process that extends from the identification of a problem through to the implementation of actions to resolve the situation. This study was commissioned, and the Phase 1 SWMP completed, to the specifications of the draft SWMP guidance[6] (dated February 2009). However, the guidance was updated in March 2010 and the four stages, and their associated sub

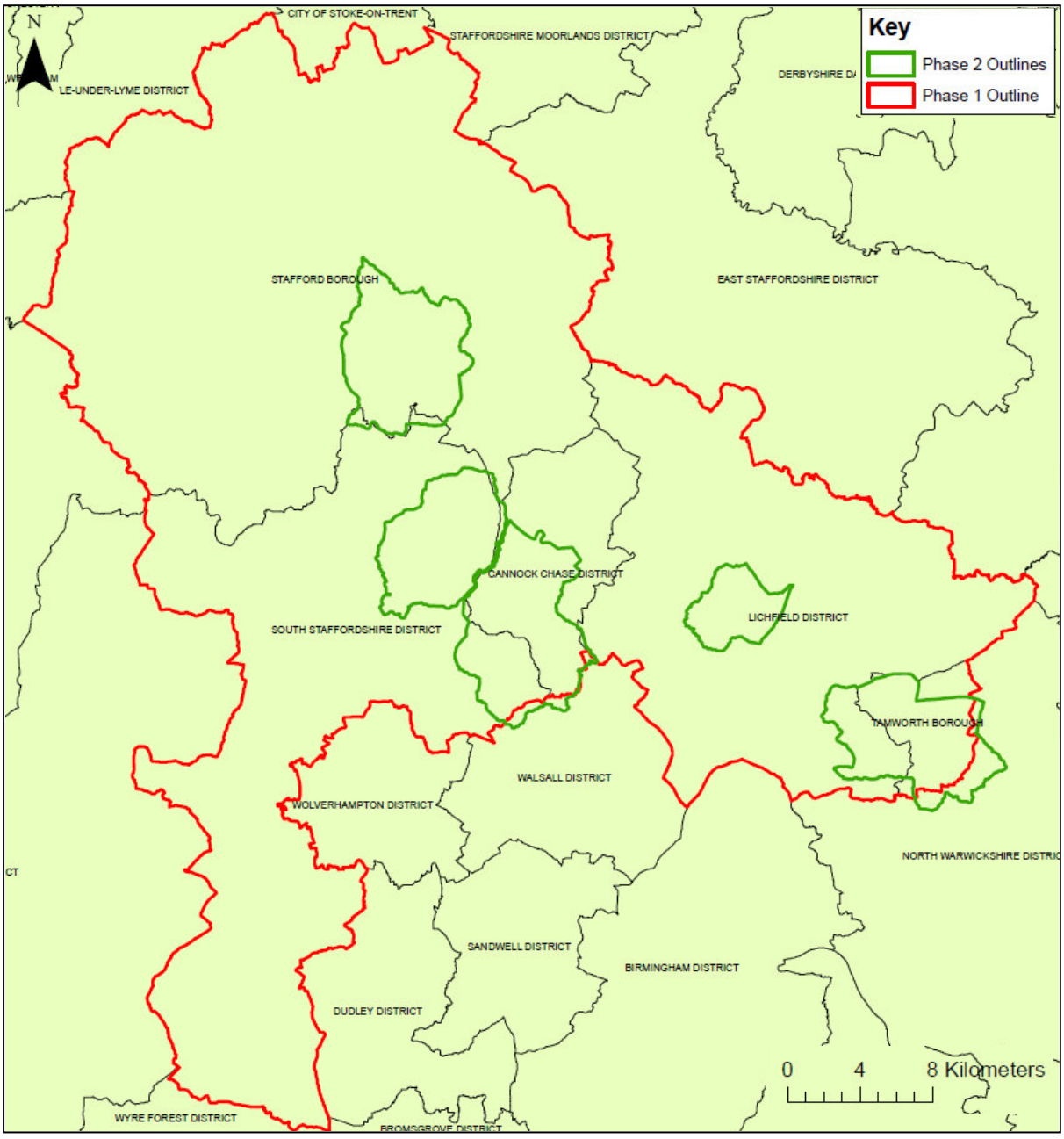
[4] Surface Water Management Plan Technical Guidance, Defra, March 2010

[5] The AStSWF is the Environment Agency's first edition national surface water flood map. Their second edition, Flood Map for Surface Water (FMfSW) had not been published at the time of the Phase 1 SWMP.

[6] Surface Water Management Plan Technical Guidance, Living Draft Version 1, Defra, 2009

stages, have been adjusted between the two versions. To assist the Councils with the progression of this SWMP at a later date (i.e. through Phases 3 and 4, if required), this Phase 2 report has been written with reference to the latest, 2010, guidance. The stages specified within this guidance are shown in **Figure 2.1**.

Figure 1.1 - SWMP Study Area - Phase 1 and Phase 2



2 OUTPUTS FROM PHASE 1

2.1 Introduction

The adjustments to the Defra 'wheel' between the draft and latest guidance have resulted in a degree of overlap between the scope of the completed Phase 1 SWMP report and the current requirements of a Phase 2 SWMP. To provide clarification, a comparison of the latest SWMP 'wheel' with the scope of the Southern Staffordshire Phase 1 and Phase 2 studies is illustrated in **Figure 2.1** below. The remainder of this section reviews the stages covered within the Phase 1 SWMP report.

Figure 2.1 - Scope of Southern Staffordshire Phase 1 and Phase 2 SWMPs Overlaid onto Defra's Final Guidance SWMP 'wheel'

2.2 Preparation

All the requirements of the Preparation stage of the latest Defra 'wheel' were covered in the Southern Staffordshire Phase 1 SWMP, namely:

- ✓ Identification of the need for a SWMP;
- ✓ Identification of partners to be involved;
- ✓ Clarification of partner roles and responsibilities;
- ✓ Determination of aims and objectives;
- ✓ Establishment of an engagement plan;
- ✓ Identification of information availability; and
- ✓ Identification of the level of assessment required.

2.3 Strategic Assessment

Phase 1 of the draft Defra SWMP guidance specified a requirement for collating, analysing and mapping surface water flooding information. Within the latest guidance, requirement is included within Phase 2 and referred to as the 'strategic assessment'.

The outputs from the Southern Staffordshire Phase 1 SWMP included maps of the entire study area (all five Districts/Boroughs) showing locations and frequency of historic surface water flooding events, the risk of future surface water flooding (based upon the Environment Agency's AStSWF) and the locations of potential future development. *Please note that following publication of the Phase 1 SWMP report, the recorded historic flood locations have been updated in line with Staffordshire County Council's Preliminary Flood Risk Assessment (PFRA). This adjustment is documented within an Addendum to the Phase 1 SWMP*[7].

From this information the Phase 1 report concluded that the following settlements were 'hotspots' for historic and, potentially future, surface water flooding and, as such required further investigation within a Phase 2 SWMP:

- ✓ Stafford town;
- ✓ Lichfield City;
- ✓ Cannock Chase town;
- ✓ Tamworth town; and
- ✓ Penkridge village.

Based upon the available information it was determined that an integrated model was the most suitable assessment method, with a separate model constructed for each of the five watersheds. As surface water flooding is not connected between these five areas, a separate model and Phase 2 SWMP report has been produced for each watershed. **This report relates to Stafford town watershed only.**

[7] Southern Staffordshire Phase 1 SWMP Addendum, Royal Haskoning, March 2011.

3 PHASE 2 SWMP: RISK ASSESSMENT

3.1 Level of Assessment

As noted, this assessment was not commissioned under the latest Defra SWMP guidance. However, it has been determined that the level of this Phase 2 SWMP covers all the required elements of an Intermediate study and many of the elements of a Detailed study. Checklists identifying which elements are included within this report are shown in **Appendix A**.

3.2 Modelling

3.2.1 Introduction

An integrated model has been constructed for Stafford town by our specialist sub consultant, Richard Allitt Associates, using the latest Infoworks ICM (Integrated Catchment Modelling) software. The model covers the area contained within the watershed of the town, as shown in **Figure 3.1** (**Appendix B**). The model has been constructed to include overland flow, fluvial flows affected by surface water and the underground drainage network (i.e. sewers), producing outputs of flood extent, depth and velocity for a variety of annual probabilities of flooding. Descriptions outlining how these different elements have been incorporated into the model are given below.

3.2.2 Overland Flow

The surface topography has been represented in the Infoworks model as a triangular mesh, varying in grid size to reflect the required level of detail of the land surface. In the open countryside the mesh is large to reduce model run-time, whereas in the centre of the town the mesh is much smaller to represent the roads and drainage pathways between buildings.

LiDAR has been procured for the entire watershed at a resolution of 1m, enabling detailed representation of the topography, including road networks, railway embankments, bridges and underpasses. Within the urban area the Council's Mastermap data has been used to depict the footprint of buildings. These footprints have been artificially raised in height to force the surface water to flow around the structures. Where information was available, openings through embankments, such as culverts, have also been included.

Overland flow is simulated in the model by applying rainfall outputs, which are then routed across the mesh, flowing down slope, along drainage routes and collecting in depressions.

3.2.3 Fluvial Flows

The Main Rivers and larger ordinary watercourses have been defined within the model as routes of surface water flow. Five Main Rivers are located within the watershed. The River Sow flows from west to east through the centre of Stafford. The Sandyford Brook and Kingston Brooks are left bank tributaries of the River Sow, flowing from north to south through the northern section of Stafford town. The River Penk is a right bank

tributary of the River Sow, flowing from south to north. Finally, the Rising Brook is a tributary of the River Penk flowing from west to east through the southern half of the town.

1d ISIS models of the Rivers Sow and Penk and the Sandyford Brook and a HEC-RAS model of the Rising Brook have been provided by the Environment Agency and, as far as possible, the survey information within these models has been included within this integrated model. Where survey information has not been available, the watercourses have been defined through the extraction of cross sections from the LiDAR. However, as LiDAR does not penetrate water, the bed level of the watercourse channels is not accurately represented using this technique, requiring manual modification. As such, the model would be improved through the inclusion of channel survey data, if undertaken in the future.

The watercourses receive outfalls from the sewer network, in addition to surface water runoff entering along the length of their banks. Where flows exceed the capacity of the watercourse, the water overtops the banks and is routed back into the surface mesh.

A baseflow provision for the fluvial watercourses has been included, but a detailed assessment of fluvial flows, included tributary inflows, water levels and downstream boundaries was not included. The resulting flooding modelled along these watercourses is therefore purely related to surface water flooding and not fluvial flooding, which may occur in parallel, resulting in a much larger flood extent.

In addition, please note that, as the 2D mesh from which flood depths are extracted does not include water levels, the resulting depth and hazard maps do not include a representation of the watercourse channels. However, where the water depth exceeds the capacity of the channel, the resulting flooding alongside the channel is mapped.

3.2.4 Underground Drainage

Severn Trent Water Limited (STWL) acts as the sewerage undertaker for the whole of Stafford Borough. They periodically assess the capacity and simulate the operation of their network and their latest model was incorporated into this integrated surface water model. Most of Stafford is served by separate foul and surface water sewers, although some combined sewers remain in the town centre. The model enables surface water flows to flow in to and out of the sewerage network. Flows enter the network where the model predicts there is capacity and leave the underground network at outfall locations (into the watercourses), and manholes (details of both the location and invert levels of such structures were included in the model).

STWL's model was produced for use within their Drainage Area Plan. As such it is mostly designed for strategic planning purposes only, although small areas of more detailed modelling may exist where investigation into sewer flooding issues have been previously investigated by STWL. With the exception of the detailed areas of modelling, the model used within this SWMP has not been subjected to detailed local verification and, in some locations, has not been verified at all by STWL. As a result, the degree of verification and model confidence varies within the model used within this SWMP. STWL therefore cannot guarantee the accuracy and correction of the models provided

and this may affect the confidence of the model outputs, including flood depths and velocities.

Where known surface water sewers were omitted from STWL's model, they were manually added to this integrated model. These sewers have not, however, been verified by STWL.

For urban areas not served by the sewerage network, or where the location of the sewer network was unknown, the rainfall runoff was routed over the surface. To offer the most conservative scenario, existing SuDS schemes located within new developments were not included. Highway and private drains have also not been included.

3.2.5 Rainfall

A volume of rainfall has been assigned across the watershed using the FEH rainfall runoff volume method and the model run for the critical storm duration[8]. For Stafford the critical storm duration was defined as the 60minute event and this was applied to all annual probabilities of flooding.

To provide a representation of infiltration, the rainfall was factored down to give 17%[9] runoff in rural areas. In urban areas it was maintained as 100% runoff. A value of 10mm of antecedent rainfall was applied over all surfaces in the model to fill surface depressions and storage areas.

The climate change scenarios were simulated by increasing the current rainfall intensity by 30%, as per current Defra guidance[10]. This represents the predicted scenario 75 - 105 years in the future (2085 - 2115).

3.2.6 Model Verification

Verification of the modelling outputs has been undertaken using known historic flooding locations and through comparison with the Environment Agency's FMfSW[11]. No formal verification was undertaken of the rainfall events.

As noted in Section 2.2., during the production of this Phase 2 SWMP, Staffordshire County Council has completed their PFRA[12], which included a revision of the historic flooding information included within the Phase 1 SWMP. As such, the PFRA data has been used for the purposes of verification rather than the Phase 1 SWMP. An addendum to the Phase 1 SWMP has been produced to reflect this adjustment and to introduce the sources and collection methodology of this latest historic flood information.

[8] The length of storm that results in the highest peak flow of surface water runoff

[9] This figure has been calculated as a benchmark through previous SWMP studies.

[10] See SWMP guidance (March 2010): pp37 and PPS25 (March 2010): pp16

[11] Please note this has been updated from the AStSWF mapping utilised in the Lichfield City Phase 2 SWMP Final Report v1, January 2011.

[12] Staffordshire Preliminary Flood Risk Assessment, Royal Haskoning and Staffordshire County Council (March 2011)

Both forms of verification have provided a good match with the Stafford model outputs. Most of the historic flooding points correlate with the modelled flood outlines and, where correlation is not obvious, the historic flooding points are attributable to fluvial flooding (also a significant source of flood risk within Stafford town). Other discrepancies are likely to be attributable to the lack of detail included within the model regarding curb heights and garden wall and fence locations. The addition of these assets will provide barriers to flow and may result in the pooling of water in particular locations and therefore the slightly deeper flood depths recorded. When compared to the Environment Agency's FMfSW, all the key flow paths are identified within the model, although with greater definition to the flood extents.

3.2.7 Model Assumptions and Limitations

The model has been constructed using the best available information, including:

- ✓ LiDAR (flown in 2010);
- ✓ Mastermap;
- ✓ STWL Sewer model;
- ✓ STWL manhole locations and invert levels;
- ✓ River Centrelines;
- ✓ River Sow and Penk 1d model;
- ✓ Sandyford Brook (1d) model;
- ✓ Rising Brook (1d) model;
- ✓ FEH rainfall;
- ✓ Culvert size and location information from Stafford Borough and Staffordshire County Councils; and
- ✓ Proposed potential development site locations

The model, as it stands at present, is considered fit for purpose. However, due to data, budget and time restrictions there are some limitations to the outputs, which must be appreciated when interpreting the model results. These are summarised in the information box below and could be modified in any future adjustments to the model.

Model Limitations / Assumptions

1. Flow routes through buildings have not been included, with buildings represented as solid objects;
2. Individual property sewer connections have not been included;
3. Road and pavement curbs have not been included;
4. Garden walls, fences and gates have not been included;
5. Where channel survey and models were not available, watercourses have been represented using LiDAR and a degree of manual interpretation for channel depths;
6. Fluvial flow has not been fully represented;
7. Surface water sewers omitted from STWL's model have been manually added and, as a result, have not been verified by STWL;
8. Rainfall inputs have not been verified;
9. Model verification is limited by the PFRA historical flooding data and the Environment Agency's FMfSW; and
10. A number of assumptions have been made regarding culvert sizes, river reaches and bridge openings[13].

[13] Shapefiles and associated databases of all assumptions within the modelling have been included with the GIS deliverables.

3.3 Model Runs

The model has been run for the following annual probabilities of surface water flooding:

- 50% *(there is a 1 in 2 chance of flooding in any given year)*;
- 20% *(there is a 1 in 5 chance of flooding in any given year);*
- 10% *(there is a 1 in 10 chance of flooding in any given year);*
- 5% *(there is a 1 in 20 chance of flooding in any given year);*
- 4% *(there is a 1 in 25 chance of flooding in any given year);*
- 3.33% *(there is a 1 in 30 chance of flooding in any given year);*
- 2% *(there is a 1 in 50 in chance of flooding in any given year);*
- 1.33% *(there is a 1 in 75 chance of flooding in any given year);*
- 1% *(there is a 1 in 100 chance of flooding in any given year);*
- 0.5% *(there is a 1 in 200 chance of flooding in any given year);*

In addition, the following climate change scenarios have been simulated (by increasing the current associated rainfall intensity by 30%):

- 5% + CC *(projected to the year 2100, there is a 1 in 20 chance of flooding in any given year);*
- 2% + CC *(projected to the year 2100, there is a 1 in 50 in chance of flooding in any given year); and*
- 1% + CC *(projected to the year 2100, there is a 1 in 100 chance of flooding in any given year).*

The outputs from these simulations have included flood extent, depth and velocities and have been used to inform the quantification of current and future surface water flood risk, outlined below.

3.4 Quantifying Current Risk

The process included within the Defra guidance for quantifying current flood risk has been followed to identify the Average Annual Damages (AAD) due to surface water flooding. The guidance recommends the consideration of the damages to property, people, the environment and critical infrastructure/services. As depth information was provided from the model simulations, a depth-damage relationship was applied, utilising the depth-damage curves and estimates included within the 'Multi-Coloured Manual'[14]. Limitations to this approach are summarised in the following box.

[14] 'The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques', Flood Hazard Research Centre (FHRC), Defra, Environment Agency (2005) - *the 'Multi-Coloured Manual' (MCM).*

Limits of Depth-Damage Calculations

Although considered to be the approach which provides the best representation of damage to properties, depth-damage curves are known to be highly sensitive to low depth predictions, introducing uncertainty to the results. As a large proportion of the flood depths (especially for the higher return periods) simulated within Stafford town are considered 'low depth' (<0.4m) they should therefore be viewed with caution.

In addition, the calculation of damages is limited to the property/infrastructure information readily available at the time of analysis. This assessment has utilised the National Receptor Database (NRD) provided by the Environment Agency, Critical Infrastructure information provided by Staffordshire County Council and the MCM 2010 damage estimate tables. This information has not been verified through site visits or surveys. It must also be noted that, as threshold surveys were not available for use, the calculations assume all property thresholds to be at ground level. In addition, no capping values were available within the NRD. As such they provide a very conservative estimate of total damages.

However, to include a limit to the number of properties assessed and to bring the mapping in line with the Environment Agency's FMfSW, property counts have been undertaken for two scenarios - water depths of greater than 0.1m and water depths of greater than 0.3m. No depth-damage assessment has been made of properties located in flood depths of less than 0.1m.

As a result of the limitations mentioned here, the damage calculations included in this report should not be considered prescriptive, but used as a rough comparative guide. More detailed depth-damage calculations are recommended as part of a cost-benefit assessment when considering particular mitigation options within Phase 3 of the SWMP (if progressed). For more information regarding the calculation of damages using depth-damage curves, please refer to the Defra SWMP and MCM guidance.

3.4.1 Damages to Property

To calculate the damages to properties, the depth of flooding was extracted from the model results at the property boundary (where a variety of depths were measured around the property, the deepest was selected for this calculation). In line with Staffordshire County Council's PFRA, the National Receptor Dataset (NRD) was used as the basis for locating affected commercial and residential properties and the County Council's detailed local dataset for critical infrastructure was used to identify the critical services at risk (e.g. schools, nursing homes, police stations, electricity installations etc).

No threshold data was available for use in this study, however, to provide some limitation on the number of properties selected, the property counts were limited to two bands - those experiencing water depths of greater than 0.1m and those experiencing water depths of greater than 0.3m. These depth bandings are in line with those utilised in the FMfSW. *Please note the mapping of the modelled flood extents includes flood depths of less than 0.1m, although the model results do not include depth simulations below 0.01m.*

Damage to residential properties was calculated using the MCM 2010 depth-damage tables, accounting for depth of flooding and property type (e.g. detached, semi-detached, terraced etc). The inclusion of social class and a social weighting (as discussed in the Defra guidance) was considered too detailed for this settlement-wide assessment. Damage to commercial properties was included through identification of use and floor area from the NRD (e.g. office, warehouse, retail etc) and comparison with the appropriate MCM depth-damage tables. No property 'capping' values were

available for use in this study. All flood events were assumed to be less than 12 hours in duration.

The number of properties, types of commercial property and vulnerable population affected by each flood event are summarised in **Tables 3.1** and **3.2** below.

Table 3.1 - Residential Properties at Risk

Flood Event (1 in…)	>0.1m Depth				>0.3m Depth			
	Number of Properties[3]	Population (Number of People)[1]	Water Depths (m)		Number of Properties[3]	Population (Number of People)[1]	Water Depths (m)	
			Min	Max			Min	Max
2	50	117	0.10	0.31	6	14	0.30	0.58
5	87	204	0.10	0.34	8	19	0.30	0.67
10	145	339	0.10	0.38	14	33	0.30	0.71
20	192	449	0.10	1.00	22	51	0.30	0.74
25	210	491	0.10	1.20	22	51	0.30	0.76
30	227	531	0.10	1.28	25	59	0.30	0.77
50	280	655	0.10	1.36	29	68	0.30	0.77
75	328	768	0.10	1.76	47	110	0.30	0.80
100	388	908	0.10	1.65	48	112	0.30	0.81
200	523	1,224	0.10	2.45	74	173	0.30	0.94
20CC[2]	263	615	0.10	0.57	30	70	0.31	0.58
50CC[2]	407	952	0.10	0.63	53	124	0.31	0.67
100CC[2]	550	1,287	0.10	2.55	81	190	0.30	0.71

NOTES:

[1] Number of properties multiplied by 2.34 (inline with the PFRA)

[2] CC represents Climate Change scenario

[3] Please note that no threshold levels have been assigned to this count and that the water depths are, for the more frequent flood events, relatively low. Therefore, although property numbers are high, most will not experience internal flooding. This assessment would be improved and property numbers reduced through the inclusion of an assessment of property thresholds.

Table 3.2 - Types of Commercial Property at Risk of Flooding (as listed in the NRD)

KEY:

✓ - at risk of flooding from 0.1m water depth ✓ - at risk of flooding from 0.3m water depth

Commercial Building* *(extracted from NRD)*	Flood Event Probability (1 in …)												
											Climate Change		
	2	5	10	20	25	30	50	75	100	200	20	50	100
ARMY SITE	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
ART GALLERY			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BANDSTAND						✓	✓	✓	✓	✓		✓	✓
BOWLING	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CAR DEALER							✓	✓	✓	✓		✓	✓
CHILDRENS NURSERY		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CHURCH			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CINEMA						✓	✓	✓	✓	✓		✓	✓
CLUB	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓

Commercial Building* *(extracted from NRD)*	Flood Event Probability (1 in …)												
											Climate Change		
	2	5	10	20	25	30	50	75	100	200	20	50	100
DEPOT	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
ELECTRICITY SUB STATION			✓	✓	✓	✓	✓	✓	✓	✓✓	✓	✓	✓✓
ENGINEERING WORKS										✓			✓
FACTORY				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FIRE STATION		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FOOTBALL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GARAGE										✓			✓
GENERAL COMMERCIAL	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
GOLF		✓	✓	✓	✓	✓	✓	✓	✓	✓✓	✓	✓	✓✓
GOVERNMENT OFFICE							✓	✓	✓	✓		✓	✓
HALL	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
HEALTH CENTRE	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
HOPPER (Storage Silo)										✓		✓	✓
HOSPICE		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
INN			✓	✓	✓	✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓
JOB CENTRE								✓	✓	✓		✓	✓
LEISURE CENTRE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LOCAL GOVERNMENT OFFICE				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
OFFICE	✓	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
POSTAL DISTRIBUTION	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
PUBLIC HOUSE										✓			✓
RESTAURANT										✓			✓
RETAIL WAREHOUSE				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SERVICE STATION						✓	✓	✓	✓	✓	✓	✓	✓
SHELTER				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SHOPPING	✓	✓	✓	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
SNOOKER			✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
SPORTS PAVILION									✓	✓			✓
SPORTS VIEWING								✓	✓	✓		✓	✓
SUPERMARKET							✓	✓	✓	✓		✓	✓
SURGERY		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
TAKE AWAY										✓			✓
TAXI BUSINESS									✓	✓			✓
TELECOMMUNICATIONS	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
UNIVERSITY				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
WORKS			✓	✓	✓	✓	✓	✓	✓	✓✓	✓	✓	✓✓
Unspecified	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
TOTAL NUMBER OF COMMERCIAL PROPERTIES AT RISK													
>0.1m Depth	**74**	**128**	**166**	**111**	**220**	**231**	**273**	**300**	**325**	**398**	**261**	**338**	**414**
>0.3m Depth	**6**	**8**	**14**	**22**	**22**	**25**	**29**	**47**	**48**	**74**	**30**	**53**	**81**

3.4.2 Damages to People

The impacts of flooding on householders include stress, health effects and the loss of possessions. The Defra guidance recommends the consideration of the following two components when considering damages to health:

1. Stress-related impacts - As per the MCM, an allowance of £200 for flooding per year per household has been included in the AAD calculations to account for stress related impacts.

2. Loss of life and injury - As water velocities and depths are generally fairly low across Stafford it was not considered necessary to include an allowance in the damage calculations for loss of life or injury.

To provide a broad estimate of the number of people potentially affected by each model simulation, an average household size of 2.34 people has been applied and included within **Table 3.1** above (this is inline with the PFRA).

3.4.3 Damages to the Environment

Surface water runoff from the urban environment can have a significant impact on receiving water quality, especially where the flood waters interact with the sewer network.

The River Penk and River Sow have been reviewed within the Humber River Basin Management Plan (RBMP). As stated in the Water Cycle Study, the River Sow has been identified as having a 'poor' ecological status upstream of the River Penk confluence and 'moderate' ecological status downstream of the River Penk confluence. The River Penk has been classified as having 'moderate' ecological status. The River Penk and upstream section of the River Sow have been assigned protected status under the Freshwater Fish, Nitrates Directives, whereas the downstream section of the River Sow has also been assigned protected status under the Urban Wastewater Treatment Directive (see the associated Southern Staffordshire WCS[15] for further information). As a result, improvement is necessary to meet the required 'good' ecological status required under the Water Framework Directive (WFD) by 2015 and a reduction in pollution entering the watercourse from its tributaries will be essential.

Table 3.3 summarises the main sources of pollution likely to affect watercourses as a result of surface water flooding within Stafford and suggestions for mitigating this risk.

If a detailed cost-benefit assessment is undertaken during any future SWMP stages, damages to environmental assets resulting from the surface water flooding will require quantification within the damage calculations. They have not been included within the high level AAD calculations within this report.

Table 3.3 - Sources of Surface Water Pollution and Potential Mitigation Measures

[15] Southern Staffordshire Outline Water Cycle Study Final Report, Royal Haskoning, 2010

Source of Pollution	Modelling Outputs	Mitigation Suggestions	Partnership
Direct runoff into watercourses			
- from rural areas	Surface runoff from rural areas to the east of Stafford drain into the town and, subsequently, into the sewer and watercourse networks.	Promotion of Codes of Good Agricultural Practice and recognition of designation as Nitrate Vulnerable Zones (see Southern Staffordshire WCS).	→ *Farmers* → *Stafford Borough Council* → *Environment Agency*
- from residential areas	Surface water drains along roads and between buildings to the low lying watercourses.	Implementation of filtering SUDS schemes to trap pollution along key drainage paths and along the banks of watercourses.	→ *Stafford Borough Council* → *Highways Agency* → *Severn Trent Water* → *Developers*
Surface Water Sewer Outfalls	At numerous places the surface water sewers outfall directly to the watercourses, having collected drainage from fairly large areas of the town.	Implementation of filtering SUDS schemes to trap pollution on a property or street scale, before the water enters the sewer network.	→ *Developers* → *Severn Trent Water*
CSO spills	Some parts of Stafford town are drained by a combined sewer network and, where foul sewers exist, rainfall may penetrate the network. If the water on the surface enters the sewer network (i.e. from surface drains), the additional water may place additional pressure on the CSOs and, as a result, increase the risk of effluent discharging into the watercourses.	Promotion of SUDS schemes to reduce surface water discharge and cease the connection of surface water discharges into the combined sewer network.	→ *Stafford Borough Council* → *Developers* → *Severn Trent Water*
Runoff from Industrial Estates	Flow routes from the rural areas outside Stafford town are often routed through the peripheral industrial estates before flowing into the watercourses.	Retrofitting of filtering SUDS schemes to trap pollution on a property or street scale, before the water enters the drainage network.	→ *Stafford Borough Council* → *Environment Agency* → *Developers*
Pollution Prevention Control sites	Flooding of a pollution prevention control site from the 1 in 10 year return period event to a depth of 2.3m.	Site specific resilience measures.	→ *Stafford Borough Council* → *Environment Agency*

3.4.4 Damages to Critical Infrastructure, Disruption to Services and Emergency Service Costs

Basic AAD calculations have been carried out for the critical infrastructure, using the local dataset provided by Staffordshire County Council, supplemented by the NRD where local information was not readily available. A full level cost benefit assessment would refine this data by ascertaining that it is up to date and accurate. It should also consider the indirect costs of the disruption caused by the flooding and the cost of service disruption (e.g. the inability of a water treatment works to supply water, an electricity sub station to function or the closure of the road network). Such an assessment should be undertaken by an appropriately trained person or organisation following the latest nationally recognised guidance (currently the MCM).

Table 3.4 below summarises the key elements of critical infrastructure within Stafford and the surface water flood risk posed to each. Please note this table only records flooding to the buildings and not the access and egress routes, which may be affected for many of these locations. Many of the flood depths are very shallow, measured as less than 250mm (the typical threshold level).

Table 3.4 - Summary of Flood Risk to Critical Infrastructure within Stafford

Critical Infrastructure	Number Affected	Vulnerable Population?	Onset of Flooding	Maximum Flood Depth
Schools[1] *(includes High, Middle, Primary and Special Needs)*	4	Yes	1 in 5 year	0.3m
Hospitals[1]				
Nursing/Care/Retirement[1] *(includes nursing homes, rest centres, private care facilities, residential adults, residential children and vulnerable people)*	8	Yes	1 in 2 year	0.52m
Police Stations[1]	1		1 in 100 year	0.16m
Ambulance and Fire Stations[1]	1		1 in 5 year	0.14m
Prisons[2]	2		1 in 10 year	0.17m
Pollution Prevention Control Site	1		1 in 10 year	0.23m
Sewage Treatment Works[2]	1		1 in 10 year	0.22m
Electricity Installations[2]	3		1 in 10 year	0.33m
Telecommunications[2]	1		1 in 2 year	0.48m
Listed Buildings[1]	2		1 in 10 year	0.3m

NOTES

White squares indicate infrastructure that is not affected by the modelled flood outlines.

Critical infrastructure classifications are based upon the designations within the PFRA guidance[16]

[1] Data extracted from Staffordshire County Council's local critical infrastructure dataset

[2] Data extracted from the NRD

The direct cost of the flooding of NRD listed properties has been included within the AAD calculations using the costings provided in the MCM. The Defra guidance also recommends the inclusion of the costs of emergency services responding to flooding

[16] Preliminary Flood Risk Assessment (PFRA) Final Guidance, Environment Agency, December 2010

incidents. The MCM recommends the inclusion of a multiplier of 10.7% in addition to property damages to account for emergency costs. This has been included in Section 3.4.5 below.

3.4.5 Average Annual Damages

The methodology for calculating Annual Average Damages (AAD) utilises the information obtained from all modelled flood events, calculating and summing the integrals between the damage calculations. Inclusion of stress related impacts calculates and sums the integrals of property numbers between the flood events. The methodology is summarised in **Appendix C**.

The AAD have been calculated for the following water depths greater than 0.1m and water depths greater than 0.3m for the following two categories:

1. Residential property total damages; and
2. Commercial property damages;

The annualised damages and property numbers for each return period for these scenarios are also included in **Appendix C**. The AAD for each are summarised in **Table 3.5** below. *Please note that the values provided for depths >0.3m are included within the values for depths >0.1m and they should not be added together to provide a total.*

Table 3.5 - AAD Calculations for Current Flood Risk Scenarios

Water Depths > 0.1m

Damage Calculation	AAD	Annualised Property Numbers	AAD including Stress Impacts	Onset of Flooding	Event with Greatest Annual Damages
Residential Total[1]	£1,172,474	65	£1,185,552	1 in 2 year	1 in 5 year
Commercial Total	£18,565,559	64	£18,578,395	1 in 2 year	1 in 5 year
Total	**£19,738,032**	**130**	**£19,763,946**	**1 in 2 year**	**1 in 5 year**
Emergency Costs (10.7%)	£2,111,969		£2,114,742		
Total Including Emergency Costs	**£21,850,002**		**£21,878,689**		

Water Depths > 0.3m

Damage Calculation	AAD	Annualised Property Numbers	AAD including Stress Impacts	Onset of Flooding	Event with Greatest Annual Damages
Residential Total[1]	£108,846	4	£109,588	1 in 2 year	1 in 5 year
Commercial Total	£5,167,805	6	£5,168,952	1 in 2 year	1 in 5 year
Total	**£5,276,651**	**9**	**£5,278,540**	**1 in 2 year**	**1 in 5 year**
Emergency Costs (10.7%)	£564,602		£564,804		
Total Including Emergency Costs	**£5,841,253**		**£5,843,344**		

[1] Total damages includes an allowance for property contents

For water depths of greater than 0.1m both residential and commercial development register an onset of flooding during the 1 in 2 year event, during which 50 residential properties and 74 commercial properties are flooded (it must be noted that the depth of flooding in many locations is very low during this event). The 1 in 5 year event generates the greatest annual average damages for both the residential and commercial properties.

When the affected properties are capped at 0.3m, although the onset of flooding and event with the greatest AAD remain the same, the property numbers are significantly reduced, reflecting the potential impact the inclusion of threshold information may have upon the depth-damage calculations.

This calculation accounts for both the size of the event (i.e. the resulting cost of flooding) and the probability of the event occurring in any one year to provide a potential 'per year' cost of each event. A 1 in 100 year event may have an estimated damage cost of £20million, but may only occur once in a fifty year period, resulting in £20million damages. A 1 in 5 year event may only cause £5million damages, but may occur more than ten times in a fifty year period, resulting in over £50million damages. It is therefore more cost effective to mitigate against the 1 in 5 year event than the 1 in 100 year event. AAD calculations scale this type of comparison down to a one year period, providing a comparative cost estimate of each event occurring in any one year. The event identified as potentially being the most expensive in a any one year is the most cost effective to mitigate against. Interventions which limit flooding from this event are therefore likely to prove the most cost-beneficial overall. Interventions which limit flooding from this event are therefore likely to prove the most cost-beneficial overall.

A much smaller second peak in the damages occurs in the 50 year storm, reflecting the exceedence of sewer capacity, but this is extremely minor, reflecting the exceedence of sewer capacity.

Due to the limitations of depth-damage curves for low water depths, the results presented here are likely to be inflated. They would probably reduce with a more robust damage calculation, including a realistic representation of property thresholds, internal

water levels and property values. However, this assessment does provide a broad indication as to the potential impacts of surface water flood events within Stafford town and which events are most cost beneficial to mitigate against - in this case the 1 in 5 year storm.

3.5 Quantifying Future Risk

3.5.1 Climate Change

To quantify future flood risk and to assist the Councils with their development control processes, the model has also been run for three climate change scenarios - the 1 in 20 year, 1 in 50 year and 1 in 100 year scenarios. These scenarios are set 100 years in the future, accounting for a 30% increase in rainfall intensity.

3.5.2 Urbanisation and Urban Creep

The Defra guidance recommends that future surface water flood risk scenarios include allowances for new development and urban creep. Such impacts may increase flood risk through decreased infiltration area and sewer capacity exceedence, but may also provide opportunities to decrease flood risk through implementation of SUDS schemes. Urban creep often occurs in the form of extensions and garden paving, which is hard to monitor; the Floods and Water Management Act, when implemented, will require that all new development proposals include a SUDS design. To provide a more detailed representation of future flood risk periodic assessments of urban creep can be made, accounting for the location, size and SUDS design of any confirmed development sites and the model adjusted and re-run.

3.5.3 Annualised Average Damages

Using the same methodology as outlined for the current scenarios, above, the AAD for the three climate change scenarios has also been calculated, as outlined in **Table 3.6**. These show a substantial increase in the AAD totals, implying that surface water flooding will become more of a significant issue within Stafford town in the future unless appropriate mitigation measures are installed.

Table 3.6 - AAD Calculations, Including Climate Change

Water Depths > 0.1m

Damage Calculation	AAD	Annualised Property Numbers	AAD including Stress Impacts	Event with Greatest Annual Damages
Residential Total	£2,527,129	140	£2,555,081	1 in 20 year + CC
Commercial Total	£30,624,677	14	£30,652,021	1 in 20 year + CC
Total	**33,151,806**	**154**	**33,207,102**	**1 in 20 year + CC**
Emergency Costs (10.7%)	£3,547,243		£3,553,160	
Total Including Emergency Costs	**£36,699,050**		**£36,760,262**	

Water Depths > 0.3m

Damage Calculation	AAD	Annualised Property Numbers	AAD including Stress Impacts	Event with Greatest Annual Damages
Residential Total	£366,034	14	£368,782	1 in 20 year + CC
Commercial Total	£10,484,566	16	£10,487,799	1 in 20 year + CC
Total	**10,850,600**	**30**	**10,856,581**	**1 in 20 year + CC**
Emergency Costs (10.7%)	£1,161,014		£1,161,654	
Total Including Emergency Costs	**£12,011,614**		**£12,018,235**	

4 PHASE 2 SWMP: MAP AND COMMUNICATE RISK

4.1 Surface Water Flood Maps

Mapping has been provided to the Steering Group in the form of Interactive PDFs to show:

- ✓ the extent of the modelled flooding for each return period (including the climate change scenarios);
- ✓ the predicted depth of flooding;
- ✓ the associated hazard; and
- ✓ the historical flood locations (from Phase 1).

4.1.1 Flood Hazard Maps

Flood Hazard Mapping brings information on flood depth and velocity (speed) of floodwater together to create a hazard rating to people within each area that could experience flooding. The hazard rating used is set out in Defra's FD2320 guidance[17]. The hazard rating is calculated using the following equation and categorises flood risk in terms of Caution, Danger for Some, Danger for Most and Danger for All, with the hazard becoming dangerous to more people as depths and velocities increase.

Hazard Rating = d * (v+0.5) + DF
Where d = depth (m), v = velocity (m/s), DF = debris factor

The results from this equation are grouped into bands, as illustrated in **Table 4.1** and **Table 4.2** below.

Table 4.1 – Description of Hazard Categories

Degree of Flood Hazard	Colour Code	Description
Low		**Caution / Low Hazard**
Moderate		**Danger for Some** (includes children, the elderly, and the infirm)
Significant		**Danger for Most** (includes the general public)
Extreme		**Danger for All** (includes the emergency services)

[17] Flood Risk Assessment Guidance for New Development Phase 2, Framework and Guidance for Assessing and Managing Flood Risk for New Development (FD2320/TR2) HR Wallingford (October 2005)

Table 4.2 – Flood Hazard Matrix*

Velocity (m/s)	Depth (m)											
	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.00												
0.10												
0.25												
0.50												
1.00												
1.50												
2.00												
2.50												
3.00												
3.50												
4.00												
4.50												
5.00												

* The green colour code is not specified in FD2320/TR2 and has been employed within the mapping in order to show maximum flood extent.

Generally surface water flood hazard across the Stafford watershed is fairly low, due to a combination of low depths and velocities. In all return periods, the majority of the flooded area is classified as 'Low' or 'No' hazard. However, the hazard does increase as flood probability decreases and in certain areas the increase is significant, especially along the routes of drainage ditches and watercourses and where the water backs up behind roads and embankments.

In the higher return period events (1 in 2 year - 1 in 20 year) event no areas in the centre of the town are identified with a flood hazard greater than 'Low', although isolated locations on the outskirts, most notably parts of the industrial estates to the east of the town and a small section of the M6 have been identified as being at risk of 'Moderate' to 'Significant' hazard. As the return periods decrease the hazard along the smaller watercourses and upstream of major roads and flow constrictions increases significantly. This is most notable on the Sandyford Brook, east of the A513 and close to the sewage treatment works.

By the 1 in 200 year event, many of the main drainage routes are depicted by 'Moderate' to 'Extreme' hazard, with the hazard being highest where the water has backed up behind culverts and embankments. In this event most of the areas noted as being at risk of 'Significant' to 'Extreme' hazard are located in undeveloped areas, with the exception of the eastern industrial estates and small pockets within the southwest quadrant of the town. These are areas which should be focussed upon when

considering emergency planning, especially with regards to their access and egress routes for both existing and potential development. The hazard is also not particularly high around the critical infrastructure locations, with the exception of the sewage treatment works, behind which it is identified as 'Extreme'.

4.2 High Risk Areas and Mitigation Suggestions

4.2.1 Current Risk

Overall the current risk (accounting for probability and consequence) from surface water flooding within the residential areas of Stafford town is relatively low, especially for the higher probability (more frequent) flood events, although a number of key flow routes have been identified within the modelling. Although property numbers appear high, only a small proportion are within areas of modelled flooding with a depth of greater than 0.3m. However, as witnessed in July 2007, certain parts of the town have a higher risk of surface water flooding and, if flow routes become blocked, the water depths may increase dramatically, especially where they combine with fluvial flooding. The risk of surface water flooding in areas that are not currently developed is much higher, especially close to the ordinary watercourses and behind flow constrictions, where the modelled water depths in the 1 in 200 year event are up to 2m deep.

Tables 4.3-4.7 on the following pages summarise: the key surface water hot spots identified within four broad high risk areas of the watershed; potential mitigation measures to improve the situation; and the stakeholders from which a partnership approach would be beneficial when considering mitigation. **Figure 4.1** in **Appendix B** shows the broad high risk areas (identified through interpretation of the modelling results) and key flow routes and is annotated with references to the flooding hot spots within them.

The overarching key mitigation strategies and quick wins are summarised for the Stafford watershed in the box below. Please note these are initial suggestions and require further discussion and development with all surface water partners as part of a Phase 3 SWMP, if undertaken. Please also note that many of the partners (including STWL, the Highways Agency and the Councils) already undertake a number of the routine maintenance tasks identified below. Where this is the case, this report encourages the continuation of such tasks.

Key Management Themes and Quick Wins for Stafford Town

- Regular monitoring, clearance and maintenance of key drainage routes, including highways drains, culverts and watercourses (the watercourses are key in transmitting surface water flow through the town);
- Maintenance of the tributary watercourse and Brooks to transmit water through the residential areas of the town;
- Investigation into enlargement of culverts under key transport links, including the M6, the A513 and the railway to reduce blockage of those routes;
- Investigation into surface water interaction with fluvial flows when considering potential mitigation options;
- Investigate the potential to alter land management practices to reduce/slow surface water runoff from the surrounding countryside, most notably to the north and east;
- Installation of SUDS in new developments (please see Section 4.3 of the Southern Staffordshire WCS for further information regarding individual SUDS techniques and STWL's guidance on surface water drainage discharges and SUDS);
- Utilisation of residential road networks to transmit flood water between properties;
- Maximisation of the existing water storage areas, such as the Doxey and Tillington Marshes, Stafford Common and the recreation ground at the downstream end of the Sandyford Brook (the latter will require discussion with the Sow and Penk IDB);
- Retrofitting of SUDS in existing development, where feasible;
- Investigation of potential to install storage ponds to accommodate surface water upstream of residential areas, perhaps through dual use of parkland or playing fields, or utilisation of motorway and railway embankments;
- Preparation of emergency plans to accommodate road closures and the evacuation of vulnerable populations from hazardous areas;
- Preparation of appropriate flood mitigation strategies for critical infrastructure;
- **Partnership working between organisations to implement the most beneficial and cost effective solutions - all mitigation options to be identified, discussed and agreed as part of a Phase 3 SWMP, if undertaken.**

Table 4.3 - Stafford Town Centre

Stafford Town Centre - Map Area 1		
Issues	**Mitigation**	**Partnership**
♦ Areas of 'moderate' flood hazard.	♦ Draw up appropriate emergency plans and prioritise evacuation from these areas in times of flood, especially for vulnerable populations. ♦ Educate local population. ♦ Implement resilience measures for affected properties.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Civil Contingencies Unit*
♦ Flooding of key access routes (including the A518 from the 1 in 5 year flood)	♦ Draw up appropriate emergency plans and be prepared for road closures/diversions in times of flood. ♦ Ensure highway drains are kept clear from debris along these routes.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Civil Contingencies Unit* → *Highways Agency*

Stafford Town Centre - Map Area 1		
Issues	**Mitigation**	**Partnership**
♦ Potential for interaction of surface water flow with fluvial flows from the River Sow and Sandyford Brook	♦ Regular maintenance to keep any watercourses clear of debris. ♦ Investigation into installation of non return flaps on surface water outfalls. ♦ Reduce surface water flow from upstream through installation of SUDS in any new developments.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Environment Agency* → *Developers* → *Sow and Penk IDB*
♦ Pooling of surface water flows along southern edge of railway embankment.	♦ Regular maintenance to keep any culverts and flow routes under railway clear. ♦ Installation/maintenance of drainage ditch alongside railway embankment.	→ *Stafford Borough Council* → *Network Rail*
♦ Key flow routes draining between residential properties / along residential roads.	♦ Adjust residential roads to act as drainage routes to route water away from properties. ♦ Property specific resilience measures. ♦ Educate local populations. ♦ Installation of SUDS in new development. ♦ Reduction in private garden / driveway paving where possible. ♦ Continued clearance and maintenance of Main and Ordinary watercourses and drainage ditches.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Developers* → *Highways Agency.* → *Severn Trent Water Limited** → *Environment Agency*
♦ Interaction and connectivity of flow routes northern and western parts of the town.	♦ Installation of SUDS in new development. ♦ Increased awareness that development in one part of the town may directly impact properties located some distance away. ♦ Regular maintenance of all highway drains, culverts, watercourses and surface water sewers[18].	→ *Stafford Borough Council* → *Staffordshire County Council* → *Developers* → *Highways Agency.* → *Severn Trent Water**
♦ Location of critical infrastructure in or close to potential flood areas.	♦ Investigate and draw up appropriate flood mitigation measures for each site.	→ *Stafford Borough Council* → *Staffordshire County Council*

NOTES: * STWL are currently only funded to address the more severe incidents of known reported sewer flooding, as recorded on their sewer flooding register. Drainage systems are designed to have a finite capacity and upsizing the underground system to cope with extreme rainfall events may not be the most cost effective means of managing surface water, with the potential to increase the risk of flooding downstream. Due to funding constraints STWL prioritise work based upon a review of the costs and benefits, as agreed with Oftwat, focussing upon the more severe incidents of known reported sewer flooding included on their sewer flooding register. All actions stated within this table require discussion between the partnership organisations during a Phase 3 SWMP, if undertaken.

[18] Please note that surface water sewers do not require regular clearing and maintenance in the same way that foul/combined sewers may require maintenance due to the lack of solids and particulate matter within the flows. However, a number of standard activities are already undertaken by STWL to ensure they operate effectively.

Table 4.4 - West of Stafford Town Centre

West of Stafford Town Centre - Map Area 2		
Issues	**Mitigation**	**Partnership**
♦ Receives runoff from agricultural land.	♦ Investigate potential to reduce surface water flow from upstream through adjustment of land management practices to reduce run off (e.g. ploughing parallel to contours, not leaving fields fallow etc).	→ *Stafford Borough Council* → *Staffordshire County Council* → *Farmers/Land Owners*
♦ Potential to receive runoff from the M6.	♦ Installation and maintenance of appropriate motorway highways drainage and storage ponds.	→ *Stafford Borough Council* → *Highways Agency*
♦ Pooling of water resulting in high water depths and flood hazard.	♦ Regular maintenance and clearance of culverts and watercourses. ♦ Investigation into potential to increase flood water transmission through area. ♦ Awareness of surface water flood risk when planning new developments. ♦ Draw up appropriate emergency plans and prioritise evacuation from these areas in times of flood, especially for vulnerable populations. ♦ Investigation into potential to create designated wetland areas.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Developers* → *Civil Contingencies Unit*
♦ Constriction in flow route at, and flooding of, the Doxey Road from the from 1 in 2 year flood event.	♦ Maintenance of existing culverts. ♦ Investigation into potential to enlarge culverts. ♦ Investigate potential to reduce volume of surface water draining into area through installation of a storage pond. ♦ Awareness of potential flood hazard arising from flood depths and velocities and prepare appropriate emergency plan.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Civil Contingencies Unit* → *Highways Agency*
♦ Recognition of the role of the Doxey and Tillington Marshes	♦ Maintenance of the marshes ♦ Investigation into potential for marshes to store additional water during heavy rainfall events.	→ *Stafford Borough Council.* → *Environment Agency.*
♦ Key flow routes draining between residential properties / along residential roads.	♦ Adjust residential roads to act as drainage routes to route water away from properties. ♦ Property specific resilience measures. ♦ Educate local populations. ♦ Installation of SUDS in new development. ♦ Reduction in private garden / driveway paving where possible. ♦ Continued clearance and maintenance of Main and Ordinary watercourses and drainage ditches.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Developers* → *Highways Agency.* → *Severn Trent Water Limited** → *Environment Agency*

Table 4.5 - North and East of Stafford Town

North and East of Stafford Town - Map Area 3		
Issues	**Mitigation**	**Partnership**
♦ Receives significant runoff from agricultural land with large upstream drainage area.	♦ Investigate potential to reduce surface water flow from upstream through adjustment of land management practices to reduce run off (e.g. ploughing parallel to contours, not leaving fields fallow etc). ♦ Implementation of SUDS in all new developments to reduce runoff below Greenfield rate[19]	→ *Stafford Borough Council.* → *Staffordshire County Council* → *Farmers/Land Owners* → *Developers*
♦ Deep flows and high hazard within industrial estates and close to critical infrastructure	♦ Draw up appropriate emergency plans and prioritise evacuation from these areas in times of flood, especially for vulnerable populations. ♦ Educate local population. ♦ Implement resilience measures for affected properties.	→ *Stafford Borough Council.* → *Staffordshire County Council* → *Civil Contingencies Unit* → *STWL*
♦ Runoff from Industrial estate flows routing towards Stafford town and the A513	♦ Retrofitting of SUDS/surface water balancing pools within development. ♦ Awareness of surface water flood risk when planning new developments. ♦ Extraction of pollutants from surface water onsite.	→ *Stafford Borough Council.* → *Staffordshire County Council* → *Developers* → *Businesses*
♦ Lack of culvert capacity upstream of disused railway embankment and A518 (a number of locations)	♦ Maintenance of existing culverts and clearance of watercourses. ♦ Investigation into potential for installation of storage pond upstream of constrictions. ♦ Awareness of potential flood hazard arising from flood depths and velocities and prepare appropriate emergency plan.	→ *Stafford Borough Council.* → *Staffordshire County Council* → *Civil Contingencies Unit*
♦ Flow route from this area extends into town centre.	♦ Keep an awareness of interconnectivity of flow routes when planning mitigation measures.	→ *Stafford Borough Council* → *Staffordshire County Council*
♦ Flooding of rural roads.	♦ Preparedness for installation of diversions during flood events. ♦ Maintenance and regular clearance of road-side drainage ditches in affected areas.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Civil Contingencies Unit* → *Highways Agency.*
♦ Capacity exceedence of rural watercourses	♦ Maintenance of existing culverts and regular clearance of watercourses, especially those identified as key drainage routes and impacting on properties. ♦	→ *Stafford Borough Council.* → *Staffordshire County Council*

[19] The Environment Agency advise this is set to an annual rate for all return periods to provide the greatest protection. We recommend the Council discuss the most appropriate rate with the Environment Agency.

North and East of Stafford Town - Map Area 3		
Issues	**Mitigation**	**Partnership**
♦ Potential for interaction of surface water flow with fluvial flows from the River Penk and Rising Brook	♦ Regular maintenance to keep any watercourses clear of debris. ♦ Investigation into installation of non return flaps on surface water outfalls. ♦ Reduce surface water flow from upstream through installation of SUDS in any new developments.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Environment Agency* → *Developers* → *Sow and Penk IDB*
♦ Key flow routes draining between residential properties / along residential roads.	♦ Adjust residential roads to act as drainage routes to route water away from properties. ♦ Property specific resilience measures. ♦ Educate local populations. ♦ Installation of SUDS in new development. ♦ Reduction in private garden / driveway paving where possible. ♦ Continued clearance and maintenance of Main and Ordinary watercourses and drainage ditches.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Developers* → *Highways Agency.* → *Severn Trent Water Limited** → *Environment Agency*

Table 4.6 - South Stafford

South Stafford - Map Area 4		
Issues	**Mitigation**	**Partnership**
♦ Flooding of M6 with 'significant' to 'extreme' flood hazard.	♦ Improve drainage, increase culvert capacity and/or install drainage area. ♦ Draw up appropriate emergency and diversion plans.	→ *Stafford Borough Council* → *Staffordshire County Council* → *Highways Agency* → *Civil Contingencies Unit*
♦ Potential for interactions with canal network	♦ Improvement in culvert capacity	→ *Stafford Borough Council* → *Staffordshire County Council* → *British Waterways*
♦ Key flow routes draining between residential properties / along residential roads.	♦ Adjust residential roads to act as drainage routes to route water away from properties. ♦ Property specific resilience measures. ♦ Educate local populations. ♦ Installation of SUDS in new development. ♦ Reduction in private garden / driveway paving where possible. ♦ Reduction in surface water originating from upstream of residential area through management of agricultural practices and reduction in surface water runoff from all new development below Greenfield rate [20].	→ *Stafford Borough Council* → *Staffordshire County Council* → *Developers* → *Highways Agency.* → *Severn Trent Water Limited**
♦ Location of critical infrastructure in potential flood areas.	♦ Investigate and draw up appropriate flood mitigation measures for each site.	→ *South Staffordshire District Council* → *Staffordshire County Council*
♦ Capacity exceedence of ordinary watercourses	♦ Maintenance of existing culverts and regular clearance of watercourses, especially those identified as key drainage routes and impacting on properties.	→ *Stafford Borough Council.* → *Staffordshire County Council*

NOTES: * STWL are currently only funded to address the more severe incidents of known reported sewer flooding, as recorded on their sewer flooding register. Drainage systems are designed to have a finite capacity and upsizing the underground system to cope with extreme rainfall events may not be the most cost effective means of managing surface water, with the potential to increase the risk of flooding downstream. Due to funding constraints STWL prioritise work based upon a review of the costs and benefits, as agreed with Ofwat, focussing upon the more severe incidents of known reported sewer flooding included on their sewer flooding register. All actions stated within this table require discussion between the partnership organisations during a Phase 3 SWMP, if undertaken.

[20] The Environment Agency advise this is set to an annual rate for all return periods to provide the greatest protection. We recommend the Council discuss the most appropriate rate with the Environment Agency.

4.2.2 Future Risk

The impact of climate change on the 1 in 20 year, 1 in 50 year and 1 in 100 year events has been included in the model runs and mapped outputs. A comparison between the climate change scenarios and the current day scenarios results in the following observations:

- Water depths in the 1 in 20 year with climate change scenario are greater than the 1 in 30 year and just lower than the 1 in 50 year current scenario;
- Water depths in the 1 in 50 year with climate change scenario are just greater than the 1 in 100 year current scenario; and
- Water depths in the 1 in 100 year with climate change scenario are greater than the 1 in 200 year current scenario.

The future risk of flooding will also be impacted by any other changes in the catchment, such as new development, alterations to land management practices and adjustments to flow regimes (e.g. culvert widening and the installation of flood storage areas). It is recommended that the models are adjusted and rerun, either to predict the impacts of alterations in the catchments, or to update the results to the latest situation.

4.3 Communication of Risk

As outlined in the Engagement Plan, drawn up as part of the Phase 1 SWMP, numerous stakeholders have an interest in surface water flooding. However, due to the nature of the outputs and the potential for property blight, the Councils will need to decide upon the most suitable method of dissemination to each group. The key groups identified as part of this study and the recommended order in which the findings should be disseminated are illustrated in the summary box below.

Dissemination of Surface Water Findings

1. Core Steering Group
- Stafford Borough Council;
- Lichfield District Council;
- Tamworth Borough Council;
- South Staffordshire District Council;
- Cannock Chase District Council;
- Staffordshire County Council (Lead Local Flood Authority);
- Environment Agency; and
- Severn Trent Water Limited.

2. Additional Surface Water Mitigation Partners
- Sow and Penk IDB
- British Waterways;
- Farmers/Land Owners;
- Civil Contingencies Unit; and
- Highways Agency

3. Other Stakeholders
- Natural England
- Environmental Groups
- Public Flood Risk Forums
- Public
- Riparian Owners; and
- Developers

5 CONCLUSIONS AND NEXT STEPS

5.1 Conclusions

This Phase 2 SWMP study and associated modelling have defined the surface water flood risk to Stafford town and its wider watershed, based upon the best available current information. The model results have substantially refined the extent of surface water flooding from the Environment Agency's FMfSW and been verified by the historical data collected during Phase 1. It must be noted that there are limitations in the modelling techniques and depth damage calculations utilised within this study - these are summarised within the text above.

The key outcomes/conclusions from this study are as follows:

Key Surface Water Flooding Issues for Stafford Town

1. Flooding across Stafford town originates from overland runoff originating both from rural areas upstream of the town and from within the urban area;
2. Limited impact has been identified from the sewer network within the town, correlating with the lack of historic sewer flooding records;
3. There is significant potential for interaction between surface water and fluvial flooding within the town. In particular, the backing up of fluvial flows along the surface water drainage network should be investigated further;
4. The M6, railway and major road embankments (both in operation and disused) act, in parts, as barriers to flow, resulting in inflated flood depth and hazard upstream. In some instances this may be reducing the flood risk to Stafford downstream, but once water has accumulated to a significant depth, this results in the flooding of the key access and egress routes;
5. Capacity exceedence is illustrated for many of the ordinary watercourses and smaller Main Rivers in the rural area;
6. Potential for surface water interactions with the canal network should be investigated further;
7. Some of the key access and egress routes are flooded in the higher probability flood events;
8. Flooding initiates during the 1 in 2 year flood event;
9. For the current situation, the flood event that generates the greatest annualised damages is the 5 year storm, which would therefore be the most cost beneficial to mitigate against;
10. The total AAD for the current situation is approximately £21.9m (>0.1m water depth), including an allowance for stress and emergency costs (significantly generated by the flooding of commercial properties);
11. The total AAD for the future flood scenarios (based on three flood probabilities) is approximately £36.8m (>0.1m water depth), indicating that climate change poses a significant increase to surface water flood risk in the City;
12. Surface water flood depths are generally low in all return periods, although increase to a maximum of 2.5m at residential property boundaries (0.9m for commercial properties) in the 1 in 200 year flood event;
13. Flood hazard within Stafford town is limited, although hazard is identified as 'significant' to 'extreme' in some areas of the watershed, parts of the M6 and the industrial estates to the east of the town;
14. Risk of pollution is closely linked to surface water flood risk and should be reduced to assist in meeting the WFD targets downstream (details of sources of pollution are provided in **Table 3.3**);

15. Critical infrastructure is at risk of surface water flooding, affecting care homes, fire stations, schools, telephone exchanges, sewage treatment works, waste management sites and electricity installations.

Key Mitigation Strategies for Stafford Town

1. Regular monitoring, clearance and maintenance of key drainage routes, including highways drains, Main River, Ordinary watercourses and culverts;
2. Investigation into the potential to increase certain culvert sizes or install additional culverts under road, railway and canal embankments;
3. Maintenance of watercourses to enable surface water to flow efficiently through the urban area;
4. Investigation of the potential to alter land management practices to reduce/slow surface water runoff from the surrounding countryside;
5. Investigation into the interactions between surface water runoff and the canal;
6. Investigation into interactions between the surface water drainage network and fluvial flooding;
7. Investigation into the potential to utilise the road network to route surface runoff between residential areas;
8. All information contained within this SWMP should be considered when site specific FRAs are undertaken for developments within this area;
9. Installation of SUDS in all new developments, with the aim to reduce runoff below Greenfield rate in the key drainage areas upstream of the town[21] (please see Section 4.3 of the Southern Staffordshire WCS for further information regarding individual SUDS techniques and STWL's guidance on surface water discharges and SUDS);
10. Retrofitting of SUDS in existing developments, where feasible;
11. Investigation of potential to install storage ponds/utilise the existing and naturally occurring storage areas to accommodate surface water runoff upstream of residential areas and flow constrictions, perhaps through dual use of parkland or playing fields;
12. Preparation of emergency plans to accommodate road closures and the evacuation of vulnerable populations from hazardous areas;
13. Maintenance of surface water sewer network for continued operation[22] and to allow effective CSO operation and minimise backing up of network below the design capacity (1 in 30 year flood event);
14. Promotion of Codes of Good Agricultural Practice and recognition of NVZ status to reduce pollution from direct runoff in rural areas;
15. Installation of pollutant filtering SUDS in industrial areas, especially to the east of the town;
16. Investigation into mitigation strategies to protect against the 1 in 5 year storm, potentially through local/ site specific Phase 3/4 SWMPs; and
17. Partnership working between organisations to implement the most beneficial and cost effective solutions (the main actions required from the key partners identified within this report are summarised in **Table 5.1** below - these require review, discussion and agreement as part of a Phase 3 SWMP, if undertaken).

[21] The Environment Agency advise this is set to an annual rate for all return periods. We recommend the Council discuss the most appropriate rate with the Environment Agency.

[22] Please note that surface water sewers do not require regular clearing and maintenance in the same way that foul/combined sewers may require maintenance due to the lack of solids and particulate matter within the flows. However, a number of standard activities are already undertaken by STWL to ensure they operate effectively.

Table 5.1 - Key Partnership Actions

Partner	Partnership Actions	
	To Reduce Surface Water Flooding / Risks from Surface Water Flooding	**To Reduce Pollution Resulting from Surface Water Flooding**
Stafford Borough Council	♦ Appropriate emergency planning and road diversions; ♦ Education of local population; ♦ Property specific resilience measures; ♦ Regular maintenance of drains in key flood risk areas; ♦ Regular maintenance/improvement of key watercourses and culverts ♦ Improved drainage of areas at risk of surface water 'pooling' ♦ Promotion of SUDS ♦ Promotion of use of SWMP in site specific FRAs ♦ Regular clearance of rural ditches ♦ Investigation of potential to utilise existing storage and natural pooling areas to store surface water runoff; ♦ Awareness of interconnectivity of flow routes when considering development control. ♦ Investigation into alternative drainage routes/storage options/wetlands ♦ Investigation into installation of culverts under road/railway/canal embankments where key surface water flow routes are identified. ♦ Installation/maintenance of drainage ditch alongside railway embankment. ♦ Investigation into dual use of residential roads as flow pathways. ♦ Reduction in private garden / driveway paving where possible. ♦ Investigation into appropriate flood mitigation measures for critical infrastructure locations. ♦ Collection of data for surface water flood events to pass onto Staffordshire County Council	♦ Promotion of Codes of Good Agricultural Practice; ♦ Recognition of NVZ designation; ♦ Alteration in land management practices to reduce rapid surface water runoff; ♦ Promotion of SUDS schemes in new development and retrofitting in Industrial Estates (filtration SUDS). ♦ Investigation into site specific flood protection for the PPC site.
Staffordshire County Council	♦ Preparation of appropriate emergency planning and road diversions ♦ Education of local population ♦ Regular maintenance of drains in key flood risk areas; ♦ Regular maintenance/improvement of key watercourses and culverts ♦ Improved drainage of areas at risk of surface water 'pooling' ♦ Promotion and approval of SUDS ♦ Awareness of interconnectivity of flow routes when considering development control. ♦ Investigation into alternative drainage routes/storage options/wetlands. ♦ Investigation into appropriate flood mitigation measures for critical infrastructure locations.	♦ Promotion of SUDS schemes in new development and retrofitting in Industrial Estates.

Partner	Partnership Actions	
	To Reduce Surface Water Flooding / Risks from Surface Water Flooding	**To Reduce Pollution Resulting from Surface Water Flooding**
	♦ Centralised recording of surface water flood events.	
Highways Agency	♦ Preparation of appropriate road diversions ♦ Regular maintenance of highways drains in key flood risk areas; ♦ Regular clearance of rural ditches ♦ Investigation into alternative drainage routes/storage options ♦ Investigation into dual use of residential roads as flow pathways. ♦ Investigation into potential M6 flood risk.	♦ Promotion of SUDS schemes
Environment Agency	♦ Appropriate review of FRAs; ♦ Clearance and maintenance of Main Rivers, most notably the Sandyford and Rising Brooks. ♦ Promotion of SUDS.	♦ Promotion of Codes of Good Agricultural Practice; ♦ Recognition of NVZ designation; ♦ Land Management to reduce rapid surface water runoff in rural areas.
Severn Trent Water Limited*	♦ Regular maintenance of surface water sewers to ensure capacity is maintained[23]; ♦ Resolution of any future sewer flooding issues.	♦ Promotion of SUDS schemes ♦ Effective CSO operation
Farmers	♦ Adjustment of land management practices; ♦ Regular maintenance of ditches/drains	♦ Promotion of Codes of Good Agricultural Practice; ♦ Recognition of NVZ designation; ♦ Land Management to reduce rapid surface water runoff in rural areas.
Developers	♦ Installation of SUDS to promote runoff below Greenfield rates[24]. ♦ Reference SWMP for site specific FRAs	♦ Promotion of SUDS schemes
Civil Contingencies Unit	♦ Appropriate emergency planning ♦ Education of local population ♦ Identification of vulnerable population at risk of flooding/moderate to significant flood hazard. ♦ Awareness of risks associated with flood hazard; ♦ Investigation into appropriate flood mitigation measures for critical infrastructure locations.	
British Waterways	♦ Maintenance of culverts / assistance in the installation of new culverts under canal.	♦ Compliance with WFD to reduce pollution risk if surface water interacts with canal

[23] Please note that surface water sewers do not require regular clearing and maintenance in the same way that foul/combined sewers may require maintenance due to the lack of solids and particulate matter within the flows. However, a number of standard activities are already undertaken by STWL to ensure they operate effectively.

[24] The Environment Agency advise this is set to an annual rate for all return periods to provide the greatest protection. We recommend the Council discuss the most appropriate rate with the Environment Agency..

Partner	Partnership Actions	
	To Reduce Surface Water Flooding / Risks from Surface Water Flooding	**To Reduce Pollution Resulting from Surface Water Flooding**
		water.
Network Rail	♦ Regular maintenance to keep any culverts and flow routes under railway clear; ♦ Partnership working with Borough and County Council if additional culverts under railway embankment are deemed necessary.	

NOTES: * STWL are currently only funded to address the more severe incidents of known reported sewer flooding, as recorded on their sewer flooding register. Drainage systems (including conventional piped systems and SUDS) are designed to have a finite capacity and upsizing the underground system to cope with extreme rainfall events may not be the most cost effective means of managing surface water, with the potential to increase the risk of flooding downstream. Due to funding constraints STWL prioritise work based upon a review of the costs and benefits, as agreed with Ofwat, focussing upon the more severe incidents of known reported sewer flooding included on their sewer flooding register. All actions stated within this table require discussion between the partnership organisations during a Phase 3 SWMP, if undertaken.

5.2 Next Steps

5.2.1 SWMP Phase 3 and 4

The Defra guidance recommends that once the surface water flood hazard has been modelled and mapped, the SWMP should be progressed to identify and assess options for surface water mitigation (Phase 3) and prepare an action plan for their implementation (Phase 4).

This Phase 2 assessment has identified a number of potential surface water mitigation actions and the key partners to be involved in implementing these actions. However, to progress this SWMP it is recommended that the AAD calculations are refined to include a full cost-benefit assessment to accurately assess options. At this stage it would be useful to refine the modelling to simulate the impact of such options.

5.2.2 Model Refinement

A number of limitations and assumptions relating to this modelling have been highlighted within this report. When new or updated information becomes available it is recommended that the model is refined and rerun.

5.2.3 Model Use

The model developed for use in this SWMP has been commissioned by the Local Authorities, but contains STWL's current drainage model. As such, ownership should be viewed as a partnership. Any adjustments or amendments made to the model should be undertaken with the consent of, and reviewed by, both partners.

It has currently not been defined how this model can be used by developers and consultants for the assessment of individual development sites. Advice will be forthcoming and should be sought from either Stafford Borough Council or Staffordshire County Council.

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Appendix A
Defra SWMP Guidance Check Lists

Table A.1 - Requirements of an Intermediate Assessment (Defra SWMP Guidance, March 2010)

Criteria	Description	Included within this Phase 2 SWMP?
Purpose	To: ♦ gain an improved understanding of surface water flooding; ♦ to identify localised flood hotspots and support decisions on whether these may require further assessment; and ♦ to identify mitigation measures to reduce surface water flooding.	 ✓ ✓ ✓
Scale	♦ Town, city or London Borough	✓
Inputs (data and information)	♦ Information from the strategic assessment ♦ Existing asset data or models (drainage, 'ordinary' watercourses, highway drainage, rivers, coast, groundwater levels) ♦ Location of proposed new development ♦ Additional evidence collated from site visits, surveys or modelling ♦ Local knowledge (EA / LPA)	✓ ✓ ✓ ✓ ✓
Process	♦ More detailed information is collated and analysed to improve the understanding of surface water flooding and to identify flood hotspots	✓
Outputs	♦ Improved mapping to support spatial and emergency planning ♦ Identification of flood hotspots which may require further, more detailed assessment (possibly through modelling approaches) ♦ Identification of plausible mitigation measures, including quick wins or immediate measures which can be put in place	✓ ✓ ✓
Benefits	♦ Improved understanding of surface water flooding within the study area ♦ Improved mapping which can be used to support spatial and emergency planning functions ♦ Identification of mitigation measures to reduce surface water flooding; in particular 'quick win' (or immediate) actions which can be taken by partners and stakeholders ♦ As the intermediate assessment identified flood hotspots, the detailed assessment can be focussed on the hotspot locations, ensuring greatest value for money.	✓ ✓ ✓ ✓

Table A.1 - Requirements of a Detailed Assessment (Defra SWMP Guidance, March 2010)

Criteria	Description	Included within this Phase 2 SWMP?
Purpose	♦ To understand the causes, probability and consequences of surface water flooding in a greater level of detail; and ♦ To test mitigation measures to reduce surface water flooding	✓
Scale	♦ In flood hotspot locations; generally considered to be at sub-settlement scale	*Larger Scale*
Inputs (data and information)	♦ Existing asset data or models (drainage, 'ordinary' watercourses, highway drainage, rivers, coast, groundwater levels) ♦ Location of new development ♦ Additional evidence collated from site visits or surveys *NB: Majority of information already collated in intermediate assessment, but additional data may need to be collected to support modelling approach (e.g. survey data, rainfall data)*	✓ ✓ *Where already available*
Process	♦ Use of modelling approaches to assess surface water flood risk (where risk = probability x consequence). ♦ The same modelling approach is used to test mitigation measures.	✓ *Not undertaken*
Outputs	♦ Understanding of 'annualised' surface water flood risk, both now and in the future. ♦ Understanding the benefits and costs of mitigation measures to reduce surface water flooding. ♦ Detailed mapping of flood risk and flood hazard (partners should consider the emerging requirements of Part 3 of the Flood Risk Regulations [2009]).	✓ *Benefit/costs not calculated* ✓
Benefits	♦ Improved understanding of the probability and consequences of flooding. ♦ Detailed understanding of the flood risk will enable informed judgements to be made of the benefits and costs of potential mitigation measures. ♦ Can assess benefits of mitigation measures (where a benefit is a reduction in damages due to surface water flooding). ♦ Can help to fulfil the requirements of the Floods Risk Regulations to produce flood risk and flood hazard maps. ♦ Can provide justification for mitigation measures based on benefits and costs.	✓ ✓ *Flood risk and flood hazard maps produced*

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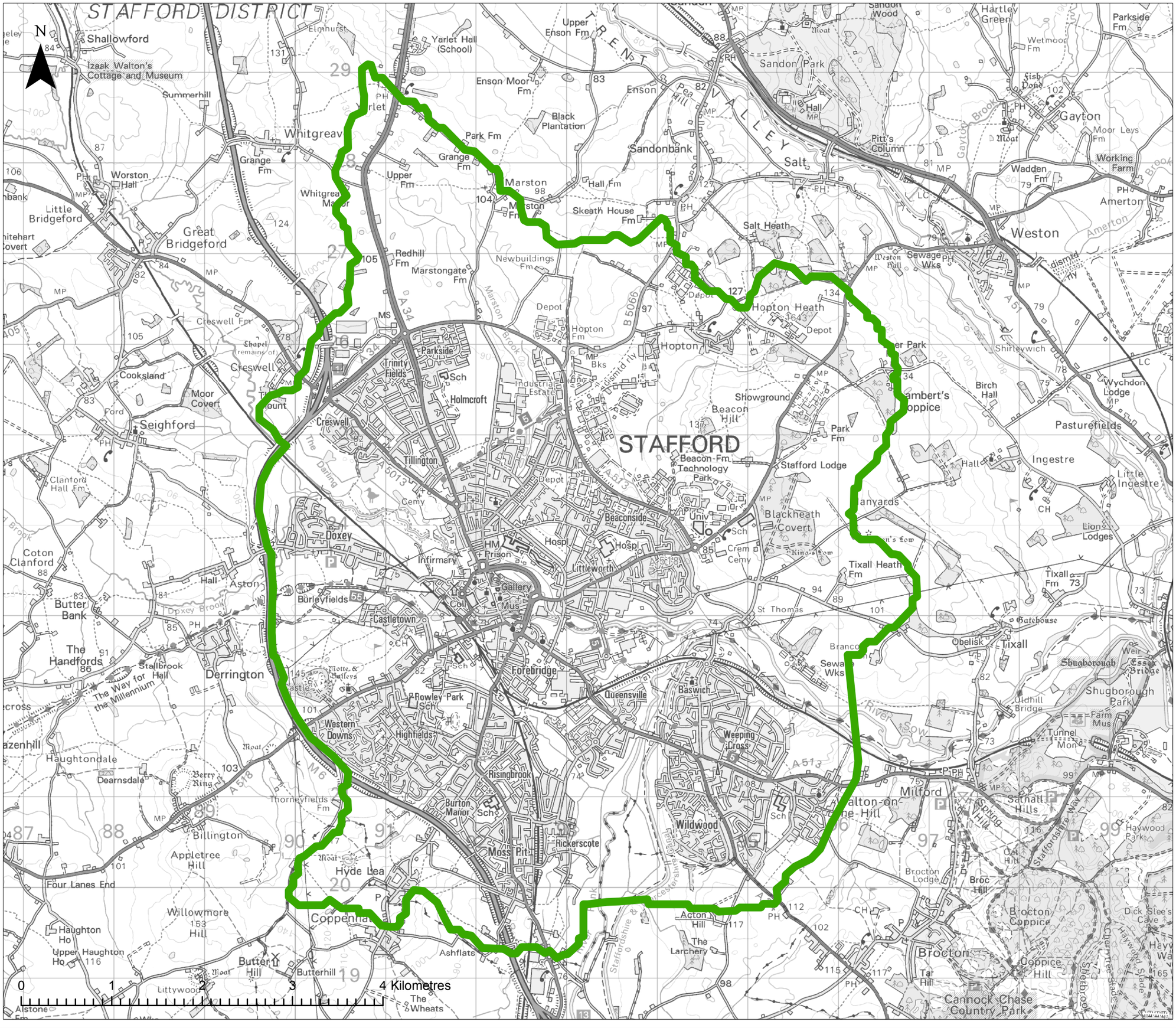
Appendix B
Figures



Key:

Watershed Outline

Title:
Watershed Boundary

Project:
Southern Staffordshire SWMP

Client:
Stafford Borough, Lichfield District, South Staffordshire District, Tamworth Borough and Cannock Chase Councils

Date:
May 2011

Scale:
1:40,000 @ A3

Figure:
3.1

ROYAL HASKONING

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N

Runoff from agricultural land

3

Runoff from agricultural land

Flooding of Access Routes

Flooding of Access Routes

Pooling of Water

Flooding of Industrial Estate

STAFFORD BOROUGH

Critical Infrastructure

Areas of Moderate - Significant Hazard

Runoff from agricultural land

1

Historic Flooding

Pooling of Water

Areas of Significant Hazard

Flow Routes through Residential Areas

2

Potential for Interaction with fluvial flows

Flooding of Railway

Potential for Interaction of Surface Water with Canal

Runoff from agricultural land

4

Deep pooling on M6

SOUTH STAFFORDSHIRE DISTRICT

SOUTH STAFFORDSHIRE DISTRICT

0 1 2 3 4 5 Kilometres

Key:

- Ordinary Watercourses
- Main Rivers
- Canals
- Key Risk Areas
- Key Flow Routes

Title:
Key Flood Risk Areas and Hotspots

Project:
Southern Staffordshire SWMP

Client:
Stafford Borough, Lichfield District, South Staffordshire District, Tamworth Borough, and Cannock Chase District Councils

Date:
May 2011

Scale:
1:35,000 @ A3

Figure:
4.1

ROYAL HASKONING

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Appendix C
Average Annual Damage Calculations

Table C.1 - Methodology for Calculating AAD

Probability of Flood Event (1 in…)	**Flood Probability**	**No of Properties Flooded**	**Damages per Event (£)**	**Annualised Damages (£)**	**Annualised Property Numbers (APN)**
2	0.5	*Extracted using GIS*	*Calculated using NPD and MCM depth-damage curves*	*(1 - 0.5) * (property damage + 0) / 2*	*(1 - 0.5) * (Number of properties flooded) / 2*
5	0.2			*(Previous flood probability - flood probability) * (property damage + property damage from previous flood probability) / 2*	*(Previous flood probability - flood probability) * (Number of properties flooded + number of properties flooded from previous flood probability) / 2*
10	0.1				
20	0.05				
25	0.04				
30	0.033				
50	0.02				
75	0.013				
100	0.01				
200	0.005				
				AAD = *Sum of above*	**Average APN** = *Sum of above*
					Health Weighting = *Average APN * £200*
				AAD including stress impacts = *Health Weighting + AAD*	

Table C.2 - Annualised Damages for Residential Property Damages (>0.1m)

Probability of Flood Event (1 in…)	Flood Probability	No of Properties Flooded	Damages per Event (£)	Annualised Damages (£)	Annualised Property Numbers (APN)
2	0.5	50	£875,888.38	£218,972.10	13
5	0.2	87	£1,593,840.35	£370,459.31	21
10	0.1	145	£2,528,917.09	£206,137.87	12
20	0.05	192	£3,520,931.18	£151,246.21	8
25	0.04	210	£3,850,274.17	£36,856.03	2
30	0.033	227	£4,161,955.89	£28,042.81	2
50	0.02	280	£5,131,623.64	£60,408.27	3
75	0.013	328	£6,029,455.31	£39,063.78	2
100	0.01	388	£7,071,252.16	£19,651.06	1
200	0.005	523	£9,583,285.51	£41,636.34	2
				AAD: **£1,172,473.76**	**Average APN:** **65**
					Health Weighting: £13,077.90
				AAD including stress impacts = **£1,185,551.66**	

(With Climate Change):

20CC	0.05	263	£4,754,704.07	£2,258,484.43	125
50CC	0.02	407	£7,338,574.46	£181,399.18	10
100CC	0.01	550	£10,110,494.81	£87,245.35	5
				AAD: **£2,527,128.96**	**Average APN:** 140
					Health Weighting: £27,952.00
				AAD including stress impacts = **£2,555,080.96**	

Table C.3 - Annualised Damages for Residential Property Total Damages (>0.3m)

Probability of Flood Event (1 in…)	Flood Probability	No of Properties Flooded	Damages per Event (£)	Annualised Damages (£)	Annualised Property Numbers (APN)
2	0.5	3	£92,987.39	£23,246.85	1
5	0.2	2	£63,164.21	£23,422.74	1
10	0.1	7	£185,583.06	£12,437.36	0
20	0.05	15	£437,283.52	£15,571.66	1
25	0.04	18	£510,491.61	£4,738.88	0
30	0.033	22	£613,870.83	£3,935.27	0
50	0.02	29	£812,393.60	£9,270.72	0
75	0.013	38	£1,058,790.40	£6,549.14	0
100	0.01	40	£1,133,022.44	£3,287.72	0
200	0.005	49	£1,421,196.71	£6,385.55	0
				AAD: **£108,845.89**	**Average APN:** **4**
					Health Weighting: £742.10
				AAD including stress impacts = **£109,587.99**	

(With Climate Change):

20CC	0.05	26	£691,632.42	£328,525.40	12
50CC	0.02	37	£990,618.33	£25,233.76	1
100CC	0.01	52	£1,464,316.97	£12,274.68	0
				AAD: **£366,033.84**	**Average APN:** 14
					Health Weighting: £2,748.00
				AAD including stress impacts = **£368,781.84**	

Table C.4 - Annualised Damages for Commercial Property Total Damages (>0.1m)

Probability of Flood Event (1 in…)	Flood Probability	No of Properties Flooded	Damages per Event (£)	Annualised Damages (£)	Annualised Property Numbers (APN)
2	0.5	74	£16,656,786.74	£4,164,196.68	19
5	0.2	128	£26,320,662.67	£6,446,617.41	30
10	0.1	166	£38,003,552.62	£3,216,210.76	15
20	0.05	111	£46,822,686.76	£2,120,655.98	7
25	0.04	220	£50,039,928.69	£484,313.08	2
30	0.033	231	£53,598,027.98	£362,732.85	2
50	0.02	273	£59,694,296.03	£736,400.11	3
75	0.013	300	£64,755,869.95	£435,575.58	2
100	0.01	325	£70,358,632.32	£202,671.75	1
200	0.005	398	£88,115,159.65	£396,184.48	2
				AAD:	**Average APN:**
				£18,565,558.69	64
					Health Weighting:
					£12,836.00
				AAD including stress impacts =	
					£18,578,394.69

(With Climate Change):

20CC	0.05	261	£58,555,141.43	£27,813,692.18	124
50CC	0.02	338	£73,628,739.27	£1,982,758.21	9
100CC	0.01	414	£92,016,661.46	£828,227.00	4
				AAD:	**Average APN:**
					137
				£30,624,677.39	**Health Weighting**:
					£27,344.00
				AAD including stress impacts =	
					£30,652,021.39

Table C.5 - Annualised Damages for Commercial Property Total Damages (>0.3m)

Probability of Flood Event (1 in…)	Flood Probability	No of Properties Flooded	Damages per Event (£)	Annualised Damages (£)	Annualised Property Numbers (APN)
2	0.5	6	£3,665,899.16	£916,474.79	2
5	0.2	8	£6,218,617.41	£1,482,677.49	2
10	0.1	14	£14,520,392.35	£1,036,950.49	1
20	0.05	22	£15,617,749.64	£753,453.55	1
25	0.04	22	£16,105,839.12	£158,617.94	0
30	0.033	25	£17,524,369.73	£117,705.73	0
50	0.02	29	£19,474,971.71	£240,495.72	0
75	0.013	47	£26,622,898.43	£161,342.55	0
100	0.01	48	£33,891,664.40	£90,771.84	0
200	0.005	74	£49,834,293.35	£209,314.89	0
				AAD: **£5,167,804.99**	**Average APN:** 6
					Health Weighting: £1,146.80
				AAD including stress impacts = **£5,168,951.79**	

(With Climate Change):

20CC	0.05	30	£19,231,165.64	£9,134,803.68	14
50CC	0.02	53	£39,146,286.81	£875,661.79	1
100CC	0.01	81	£55,673,837.66	£474,100.62	1
				AAD: **£10,484,566.09**	**Average APN:** 16
					Health Weighting: £3,233.00
				AAD including stress impacts = **£10,487,799.09**	