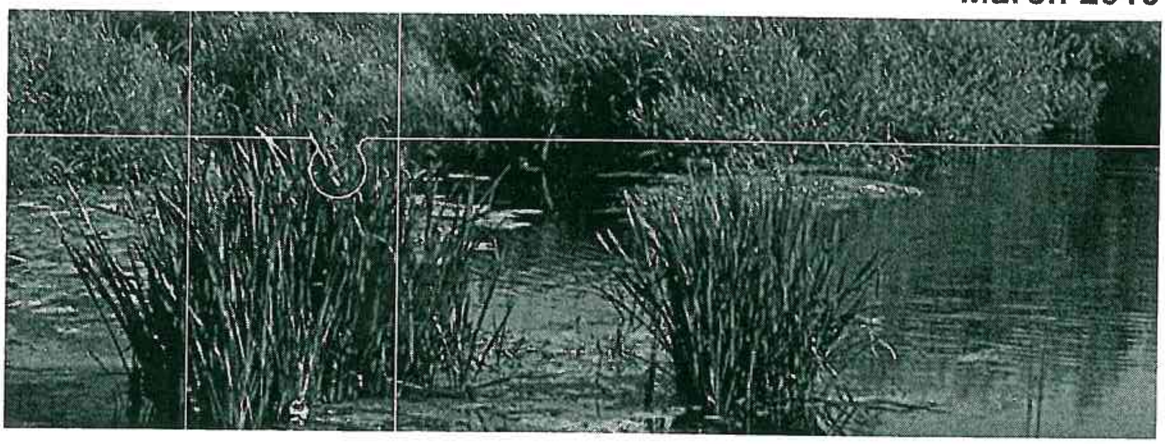
# Stafford Borough Council

# Westbridge Park, Stone, Staffordshire

## Flood Constraints Report
## Final

March 2010



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| Issue Date | Version | Status | Revisions | Originated by | Checked by | Approved by |
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| | | | | | | |

# 1. Introduction

1.1 Capita Symonds Ltd has been commissioned by Stafford Borough Council to prepare a Flood Constraints Report in relation to a potential re-development site in the Westbridge Park area of Stone, Staffordshire, NGR: 390273 333615. Appendix A shows the site location.

1.2 This follows a commission by the Environment Agency to undertake Strategic Flood Risk Mapping of the River Trent through Stoke and a subsequent extension of the model to include the town of Stone. As part of these two commissions Capita Symonds has constructed a hydraulic model of the River Trent in this area. The model has been run simulating the 5%, 1%, 1% with a 20% increase in flows to represent climate change and 0.1% Annual Exceedence Probability (AEP) events. The 5% AEP event corresponds to a 20 year event (Flood Zone 3b) in reference to PPS25, the 1% event corresponds to the 100 year event (Flood Zone 3a) and the 0.1% AEP event corresponds to the 1000 year event (Flood Zone 2).

1.3 A Map showing the associated flood outlines for these events in the location of the proposed development has been produced and is included in Appendix C. Appendix D outlines the methodology applied to producing the hydraulic model and associated floodplain outlines.

1.4 Further detailed information on the risk of flooding has been provided by the Environment Agency and has been used to inform this assessment. This constraints report is written with reference to the guidance outlined in 'Planning Policy Statement 25 (PPS25) – Development and Flood Risk'[1] and the accompanying practice guide[2].

1.5 This Flood Constraints Report presents details of the associated planning and policy guidance with respect to flood risk, it identifies the risk of fluvial flooding at the site, and indicates how flood risk at the site could be managed such that re-development would not be at flood risk or contribute to an increased flood risk to the surrounding areas. It also considers opportunities to reduce flood risk and enhance the environment. A summary is provided of the constraints and opportunities along with recommendations on the next steps to take.

[1] Communities and Local Government. December 2006. Planning Policy Statement 25: Development and Flood Risk. TSO, London.
[2] Communities and Local Government. December 2006. Planning Policy Statement 25: Development and Flood Risk Practice Guide. TSO, London.

# 2. Policy and Guidance

## Planning Policy Statement 25 (PPS25)

2.1 Planning Policy Statement 25: Development and Flood Risk (PPS 25) was issued by the Department for Communities and Local Government (DCLG) in December 2006.

2.2 PPS 25 advises that a strategic approach be adopted, in keeping with Government aims to ensure that new development is sustainable. The PPS requires that a risk based approach to flood risk is adopted at all levels of planning. It introduces:

- The concept of classification of the vulnerability of development to flood risk;
- The need to conform to the requirements of the "Exception Test" in circumstances where it is deemed necessary to locate new development in "high risk" Flood Zones; and
- The need to apply Strategic Flood Risk Assessment to decisions taken at all levels of planning, i.e. the need for assessment at the Regional Spatial Strategy.

2.3 Additionally the PPS introduces the concept of Flood Risk Reduction, particularly in circumstances where development has been sanctioned on the basis of the "Exception Test".

2.4 PPS 25 classifies three Flood Zones, Zone 1, "Low probability", Zone 2, "Medium probability" and Zone 3, "High probability". Land designated as "Low probability" is identified in PPS25 as suitable for all uses of land although this does not negate the need to apply the Sequential Test, however, it should be a relative formality. The vulnerability to flooding from other sources of flooding and the potential to increase flood risk elsewhere through an increase in hard surfaces and the effect of the new development on surface water runoff, should be incorporated into a Flood Risk Assessment (FRA). In this zone developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area and beyond through the layout and form of the development, and the appropriate application of sustainable drainage techniques.

2.5 Land designated as "Medium probability" is identified in PPS 25 as suitable for water compatible, less vulnerable (e.g. commercial, retail or light industrial uses) and more vulnerable (e.g. residential, education and entertainment) uses of land and essential infrastructure (e.g. utilities and transport). Subject to the Sequential Test being applied, the highly vulnerable uses in Table D.2 (e.g. ambulance, police, fire and high hazard chemical facilities) are only appropriate if the Exception Test is passed. Essential infrastructure permitted in this zone should be designed and constructed to remain operational and safe for users in times of flood.

2.6 Land designated as "High probability" is identified in PPS 25 as suitable for water compatible and less vulnerable uses of land only. The highly vulnerable uses in Table D.2 should not be permitted in this zone. The more vulnerable and essential infrastructure uses in Table D.2 should only be permitted in this zone if the Exception Test is passed. Essential infrastructure permitted in this zone should be designed and constructed to remain operational and safe for users in times of flood.

2.7 It is a requirement of PPS25 that all development proposals in Flood Zones 2 or 3 are accompanied by an FRA. In these zones, developers and local authorities should seek opportunities to:

i) reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage techniques;
ii) relocate existing development to land in zones with a lower probability of flooding; and
iii) create space for flooding to occur by restoring functional floodplain and flood flow pathways and by identifying, allocating and safeguarding open space for flood storage.

# 3. Description and Location of Proposed Re-development

## Development Type and Location

3.1 The outline proposals for Westbridge Park include interest for the development of a non-residential community building or a General Practitioner's surgery within an existing area of developed land. A location plan is included in Appendix A.

## Vulnerability Classification

3.2 With reference to Table D.2 of PPS 25, the Flood Risk Vulnerability Classification of the proposed non-residential community building is classified as a 'Less Vulnerable' use of land. A General Practitioner's Surgery is classified as 'More Vulnerable'.

3.3 PPS 25, Table D.3 'Flood Risk Vulnerability and Flood Zone Compatibility' is reproduced in Table 3.1, below. The table shows that 'Less Vulnerable' development is considered to be appropriate within Flood Zones 2 and 3a and does not require the Exception Test to be applied to the proposals. Any proposals for less vulnerable development would therefore be appropriate subject to passing the Sequential Test.

3.4 As 'More Vulnerable' development the GPs Surgery is considered appropriate within Flood Zone 2 only, however the Exception Test would need to be applied and passed if it were proposed to locate the GP surgery within Flood Zone 3a.

**Table 3-1: Flood Risk Vulnerability and Flood Zone Compatibility (PPS 25, Table D.3)**

| Flood Risk Vulnerability classification (see Table D2) | | Essential Infrastructure | Water compatible | Highly Vulnerable | More Vulnerable | Less Vulnerable |
|---|---|---|---|---|---|---|
| Flood Zone (see Table D.1) | Zone 1 | ✔ | ✔ | ✔ | ✔ | ✔ |
| | Zone 2 | ✔ | ✔ | Exception Test required | ✔ | ✔ |
| | Zone 3a | Exception Test required | ✔ | ✗ | Exception Test required | ✔ |
| | Zone 3b 'Functional Floodplain' | Exception Test required | ✔ | ✗ | ✗ | ✗ |

Key:

✔ Development is appropriate

✗ Development should not be permitted

## Sequential Test/Exception Test

3.5 The overall aim of the Sequential Test is to direct 'new development towards locations with the lowest flood risk possible. It therefore requires that the developer show that other sites at a lower risk have been considered for redevelopment.

3.6 Therefore, whilst the non-residential development proposed for the site is classified as 'Less Vulnerable' and is considered appropriate within Flood Zones 2 and 3a it would still need to be shown that there are no available sites for this development that have a lower risk of flooding. It is the Local Planning Authority's responsibility to apply this test, though it is often undertaken by developers or their agents with the results of the test ratified by the Planning Authority.

3.7 Similarly, the 'More Vulnerable' GP Surgery is considered appropriate within Flood Zone 2 as long as the Sequential Test is successfully applied. If it were proposed to locate the GP surgery within Flood Zone 3a then in addition to showing that no lower risk sites are available the Exception Test would also need to be successfully passed.

3.8 The Level 1 Strategic Flood Risk Assessment (SFRA) for Stafford Borough Council was completed in January 2008. A summary document available on the Stafford Borough Council website outlines the SFRA objectives and how it should be utilised. In relation to the Sequential Test it outlines the following:

> "A key aim of a Level 1 SFRA is to guide development to the appropriate Flood Zone using the Sequential Test. This is a process whereby preference is given to locating a new development in Flood Zone 1. Where there are no reasonably available sites in Flood Zone 1, decision-makers should take into account the flood risk vulnerability of the development and consider reasonably available sites in Flood Zone 2, applying the Exception Test if required. Only where there are no reasonably available sites in Flood Zones 1 and 2 should decision-makers consider the suitability of sites in Flood Zone 3, taking into account the flood risk vulnerability of land uses and applying the Exception Test if required. Within each Flood Zone, new development should be directed to sites at the lowest probability of flooding from other sources, also depicted on the strategic flood risk maps. The flood vulnerability of the development should be matched to the flood risk of the site, e.g. higher vulnerability uses should be located on parts of the site at lowest probability of flooding. The Sequential Test therefore demonstrates that there are no reasonably available sites, in areas with a lower probability of flooding that would be appropriate to the type of development or land use proposed." [3]

3.9 The above confirms the requirements of the Sequential and Exception Test but also clarifies that the location of any development within the site should be steered towards the lower risk locations that lie within Flood Zone 2 instead of Flood Zone 3.

3.10 For the Exception Test to be passed:

a) it must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by an SFRA where one has been prepared;

b) the development should be on developable, previously developed land or, if it is not on previously developed land that there are no reasonable alternative sites on developable previously developed land; and

c) a Flood Risk Assessment (FRA) must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

3.11 It is the responsibility of the developer to provide evidence to meet the requirements of Parts a) and b) of the Exception Test. Part c), the demonstration of the safety of the development, will be met by an FRA.

[3] Stafford Borough Council, Strategic Flood Risk Assessment, Level 1, January 2008, Halcrow Group Limited

Part c) must consider flood risk for the lifetime of the development and therefore take into account the anticipated effects of climate change. It should be noted that climate change is expected to bring the entire site into Flood Zone 3a, as indicated in Appendix C.

3.12 The determination of whether a site is safe can require the identification of flood hazard, which is a function of depth and velocity. If this is the case then the available hydraulic model can used to produce depth, velocity and hazard grids that can provide the detail required to outline flood hazard at the site.

# 4. Existing Flood Risk

## Introduction

4.1 The existing Environment Agency Flood Zone Map shows that the Westbridge Park site lies within areas at medium and high risk of flooding, Flood Zone 2 (between 1% and 0.1% chance of flooding or within the 1 in 1000 year return period flood outline) and Flood Zone 3 (≥1% or within the 1 in 100 year return period flood outline).

4.2 The Flood Zones produced from the hydraulic model constructed by Capita Symonds provide more detail of the outline of the flood zones in relation to the development site. The model was built to the Environment Agency's Strategic Flood Risk Mapping specification and was developed to, amongst other things, produce flood zone outlines that can be used to update the Environment Agency's Flood Zone Maps, including the flood map on the internet. The results can therefore be relied upon to reflect imminent changes to the flood zones that national and local planning policy will reference. It should be noted, however, that the modelling was only concerned with fluvial flooding and consequently any Flood Risk Assessment will need to consider other sources of flooding, as specified in PPS25.

## Flood Zones

4.3 The Environment Agency's existing Flood Zone map is presented in Appendix B, which show that the northern half of the site is within Flood Zone 2 and that the southern part of the site is within Flood Zone 3. However, based on the hydraulic model output maps produced by Capita Symonds, which show significantly different flood extents, the western half of the proposed development area at Westbridge Park is in Flood Zone 3 with the remainder situated within Flood Zone 2. Flood Zone 3 can be split further into 3a and 3b with 3b being the Functional Floodplain. The functional floodplain is usually represented by the 20 year return period event (5% AEP) and this is shown by the yellow outline in Appendix C. The site does not lie within Flood Zone 3b. The flood maps are prepared ignoring the presence of flood defences.

## Flood Levels

4.4 Table 4.1 below shows the levels from the results of the modelling of the watercourses from around the site area. Appendix E shows the location of the model node points that these levels relate to.

**4-1: Simulated flood levels for the 100-year and 100-year with an allowance for climate change in the vicinity of the site.**

| Node Label | 100 yr flood levels (mAOD) | 100 yr + climate change flood levels (mAOD) |
|---|---|---|
| SB0045.1 | 85.9 | 86.0 |
| SB0000.1 | 85.9 | 86.0 |
| Halc_165br.1 | 85.9 | 86.0 |
| Halc_165br.2 | 85.8 | 85.9 |
| Halc_165D.2 | 85.7 | 85.9 |
| Halc_18br.2 | 85.7 | 85.8 |
| Halc_18D.2 | 85.6 | 85.7 |
| RT419545br.1 | 85.6 | 85.7 |

| Node Label | 100 yr flood levels (mAOD) | 100 yr + climate change flood levels (mAOD) |
|---|---|---|
| RT419545br.2 | 85.6 | 85.7 |
| RT419527br.1 | 85.6 | 85.7 |
| RT419527br.2 | 85.5 | 85.7 |
| RT419214.1 | 84.7 | 84.8 |
| RT418900.1 | 84.1 | 84.1 |

4.5 Model results have been provided in electronic format on CD to Stafford Borough Council and the Environment Agency along with this report.

# 5. Summary of Constraints

5.1 The above sections outline the opportunities and constraints to the proposed redevelopment site with respect to planning policy and flood risk.

5.2 The proposed redevelopment site is located within both Flood Zones 2 and 3 and flood risk therefore presents a number of constraints to redevelopment of the site:

- As identified in Section 3, the Sequential test will need to be passed, which will require the developer and/or Stafford Borough Council to show that there are no alternative locations at a lower risk from flooding that are available for the proposed development and that development within the site is sequentially located;

- Depending upon the final proposals, the Exception Test may need to be passed showing that the development provides wider sustainability benefits that out weight flood risk and it will need to be accompanied by a PPS25 compliant flood risk assessment. The site is on brownfield land so part b) should be considered a formality;

- The Environment Agency has stated their standard requirement for development within these zones should have floor levels set 600mm above the 100 year plus climate change level, which would place required finished floor levels at or above 86.6m AOD;

- Climate change will increase flood levels and extents on site such that the site would be brought almost entirely into Flood Zone 3a within the its lifetime (assumed to be 100-years for residential property);

- Compensatory storage will need to be provided on a like for like basis where development within the floodplain results in storage being lost;

- The FRA should show that the site will be safe for users during a flood event which involves signing up to the Environment Agency's flood warning system and compiling an emergency flood response plan outlining procedures on receipt of a flood warning and identifying safe (and ideally dry) access and egress routes;

- It is recommended that resilience measures are incorporated within developments within high risk flood zones and guidance recommends these are incorporated approximately 600mm above finished floor levels; and

- Measures to implement sustainable drainage systems (SuDS) on site to reduce surface water runoff should be considered as part of the development proposals.

# 6. Looking Forward

6.1 In light of the above constraints there are a number of issues that should be addressed in order to further the redevelopment of the site.

## Sequential Test

6.2 First and foremost, as the site is partly within Flood Zone 2 and Flood Zone 3, a Sequential Test should be undertaken. The Sequential Test should be undertaken as early as possible within the planning process and should consider alternative locations for the proposed development within the Borough. The Sequential Test, depending upon the results, should indicate which type of development at the site is more likely to be suitable at the site and indeed whether the site is developable at all.

## Flood Risk Management

6.3 If the Sequential Test indicates that the site can be developed for one or both of the types of development proposed, the next important thing to ascertain is whether it is possible to provide compensatory storage and flood protection to the site over the lifetime of the development and without increasing flood risk elsewhere.

6.4 This stage will inevitably require the use of the hydraulic model of the River Trent used to define the flood levels and flood zones at the site to test potential solutions. Key considerations with respect to this will be the location of the development within the site, the land take of the development and the land available to provide compensatory storage and finally the location of access to the site and the elevation of the access. It will be important for the flood risk assessment that this stage be used to develop a solution in which the site can be developed without increasing flood risk and ensuring safe access for occupiers and visitors.

6.5 As stated in Section 4 and in Appendix D the flood levels at the site are approximately 86m AOD for the 100 year event with an allowance for climate change. The, proposed redevelopment should therefore have finished floor levels on or above 86.6m AOD in order to meet with the Environment Agency's requirements for 600mm freeboard. Ground levels taken from a topographic survey provided by Stafford Borough Council indicate that existing ground levels are approximately 85.4m AOD in the north west area and approximately 86m AOD across the remainder of the site.

6.6 In order to ensure that flood risk is not increased in areas adjacent or downstream of the site floodplain compensation storage will need to be provided on or near to the site on a like-for-like basis in order to offset any increases in flood level as a result of developing and raising ground levels within the floodplain.

6.7 As indicated above, as well as ensuring that the development itself is not at risk and doesn't increase elsewhere, the development will need to provide safe access and egress for site users and emergency services. Access should therefore be considered at the same time as raising ground levels and the provision of compensatory storage.

## Flood Risk Assessment

6.8 Once it is clear that the development is both feasible from a planning perspective and from a technical perspective, a flood risk assessment can then be produced that presents the results of these assessments and which provides additional detail that is required within this document. This includes:

- Details of the surface water management strategy and how surface water will be managed; and
- Details of the residual risks to the site and how they will be managed.

6.9 The surface water management strategy will need to identify the existing surface water runoff regime and the impact that development will have on rates and volumes. It will need to provide sufficient detail to understand how the surface water will be managed and to provide confidence that it can and will work. It should include the use of Sustainable Drainage Systems (SuDS) wherever possible.

6.10 There are a number of options that can be incorporated into development sites including the use of Sustainable Drainage Systems (SuDS) which are designed to reduce the surface water runoff from the site. There are many types of SuDS available such as swales, balancing ponds, permeable paving with underground storage, filter strips, green roofs, etc. Guidance for the available SuDS can be found in the SuDS Manual, CIRIA C697, 2007 document. SuDS are recommended in the Stafford Borough Council Level One Strategic Flood Risk Assessment.

6.11 A ground investigation of the site area to understand the underlying geology and permeability of the soil will be useful in recommending any appropriate SuDS to be implemented. Space appears to be limited and therefore it would be recommended that provision of surface water storage be considered at the earliest stages of design with sufficient space provided to locate storm water storage at the lowest point of the site. Management of surface water runoff should also consider exceedence events where the system capacity is overwhelmed.

6.12 It is recommended that a flood warning and evacuation plan is developed alongside an assessment of residual risks to show how the residual risks at the site will be managed. The proposed development site is located within an area that is currently provided with a flood warning service and it is recommended that site users sign up to receive flood warnings for their area by contacting the Environment Agency (www.environment-agency.gov.uk). An evacuation plan should be produced for the site and users should be informed prior to the occupancy of the buildings during as part of an induction phase for the users. The evacuation plan should include the procedures on receipt of a flood warning for the site and include safe access and egress routes for users of the site in order to gain safe access to and from the site during a flood event. It is recommended that emergency exercises are periodically carried out to test the plans. This should be completed in collaboration with the Environment Agency and Stafford Borough Council's Emergency Planning team.

6.13 Residual risks can also be managed by the installation of flood resilience and resistance measures in the design of any buildings and structures. Any resilience measures installed can significantly reduce the recovery time following flooding, potentially allowing re-occupancy to take place earlier than if the measures aren't undertaken. Resilience measures can for example take the form of hard stone flooring, horizontal plaster board rather than vertical (making there less to replace), moving electrical connection points to above the flood level, etc.

6.14 Guidance on the introduction of flood resilience measures can be found in *Improving the flood performance of new buildings, flood resilient construction* (Department for Communities and Local Government: London, May 2007)[4]. Useful information is also available on the Construction Industry Research and Information Association (CIRIA) website[5].

[4] http://www.planningportal.gov.uk/uploads/br/flood_performance.pdf

[5] www.ciria.org.uk

# 7. Conclusions

7.1 Capita Symonds Ltd was commissioned by Stafford Borough Council to prepare a Flood Constraints Report to assess flood risk in relation to the potential re-development of a non-residential community building or General Practitioner's surgery in Westbridge Park in Stone, Staffordshire.

7.2 A hydraulic model was produced by Capita Symonds on behalf of Stafford Borough Council and the Environment Agency and the outputs show the proposed development area at Westbridge Park is within both Flood Zones 2 and 3. It is a requirement of PPS25 that all development proposals in Flood Zones 2 or 3 are accompanied by a Flood Risk Assessment (FRA) that should show that the development is safe from flooding, does not increase flood risk elsewhere and, where possible, there is a flood risk benefit.

7.3 PPS25 requires that all developments pass the Sequential Test, designed to steer development to areas of low flood risk. Stafford Borough Council or their agents would need to show that there are no alternative sites that are at a lower risk from flooding and which are considered available.

7.4 Assuming that the Sequential Test can be passed, and with reference to Table D.2 of PPS 25, the Flood Risk Vulnerability Classification of the proposed non-residential community building can be classified as 'Less Vulnerable' uses of land. A General Practitioner's Surgery can be classified as 'More Vulnerable'.

7.5 Table D.3 of PPS 25 'Flood Risk Vulnerability and Flood Zone Compatibility' indicates that 'Less Vulnerable' development would be appropriate within Flood Zones 2 and 3a. 'More Vulnerable' development would be appropriate within Flood Zone 2, however the Exception Test would be required if it were proposed to locate the GP surgery within Flood Zone 3a.

7.6 Capita Symonds recommend that a Sequential Test be undertaken as a priority to determine whether the development is feasible from a planning perspective. Only then should further consideration of whether the site is or can be safe from flooding be undertaken.

7.7 Assuming that the Sequential Test is passed, it is recommended that further analysis be undertaken into whether the development can be safe from flooding and will not increase flood risk elsewhere. The existing hydraulic model of the River Trent will be suitable for this and will provide the basis for identifying and testing mitigation options. This is likely to focus on the availability of compensatory storage on a like-for-like basis given the anticipated need to raise floor levels above the current 100-year flood level (plus an allowance for climate change) of 86.0m AOD. In addition to compensatory storage, the site will ideally need dry access.

7.8 If it is both technically feasible to develop the site and acceptable from a planning perspective then a flood risk assessment that meets the requirements of PPS25 will be required. The flood risk assessment will need to show that there has been consideration of climate change for the anticipated lifetime of the development and that residual risks from events in excess of the 100-year plus climate change have been considered including evacuation planning in the event of a flood event.

7.9 In addition, it should also show how surface water runoff at the site will be managed to ensure no increase in runoff rates and ideally volumes. The Stafford Borough Council Level One Strategic Flood Risk Assessment (SFRA) advocates the incorporation of Sustainable Drainage Systems (SuDS) within new development where practical and any appropriate land management techniques that could reduce surface runoff. Management of surface water runoff should also consider exceedence events where the system capacity is overwhelmed.

# Appendix A – Site location




| Rev. | Drawn | Comment | Date |
|---|---|---|---|

HULME UPRIGHT MANNING
ARCHITECTS TOWN PLANNERS INTERIOR DESIGNERS

Highpoint
Festival Park
Hanley
Stoke-on-Trent
ST1 5SH

LEEK
MANCHESTER
STOKE-ON-TRENT

Tel: 01782 208400
Fax: 01782 206080
Email: stoke@hum-arch.co.uk
www.hulmeupright.co.uk

Client
STONE MARKET TOWN INITIATIVE

Project
STONE COMMUNITY FACILITY
WESTBRIDGE PARK

Title
SITE LOCATION PLAN

Status
PRELIMINARY

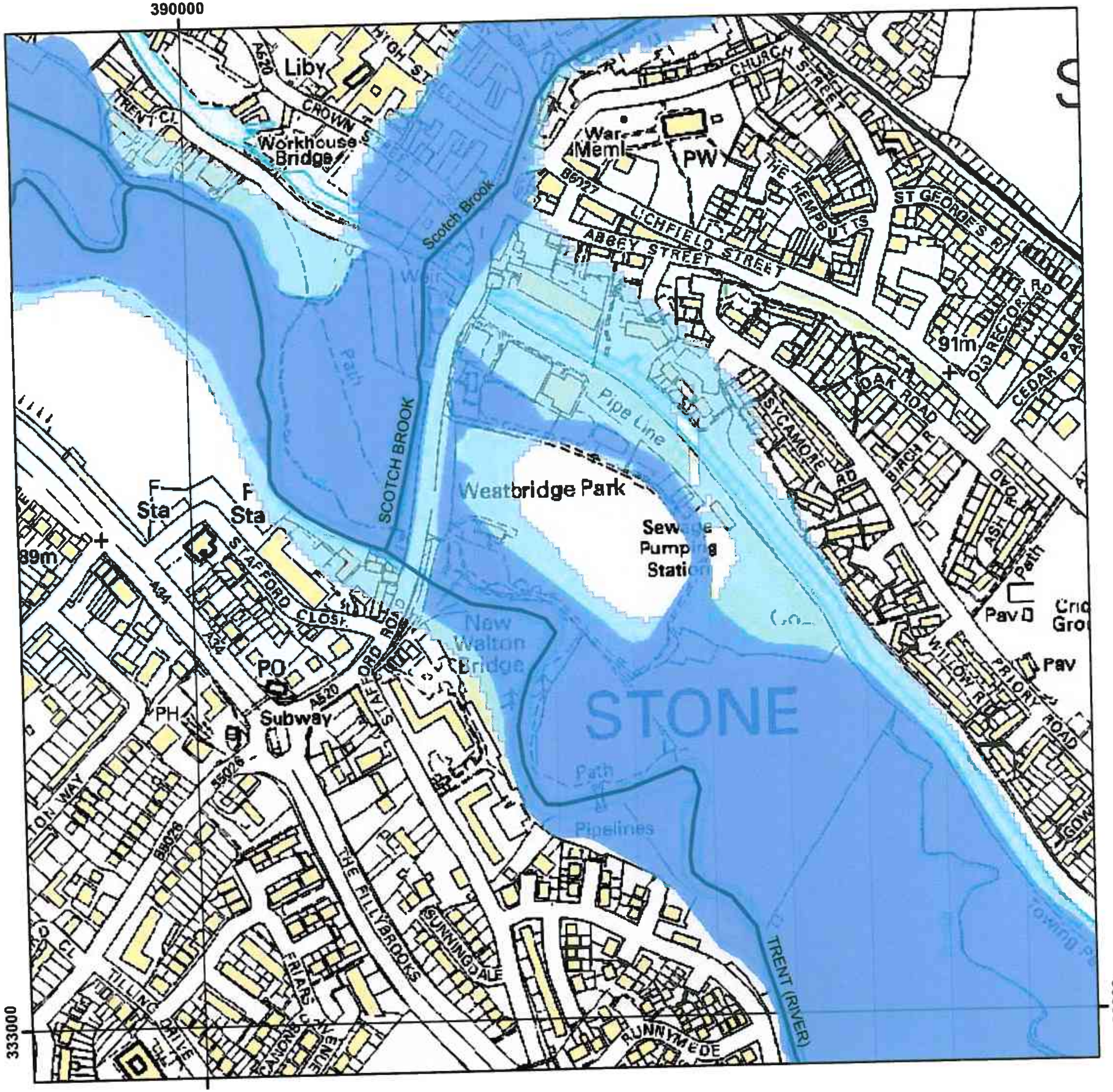
Date FEB 2008
Drawn NJH

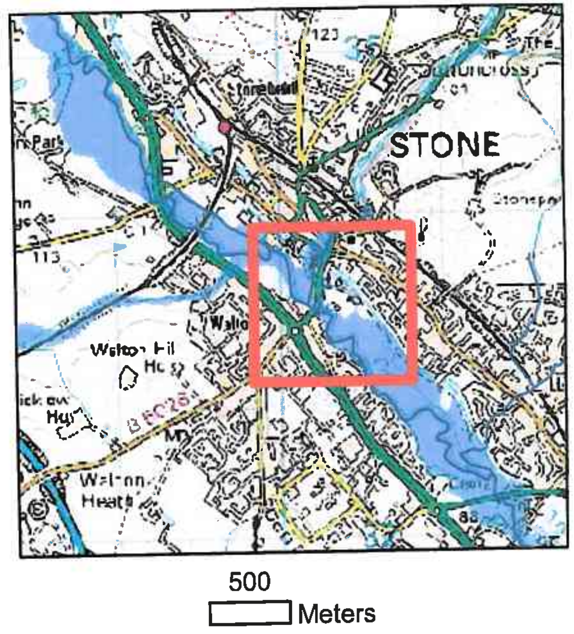
Scale @A3 1:1250
Checked

Project No 20148
Drawing No. AS(0)01
Rev

# Appendix B – Environment Agency Flood Zones

# Stone published FloodMap



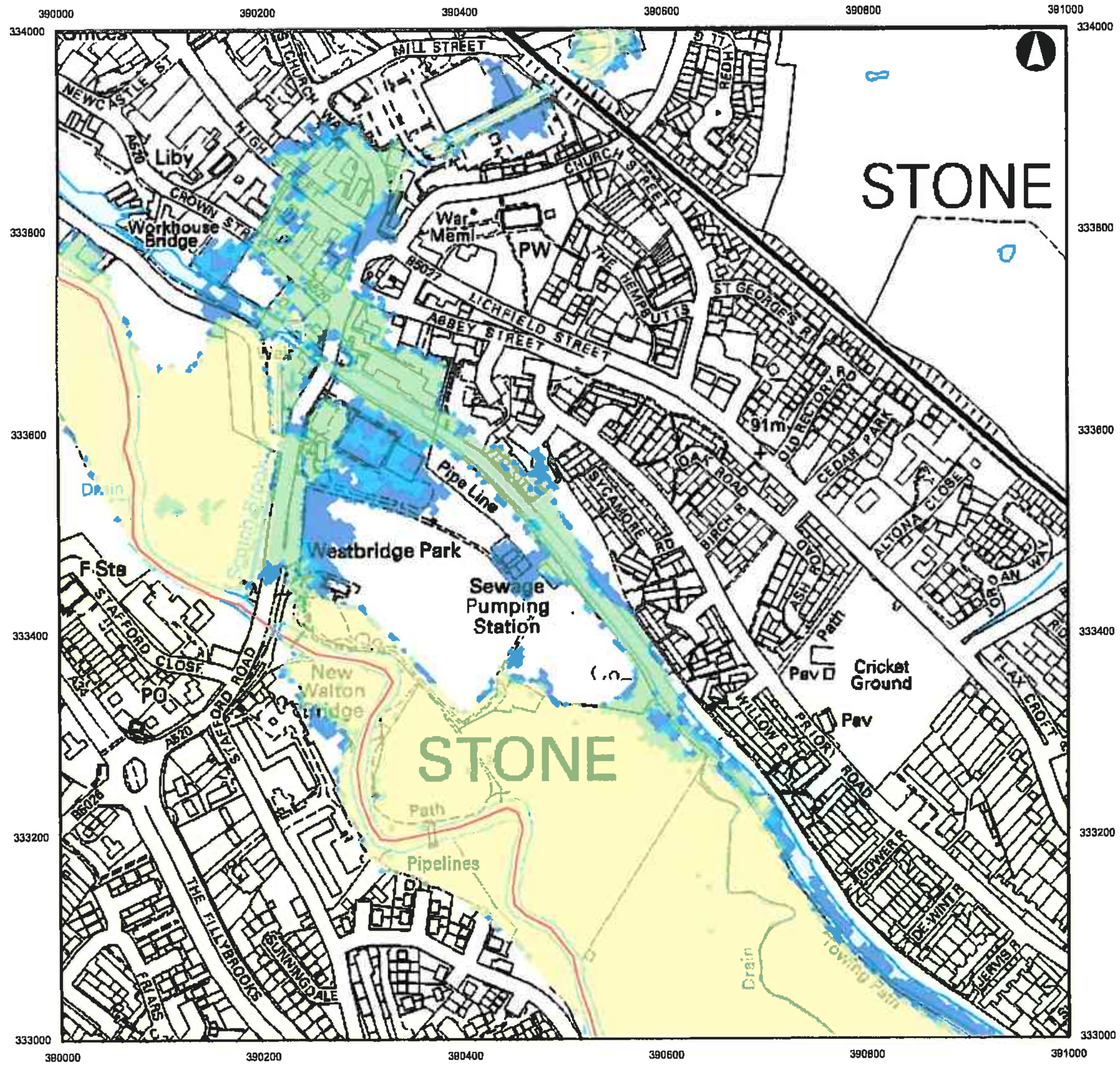




**Legend**

- Floodzone 3 (1 in 100 year floodplain)
- Floodzone 2 (1 in 1000 year floodplain)
- Main River

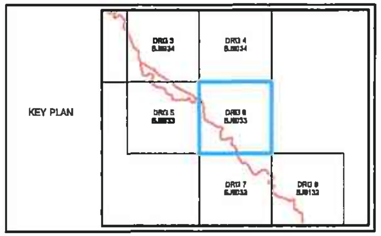
100 Meters

# Appendix C – Revised Flood Zones




## KEY

- Watercourse
- 5% AEP Flood Outline
- 1% AEP Flood Outline
- 1% AEP plus Climate Change Flood Outline
- 0.1% AEP Flood Outline




TECHNICAL NOTE
It should be noted that certain locations not shown may be at risk of flooding from other sources (piped drain systems, watermains etc.) and from other watercourses not shown in this study.

Channel roughness used in the model represents average conditions without any blockages and would not reflect the position if heavy weed growth or debris were allowed to build up in the river channel. It is assumed that embankments remain intact during flood events and act as an impermeable barrier. Were embankments to fail this could result in greater inundation.

USER NOTE
All model results have been produced in accordance with the requirements of the specification for flood risk mapping version 1 January 2004. Because the information is indicative rather than specific, local planning authorities will nevertheless need to consult the Environment Agency on individual applications. Users should note that flood plain extents were mapped at 5000 scale, as appropriate to the level of investigation and are based on information available at the time of survey. Amendments will be required in future to account for information gathered subsequently eg changes in hydrological river response or observations following flood events.

It should be noted that locations adjacent to rivers not included in this stage of the survey may be at risk of flooding. When in doubt the Environment Agency should be consulted.

Mapped model results for the Fluvial River Trent representing all standard SFRM floodplain maps without the influence of defences

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Environment Agency



**FLOODABLE AREAS NOT SHOWN**
**Areas affected by flooding from the sea (tidal flooding) Areas susceptible to drainage system inadequacies or localised ponding Areas flooding due to debris blockage**

PROJECT TITLE
River Trent Model Through Stone

DRAWING TITLE
SFRM Floodplain Maps

| ORIGINATED BY | DRAWN BY | CHECKED BY | APPROVED BY |
|---|---|---|---|
| AB | AB | BK | JT |
| DATE 11/01/10 | DATE 11/01/10 | DATE 11/01/10 | DATE 11/01/10 |

Scale @ A3 1:5000

CS033129_FO_EXT_02 - 6

# Appendix D – Hydraulic Modelling of the River Trent

# Appendix D - Hydrology extract from the Stoke on Trent SFRM commission

## 1. Summary of results

Table 24 summarises the peak flow estimates derived using each methodology and Table 25 provides a comparison with the flow estimates derived during the previous study.

**Table 24. Final peak flow estimates derived using each methodology**

| Estimation method | Flow Node | Return period peak flow ($m^3/s$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Statistical** | | **2** | **5** | **10** | **20** | **50** | **75** | **100** | **100+cc** | **200** | **1000** |
| **Single site (based on Stoke)** | **US** | 4.9 | 6.9 | 8.8 | 11.2 | 15.5 | 18.0 | **20.1** | 24.1 | 26.2 | 49.8 |
| | **Stoke** | 12.9 | 18.1 | 23.0 | 29.2 | 40.6 | 47.2 | **52.6** | 63.1 | 68.6 | 130.3 |
| | **Darlaston** | 34.8 | 49.0 | 62.1 | 79.0 | 109.7 | 127.5 | **142.1** | 170.5 | 185.5 | 352.2 |
| | **Lyme** | 9.7 | 13.6 | 17.3 | 21.9 | 30.5 | 35.4 | **39.5** | 47.4 | 51.5 | 97.9 |
| | **Aston Mill** | 38.6 | 54.4 | 68.9 | 87.6 | 121.7 | 141.5 | **157.7** | 189.2 | 205.7 | 390.7 |
| **Pooling group (based on Stoke Q100 group)** | **US** | 4.9 | 6.4 | 7.5 | 8.8 | 10.7 | 11.7 | **12.4** | 14.9 | 12.6^ | 16.7^ |
| | **Stoke** | 12.9 | 16.4 | 19.1 | 22.0 | 26.5 | 28.8 | **30.6** | 36.7 | 30.9^ | 40.6^ |
| | **Darlaston** | 34.8 | 43.6 | 50.1 | 57.3 | 68.5 | 74.2 | **78.5** | 94.2 | 79.1^ | 102.7^ |
| | **Lyme** | 9.7 | 11.9 | 13.6 | 15.5 | 18.4 | 19.9 | **21.0** | 25.2 | 21.1^ | 27.2^ |
| | **Aston Mill** | 38.6 | 48.7 | 56.3 | 64.6 | 77.4 | 84.0 | **89.0** | 106.8 | 89.8^ | 117.2^ |
| **ReFH** | | **2** | **5** | **10** | **20** | **50** | **75** | **100** | **100+cc** | **200** | **1000** |
| **Optimised parameters (10h critical storm duration)** | **US** | 7.5 | 10.0 | 11.9 | 13.9 | 17.1 | 18.8 | **20.2** | 24.2 | 24.0 | 37.6 |
| | **Stoke** | 22.2 | 29.6 | 35.5 | 41.3 | 50.7 | 55.8 | **59.8** | 71.8 | 71.2 | 111.2 |
| | **Darlaston** | 52.6 | 69.4 | 82.8 | 95.9 | 117.3 | 128.6 | **137.6** | 165.1 | 162.8 | 250.8 |
| | **Lyme** | 13.3 | 17.8 | 21.3 | 24.8 | 30.5 | 33.5 | **35.9** | 43.1 | 42.6 | 66.3 |
| | **Aston Mill** | 54.2 | 71.2 | 84.9 | 98.2 | 119.7 | 131.2 | **140.3** | 168.4 | 165.9 | 254.6 |

^ Q200 Stoke pooling group

**Table 25. Comparison of peak flow estimates at Stoke flow nodes with previous study**

| Return period | Black & Veatch Study 2005 | | Capita Symonds Study 2008 | | |
|---|---|---|---|---|---|
| | Statistical single site | Rainfall run-off (winter)* | Statistical single site | Statistical pooled (Q100 group) | ReFH (optimised) |
| **2** | 11.6 | 15.4 | 12.9 | 12.9 | 22.2 |
| **5** | 16.6 | 24.0 | 18.1 | 16.4 | 29.6 |
| **10** | 21.0 | 30.3 | 23.0 | 19.1 | 35.5 |
| **20** | NA | N/A | 29.2 | 22.0 | 41.3 |
| **25** | 30.0 | 45.6 | N/A | N/A | N/A |
| **50** | 39.0 | 58.5 | 40.6 | 26.5 | 50.7 |
| **75** | 45.0 | 72.7 | 47.2 | 28.8 | 55.8 |
| **100** | **51.0** | **77.1 (84.0**)** | **52.6** | **30.6** | **59.8** |
| **100+cc** | 61.2 | 92.6 | 63.1 | 36.7 | 71.8 |
| **200** | 68.0 | 88.8 | 68.6 | 30.9^ | 71.2 |
| **1000** | N/A | N/A | 130.3 | 40.6^ | 111.2 |

^ Q200 Stoke pooling group.
* Rainfall Run-off flows were not quoted in the Black & Veatch 2005 study report. Flows provided are approximated by combining modelled inflows 1 - 3.
** Quoted in Black & Veatch 2005 Study Hydrology Report for Q100 for the Stoke gauging station.

## 2. Discussion and recommendations

All flows incorporate updated URBEXT values to 2008; QMED values are based upon the latest QMED equation and have been adjusted in line with the Stoke donor station.

*Lower return period flows (2-50 year return periods)*

The Stoke gauging station is a good quality gauge with a flow record of 41 years of data for the urban catchments. Following the 5T rule, there is high confidence in the results of the single site analysis up to at least a 10 year return period. All three flood estimation techniques provide similar flow estimates up to a 1 in 50 year return period, with the single site providing an estimate between the pooled and ReFH approaches. For this reason it is considered appropriate to use the results of the single site analysis up to a 1 in 50 year return period event, as summarised in Table 24. The use of the single site method in estimating flows beyond the 5T limits is not recommended within the FEH as beyond this point the length of data set from the one gauging station is not of an appropriate length for estimating the higher return period flows. There is also a general tendency of single site analysis to over-estimate beyond the 5T limits, which becomes evident in the 1 in 200 year return period flow estimates and more so in the 1 in 1000 year return period estimates within this study. The lower return period flows for the two rural tributaries have been estimated through pooled analysis, as the Stoke gauging station was not suitable for donor transfer.

*Higher return period flows (75-1000 year return periods)*

Flows for return periods greater than the 1 in 50 year have been estimated using the ReFH methodology with optimised parameters for sub-catchments hydrologically similar to Stoke gauging station, and default catchment descriptors for others, and a 10 hour critical storm duration.

The ReFH methodology provided larger flow estimates that the Statistical Pooled Method, which was thought to under-estimate flows in this catchment due to the need to include a number of stations which were known to bypass.

*Comparison with the Black & Veatch 2005 Study*

The FEH statistical pooled method was not considered suitable for use in this study due to the lack of suitable gauged sites in the FEH dataset. This approach was also followed during the original Black & Veatch 2005 study.

The final flows in the Black & Veatch Study were derived using the FEH Rainfall Runoff methodology which has only recently been superseded by the ReFH methodology.

The peak flood flows derived using the ReFH methodology in this study are lower than those produced in the Black & Veatch Study using the FEH Rainfall Runoff Method. This is not unexpected as the FEH Rainfall Runoff Method was known to over-estimate flood flows which was a primary reason for it being superseded by the ReFH Method.

The Black & Veatch Study showed a reduction in the peak Q100 outflow from Model 1 (upstream of Darlaston) of 136$m^3$/s to the inflow into Model 2 (downstream of Darlaston) of 123$m^3$/s. This Capita Symonds study also shows that higher flows are estimated from the upper catchments compared with the more downstream catchments. There is only a 2% increase in flow for the 100 year return period between Darlaston and Aston Mill which corresponds to a 19% increase in catchment area. This is likely to be due to the change in catchment characteristics from the urban area of Stoke upstream of the Darlaston flow node to more rural catchments downstream of the Darlaston flow node.

*Final flows*

The final flows recommended for use in the hydraulic model are derived from a combination of single site statistical (urban catchments), pooled statistical (rural catchments) and ReFH methodologies, as summarised in Table 26.

As discussed in Chapter 6, it is recommended that sensitivity testing is undertaken on the 1 in 100 year return period hydraulic model to determine the critical duration for the design storm. Should the sensitivity testing result in critical duration variant to 10hrs, the summarised peak flood flows for return periods greater than a 1 in 50 year event will be affected.

**Table 26 Final flows recommended for use in the hydraulic model (subject to sensitivity testing)**

| Flow Node | Return Period Peak Flow ($m^3/s$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 20 | 50 | 75 | 100 | 100+cc | 200 | 1000 |
| | FEH single site method (*FEH pooled method) | | | | | ReFH method (10h critical duration) | | | | |
| Head of Model | 2.5 | 3.5 | 4.5 | 5.7 | 7.9 | 11.7 | 12.5 | 15.0 | 14.9 | 23.6 |
| US (B&V1) | 4.9 | 6.9 | 8.8 | 11.2 | 15.5 | 18.8 | 20.2 | 24.2 | 24.0 | 37.6 |
| Stoke (B&V3) | 12.9 | 18.1 | 23.0 | 29.2 | 40.6 | 55.8 | 59.8 | 71.8 | 71.2 | 111.2 |
| Darlaston (B&V8) | 34.8 | 49.0 | 62.1 | 79.0 | 109.7 | 128.6 | 137.6 | 165.1 | 162.8 | 250.8 |
| Lyme (B&V5) | 9.7 | 13.6 | 17.3 | 21.9 | 30.5 | 33.5 | 35.9 | 43.1 | 42.6 | 66.3 |
| B&V2 | 6.4 | 9.0 | 11.5 | 14.6 | 20.3 | 21.9 | 23.5 | 28.2 | 28.0 | 44.0 |
| B&V4 | 7.7 | 10.8 | 13.7 | 17.5 | 24.3 | 30.5 | 32.7 | 39.2 | 38.8 | 60.3 |
| B&V6 | 6.7 | 9.4 | 12.0 | 15.2 | 21.1 | 22.2 | 23.8 | 28.6 | 28.4 | 44.7 |
| B&V7 | 3.2 | 4.5 | 5.7 | 7.3 | 10.1 | 13.1 | 14.0 | 16.9 | 16.7 | 25.9 |
| Stone_trib | 1.6* | 2.5* | 3.2* | 3.9* | 5.1* | 5.4 | 5.7 | 6.8 | 6.6 | 9.8 |
| Scotch Brook | 3.8* | 5.8* | 7.3* | 9.0* | 11.8* | 14.2 | 15.1 | 18.1 | 17.6 | 26.3 |
| Aston Lodge Brook | 1.3 | 1.9 | 2.4 | 3.1 | 4.3 | 4.3 | 4.6 | 5.5 | 5.4 | 8.1 |
| Aston Mill | 38.6 | 54.4 | 68.9 | 87.6 | 121.7 | 131.3 | 140.3 | 168.4 | 165.9 | 254.6 |

*Inclusion into hydraulic model*

The final flows reported in Table 26 are estimates of the peak cumulative flood flow at each of flow node within the hydraulic model. For hydraulic modelling purposes it is necessary to prepare incremental flows for flow nodes which include the flow contribution from an upstream node. Incremental adjustments were required for four flow nodes on the main River Trent (US, Stoke, Darlastan, Aston Mill). No adjustment is necessary for the upper most node (Head) or the tributary catchments.

For the lower return period flows (2yr to 50yr) which were derived using the Statistical Method, adjustment was undertaken by subtracting upstream flow estimates from the cumulative estimate.

For the higher return period flows (75yr to 1000yr) which were derived using the ReFH method, adjustment was undertaken by modifying catchment descripors to reflect the incremental catchment, using standard procedures outlined in the Flood Estimation Handbook.

Once included in the hydraulic model, flood flows can be attenuated due to the presence of hydraulic structures. It is anticipated that the inflows to the hydraulic model will be calibrated to match the modelled flows against hydrological flow estimates. For this study it is recommended that this calibration exercise be undertaken at the Stoke Gauging Station as the hydrological estimates are most certain in this location. The calibration to this point may lead to slight variations between the modelled total flow and cumulative estimates at the remaining three incremental flow nodes.

Due to the interaction of the Trent and Mersey Canal with the tributaries of Scotch Brook and Aston Lodge Brook within Stone all or part of the flows estimated at the flow nodes of these tributary watercourses may require to be input into the canal rather than the main River Trent. This will require consideration of the hydraulic modeller through the build of the model and interaction of the tributaries and canal being incorporated into the model.

*Recommendations for future studies*

A number of recommendations have been highlighted during this study including:

- Further hydrological assessment is recommended for more detailed studies within Stone. In particular, more detailed studies should make use of the Ivy Mill level gauge, investigate the impact of alternative critical durations, and seek to further understand the interaction between the watercourses and Trent and Merseyside Canal.
- The value of the data recorded at Ivy Mill would be significantly improved if the station was provided with a surveyed datum, and was rated.

# Appendix D - Hydraulic model of the River Trent

## Hydrology

1.1 A hydrology assessment was undertaken as part of Capita Symonds' Strategic Flood Risk Mapping (SFRM) study of Stoke on Trent (March 2009) and was extended to incorporate the urban area of Stone.

1.2 An additional four flow nodes were included in the assessment for the downstream catchment area including the significant tributaries to the River Trent (notably Scotch Brook and the Stone tributary) and the extended downstream model extent at Aston Mill.

1.3 The methodology used to estimate flood flows at the additional four nodes was based on the findings of the interim hydrological assessment, which was largely focused on the use of gauged data within the urban centre of Stoke. This methodology was considered when applying hydrological estimates to the more detailed model within the Stone area.

1.4 An extract from the Hydrology Report, which includes the summary of results and discussion and recommendations used in the hydraulic model for Stone is included in Appendix G. The full version of the hydrology report is available on request.

## Hydraulic model description

1.5 The hydraulic model of the River Trent in this area starts immediately downstream of the roundabout at Meaford (388557, 335500) immediately south of Darlaston Bridge where the river flows through a rural landscape with an extensive floodplain affecting rural land to the west of the A34 from the right bank (west) of the river. From here the river flows south east towards Stonefield where it splits into two channels with the largest floodplain affecting rural areas downstream of Fillybrook Bridge either side of the railway bridge. The Trent flows towards Stone and the floodplain extends into rural areas upstream of the A520 access road to Stone. The floodplain is also influenced by the Scotch Brook which runs from north to south through the town to flow into the Trent south west of Westbridge Park. The Scotch Brook poses more of a flood risk to Stone than the Trent and Flood Zones 2 and 3 encroach on the town in a number of places, namely Christchurch Way, High Street, Crown Street, Stafford Road and Trent Close. This may be due to the reverse flow of the Trent up the Brook, rather than from the Brook alone. See Appendix C for the Flood Zone outlines.

1.6 South of Stone the floodplain remains wide and affects only the rural landscape. However, the Flood Zones suggest that there could be some interactions during larger flood events with the Trent and Mersey Canal.

## Purpose of modelling

1.7 The aim of this commission was to develop a hydraulic model that will produce standard SFRM deliverables including flood mapping for a range of return periods for the Stone area. The Environment Agency currently has four ISIS hydraulic models of the River Trent. One of these models, Model Two of the River Trent Fluvial Strategy, covers a similar study area to this commission and has thus been used as the basis for a new improved 1D/2D hydraulic model. This model will be used to prepare flood maps for event scenarios for Stone with an Annual Exceedance Probability (AEP) of 5%, 1%, and 0.1%. In addition, a climate change scenario has been applied to the 1% event.

## Choice of software

1.8 As identified in the recently completed Trent Strategy Model One Extension and improvements project, a decision was made to develop a 1D/2D hydraulic model. ESTRY-TUFLOW was selected as it is a 1D/2D unsteady state hydraulic modelling package.

1.9 TUFLOW is a fully hydrodynamic 2D model. TUFLOW solves the depth averaged 2D shallow water equations (SWE). The SWE are the equations of fluid motion used for modelling long waves such as floods, ocean tides and storm surges. They are derived using the hypotheses of vertically uniform horizontal velocity and negligible vertical acceleration (i.e. a hydrostatic pressure distribution). These assumptions are valid where the wave length is much greater than the depth of water. A powerful feature of TUFLOW is its ability to dynamically link to the 1D network (quasi-2D) hydrodynamic program ESTRY and its ability to represent structures and defences.

1.10 The benefit of linking 1D and 2D models is the ability to maintain the advantages of 1D modelling for channel networks and structures and to make use of 2D modelling of the floodplain. The 1D and 2D models can be fully linked so that flow is transferred between the 1D model network and the 2D model at every time step. In a 1D model flow paths have to be pre-defined, however using a 2D model allows these pathways to be determined within the model based on the underlying Digital Terrain Model (DTM) and land use roughness. This means that water is able to flow where it should rather that following predetermined routes. A further benefit of 2D modelling is that as well as defining the extent of flood inundation, TUFLOW reports depth and velocity data for the 2D domain enabling flood hazard mapping of the floodplain to be readily produced. The hydraulic model of the River Trent was constructed using ESTRY-TUFLOW version 2008-08-AE-iDP.

## Previous Hydraulic Models

1.11 The Environment Agency currently has four ISIS hydraulic models of the River Trent developed by Black and Veatch in 2004 as part of the River Trent Fluvial Strategy. The four models provide continuous coverage of the Trent from Stoke on Trent (SJ 90080 51020) to Newark (SK 80920 61140). The model of interest covering the study area for this commission is Model Two. The model was constructed based on survey carried out in June 2002 by Cartographical Surveys Ltd.

1.12 In addition to the aforementioned River Trent models, the Environment Agency also has a model of the Scotch Brook.

## Model extent

1.13 The River Trent model extents for this model encompass the study extents of the Stoke-on-Trent SFRM. The study reach of the River Trent is approximately 7.5km in length. The upstream extent is located just south of Darlaston Bridge (388557, 335500). The downstream extent is located just north of Upper Burston Bridge (393111, 330252).The model length of Scotch Brook is approximately 1km, the upstream extent is located north ~200m from Mill Street (390495, 334175) and the downstream is located just before the Stafford Road (390185, 333443).

1.14 The exact model extents included in the Stone Model of each watercourse are listed below in Table 4.1.

**Table 4.1 Model Extents included in the Stone Model**

| River Name | Upstream NGR | Downstream NGR | Approx. length (km) |
|---|---|---|---|
| River Trent – Stone Extension | 388557, 335500 | 393111, 330252 | 7.5km |
| Scotch Brook | 390495, 334175 | 390185, 333443 | 1.0km |

## Structures

1.15 A total of 11 structures are included in the Stone model river network, comprised of eight bridges and three culverts. The Scotch Brook branch has 21 structures, comprised of six bridges, six culverts and nine weirs.

1.16 In the study area there are bridges of both rectangular and arch bridge construction. The rectangular bridges were of two types, i) rectangular opening with bridge piers restricting flow in the lateral direction, and ii) rectangular opening with a deck over the top of the channel that does not restrict flow. In the latter case, a constant bridge loss of zero is applied up until the underside of the bridge deck as there is no restriction in flow. Above the underside of the bridge deck, TUFLOW automatically applies a loss figure. This value is subject to adjustment depending on the approaching and departing velocities upstream and downstream of the structure. For arch bridges and rectangular bridges with piers in the channel, bridge losses were calculated based on theory in 'Afflux at Arch Bridges'[1].

1.17 Two culverts were modelled in 1D at the A51 to model the any flow from the North to South side of the road, these were identified in the site visit. The dimensions of the culverts are estimated from the field photos.

1.18 A siphon is located where the Scotch Brook passes underneath the canal near to the outfall of Scotch Brook. Data was taken from survey and the original iSIS model. At the downstream end of the culvert, the bed level rises. Large changes in bed level can often cause instabilities in models as was initially the case with this model. In order to overcome these instabilities, two weirs were input into the model at the upstream and downstream ends of the culvert where the changes in bed level occur. The upstream weir dimensions have been taken from the upstream surveyed cross-section. The downstream weir dimensions have been taken from the dimensions of the culvert.

1.19 The culverts modelled have a variety of shapes and sizes, and they are observed to occur in series and parallel. Circular, rectangular and irregular shaped culverts are used in the model. The irregular culvert option in TUFLOW defines the shape of the culvert by relating flow width to elevation. These types of culverts have been used in the case where the culvert does not have circular or rectangular geometry or is arched, thereby preserving the flow area of surveyed culverts.

1.20 The Manning's n roughness values assigned to the culverts along the watercourse varies. These values are based on guidance in the literature[2] and photographs. Culvert investigations have shown that where there are bends in the culverts or changes in shape along the culvert length, this transition is relatively smooth and therefore no additional losses have been applied to culverts to represent these transitions.

---

[1] 'Afflux at Arch Bridges', HR Wallingford Report SR 182, December 1989

[2] Chow, V.T. (1984) 'Open Channel Hydraulics' McGraw Hill, Singapore

## Quality assurance

1.21 TUFLOW automatically generates a list of errors warnings and notes for each model run which inform the modeller of assumptions the model is making. A review of these messages was undertaken to assess any potential problems with the model and corrected where necessary.

## Design Runs

1.22 The final design model was run for the following fluvial flood events (Table 4.2):

**Table 4.2 Stone model design runs**

| | |
|---|---|
| Undefended | 5% AEP; 1% AEP; 0.1% AEP. |
| Undefended + climate change | 1% AEP |

1.23 The model was run for 36 hours, a duration chosen to ensure that the flood passed through the study area and that the peak flood level was reached in all locations in the model.

## Results

1.24 Table 4.3 below shows the levels from the results of the modelling of the watercourses from around the site area. Appendix E shows the location of the model node points that these levels relate to.

**Table 4.3 Flood levels from the model for the Stone area**

| Node Label | 100 yr flood levels (mAOD) | 100 yr + climate change flood levels (mAOD) |
|---|---|---|
| SB0045.1 | 85.9 | 86.0 |
| SB0000.1 | 85.9 | 86.0 |
| Halc_165br.1 | 85.9 | 86.0 |
| Halc_165br.2 | 85.8 | 85.9 |
| Halc_165D.2 | 85.7 | 85.9 |
| Halc_18br.2 | 85.7 | 85.8 |
| Halc_18D.2 | 85.6 | 85.7 |
| RT419545br.1 | 85.6 | 85.7 |
| RT419545br.2 | 85.6 | 85.7 |
| RT419527br.1 | 85.6 | 85.7 |
| RT419527br.2 | 85.5 | 85.7 |
| RT419214.1 | 84.7 | 84.8 |
| RT418900.1 | 84.1 | 84.1 |

1.25 Model results have been provided in electronic format on CD to Stafford Borough Council and the Environment Agency along with this report.

# Appendix E – Modelled Flood Level Locations


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River Stone Model

Appendix D: Modelled Flood Level Locations

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