ESG Herefordshire Limited

Yazor Brook Flood Alleviation Scheme

Flood Risk Assessment

Date: September 2009

CAPITA SYMONDS

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Executive Summary

This Flood Risk Assessment has been produced to support the proposed Flood Alleviation Scheme (FAS) for the ESG regeneration area, Hereford. This report outlines the existing flood behaviour, considers the impacts of the proposed scheme and addresses the requirements set out in Planning Policy Statement PPS25 (December 2006). The report should be read in conjunction with the Environmental Statement, completed in support of the strategic flood mitigation scheme.

The proposed FAS will divert high flows from the Yazor Brook into the River Wye, upstream of Hereford. This will reduce flood risk in Hereford from the Yazor Brook, without increasing flood risk from the River Wye.

The route of the proposed FAS is predominantly rural, with a generally low probability of flooding (less than 0.1% Annual Exceedance Probability). The exceptions are land associated with the off-take and outfall structures that are located within the channel and floodplain of the Yazor Brook and River Wye respectively. The proposed FAS is classified as a "water compatible" land use with regard to flood risk, as defined in Table D.2 of PPS25. In accordance with PPS25 this classification of land use is considered appropriate development within Flood Zones 1, 2 and 3.

PPS25 requires that all potential sources of flooding be assessed. This FRA has concluded that the principal source of flooding relevant to the proposed FAS is river flooding from the Yazor Brook and River Wye.

Computational hydraulic models have been used to assess current risk and the impact of the proposed scheme on flooding. The results from the analyses indicate that the proposed FAS significantly reduces the risk of flooding from the Yazor Brook downstream, both within the ESG area and elsewhere within Hereford.

The proposed scheme was demonstrated to have no adverse impact to flood risk for adjacent land or to communities downstream.

Contents

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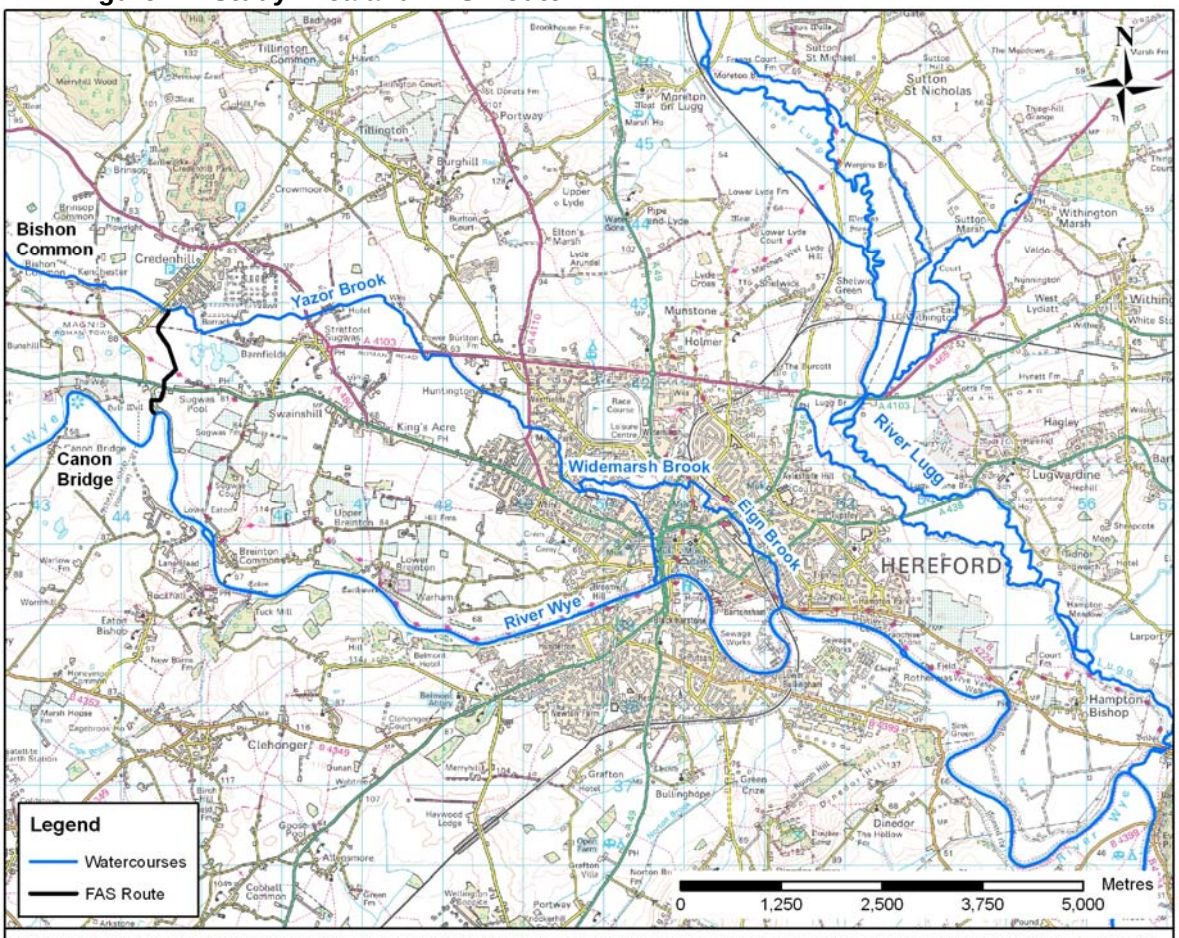
1. Introduction

Capita Symonds Ltd. was commissioned by ESG Herefordshire Ltd to produce a Flood Risk Assessment (FRA) in support of its planning application for a Flood Alleviation Scheme (FAS) upstream of Hereford. The FAS is designed to reduce flood risk within Hereford facilitating delivery of the ESG Masterplan. This FRA does not assess flood risk at the ESG redevelopment site, which in itself will be subject to separate FRA at a later date to support development proposals and applications.

The ESG area has been shown to be at risk of frequent flooding from the Widemarsh Brook. In order to proceed with plans for regenerating the ESG area it is essential that flooding within the site be reduced to an acceptable level. Without significant reduction in the flood risk within ESG aspects of the proposed Masterplan will not be deliverable.

The purpose of the proposed FAS is to divert flood waters upstream of Hereford via culvert from the Yazor Brook into the River Wye during times of high flow in order to reduce flooding downstream and specifically within the ESG area. The study area and the route of the proposed FAS are shown in Figure 1. The scheme development proposals include an off-take structure from the Yazor Brook, a culverted flood flow route between the Yazor Brook and the River Wye, a velocity/energy reduction chamber and an outfall structure into the River Wye. The total length of works for the proposed FAS is approximately 1.8km.

Figure 1 – Study Area and FAS Route



The route of the proposed FAS is currently open agricultural land with hedge and tree lined field boundaries. The general topography of the area slopes gently from north to south with ground levels of approximately 77m AOD at the off-take from the Yazor Brook and 60m AOD at the outfall into the River Wye.

This report is a Flood Risk Assessment in support of the development proposals and considers the impacts of the proposed FAS on flooding. This FRA addresses the requirements set out in Planning Policy Statement PPS25 (PPS25) (December 2006). The FRA has regard to all sources of flooding, as identified in PPS25, and considers both the impact and benefits of the scheme on flooding.

In the course of preparing the FAS consultation has been held with the Environment Agency and Herefordshire Council. This FRA has focused on the issues that are understood to be of particular importance to the Environment Agency with respect to flood risk.

Supporting studies report the benefits associated with delivery of the scheme and the extent of flood inundation resulting from a range of Annual Exceedance Probability (AEP) flood events (most notably the 5% and 1% AEP events) from the Yazor Brook pre and post construction. They also consider the inundation resulting from a 1% AEP flood event with an allowance for the impact of climate change (20% increase in inflows). This FRA has reproduced outputs from the pre and post scheme assessment in Appendix B. The FRA also comments on the potential effects arising from the construction of the proposed scheme on flooding, and describes engineering design recommendations to mitigate any residual risks identified.

Review of the Environment Agency flood maps indicate that the majority of the proposed FAS route is within Flood Zone 1, which is defined by PPS25 as being land assessed at low probability of flooding and less than 1 in 1000 annual probability in any year (0.1% AEP or less). However, the proposals are also partly located within the channel and floodplain of the Yazor Brook and River Wye, and so both the upstream and downstream extents of the FAS are within Flood Zones 3 (land assessed to have a flood risk greater than 1% AEP).

Studies to support the design of the FAS have required development of a dynamically linked one-dimensional (1D) and two-dimensional (2D) hydraulic model to understand the complex interaction of flows associated with watercourses, floodplains and the FAS. Outputs from these studies have been used to inform this FRA.

2. Policy and Guidance

Policy and guidance relevant to the assessment of flood risk is reviewed in the sections below.

2.1 Planning Policy Statement 25: Development and Flood Risk (PPS25)

PPS25 was published by Communities and Local Government (CLG) in December 2006 and an accompanying Practice Guide in June 2008. PPS25 sets out the Government's national policies on flood risk in relation to land use planning in England. It advises that a strategic approach should be adopted in keeping with the Government's aims to ensure that any proposals are sustainable. Notably it reinforces:

- the concept of classification of vulnerability of the proposals to the consequences of flooding;
- the need to undertake different levels of flood risk assessment to inform all levels of planning (i.e. the need for Regional Flood Risk Appraisals, Strategic Flood Risk Assessments and site-specific Flood Risk Assessments);
- the need to perform the 'Sequential Test' so that flood risk is appropriately considered along side other sustainability factors when allocating sites for new development;
- the requirement to conform to the 'Exception Test' in circumstances where it is necessary to locate certain types of new developments in medium and high probability zones;
- the concept of flood risk reduction, particularly where development has been sanctioned on the basis of the 'Exception Test'.

2.2 The Pitt Review: Lessons learned from the 2007 floods (June 2008)

Following extensive flooding in June and July 2007 the Government requested that a thorough and independent assessment be undertaken of what happened over this period and what could be done differently in the future. The Pitt Review made more than 90 recommendations to reduce the likelihood and impact of flooding. The recommendations covered all flood related issues including forecasting, prediction and flood modelling, flood risk and warning, sources of flooding, flood management including planning considerations and building methods, local and national flood protocol, the availability of flood data and records and adaptation and mitigation for climate change. They included:

- Controls or guidance around development (building regulations, planning controls);
- Steps to encourage more sustainable new development or greater resilience in the existing housing stock;
- Much clearer leadership locally to manage flood risk;
- A risk-based approach to sewerage design and investment in flood defence; and
- Better mapping of flood risk to support that role.

Five of the recommendations are particularly pertinent to the proposed FAS (and regeneration of ESG), these are:

- Recommendation 1: Given the predicted increase in the range of future extremes of weather, the Government should give priority to both adaptation and mitigation in its programmes to help society cope with climate change.

- Recommendation 7: There should be a presumption against building in high flood risk areas in accordance with PPS25, including giving consideration to all sources of flood risk, and ensuring that developers make a full contribution to the costs both of building and maintaining any necessary defences.

- Recommendation 23: The Government should commit to a strategic long-term approach to its investment in flood risk management, planning up to 25 years ahead.

- Recommendation 24: The Government should develop a scheme which allows and encourages local communities to invest in flood risk management measures.

- Recommendation 27: Defra, the Environment Agency and Natural England should work with partners to establish a programme through Catchment Flood Management Plans and Shoreline Management Plans to achieve greater working with natural processes.

2.3 Development and Flood Risk: Guidance for the Construction Industry (C624)

CIRIA publication C624 (2004) provides guidance to developers and the construction industry on the implementation of good practice in relation to flood risk and the development process. Although the proposals do not entail any development as such the guidance within this document should be noted and followed where appropriate.

2.4 CIRIA Sustainable Drainage System (SuDS) Manual

The CIRIA SuDS Manual (2007) aims to provide comprehensive advice on the implementation of sustainable drainage techniques in the UK. It provides guidance on all aspects of SuDS including planning, design through to construction and SuDS management.

2.5 Strategic Flood Risk Assessments and Catchment Flood Management Plans

The Strategic Flood Risk Assessment (SFRA) for Hereford

The Hereford SFRA has been prepared for Herefordshire Council to help identify those areas in the County most at risk of flooding and to provide the basis from which to apply PPS25 to planning applications. The SFRA is part of the emerging Local Development Framework process and sets out the procedure to be followed when assessing new development sites that fall within a flood risk area. It provides a planning tool that enables the Council to select and develop sites through suitable flood risk assessment and management.

The Wye and Usk Catchment Flood Management Plan

The Wye and Usk Catchment Flood Management Plan (CFMP) is a high level strategic planning document through which the Environment Agency seek to work with other main decision-makers within a river catchment. CFMPs will set out the policies the Environment Agency will adopt to manage flood risk in each area for the next 50 to 100 years. The CFMP considers all types of flooding, whether from rivers, groundwater, surface water or sewers and is based on a standard approach to ensure it provides a consistent assessment of flood risk and policy options. The draft Wye and Usk CFMP is currently out to public consultation prior to being finalised.

The draft CFMP area is divided into ‘policy units’ which are areas with similar flood, economic and environmental characteristics. Each policy unit has then been assessed to decide which policy will provide the most appropriate level and direction of flood risk management for both now and in the future. One of six standard flood risk management policies has been applied to each policy unit.

Hereford and the proposed FAS route are within policy unit 5 of the draft CFMP. This policy unit has been assigned a policy 3 - continue with existing or alternative actions to manage flood risk at the current level. A policy 3 is applied where the risks are currently managed appropriately and/or where the risk of flooding is not expected to increase significantly in the long term and where the overall level of current flood risk management activity is in balance with the risks. The selection of policy 3 was based on the presumption that a strategic solution to flooding within Hereford from the Yazor Brook would be progressed.

2.6 Regional Strategy

The West Midlands Regional Spatial Strategy (January 2008) refers to national policy and does not include a specific policy in respect of development and flood risk. To provide regionally specific guidance, the West Midlands Regional Flood Risk Appraisal (RFRA) was produced in 2007 to inform flood risk policies when preparing Regional Spatial Strategies. The outputs of the RFRA are flood risk profiles which consider actual and inherent flood risk that can be referenced when allocating future housing numbers. The RFRA cites Herefordshire as having high housing growth allocation figure, and the flood risk profile was determined to be of medium significance.

2.7 Local development documents

The Herefordshire Unitary Development Plan (UDP) was adopted on 23rd March 2007 and will guide development within the County until 2010. The UDP has the status of a Development Plan Document. It will be operative as part of the Local Development Framework for a three year period from the date of adoption.

The UDP considers flood risk through policy DR7 – Flood Risk and PPS25, and stresses the following objectives and policy statements:

- The need to manage the floodplain and avoid inappropriate development;
- Development should be concentrated in existing settlements- Hereford is considered the most sustainable location for the majority of new development;
- Adopt a sequential, risk based approach to managing flood risk in a planning context; and
- Balanced flexible approach is required which addresses the risks of flooding whilst recognising the blight from under investment and development.

The Herefordshire UDP will be replaced over time by the Local Development Framework.

3. FAS Proposal Description and Location

Full details of the scheme have been submitted along with the planning application are not replicated here. Brief details are noted below.

3.1 FAS Proposals and Location

The route of the proposed FAS is located to the west of Hereford, between the Yazor Brook at Credenhill and the River Wye. Figure 1, Section 1 of this report indicates the approximate route and the surrounding area.

The proposed route corridor is currently open agricultural land with hedgerow and tree lined field boundaries. The general topography slopes gently from north to south with ground levels of approximately 77m AOD at the off-take from the Yazor Brook and 60m AOD at the outfall into the River Wye.

The FAS is made up of the following components:

- A flow control structure within the Yazor Brook channel;
- The off take structure;
- The culverted channel (approx. 1.4km) between the Yazor Brook and the River Wye;
- A velocity/energy reduction chamber at the downstream end of the culvert; and
- An outfall structure onto the River Wye floodplain.

The proposed route lies to the west of existing gravel pit lakes; other than these artificial lakes and the Yazor Brook and River Wye there are no hydrological environmental features within close proximity of the proposed FAS. The upstream and downstream reaches of the proposed FAS, due to its nature, are located within Flood Zone 3 as identified by the Environment Agency's Flood Map.

3.2 PPS25 Status

The proposed FAS scheme is classified as "Water Compatible" according to Table D.2 in PPS25, which is compatible and a suitable land use within Flood Zones 1, 2 and 3. An appraisal of possible options to reduce flooding from the Yazor Brook within Hereford was completed in 2006, as reported on in the Yazor Brook FAS Environmental Statement. The assessment considered the opportunities and constraints of various mitigation options including flood storage, flood flow diversion, and on-site works. Based on consideration of engineering, economic and environmental issues the proposed FAS scheme was selected as the most viable scheme to deliver the required level of flood risk management.

4. Sources and Probability of Flooding

PPS25 requires that all sources of flooding be considered when assessing flood risk. This section identifies the sources, potential flood mechanisms and probability of these sources of flooding occurring within the area of the development.

4.1 Flooding from rivers

The proposed FAS is designed to reduce flood risk from the Yazor Brook to the EAG area by transferring high flows from the Yazor Brook, to the Wye upstream of Hereford. The Environment Agency's Flood Map shows that the off take structure will be located in Flood Zone 3 (at high risk of flooding from rivers).

Flooding from river is discussed further in Section 5 of this report.

4.2 Flooding from the sea/ tidally influenced flooding

The FAS route is not located within a coastal area and is therefore not at risk of direct sea flooding.

The tidally influenced reach of the River Wye extends from its outfall to the River Severn to upstream of Llandogo, around Bigsweir Bridge. The proposed FAS route is located a significant distance, more than 70km, upstream from the tidally influenced reach of the River Wye. Therefore, tidal flood risk is not considered a concern in relation to the FAS proposals.

Flooding from sea and tidally influenced flooding has not been considered further.

4.3 Flooding from land (surface water)

Surface water flooding occurs when runoff from high intensity storms (often of short duration) is unable to infiltrate into the ground or enter surface water drainage systems. This water remains on the ground surface where it either ponds or flows overland (overland flow) to lower lying areas prior to infiltrating/evaporating or entering the surface water drainage system.

Surface water flooding is considered to be limited within the development area due to the essentially rural nature of the landscape. Rainfall is likely to infiltrate soils and shallow geology or be naturally attenuated due to undulations in topography. The Wye and Usk CFMP notes that surface water flooding was recorded in the catchment in April 2008 and within Hereford during June and July 2007, however no specific reference is made to surface water flooding along the route of the scheme.

The scheme proposals will not increase the area of hard standing or reduce the natural capacity of the catchment to attenuate intense rainfall. Detailed design of the offtake and discharge structures is likely to incorporate measures to manage local runoff or interruption of overland flow routes as appropriate. Consequently this source of flooding is not explored further in this FRA.

4.4 Flooding from groundwater

Groundwater flooding occurs when the sub-surface water table rises to intersect with ground level. This can occur at one individual location, or in a diffuse fashion over a wider area. The likelihood of groundwater flooding occurring depends on the underlying geology, soil and topography.

From British Geological Society mapping the solid geology within the proposed FAS route corridor is Raglan Mudstone that is overlain in locations with Alluvium, Fluvio-glacial Deposits and Morainic Deposits. The Raglan Mudstone formation is classified by the Environment Agency as a minor aquifer, providing local water supplies and supplying base flow for rivers.

The Strategy for Flood and Coastal Erosion Risk Management (Defra, September 2006) identifies several sources of groundwater flooding within non-chalk aquifers including the rise of groundwater levels in response to extreme rainfall. However, groundwater levels in the area of the proposed FAS are considered to rise and fall slowly and they do not respond quickly to wet weather. High groundwater levels and resultant spring flows are not a significant source of flooding along the scheme route and therefore this source of flooding is not explored further.

4.5 Flooding from sewers

Welsh Water is the sewerage undertaker in Hereford and surrounding area. The proposed FAS route is through open agricultural land and is not currently associated with any sewerage system. The proposed FAS does not include any construction of buildings or increases in impermeable surface and therefore does not alter the existing drainage situation.

This source of flooding is not considered a notable risk for the proposals and is not explored further.

4.6 Flooding from artificial sources

PPS25 describes non-natural or artificial sources of flooding such as reservoirs, canals and lakes where water is retained above natural ground level. PPS25 also includes operational and redundant industrial processes including mining, quarrying, and sand and gravel extraction as they may increase water depths and velocities in adjacent areas.

Although there are a several former gravel pit lakes located to the east of the proposed FAS route there are no known incidents of flooding associated with these features. As such, this source of flooding has not been explored further.

4.7 Existing Flood Defence Management

There are no existing flood defences protecting the proposed FAS route corridor site from inundation from any source of flooding.

4.8 Historical Flooding

There are no historical records of flooding along the route of the proposed FAS.

5. Flooding from Rivers

5.1 Flooding from rivers

The proposed FAS has been designed to relieve flooding from the Widemarsh Brook in the ESG area by transferring high flows, from the Yazor Brook into the River Wye. To test the design of the FAS and demonstrate its safe operation a number of technical studies have been carried out to assess the hydrology and hydraulics of the River Wye and Yazor Brook catchments. A brief explanation of the technical work is detailed within this chapter. The results of the studies have been comprehensively interpreted to assess the flood risk from these rivers.

5.2 Hydrology

5.2.1 *Yazor Brook Catchment*

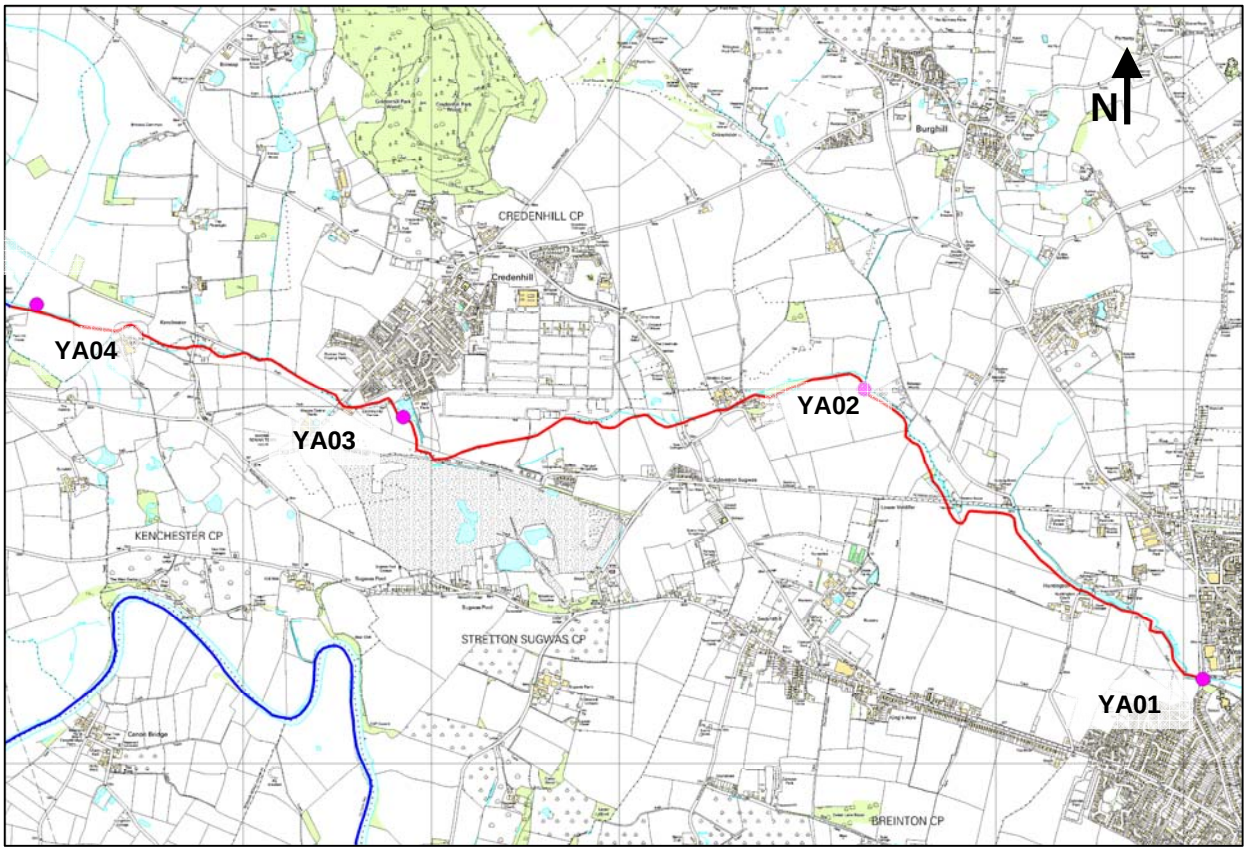
Extensive investigations to determine accurate estimates of flood flows were carried out in close partnership with the Environment Agency. The final design flows have been derived using the Revitalised Flood Studies Report (FSR) / Flood Estimation Handbook (FEH) Rainfall Runoff (ReFH) method. Data from the Three Elms gauging station has been used to adjust the time-to-peak (Tp) parameter within the ReFH model and to define the design storm duration. This work endeavours to provide design flows and hydrographs which are more representative of the catchment response than those derived from catchment descriptors alone.

The design flows at each flow node, generated using the ReFH method, are provided in Table 5.1 with the node locations shown in Figure 2. The cumulative flow to YA01, for the 1% AEP event, is also provided. The sum of incremental flows for each node will not equal the cumulative flow at YA01 due to the artificial timing differences which are applied when the catchment is split into smaller (incremental) areas.

Table 5.1 – ReFH design flows (m^3/s)

Flow node	5% AEP	1% AEP	0.1% AEP
YA01 Inc.	2.2	3.0	5.1
YA02 Inc.	2.1	2.9	5.0
YA03 Inc.	2.4	3.3	5.5
YA04	3.7	5.1	8.7
Sum of incremental flows		**14.3**	
YA01 Cum.		9.8	

Figure 2 – Flow distribution in hydraulic model



The Environment Agency Wye / Lugg confluence hydraulic model (version 3.1), was used as the basis for the River Wye model, including the flow estimates. The model was created by Atkins and has been developed over a number of Environment Agency commissions. The hydrological methodology can be found in the 2004 and 2007 Atkins reports.

The hydrographs selected for use were those for the 4%, 4% with Climate Change, 1%, 1% with Climate Change and 0.1% AEP events. The 4% AEP (1 in 25 year) event was used as the event closest to 5% AEP (1 in 20 year functional floodplain) event for which hydrographs had been calculated. A 20% increase in flows has been used as the climate change allowance.

To allow the model to be extended upstream flow node ‘1.072’ was relocated to the new upstream boundary of the extended hydraulic model. As the increase in catchment area between these two locations is very small, approximately 0.002% difference, and the consequent increase in flow is likely to be negligible in the wider context, the decision was made to use the original flows without further adjustment.

The River Wye design hydrology is summarised in Table 5.2.

Table 5.2 – Summary of River Wye peak flow estimates

AEP (%)	Peak Flow Estimate (m^3/s)
4%	658
1%	808
1% plus climate change	970
0.1%	1252

5.3 Hydraulic Modelling

A number of computational hydraulic models have been constructed and/or amended to assess the current flood risk on the Yazor Brook and River Wye and any potential change to flood risk as a result of the construction of the proposed FAS. These include:

- A linked 1-Dimensional – 2-Dimensional (1D/2D), ISIS-TUFLOW model of the Yazor Brook; and
- A 1D ISIS model of the River Wye.

5.3.1 *Yazor Brook Catchment*

A hydraulic model has been constructed in order to assess the fluvial flood risk from the Yazor, Widemarsh and Eign Brooks. The model represents a section from Bishopston to the Yazor Brook and Eign Brook confluences with the River Wye and incorporates the proposed FAS at Credenhill.

The basis of the Yazor Brook hydraulic model originated from the Hereford Critical Ordinary Watercourses (COWs) flood mapping study for Wales Region of the Environment Agency, carried out by Capita Symonds in 2006. This model consists of a TUFLOW / ISIS model of a 3.8km reach of the Brook, from downstream of Three Elms Bridge to its outfall into the River Wye at Greyfriars Bridge.

The previous Environment Agency model was a hydro-dynamically linked 1D/2D ISIS-TUFLOW model of the Yazor Brook. The same packages and approaches were used for the Yazor Brook FAS modelling. The model was extended 8km upstream of Three Elms gauging station using additional topographic survey of the river channel and structures, collected to EA National Survey Specification, and LIDAR data provided by the Environment Agency.

The inflow node from the Environment Agency model has been retained and an additional three inflows have been added into the hydraulic model. The design hydrographs were generated using the ReFH method as detailed in Section 5.2.1. The three additional hydrographs have been distributed at various points along the reach of the Yazor Brook as lateral inflows in iSIS. The lateral inflow unit distributes the hydrograph across multiple river reaches as opposed to a single node. This is an accurate representation of flow into a watercourse from a rural catchment without major tributaries.

The downstream boundary of the model has been retained as a fixed level for the River Wye, which was obtained from the Environment Agency model. This uses a 50% AEP event water level for the downstream boundary on

the River Wye for modelled events up to 1% AEP event for the Yazor Brook, and a 20% AEP event level on the Wye for events greater than the 1% AEP event on the Yazor Brook, due to the improbability of the flood peaks from the River Wye and Yazor Brook coinciding.

5.3.2 *River Wye Catchment*

To enable the assessment of flood risk to the River Wye the existing Environment Agency Wye / Lugg Confluence Model v3.1 iSIS model, constructed by Atkins, was extended approximately 7.8km upstream of its current upstream extent and a flow node was added to represent flow coming in from the Yazor Brook FAS.

The Wye / Lugg confluence model (version 3.1) was provided to Capita Symonds by the Environment Agency in October 2008. The model was created by Atkins and has been developed throughout of number of commissions, as detailed in Table 5.3.

Table 5.3 – Model History

Date	Model	Description
2004	v2 River Wye Model (Atkins)	Hereford Flood Alleviation Project - Project Appraisal Stage Model built to assess the existing case and proposed defence options. iSIS model created from previous HEC-RAS model; Hydrology reassessed.
2006	Wye Lugg Confluence Model v3 (Atkins)	SFRM Wye Lugg Confluence Modelling Model used for flood risk mapping of the Wye Lugg confluence. Existing model extended downstream to a point near Holme Lacy bridge; Wye/Lugg and Lugg/Frome confluences added; Hydrology reassessed to include confluence. Survey of extended section completed by Infomap Surveys and Mapping, May 2005.
2008	Wye Lugg Confluence Model v3.1 (Atkins)	Updated 2006 model.

The river reaches represented in the Wye / Lugg confluence model (version 3.1) are as follows:

- a 22.6km reach of the River Wye between Belmont Gauging Station upstream of Hereford to a point downstream of Fownhope;
- a 6km stretch of the River Lugg upstream of its confluence with the River Wye; and
- approximately 1km of the Frome tributary upstream of its confluence with the Lugg.

Details of the Wye / Lugg Confluence Model v3 calibration can be found in 'SFRM Wye Lugg Confluence Modelling - Final Modelling Report – Issue 2'. Confidence and be taken from the good degree of model calibration achieved in the previous model construction and testing. The model provided by the Environment Agency has been accepted as the final and most current model.

To enable the model to be used to assess the impact of the Yazor Brook FAS the following modifications were made:

- extension of the cross sections further upstream along the River Wye;
- inclusion of new defences in the model located on the south bank of the River Wye in Hereford; and
- inclusion of the flow from the Yazor Brook FAS.

5.3.3 *Hydraulic Modelling Results*

Results from the hydraulic modelling are summarised in Table 5.4 and the locations of key model nodes are shown in Figure 3. Further, more detailed, flood maps and tables of results can be found in Appendix A (Yazor Brook) and Appendix B (River Wye).

Figure 3 - Location of Hydraulic Modelling Results in Tables 5.4

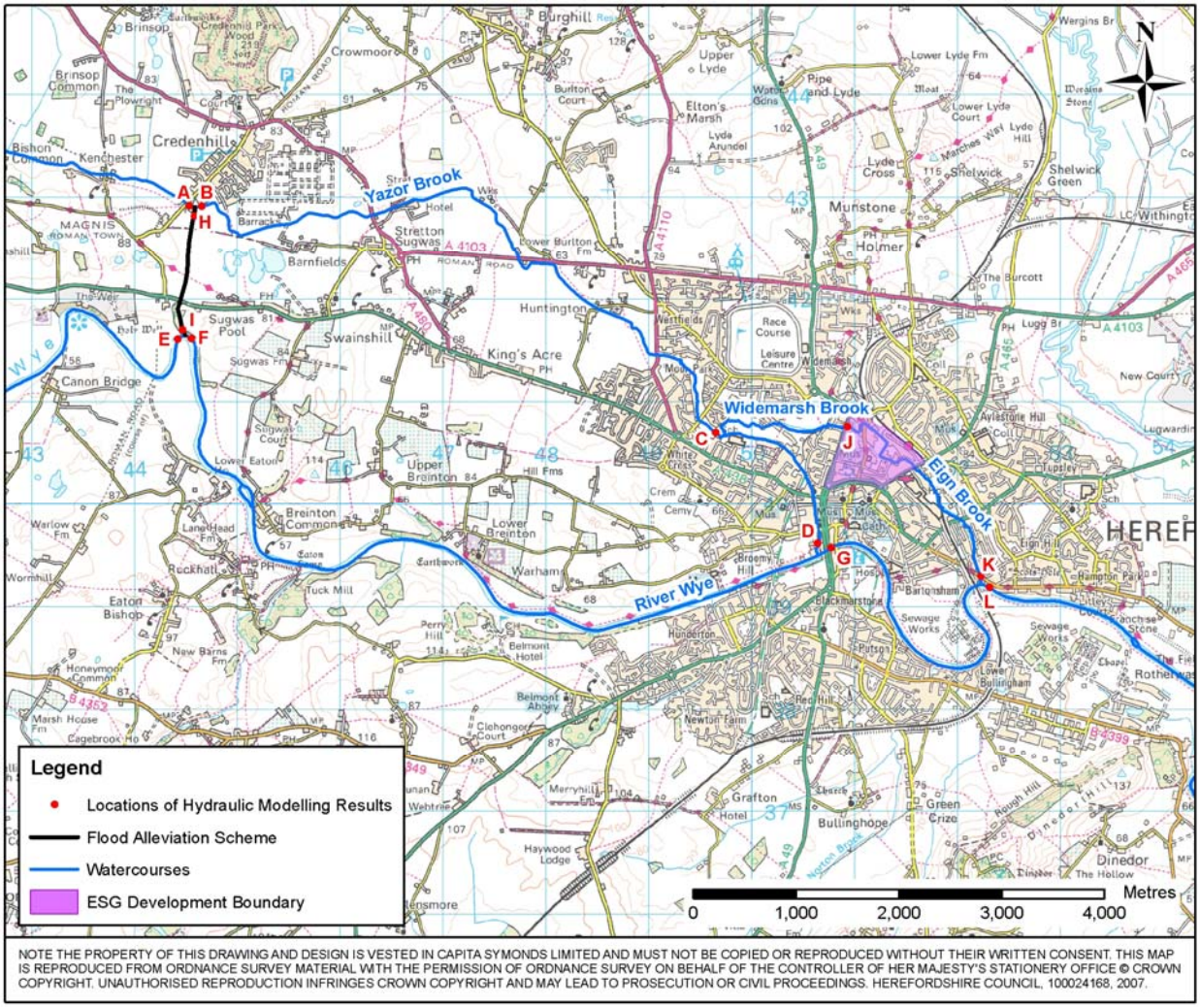


Table 5.4 Baseline and Post Scheme Hydraulic Modelling Results for the 1% AEP Flood Event

Watercourse	*Reference - Location Description*	*Model Node*	*Baseline*		*Proposed*		*Change Baseline to Proposed*	
			Max Water Level (m AOD)	Peak Flow (m^3/s)	Max Water Level (m AOD)	Peak Flow (m^3/s)	Max Water Level (m)	Peak Flow (m^3/s)
Yazor Brook	A - Upstream of the FAS development offtake	YB_9083	76.09	6.44	76.09	6.43	0.00	-0.01
Yazor Brook	B - Downstream of the FAS development offtake	YB_9031	75.73	7.77	75.50	1.99	-0.23	-5.78
Yazor Brook	C - Centre of Hereford upstream of Widemarsh Brook	YB1761U	56.99	11.79	56.91	6.92	-0.08	-4.87
Yazor Brook	D - Upstream of confluence with River Wye	YBCC3D	49.64	1.08	49.64	1.03	0.00	-0.04
River Wye	E - Upstream of FAS development outfall	WYE_1580	55.79	804.09	55.80	803.89	0.02	-0.21
River Wye	F - Downstream of FAS development outfall	WYE_1529	55.55	802.80	55.57	808.36	0.02	5.55
River Wye	G - Downstream of confluence with Yazor Brook	1.054	52.31	778.97	52.33	783.44	0.02	4.47
FAS development	H - Downstream of the offtake from Yazor Brook	DC10000	NA	N/A	N/A	5.84	N/A	N/A
FAS development	I - Upstream of the outfall into the River Wye	Wye_1552	N/A	N/A	N/A	5.84	N/A	N/A
Widemarsh Brook	J - Widemarsh Brook at ESG site	WB2511	53.90	9.84	53.71	4.34	-0.19	-5.49
Eign Brook	K - Upstream of outfall into River Wye	EB0045	49.21	9.06	49.21	4.23	0.00	-4.83
River Wye	L - Downstream of confluence with Eign Brook	1.025	50.21	791.08	50.22	795.51	0.01	4.43

Source: Capita Symonds Ltd.

5.4 Assessment of Impact

5.4.1 *Yazor Brook Catchment*

The results of the hydraulic modelling for the current conditions indicate that there is substantial flood risk both to small communities alongside the Yazor Brook, downstream of the proposed FAS off-take at Credenhill and within the urban area of Hereford for the 5%, 1% and 0.1% AEP events. The areas shown as being at risk include

residential properties, industrial units, agricultural buildings and open agricultural land. Modelling results also indicate flood risk to infrastructure and transport links including 'A' roads such as the A49.

The Environment Agency Flood Map indicates that the southern area of the village of Credenhill is at risk of flooding from the 1% AEP event. The baseline hydraulic modelling undertaken in support of the scheme suggests that this is not the case, with flood extents remaining within the agricultural land to the south of Credenhill.

The Environment Agency Flood Map and studies completed in support of the FAS show that the majority of the route corridor of the proposed FAS is not at risk of flooding up to and including the 0.1% AEP event. Due to the required connectivity with the Yazor Brook and River Wye the off-take and outfall areas of the proposed Scheme are at risk from flooding from the 5%, 1% and 0.1% AEP events.

5.4.2 *River Wye Catchment*

The scheme will increase flows in the River Wye and therefore has the potential to increase flood risk to communities downstream as far as the natural confluence with the Eign Brook and River Wye. To assess the potential impact to downstream communities a hydraulic model and set of precautionary assumptions has been enlisted. For this purpose a 1D hydraulic model of the River Wye was obtained from the Environment Agency and extended to upstream of the FAS outfall.

The design of the FAS limits the diverted flow from the Yazor Brook to a theoretical maximum 7.5m^3/s. For a 1% AEP event on the Yazor Brook the FAS will divert a peak flow of 5.8m^3/s. This increase in peak flow within the Wye is considered to be negligible when compared to the 808m^3/s peak flow already in the Wye for the 1% AEP. This would result in a 0.7% increase in peak flows in the Wye if the peak of 1% AEP event on the Yazor Brook where to coincide with the peak of a 1% AEP event on the Wye.

Upstream of the FAS offtake the Yazor Brook has a catchment area of just 24km^2, compared to the catchment area of the Wye at the outfall of 1,861km^2. Average flows in the Yazor Brook are 0.2m^3/s in comparison to the River Wye's average of 47.4m^3/s. Given these large differences between the two catchments the likelihood of peak flows on the Yazor Brook (and so peak discharge from the alleviation scheme outfall) coinciding with peak flows on the River Wye is considered low.

Having judged from the investigations above that the impact of the FAS development on River Wye flood levels was likely to be very small it was decided that the assessment should compare the baseline against a robustly precautionary scenario, regardless of likelihood. The assessment therefore assumed that the flood peaks on the Yazor Brook and River Wye exactly coincide during a flood event and that both rivers experience a 1% AEP magnitude event at the same time. In reality, the joint probability of peaks coinciding and both rivers experiencing 1% AEP events would be considerably less probable than a 1% AEP event. The reason for this is that such significantly different catchments will respond very differently to the same rainfall event. The River Wye is slow to respond with flooding generally caused by slow moving widespread weather systems, and the Yazor Brook is susceptible to short lived intense rainfall events with a rapid catchment response.

On the basis of the precautionary approach the hydraulic model shows a maximum increase in peak flood level within Hereford of 0.02m (20mm). This contrasts with a flood level already approximately 2m above top of bank and with a water depth within the river channel of approximately 8.5m for the 1% AEP event. As a percentage this is a 0.002% increase of in-channel water level and a 0.01% increase of floodplain water level.

Given the very precautionary assessment this increase in water level in the Wye as a result of scheme discharge is negligible and within the bounds of uncertainties associated with supporting analyses; and will thus not increase flood risk.

5.5 FAS Benefits

The diversion scheme will alleviate flooding associated with the Yazor, Widemarsh and Eign Brooks downstream of the Yazor Brook offtake at Credenhill. The benefit will extend as far as the outfall of these watercourses into the River Wye at Broomy Hill and Eign, Hereford. When the FAS is in operation many parts of the Hereford urban area adjacent to the Brook corridors will see a reduced risk of flooding; notably housing and commercial/employment areas, public open space, allotments, and areas of car parking (including at the County Hospital). Transport links within the City including the A438 and the A49 trunk roads will also benefit. Upstream, and as far west of Hereford as Credenhill, large areas of agricultural land and scattered property will also benefit.

Within the ESG area there will be in particular a significant reduction in the extent of functional floodplain (zone 3B), which will become confined to parts Merton Meadow and the Police playing field.

The hydraulic modelling results indicate a 0.23m reduction in peak flood level and 5.8m^3/s reduction in peak flow for the 1% AEP event within the Yazor Brook immediately downstream of the FAS development. The 1% AEP event peak flood levels and flows are expected to be reduced within the ESG development area by approximately 0.08m and 4.9m^3/s.

Table 5.5 Numbers of properties benefitting from the scheme, Hereford

	Property type	5% AEP (1 in 20)	1% AEP (1 in 100)	0.1% AEP (1 in 1000)
Baseline	Commercial / other	36	85	137
	Residential	88	146	318
	Total	124	231	455
Post scheme	Commercial / other	6	26	112
	Residential	3	40	203
	Total	9	66	315
Difference	Commercial / other	30 (83%)	59 (69%)	25 (18%)
	Residential	85 (96%)	106 (72%)	115 (36%)
	Total	115 (93%)	165 (71%)	140 (30%)

Table 5.5 demonstrates the significant benefits that the scheme will bring to residential and commercial properties throughout the City. In terms of the 5% AEP event almost all (96%) of the residential property presently affected will no longer be subject to this level of flood risk when the scheme is in operation. The residential areas around Millbrook Street, Nolan Road and Edgar Street will particularly benefit. Overall, for this AEP event the results indicate that only nine properties in Hereford will continue to be at risk of flooding when the scheme is in operation.

For the 1% AEP event the scheme continues to show significant benefits in terms of numbers of properties removed from flood risk. The results show an increase in the number of properties protected over those identified for the 5% AEP event, although the relative percentage benefits are lower as a consequence of a much greater number of properties at risk of inundation.

For the 0.1% AEP event level of flood risk the scheme is seen to continue to have a positive impact, with 115 residential properties benefitting. However the scheme again has a reduced proportionate impact, reflecting a further significant increase in the overall number of properties likely to be inundated by a flood event of this severity and the design parameters of the scheme which favour a greater efficiency for the more regular flood events.

Table 5.6 Property damage benefits, Hereford.

	Property type	5% AEP (1 in 20) £m	1% AEP (1 in 100) £m	0.1% AEP (1 in 1000) £m	Annual average damages £
Baseline	Commercial / other	1.7	4.5	10.9	205,586
	Residential	1.2	2.3	5.7	113,813
	Total	2.9	6.8	16.6	319,399
Post scheme	Commercial / other	0.08	0.9	7.7	65,564
	Residential	0.06	0.5	2.7	29,736
	Total	0.14	1.4	10.4	95,300
Difference	Commercial / other	1.6 (94%)	3.6 (80%)	3.1 (28%)	140,022 (68%)
	Residential	1.1 (91%)	1.8 (78%)	3.0 (52%)	84,077 (74%)
	Total	2.7 (93%)	5.4 (79%)	6.1 (36%)	224,098 (70%)

The results of the hydraulic modelling have also been use to carry out a broadscale assessment of the economic benefits in reduced property damages, as summarised in Table 5.6. This assessment does not include any economic consideration of other costs relating to flooding such as transport and commerce disruption, damage to infrastructure, health related impacts and urban development blight.

For properties affected by the 5% AEP event results indicate that the scheme reduces the costs of remediating flood damage to a low absolute level and to show very significant percentage benefits – in excess of 90% for all property types. For the 1% AEP event the absolute cost of repairing property damage post-scheme is again seen to be low, with cost reductions overall in the order of 80% compared to the pre-scheme, baseline position. For the 0.1% AEP event the estimated costs of dealing with flood damage to property in the baseline position are very significant, as can be expected from the greatly increased number of properties involved. In this situation, the diversion scheme continues to have a positive impact and to show a reduction in those costs, although residual costs are assessed as higher than for the other two return periods and the proportionate effect of the scheme is lower. Again, this reflects the design parameters of the scheme and the severity of floods associated with the 0.1% AEP event.

Finally, annual average damages to property have been calculated taking into account the three AEP events. These demonstrate that the annual average cost of repairing flood damage to residential properties presently at risk can be expected to fall by 74% post-scheme, with the overall costs to property falling by 70%.

6. Climate Change

The latest Government guidance suggests that climate change will increase rainfall intensity, increase river flow and raise sea levels. Tables B1 and B2 of PPS25 recommend national precautionary sensitivity ranges for various parameters to assist in assessing climate change impacts.

6.1 Flooding from rivers

In accordance with Table B2 of PPS25, the hydraulic model was re-run with a 20% increase on the 1% AEP flows to assess the potential impacts of climate change on river flooding and the benefits of the scheme.

There is no increase in flood risk associated with the proposed FAS route corridor. Furthermore the scheme will continue to operate and deliver significant benefit to communities downstream on the Yazor Brook.

The model results show that although climate change increases water levels on the Wye through Hereford by over 0.5m (1% AEP event), the Yazor Brook continues to have a negligible impact on water levels increasing them by only 13mm.

Increased water levels on the Wye flood plain close to the FAS outfall as a result of the impact of climate change have been considered in the design of the scheme, including the operation of the energy dissipation structure.

7. Flood Risk Management Measures

7.1 Scheme Design

There are no notable flood risk management measures required. Details of the scheme design are included in the documents listed in Appendix B. Section 8 of this report summarises those design features included to minimise residual risk. These include design of the offtake and associated structures, inclusion of telemetred water level instrumentation, and location of culvert access points. Further detailed construction design will include steps to mitigate the impact of scheme construction on localised surface drainage, shallow groundwater and issues associated with construction and temporary works.

8. Residual Risks

8.1 Residual Risks

Residual risk is the risk remaining after application of the sequential approach and implementation of mitigation measures. Examples of residual risks include failure of flood risk management infrastructure, such as breach of raised flood defences, or a severe flood event that exceeds flood management design standard.

The proposals are fully water-compatible and do not include any buildings or structures intended for residential, commercial or industrial use.

No residual risks have been identified from sea/tidally influenced flooding, surface water flooding, groundwater flooding, sewer flooding or from artificial sources flooding.

8.2 Residual Risks from river flooding

8.2.1 *Associated with the Yazor Brook*

If the off-take structure from the Yazor Brook into the FAS culvert were to partially or fully block flows would continue to progress along the Yazor Brook. Flows progressing downstream would be partially restricted by the flow control structure within the brook. Under normal operating conditions the structure will restrict flows in the brook in order to increase water levels locally upstream and improve the efficiency of the offtake to the FAS. The structure has been designed so that increases in water level remain localised upstream, not extending upstream of Station Road. Above its design threshold excess flood flows in the brook will continue downstream unimpeded. Similarly, should the downstream control structure block it is design to weir over the structure and adjacent bank minimising the impact of blockage.

The off take structure has been over design to effectively manage and monitor or blockage of the trash screens. Testing has shown no notable change in performance during a 1%AEP event with a 25% blockage, and only a 12% decrease in peak flow into the diversion culvert for a 50% blockage. In the event of a major blockage occurring at the offtake flood flows in the brook flows will continue downstream unaffected by the FAS. This situation will be no worse than the current baseline conditions. Blockage risk will be further reduced through the implementation of a maintenance schedule and telemetred water levels at the structure which will assist in the mobilisation of staff to remove build up of debris from both the off-take structure and in-channel control structure.

8.2.2 *Associated with the River Wye*

Flows in the FAS are limited through the design of the offtake structure to in the order of 7 to 7.5m^3/s. The design of the offtake includes a penstock structure. This structure has been incorporated to provide additional surety in the limitation of flows entering the FAS and provides additional benefits for future scheme optimisation and culvert maintenance. The potential for increased impacts on flood levels in the river Wye is therefore negated. No further risk associated with the FAS conveying flows in excess of the design standard can be foreseen.

8.2.3 *Exceedance of design standard*

Steps taken to minimise the potential for excessive flows within the FAS are outlined in section 8.2.2 above. Design of the offtake, chamber and penstock prevents flows above the design standard entering the culverted section. Construction design including materials, foundations and ground fixings will be determined during the detailed design and will include appropriate factors of safety, to minimise the risk of failure or exceedance. Particular consideration will be given to the potential for failure at access points. Access will be provided along

the culvert length. Access points have been included to provide frequent and spaced access, at changes in alignment and in consideration of the risk of surcharging at these locations. In the unlikely event of a structural failure or exceedance the potential for surcharged flows to impact properties north of the A438 around Sugwas Pool was recognised. As a consequence culvert access points in this area have been situated, where in the unlikely event of a failure, the topography will direct overland flows away from properties and towards Sugwas Quarry.

8.3 Impact of the Construction Phase

8.3.1 *Possible Impacts*

The construction programme for the scheme is to be defined. The potential impacts on flooding of the temporary construction works will be considered in greater detail following the completion of the detailed design and programming.

The hydraulic impacts during the construction of the scheme may include:

- An obstruction to channel conveyance;
- An obstruction to floodplain conveyance;
- Temporary diversion of the Yazor Brook;
- A loss of floodplain storage volume;
- A temporary change in the flow velocities in the vicinity of the construction site with scour of the riverbed as a result; and
- An increase in the maximum water levels during flood events.

Quantification and mitigation of the impact of the construction works will be defined during detailed design and construction programming.

8.3.2 *Probability of Flooding During Construction*

The duration of the construction works will be in the order of 9 months. As a result, the chance that a flood event with a return period of 1 in 100 years occurs during construction is significantly smaller than during the life cycle of the scheme (the situation after construction). The probability of construction works being impacted by flooding will be defined once the programme of the works is known.

The impact of the final programme of works on flood risk should further quantify this risk and the following mitigation measures will be further considered:

- Minimise the duration of in channel works;
- Appropriate flood warning procedures should be agreed upon with the Environment Agency and in place to ensure the safety of the construction site;
- The siting of temporary works and stockpiled materials should be sensitive to flood risk;
- To minimise the impact of any additional discharge and drainage into the brook during the period of temporary works, construction of the proposed habitat feature or other aspects of the localised structure drainage should occur early on in the programme; and
- Continuous dialogue should be maintained with the Environment Agency regarding mitigation measures, construction procedures and best practice guidelines

9. Summary and Conclusion

This flood risk assessment (FRA) has assessed the impact of a proposed flood alleviation scheme (FAS) on flooding.

The FRA has reported the benefits of the scheme, as demonstrated in the studies noted above, to communities downstream of it and specifically within Hereford and the ESG area. All sources of flooding as set out within PPS25 have been considered in the FRA.

The majority of the proposed route lies within Flood Zone 1 (PPS25) and is assessed as not being at risk of flooding. Due to the inherent nature of the proposals the upstream and downstream extents are assessed as being at risk of flooding, being located within the channel and floodplain of the Yazor Brook and River Wye (Flood Zone 3). Previous studies have reported the selection of the scheme over other alternatives. The options appraisal considered engineering, environmental and economic issues. The options appraisal demonstrates a sequential approach to the selection of the scheme site.

The development proposal is water compatible use and so in accordance with PPS25 is considered appropriate development.

The FRA has demonstrated that no notable risk to the scheme or as a result of development of the scheme exists in relation to sea, tidally influenced, groundwater or surface water flooding. In regard to flooding from rivers the FRA has identified that:

1. The scheme will deliver a reduction in flood risk and significant benefit to communities within Hereford, the ESG area, and the lower catchment;

2. The scheme route is predominantly on land with a low probability of flooding. At the offtake and discharge development is within land assessed as functional floodplain or having a high probability of flooding;

3. Operation of the scheme will have no adverse impact on flooding from the Yazor Brook and the impact of discharge of flood flows to the River Wye have been demonstrated to be negligible and within the bounds of uncertainties associated with the supporting analyses;

4. The scheme has allowed for the impact of climate change and continues to provide flood risk management benefit to communities downstream;

5. Residual risks associated with design accidence, operational failure and blockage have been addressed through design and will continue to be considered during the detailed construction design; and

6. The impacts of the construction of the scheme and associated temporary works will be defined once the detailed design, construction methods and programme have been defined.

A. Yazor Brook Model Results

- Flood Maps
- Tabulated Flows & Water Levels

B. River Wye Model Results

C. PPS25 pro-forma

1 Development description and location
1a. What type of development is proposed and where will it be located? The proposals are for a flood alleviation scheme with a total length of approximately 2km incorporating an off-take structure, a flow control structure, a culverted diversion of flood flows, a velocity/energy reduction chamber and outfall structure.
1b. What is its vulnerability classification? Classified within Table D.2 of PPS25 as 'Water-compatible'
1c. Is the proposed development consistent with the Local Development Documents? Yes as it supports the Edgar Street Grid redevelopment area within Hereford town centre.
1d. Please provide evidence that the Sequential Test or Exception Test has been applied in the selection of this site for this development type? Options appraisal has been completed. Based on consideration of engineering, environmental and economic issues the scheme was selected over other alternatives. A sequential approach to scheme selection has been demonstrated. Due to the nature of the proposals the works can not be located in an area of lesser flood risk. 'Water-compatible' development/ works are compatible with Flood Zones 1, 2 and 3; therefore the Exception Test does not need to be undertaken.
2. Definition of the flood hazard
2a. What sources of flooding could affect the site? (see Annex C, PPS25) All sources of flooding have been considered within the assessment. River flooding to the scheme and as a result of the scheme relating to both the Yazor Brook and River Wye have been considered. Flooding from sea/tidally influenced flooding, groundwater, surface water, sewer and artificial sources are not expected to affect the proposals.
2b. For each identified source, describe how flooding would occur, with reference to any historic records wherever these are available River flooding may occur to the upstream and downstream extents/structures of the proposed FAS route due to the inherent nature and required in-channel and floodplain location of the proposals. The scheme has been demonstrated to provide flood risk management benefit to communities in the lower catchment and specifically Hereford City Centre.
2c. What are the existing surface water drainage arrangements for the site? There are no existing surface water drainage arrangements for the area of the proposals.
3. Probability
3a Which flood zone is the site within? The proposed FAS route corridor is largely within Flood Zone 1, however, the upstream and downstream extents are within Flood Zones 3.
3b If there is a Strategic Flood Risk Assessment covering this site, what does it show? The Strategic Flood Risk Assessment for Herefordshire is currently being produced.
3c What is the probability of the site flooding taking account of the contents of the SFRA and of any further site-specific assessment? The majority of the proposed FAS route is considered to be of low flood risk probability, with short reaches at the upstream and downstream extents being of high probability.
3d What are the existing rates and volumes of run-off generated by the site? The existing runoff and surface water drainage is not affected by the proposals.
4. Climate change
4a How is flood risk at the site likely to be affected by climate change?

Slight increase in risk from river flooding within the downstream area due to increased water levels within the River Wye. The scheme continues to deliver benefit to downstream communities taking into account the impacts of climate change.

5. Detailed development proposals
5a Please provide details of the development layout, referring to the relevant drawings The proposals include an off-take structure from the Yazor Brook, a flow control structure within the Yazor Brook, construction of a culverted watercourse, a velocity reduction chamber and outfall structure. The total length of works for the FAS is approximately 2km.
5b Where appropriate, demonstrate how land-uses most sensitive to flood damage have been placed in areas within the site that are at least risk of flooding The proposals are considered to be 'water-compatible' within PPS25.
6. Flood risk management measures
6a. How will the site be protected from flooding, including the potential impacts of climate change, over the development's lifetime? No measures are required to protect the proposals from flooding.
7. Off site impacts
7a How will you ensure that your proposed development and the measures to protect your site from flooding will not increase flood risk elsewhere? Hydraulic modelling has demonstrated that the proposals do not increase fluvial flood risk elsewhere.
7b How will you prevent run-off from the completed development causing an impact elsewhere? The existing runoff and surface water drainage is not affected by the proposals. Detailed design of the velocity/energy dissipation structure will include mitigation of the very localised impact of the structure on land drainage.
8. Residual risks
8a What flood-related risks will remain after you have implemented the measures to protect the site from flooding? Residual risks include structure blockage (off-take and flow control structure) within the Yazor Brook; design flow exceedance (whole scheme); structural failure (culvert and access points). Residual risks have been minimised through design of the scheme including the nature of the offtake structure to minimise the risk of blockage; offtake, chamber and penstock arrangement to prevent the design flow in the culvert being exceeded; and the location of culvert access points to reduce the risk of surcharged overland flows impacting people and property.
8b How, and by whom, will these risks be managed over the lifetime of the development? Operation and ownership of the scheme is to be confirmed. It is understood that the Environment Agency will adopt the scheme. The eventual scheme operator will instigate appropriate maintenance and management programmes including screen clearance, blockage clearance, structural inspection etc to minimise residual risks.

Table B1 - Maximum Water Levels

iSIS Node	*WITHOUT* Yazor Brook Input (RWY_EXT_NYB_109)					*WITH* Yazor Brook FAS Inflow with Coinciding Hydrograph Peaks (RWY_EXT_109)									
	Maximum Water Level (mAOD)					Maximum Water Level (mAOD)					Maximum Water Level Change (+/- mm)				
	4%	4%+CC	1%	1%+CC	0.1%	4%	4%+CC	1%	1%+CC	0.1%	4%	4%+CC	1%	1%+CC	0.1%
Around Hereford City Centre (River)															
1.057	51.82	52.30	52.37	52.96	53.76	51.84	52.32	52.39	52.98	53.77	0.02	0.02	0.02	0.02	0.01
1.056	51.84	52.34	52.41	53.03	53.89	51.86	52.36	52.43	53.05	53.90	0.02	0.02	0.02	0.02	0.01
1.055	51.81	52.33	52.40	53.03	53.89	51.84	52.35	52.42	53.05	53.90	0.02	0.02	0.02	0.02	0.01
1.054	51.75	52.24	52.31	52.91	53.76	51.78	52.26	52.33	52.93	53.77	0.02	0.02	0.02	0.02	0.01
1.053	51.74	52.19	52.25	52.80	53.60	51.76	52.21	52.27	52.81	53.61	0.02	0.02	0.02	0.02	0.01
1.052	51.40	51.71	51.75	52.11	52.64	51.41	51.72	51.76	52.12	52.64	0.01	0.01	0.01	0.01	0.00
1.051	51.38	51.70	51.75	52.12	52.70	51.39	51.72	51.76	52.14	52.70	0.01	0.02	0.01	0.01	0.00
1.0505	51.35	51.66	51.70	52.06	52.63	51.36	51.67	51.71	52.08	52.64	0.01	0.01	0.01	0.01	0.00
1.05	51.31	51.62	51.67	52.02	52.58	51.33	51.64	51.68	52.04	52.59	0.01	0.01	0.01	0.01	0.00
1.049	51.30	51.62	51.67	52.05	52.64	51.31	51.63	51.68	52.06	52.64	0.01	0.02	0.01	0.01	0.00
1.048	51.25	51.56	51.61	51.97	52.55	51.26	51.58	51.62	51.98	52.55	0.02	0.01	0.01	0.01	0.00
1.047	51.27	51.59	51.63	51.99	52.55	51.28	51.60	51.65	52.00	52.56	0.02	0.01	0.01	0.01	0.00
1.046	51.19	51.51	51.55	51.89	52.43	51.21	51.52	51.56	51.90	52.43	0.02	0.01	0.01	0.01	0.00
1.045	51.13	51.44	51.48	51.81	52.32	51.15	51.45	51.49	51.82	52.32	0.02	0.01	0.01	0.01	0.00
Around Hereford City Centre (Floodplain)															
S1.056RR	51.24	51.56	51.61	51.97	52.64	51.25	51.58	51.62	51.98	52.65	0.02	0.01	0.01	0.01	0.01
S1.055RR	51.24	51.56	51.61	51.97	52.64	51.25	51.58	51.62	51.98	52.65	0.02	0.01	0.01	0.01	0.01
S1.054RR	51.24	51.56	51.61	51.97	52.64	51.25	51.58	51.62	51.98	52.65	0.02	0.01	0.01	0.01	0.01
RES1RD	51.24	51.56	51.61	51.97	52.64	51.25	51.58	51.62	51.98	52.65	0.02	0.01	0.01	0.01	0.01
RES2RU	51.24	51.56	51.61	51.97	52.57	51.25	51.58	51.62	51.98	52.58	0.02	0.01	0.01	0.01	0.01
S1053RR	51.24	51.56	51.61	51.97	52.57	51.25	51.58	51.62	51.98	52.58	0.02	0.01	0.01	0.01	0.01
S10525RR	51.24	51.56	51.61	51.97	52.57	51.25	51.58	51.62	51.98	52.58	0.02	0.01	0.01	0.01	0.01
RES2RD	51.24	51.56	51.61	51.97	52.57	51.25	51.58	51.62	51.98	52.58	0.02	0.01	0.01	0.01	0.01
RES2RDb	51.24	51.56	51.61	51.97	52.57	51.25	51.58	51.62	51.98	52.58	0.02	0.01	0.01	0.01	0.01
RES3RU	51.24	51.56	51.61	51.97	52.56	51.25	51.58	51.62	51.98	52.57	0.02	0.01	0.01	0.01	0.00
S1.052RR	51.24	51.56	51.61	51.97	52.56	51.25	51.58	51.62	51.98	52.57	0.02	0.01	0.01	0.01	0.00
S1.051RR	51.24	51.56	51.61	51.97	52.56	51.25	51.58	51.62	51.98	52.57	0.02	0.01	0.01	0.01	0.00
RES3RD	51.24	51.56	51.61	51.97	52.56	51.25	51.58	51.62	51.98	52.57	0.02	0.01	0.01	0.01	0.00
S10505RR	51.24	51.56	51.61	51.97	52.55	51.25	51.58	51.62	51.98	52.55	0.02	0.01	0.01	0.01	0.00
RES4RU	51.24	51.56	51.61	51.97	52.55	51.25	51.58	51.62	51.98	52.55	0.02	0.01	0.01	0.01	0.00
S1.050RR	51.24	51.56	51.61	51.97	52.55	51.25	51.58	51.62	51.98	52.55	0.02	0.01	0.01	0.01	0.00
S1.049RR	51.24	51.56	51.61	51.97	52.55	51.25	51.58	51.62	51.98	52.55	0.02	0.01	0.01	0.01	0.00
S1.048RR	51.24	51.56	51.61	51.97	52.55	51.25	51.58	51.62	51.98	52.55	0.02	0.01	0.01	0.01	0.00
S1.047RR	51.24	51.56	51.61	51.97	52.55	51.25	51.58	51.62	51.98	52.55	0.02	0.01	0.01	0.01	0.00
S1.046RR	51.24	51.56	51.61	51.97	52.55	51.25	51.58	51.62	51.98	52.55	0.02	0.01	0.01	0.01	0.00
S1.045RR	51.24	51.56	51.61	51.97	52.55	51.25	51.58	51.62	51.98	52.55	0.02	0.01	0.01	0.01	0.00
RES4RUb	51.24	51.56	51.61	51.97	52.55	51.25	51.58	51.62	51.98	52.55	0.02	0.01	0.01	0.01	0.00
S1.040RR	50.81	51.13	51.18	51.55	52.16	50.83	51.15	51.19	51.57	52.16	0.02	0.01	0.01	0.01	0.00
S1.039RR	50.81	51.13	51.18	51.55	52.16	50.83	51.15	51.19	51.57	52.16	0.02	0.01	0.01	0.01	0.00
S1.037RR	50.81	51.13	51.18	51.55	52.16	50.83	51.15	51.19	51.57	52.16	0.02	0.01	0.01	0.01	0.00

Table B1 - Maximum Water Levels

iSIS Node	*WITHOUT* Yazor Brook Input (RWY_EXT_NYB_109)					*WITH* Yazor Brook FAS Inflow with Coinciding Hydrograph Peaks (RWY_EXT_109)									
	Maximum Water Level (mAOD)					Maximum Water Level (mAOD)					Maximum Water Level Change (+/- mm)				
	4%	4%+CC	1%	1%+CC	0.1%	4%	4%+CC	1%	1%+CC	0.1%	4%	4%+CC	1%	1%+CC	0.1%
Upstream and Downstream of Confluence with Yazor Flood Alleviation Scheme															
WYE_1775	56.21	56.57	56.62	57.03	57.74	56.22	56.58	56.63	57.04	57.75	0.01	0.01	0.01	0.01	0.01
WYE_1753	56.15	56.52	56.57	57.00	57.72	56.15	56.53	56.58	57.00	57.73	0.01	0.01	0.01	0.01	0.01
WYE_1734	56.05	56.42	56.47	56.89	57.62	56.05	56.42	56.47	56.90	57.63	0.01	0.01	0.01	0.01	0.01
WYE_1715	55.55	55.97	56.02	56.48	57.27	55.57	55.98	56.04	56.49	57.28	0.01	0.01	0.01	0.01	0.01
WYE_1681	55.46	55.85	55.91	56.39	57.23	55.47	55.87	55.92	56.40	57.24	0.01	0.01	0.01	0.02	0.01
WYE_1658	55.53	55.90	55.95	56.41	57.23	55.54	55.91	55.96	56.42	57.24	0.01	0.01	0.01	0.01	0.01
WYE_1628	55.46	55.84	55.89	56.35	57.18	55.48	55.85	55.90	56.36	57.20	0.01	0.01	0.01	0.01	0.02
WYE_1598	55.40	55.78	55.84	56.30	57.15	55.42	55.80	55.85	56.32	57.17	0.01	0.01	0.01	0.02	0.02
WYE_1580	55.35	55.73	55.79	56.26	57.12	55.36	55.75	55.80	56.28	57.14	0.01	0.02	0.02	0.02	0.02
WYE_1552	55.16	55.61	55.66	56.17	57.06	55.18	55.62	55.68	56.19	57.08	0.02	0.02	0.02	0.02	0.02
WYE_1529	55.02	55.49	55.55	56.08	56.99	55.05	55.50	55.57	56.09	57.01	0.02	0.02	0.02	0.02	0.02
WYE_1495	54.87	55.36	55.42	55.97	56.92	54.90	55.38	55.44	55.99	56.94	0.02	0.02	0.02	0.02	0.02
WYE_1470	54.71	55.23	55.30	55.89	56.88	54.73	55.25	55.32	55.91	56.90	0.02	0.02	0.02	0.02	0.02
WYE_1445	54.57	55.10	55.18	55.81	56.84	54.60	55.12	55.20	55.83	56.85	0.02	0.02	0.02	0.02	0.02
WYE_1415	54.49	55.02	55.09	55.71	56.76	54.52	55.04	55.11	55.73	56.78	0.02	0.02	0.02	0.02	0.02
WYE_1396	54.41	54.94	55.02	55.66	56.73	54.43	54.97	55.04	55.68	56.75	0.02	0.02	0.02	0.02	0.02
WYE_1377	54.22	54.77	54.84	55.49	56.59	54.25	54.79	54.86	55.51	56.61	0.02	0.02	0.02	0.02	0.02
WYE_1357	54.20	54.73	54.80	55.45	56.56	54.22	54.75	54.83	55.47	56.58	0.02	0.02	0.02	0.02	0.02
WYE_1326	54.05	54.61	54.68	55.35	56.49	54.08	54.63	54.71	55.37	56.51	0.03	0.02	0.02	0.02	0.02
WYE_1301	53.89	54.45	54.53	55.21	56.38	53.92	54.47	54.55	55.23	56.40	0.03	0.02	0.02	0.02	0.02
WYE_1266	53.84	54.41	54.48	55.17	56.35	53.87	54.43	54.51	55.19	56.37	0.03	0.02	0.02	0.02	0.02
WYE_1244	53.75	54.32	54.40	55.09	56.29	53.78	54.34	54.42	55.12	56.31	0.03	0.02	0.02	0.02	0.02
WYE_1221	53.58	54.17	54.25	54.97	56.20	53.61	54.19	54.28	54.99	56.22	0.03	0.02	0.02	0.02	0.02
WYE_1196	53.46	54.04	54.12	54.85	56.11	53.49	54.07	54.15	54.88	56.13	0.03	0.02	0.02	0.03	0.02
WYE_1171	53.37	53.95	54.04	54.77	56.04	53.40	53.98	54.06	54.79	56.06	0.03	0.02	0.02	0.03	0.02
WYE_1147	53.24	53.83	53.92	54.67	55.97	53.27	53.86	53.94	54.70	55.99	0.03	0.02	0.03	0.02	0.02
WYE_1118	53.11	53.70	53.78	54.54	55.86	53.13	53.72	53.81	54.57	55.88	0.03	0.02	0.02	0.03	0.02
WYE_1094	52.97	53.59	53.68	54.47	55.81	53.00	53.62	53.71	54.50	55.84	0.03	0.03	0.03	0.03	0.02
WYE_1071	52.96	53.57	53.66	54.45	55.80	52.99	53.60	53.69	54.48	55.82	0.03	0.03	0.03	0.03	0.02
WYE_1043	52.91	53.52	53.62	54.41	55.77	52.94	53.55	53.64	54.44	55.79	0.03	0.03	0.03	0.03	0.02
WYE_1020	52.86	53.48	53.57	54.38	55.75	52.88	53.51	53.60	54.41	55.77	0.03	0.03	0.03	0.03	0.02

Table B2 - Maximum Water Levels

iSIS Node	*WITHOUT* Yazor Brook Input (RWY_EXT_NYB_109)					*WITHOUT* Yazor Brook FAS Inflow with Non-coinciding Hydrograph Peaks (RWY_EXT_SYB_109)									
	Maximum Water Level (mAOD)					Maximum Water Level (mAOD)					Maximum Water Level Change (+/- mm)				
	4%	4%+CC	1%	1%+CC	0.1%	4%	4%+CC	1%	1%+CC	0.1%	4%	4%+CC	1%	1%+CC	0.1%
Around Hereford City Centre (River)															
1.057	51.82	52.30	52.37	52.96	53.76	51.83	52.31	52.38	52.97	53.77	0.01	0.01	0.01	0.01	0.00
1.056	51.84	52.34	52.41	53.03	53.89	51.85	52.35	52.43	53.04	53.90	0.01	0.01	0.01	0.01	0.01
1.055	51.81	52.33	52.40	53.03	53.89	51.83	52.34	52.41	53.04	53.90	0.01	0.01	0.01	0.01	0.01
1.054	51.75	52.24	52.31	52.91	53.76	51.77	52.25	52.32	52.92	53.76	0.01	0.01	0.01	0.01	0.00
1.053	51.74	52.19	52.25	52.80	53.60	51.75	52.20	52.26	52.81	53.60	0.01	0.01	0.01	0.01	0.00
1.052	51.40	51.71	51.75	52.11	52.64	51.41	51.71	51.76	52.12	52.64	0.01	0.01	0.01	0.01	0.00
1.051	51.38	51.70	51.75	52.12	52.70	51.39	51.71	51.75	52.13	52.70	0.01	0.01	0.01	0.01	0.00
1.0505	51.35	51.66	51.70	52.06	52.63	51.35	51.66	51.71	52.07	52.64	0.01	0.01	0.01	0.01	0.00
1.05	51.31	51.62	51.67	52.02	52.58	51.32	51.63	51.68	52.03	52.59	0.01	0.00	0.01	0.01	0.00
1.049	51.30	51.62	51.67	52.05	52.64	51.31	51.62	51.67	52.06	52.64	0.01	0.01	0.01	0.01	0.00
1.048	51.25	51.56	51.61	51.97	52.55	51.25	51.57	51.62	51.97	52.55	0.01	0.01	0.01	0.01	0.00
1.047	51.27	51.59	51.63	51.99	52.55	51.28	51.60	51.64	52.00	52.56	0.01	0.00	0.01	0.01	0.00
1.046	51.19	51.51	51.55	51.89	52.43	51.20	51.51	51.55	51.89	52.43	0.01	0.00	0.01	0.01	0.00
1.045	51.13	51.44	51.48	51.81	52.32	51.14	51.45	51.49	51.81	52.32	0.01	0.00	0.01	0.01	0.00
Around Hereford City Centre (Floodplain)															
S1.056RR	51.24	51.56	51.61	51.97	52.64	51.25	51.57	51.61	51.98	52.64	0.01	0.01	0.01	0.01	0.00
S1.055RR	51.24	51.56	51.61	51.97	52.64	51.25	51.57	51.61	51.98	52.64	0.01	0.01	0.01	0.01	0.00
S1.054RR	51.24	51.56	51.61	51.97	52.64	51.25	51.57	51.61	51.98	52.64	0.01	0.01	0.01	0.01	0.00
RES1RD	51.24	51.56	51.61	51.97	52.64	51.25	51.57	51.61	51.98	52.64	0.01	0.01	0.01	0.01	0.00
RES2RU	51.24	51.56	51.61	51.97	52.57	51.25	51.57	51.61	51.98	52.58	0.01	0.01	0.01	0.01	0.00
S1053RR	51.24	51.56	51.61	51.97	52.57	51.25	51.57	51.61	51.98	52.58	0.01	0.01	0.01	0.01	0.00
S10525RR	51.24	51.56	51.61	51.97	52.57	51.25	51.57	51.61	51.98	52.58	0.01	0.01	0.01	0.01	0.00
RES2RD	51.24	51.56	51.61	51.97	52.57	51.25	51.57	51.61	51.98	52.58	0.01	0.01	0.01	0.01	0.00
RES2RDb	51.24	51.56	51.61	51.97	52.57	51.25	51.57	51.61	51.98	52.58	0.01	0.01	0.01	0.01	0.00
RES3RU	51.24	51.56	51.61	51.97	52.56	51.25	51.57	51.61	51.98	52.57	0.01	0.01	0.01	0.01	0.00
S1.052RR	51.24	51.56	51.61	51.97	52.56	51.25	51.57	51.61	51.98	52.57	0.01	0.01	0.01	0.01	0.00
S1.051RR	51.24	51.56	51.61	51.97	52.56	51.25	51.57	51.61	51.98	52.57	0.01	0.01	0.01	0.01	0.00
RES3RD	51.24	51.56	51.61	51.97	52.56	51.25	51.57	51.61	51.98	52.57	0.01	0.01	0.01	0.01	0.00
S10505RR	51.24	51.56	51.61	51.97	52.55	51.25	51.57	51.61	51.98	52.55	0.01	0.01	0.01	0.01	0.00
RES4RU	51.24	51.56	51.61	51.97	52.55	51.25	51.57	51.61	51.98	52.55	0.01	0.01	0.01	0.01	0.00
S1.050RR	51.24	51.56	51.61	51.97	52.55	51.25	51.57	51.61	51.98	52.55	0.01	0.01	0.01	0.01	0.00
S1.049RR	51.24	51.56	51.61	51.97	52.55	51.25	51.57	51.61	51.98	52.55	0.01	0.01	0.01	0.01	0.00
S1.048RR	51.24	51.56	51.61	51.97	52.55	51.25	51.57	51.61	51.98	52.55	0.01	0.01	0.01	0.01	0.00
S1.047RR	51.24	51.56	51.61	51.97	52.55	51.25	51.57	51.61	51.98	52.55	0.01	0.01	0.01	0.01	0.00
S1.046RR	51.24	51.56	51.61	51.97	52.55	51.25	51.57	51.61	51.98	52.55	0.01	0.01	0.01	0.01	0.00
S1.045RR	51.24	51.56	51.61	51.97	52.55	51.25	51.57	51.61	51.98	52.55	0.01	0.01	0.01	0.01	0.00
RES4RUb	51.24	51.56	51.61	51.97	52.55	51.25	51.57	51.61	51.98	52.55	0.01	0.01	0.01	0.01	0.00
S1.040RR	50.81	51.13	51.18	51.55	52.16	50.82	51.14	51.18	51.56	52.16	0.01	0.00	0.01	0.01	0.00
S1.039RR	50.81	51.13	51.18	51.55	52.16	50.82	51.14	51.18	51.56	52.16	0.01	0.00	0.01	0.01	0.00
S1.037RR	50.81	51.13	51.18	51.55	52.16	50.82	51.14	51.18	51.56	52.16	0.01	0.00	0.01	0.01	0.00

Table B2 - Maximum Water Levels

iSIS Node	*WITHOUT* Yazor Brook Input (RWY_EXT_NYB_109)					*WITHOUT* Yazor Brook FAS Inflow with Non-coinciding Hydrograph Peaks (RWY_EXT_SYB_109)									
	Maximum Water Level (mAOD)					Maximum Water Level (mAOD)					Maximum Water Level Change (+/- mm)				
	4%	4%+CC	1%	1%+CC	0.1%	4%	4%+CC	1%	1%+CC	0.1%	4%	4%+CC	1%	1%+CC	0.1%
Upstream and Downstream of Confluence with Yazor Flood Alleviation Scheme															
WYE_1775	56.21	56.57	56.62	57.03	57.74	56.22	56.58	56.63	57.04	57.75	0.00	0.00	0.00	0.00	0.00
WYE_1753	56.15	56.52	56.57	57.00	57.72	56.15	56.53	56.58	57.00	57.72	0.00	0.00	0.00	0.01	0.00
WYE_1734	56.05	56.42	56.47	56.89	57.62	56.05	56.42	56.47	56.89	57.63	0.00	0.00	0.00	0.01	0.01
WYE_1715	55.55	55.97	56.02	56.48	57.27	55.56	55.98	56.03	56.49	57.27	0.01	0.01	0.01	0.01	0.01
WYE_1681	55.46	55.85	55.91	56.39	57.23	55.47	55.86	55.92	56.40	57.24	0.01	0.01	0.01	0.01	0.01
WYE_1658	55.53	55.90	55.95	56.41	57.23	55.54	55.91	55.96	56.41	57.23	0.01	0.01	0.01	0.01	0.01
WYE_1628	55.46	55.84	55.89	56.35	57.18	55.47	55.84	55.89	56.36	57.19	0.01	0.01	0.01	0.01	0.01
WYE_1598	55.40	55.78	55.84	56.30	57.15	55.41	55.79	55.84	56.31	57.16	0.01	0.01	0.01	0.01	0.01
WYE_1580	55.35	55.73	55.79	56.26	57.12	55.36	55.74	55.79	56.27	57.13	0.01	0.01	0.01	0.01	0.01
WYE_1552	55.16	55.61	55.66	56.17	57.06	55.18	55.61	55.67	56.18	57.07	0.01	0.01	0.01	0.01	0.01
WYE_1529	55.02	55.49	55.55	56.08	56.99	55.04	55.50	55.56	56.09	57.00	0.01	0.01	0.01	0.01	0.01
WYE_1495	54.87	55.36	55.42	55.97	56.92	54.89	55.37	55.43	55.99	56.93	0.01	0.01	0.01	0.01	0.01
WYE_1470	54.71	55.23	55.30	55.89	56.88	54.72	55.24	55.31	55.90	56.89	0.01	0.01	0.01	0.01	0.01
WYE_1445	54.57	55.10	55.18	55.81	56.84	54.58	55.11	55.19	55.82	56.85	0.01	0.01	0.01	0.01	0.01
WYE_1415	54.49	55.02	55.09	55.71	56.76	54.51	55.03	55.10	55.72	56.77	0.01	0.01	0.01	0.01	0.01
WYE_1396	54.41	54.94	55.02	55.66	56.73	54.42	54.96	55.03	55.67	56.74	0.01	0.01	0.01	0.01	0.01
WYE_1377	54.22	54.77	54.84	55.49	56.59	54.24	54.78	54.85	55.50	56.60	0.01	0.01	0.01	0.01	0.01
WYE_1357	54.20	54.73	54.80	55.45	56.56	54.21	54.74	54.82	55.46	56.57	0.01	0.01	0.01	0.01	0.01
WYE_1326	54.05	54.61	54.68	55.35	56.49	54.07	54.62	54.70	55.36	56.50	0.02	0.01	0.01	0.01	0.01
WYE_1301	53.89	54.45	54.53	55.21	56.38	53.91	54.46	54.54	55.22	56.39	0.01	0.01	0.01	0.01	0.01
WYE_1266	53.84	54.41	54.48	55.17	56.35	53.86	54.42	54.50	55.18	56.36	0.02	0.01	0.01	0.01	0.01
WYE_1244	53.75	54.32	54.40	55.09	56.29	53.76	54.33	54.41	55.11	56.30	0.02	0.01	0.01	0.01	0.01
WYE_1221	53.58	54.17	54.25	54.97	56.20	53.60	54.18	54.26	54.98	56.21	0.02	0.01	0.01	0.02	0.01
WYE_1196	53.46	54.04	54.12	54.85	56.11	53.48	54.06	54.14	54.87	56.12	0.01	0.01	0.01	0.02	0.01
WYE_1171	53.37	53.95	54.04	54.77	56.04	53.39	53.97	54.05	54.78	56.05	0.02	0.01	0.01	0.02	0.01
WYE_1147	53.24	53.83	53.92	54.67	55.97	53.26	53.85	53.93	54.69	55.98	0.01	0.01	0.01	0.02	0.01
WYE_1118	53.11	53.70	53.78	54.54	55.86	53.12	53.71	53.80	54.56	55.87	0.02	0.01	0.01	0.02	0.01
WYE_1094	52.97	53.59	53.68	54.47	55.81	52.99	53.60	53.69	54.49	55.83	0.02	0.01	0.01	0.02	0.01
WYE_1071	52.96	53.57	53.66	54.45	55.80	52.98	53.59	53.68	54.47	55.81	0.02	0.01	0.01	0.02	0.01
WYE_1043	52.91	53.52	53.62	54.41	55.77	52.92	53.54	53.63	54.43	55.78	0.02	0.01	0.01	0.02	0.01
WYE_1020	52.86	53.48	53.57	54.38	55.75	52.87	53.49	53.59	54.39	55.76	0.02	0.01	0.01	0.02	0.01