E118

High Speed Two Phase 2a (West Midlands - Crewe)

Background Information and Data

CA2: Colwich to Yarlet

Hydraulic modelling report - Great Haywood Viaduct

(BID-WR-004-005)

July 2017

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Department for Transport

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1 Introduction

1.1 Background

1.1.1 This document presents the results of the hydraulic modelling carried out in the Colwich to Yarlet area (CA2) relevant to High Speed Rail (West Midlands - Crewe).

1.1.2 The Hydraulic modelling report - Hopton (Volume 5: Background Information and Data 004, BID-WR-004-006) is also relevant to the Colwich to Yarlet area:

1.1.3 The water resources and flood risk assessment is detailed in the High Speed Rail (West Midlands - Crewe) Environmental Statement (ES)[1]. Volumes 2, 3 and 4 discuss water resource and flood risk effects and Volume 5, Appendices sets out the following relevant to the Colwich to Yarlet area:

- a route-wide Water Framework Directive compliance assessment (Volume 5: Appendix WR-001-000);
- a water resources assessment (Volume 5: WR-002-002);
- a flood risk assessment (Volume 5: WR-003-002); and
- a route-wide draft water resources and flood risk operation and maintenance plan (Volume 5: Appendix WR-005-000).

1.2 Aims

1.2.1 The Proposed Scheme includes a number of locations where the route is to cross watercourses and their floodplains. These Proposed Scheme crossing locations have the potential to increase flood risk where they restrict flood flows or change floodplain dynamics.

1.2.2 At the locations detailed in this report, the route will cross the River Trent, the Trent and Mersey Canal and a number of unnamed watercourses on the proposed Great Haywood viaduct.

1.2.3 A hydraulic model of the River Trent and River Sow was created to simulate the risk of flooding in this location for an approximate 14km stretch of the River Trent and an approximate 3.6km stretch of the River Sow (including the Shugborough Hall braided channel) prior to the confluence with the River Trent at Great Haywood. This report documents the methods used and discusses the results, assumptions and limitations imposed by them.

1.2.4 Hydraulic models of the existing conditions and with the Proposed Scheme included have been evaluated to assess the impact of the Proposed Scheme on

[1] HS2 Ltd (2017), *High Speed Rail (West Midlands - Crewe) Environmental Statement (ES)*, www.gov.uk/hs2

flood risk and to derive peak flood water levels relative to the proposed structures.

1.2.5 This report details the existing hydrological and hydraulic processes of the reaches modelled and how these will be affected by the Proposed Scheme.

1.3 Objectives

1.3.1 The objectives were to:

- conduct, where feasible, a site visit to inform understanding of existing conditions, including existing channel and floodplain characteristics, hydraulic structures and flow paths;
- estimate flow hydrographs at the Proposed Scheme crossing location;
- develop a hydraulic model, commensurate with the level of detail required and available at this stage, to provide peak levels at key structures for the Proposed Scheme, based on the most suitable data available and flow hydrographs developed; and
- analyse the impact of the Proposed Scheme on flood risk levels obtained from the results of the following Annual Exceedance Probabilities (AEP): 50%, 20%, 5.0%, 1.33%, 1.0%, 1.0%+climate change (CC), 0.5% and 0.1%.

1.4 Justification of approach

1.4.1 The hydraulic model has been constructed to provide an awareness of existing flood risk to inform the Proposed Scheme design. The detail included identifies potential impacts of the Proposed Scheme on surrounding land, and to ensure that 0.6m freeboard to soffit is provided in a 1.0% + CC AEP event and 1.0m freeboard to track level is provided in a 0.1%AEP event.

1.4.2 A 1D-2D linked hydrodynamic model approach was selected for this study because this method is particularly suited to the inclusion of complex pathways within the floodplain as well as allowing the channel and floodplain interactions and flow dynamics to be represented.

1.4.3 An existing 1D model containing cross-sectional survey data was provided by the Environment Agency for the River Trent and lower reaches of the River Sow. The floodplain element was originally modelled in 1D only, and combining this with a new 2D model domain provides an improved representation of the floodplain.

1.4.4 Due to the Proposed Scheme crossing the floodplain on a viaduct and thus causing a high level of risk for the design of the project and its impact on the environment, it was proposed that hydrological calculations be undertaken to a full level of detail. This considered Flood Estimation Handbook (FEH) Statistical, Revitalised Flood Hydrograph 2 (ReFH2) and the hybrid methods.

1.5 Scope

1.5.1 The scope of the study is to undertake hydraulic modelling to enable an assessment to be made of the impact of the Proposed Scheme on the local environment. The models should be detailed enough to allow future assessment of different options associated with each crossing location, to allow the management of flood risk and correct sizing of crossing openings.

1.5.2 The report focuses upon:

- discussion of all relevant datasets, quality and gaps;
- hydrological analysis undertaken, approach used and calculation steps;
- integration of the hydrological analysis with the hydraulic modelling;
- hydraulic modelling methodology chosen, with clear identification of general methodologies and justification; and
- hydraulic modelling parameters, assumptions, limitations and uncertainty.

2 Site characteristics

2.1 Description of the study area

Model reach

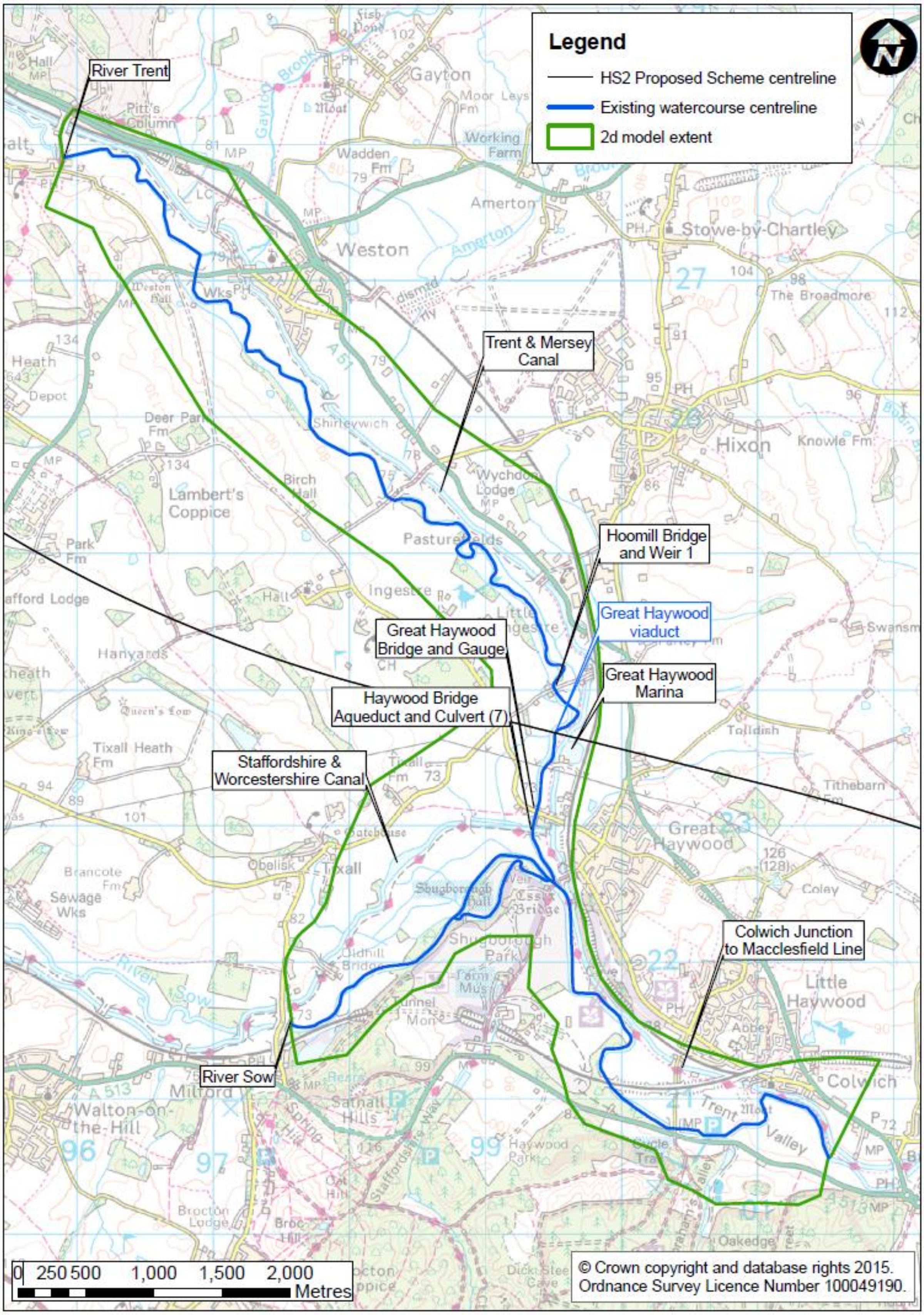
2.1.1 The section of the River Trent being modelled is located between Casey Bridge near the village of Salt and south of Colwich. Figure 1 shows the modelled extent, with the model upstream boundary located at the downstream face of Casey Bridge and the downstream boundary located approximately 650m upstream of the A51 Lichfield Road crossing. The upstream extent of the River Sow is located approximately 60m downstream of Holdiford Bridge and the downstream boundary is located at the confluence with the River Trent. Approximately 13km of the River Trent and 3.5km of the River Sow has been modelled.

2.1.2 The River Sow bifurcates into two distinct channels in the vicinity of Shugborough Hall. Both the River Sow and River Trent are classified as Main Rivers by the Environment Agency. The study area is predominately rural. Several minor roads connecting settlements cross the River Trent within the model extent, while the A518 Stafford Road also crosses the River Trent at Weston. The built-up areas of Weston, Great Haywood, Little Haywood and Colwich occupy some parts of the left bank of the River Trent, although most properties are on the left bank of the Trent and Mersey Canal.

2.1.3 The Trent and Mersey Canal runs very close to the course of the River Trent throughout the length of the study area.

2.1.4 Linked to the Trent and Mersey Canal is the Great Haywood Marina. This Marina is situated on the downstream side of the Proposed Scheme, on the opposite side of the canal to the River Trent.

Figure 1: Schematic of key features within the study area



Hydrological description

2.1.5 The River Trent originates in the Pennines to the north of Stoke-on-Trent.

2.1.6 The catchment area contributing to the downstream boundary of the proposed hydraulic model drains an area of the River Trent of 320.0km^2 at the Haywood Bridge Aqueduct. The catchment is significantly urbanised, draining Stone and Stoke-on-Trent. The River Sow drains an area of 589.0km^2 at its confluence with the River Trent.

2.1.7 The River Trent drains predominantly in a south-easterly direction, with flows from the River Sow flowing north-eastwards towards the confluence. There are no other major tributaries contributing to the flow through this area.

2.1.8 The River Trent is gauged at Great Haywood and the River Sow is gauged at Milford. The Great Haywood river gauge is level only and has a period of record from 1972 to present. The Milford river gauge is also level only and has a period of record from 1968 to present.

2.1.9 The Great Haywood level gauge is located 1.3km (0.8 miles) downstream of the Proposed Scheme.

2.1.10 Standard annual average rainfall for the combined catchment at the model downstream boundary is 743mm.

Railway alignment

2.1.11 The route of the Proposed Scheme crosses the study area from east to west, passing over the River Trent and the Trent and Mersey Canal on the Great Haywood viaduct. Further detail on this structure can be found in Map CT-06-212 in the Volume 2 Map Book.

Flood mechanisms

2.1.12 The floodplain upstream and downstream of the Proposed Scheme is characterised by wide floodplain with a network of drainage ditches.

2.1.13 The Hoo Mill Bridge is situated upstream of the Proposed Scheme. This bridge forms a throttle on the River Trent, this results in flows across Hoo Mill Lane on both sides. There is a bridge marked on the right bank where Hoo Mill Lane crosses an undefined watercourse; this forms a distinct flow path bypassing the main bridge at higher flows. There is an uneven weir structure present beneath the Hoo Mill Bridge on the downstream side. A photograph of this structure is shown in Figure 3.

2.1.14 Downstream of the Proposed Scheme, the single arched Great Haywood Bridge takes Mill Lane over the River Trent. Following this, an industrial site occupies the 100m of the left bank leading down to the Haywood Bridge Aqueduct. This aqueduct is a four-arched crossing taking the Staffordshire and Worcestershire Canal across the River Trent to join the Trent and Mersey Canal at the Great Haywood Junction. Approximately 50m in from the channel on the left bank an unnamed throughway leads from the aforementioned developed site passing beneath the raised canal to the downstream side.

2.1.15 The Staffordshire and Worcestershire Canal crosses the whole right bank floodplain of the River Trent effectively separating the floodplains of the River Sow and River Trent.

2.2 Existing understanding of flood risk

Sources of information

2.2.1 Sources of Environment Agency data were assessed as below:

- Flood Map for Planning (Rivers and Sea)[2]; and
- updated Flood Map for Surface Water (uFMfSW)[3].

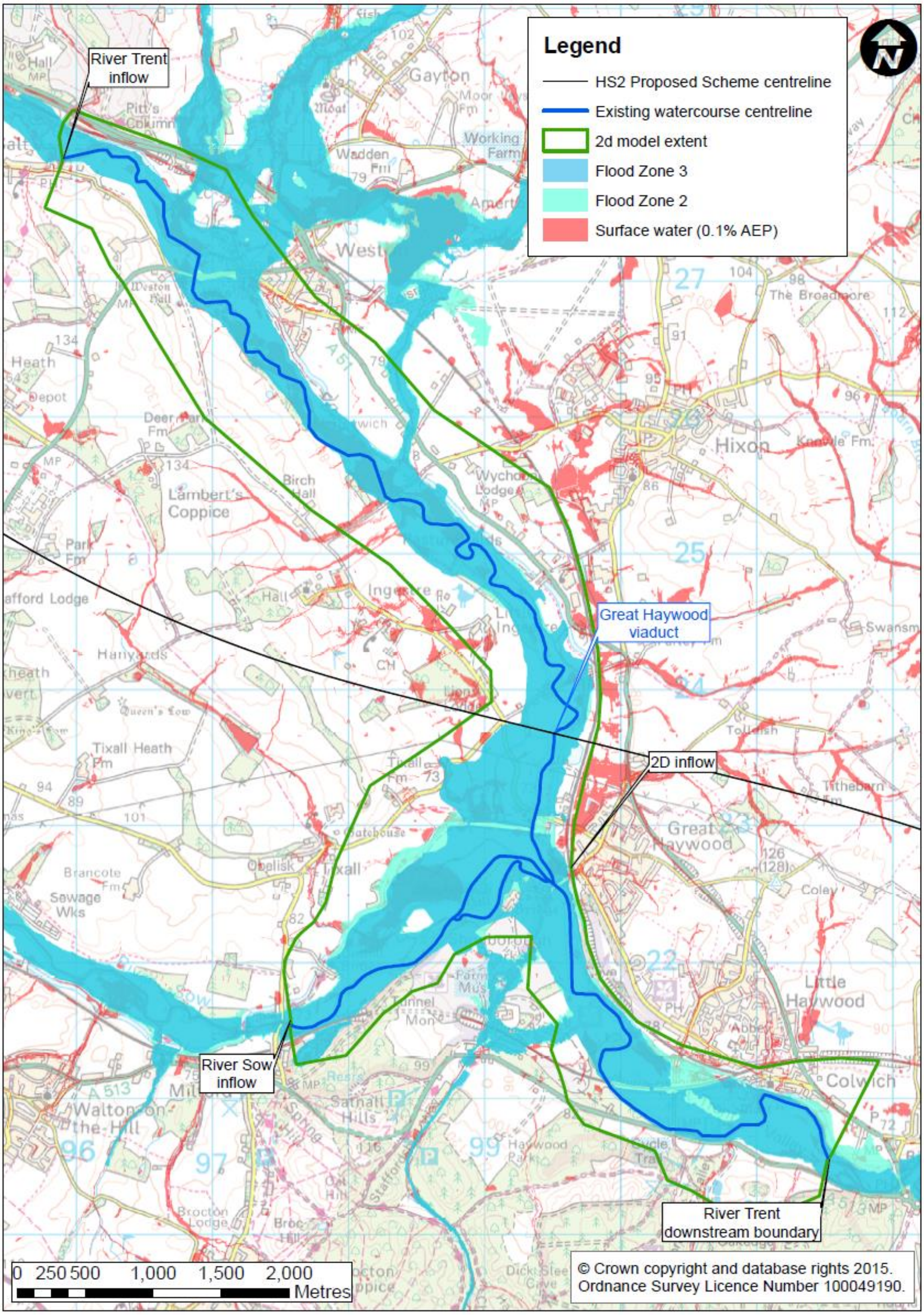
2.2.2 The proposed Great Haywood viaduct spans Flood Zones 2 (0.1%AEP) and 3 (1.0%AEP) of the Environment Agency Flood Map for Planning as shown in Figure 2. The Proposed Scheme embankments and viaduct piers are not shown in this figure due to the viaduct spanning more than the modelled width of the floodplain, in addition to the scale making the piers too small to be visible. The piers are shown in insets in Appendix A.

2.2.3 Available information does not indicate the presence of any flood defences within the model extent.

2.2.4 The Environment Agency Flood Zone 2 maps are believed to be derived from National Generalised Modelling.

[2] Gov.uk, *Flood map for planning*, https://flood-map-for-planning.service.gov.uk
[3] Gov.uk, *Long term flood risk information*, https://flood-warning-information.service.gov.uk/long-term-flood-risk/map?map=SurfaceWater

Figure 2: Environment Agency Flood Zones 2 and 3 and uFMfSW (0.1%AEP) at the River Trent at Great Haywood.



2.3 Availability of existing hydraulic models

2.3.1 An existing hydraulic model was supplied by the Environment Agency for this study.

2.3.2 The model provided was a 1D (ISIS) only model received in 2016. The model was developed in 2004.

2.3.3 The model was developed on behalf of the Environment Agency for the Trent Strategy. This 1D only model was constructed with peak flood levels then extrapolated across the floodplain to form the flood map. The study area lies within Trent Strategy Model 2, which covers from Darlaston near Stoke, to Drakelow Park near Burton-on-Trent. The maximum return period at which this model was run was the 0.5%AEP event. Therefore, the 0.1%AEP for this area is believed to be derived from National Generalised Modelling. It is unknown if the Flood Zone 3 shown on the Flood Map for Planning is that derived from this model.

2.4 Site visit

2.4.1 A site visit was undertaken in June 2016 to determine the dimensions of the channel and any existing infrastructure.

2.4.2 Several structures were visited along the River Trent however not all could be visited due to site access restrictions and general accessibility issues. For the structures that were visited, images were taken to ascertain dimensions and roughness.

2.4.3 The weir shown in Figure 3 is located directly downstream of the Hoo Mill Bridge, 500m upstream of the Proposed Scheme. Following observations from this visit, this structure was identified as consisting of sheet piles at uneven intervals.

Figure 3: Hoo Mill Bridge Images of the River Trent

3 Model approach and justification

3.1 Model conceptualisation

3.1.1 Model extents were carefully selected to ensure that the model boundaries did not have any impact on the flood extent in the area of interest.

3.1.2 Utilising a 1D-2D modelling approach is appropriate for a floodplain of this nature because there are complex overland flow paths between the River Sow and the River Trent and across the floodplain itself upstream of the proposed Great Haywood viaduct. Using such an approach allows more confidence to be gained in assessing the impact of the Proposed Scheme on receptors, while also allowing more confidence in hydrology as floodplain flows can be properly accounted for.

3.1.3 The hydraulic model supplied by the Environment Agency has been used as the basis of the study. The ISIS model, which covers the River Trent within the area of interest was truncated and then converted to a 1D-2D Flood Modeller- Two-dimensional Unsteady FLOW (TUFLOW) model.

3.1.4 The supplied model was taken and updated to improve representation of the river channel and to better represent the flow paths upstream of the River Trent confluence on the River Sow through the Shugborough Hall estate.

3.2 Software

3.2.1 Flood Modeller 4.1 has been used for the 1D component of the modelling. For the 2D component, TUFLOW (2016-AA) has been used. This methodology is in line with standard practice to use the latest available build at the time modelling commenced, while Flood Modeller and TUFLOW are industry standard software.

3.3 Topographic survey

3.3.1 No additional topographical survey was commissioned for this study. Therefore, the model uses existing cross-sectional information provided in the model supplied by the Environment Agency however the raw data itself was not supplied.

3.4 Input data

3.4.1 The elevation data for the study area was produced using 200mm Light Detection and Ranging (LiDAR) flown specifically for HS2 Ltd and covers 500m either side of the route centreline. In addition, 1m and 2m LiDAR provided by the Environment Agency was used for the remainder of the extent.

3.4.2 The 1D model was re-schematised as the distance between cross-sections was not consistent with identified structures, and the model was not originally georeferenced. Using bank levels and local structures as a guide, the sections were repositioned. This necessitated changes to the node names of all nodes within the hydraulic model to reflect the distance to the downstream reference point.

4 Technical method and implementation

4.1 Hydrological assessment

4.1.1 The estimation of design peak flows and hydrographs was based on the application of the methodologies pre-approved by HS2 Ltd. These are standard in the UK flood risk management industry.

4.1.2 The FEH methodologies were followed, in particular the Statistical Method. The FEH Pooling Group methodology was adopted; which uses recorded river flows in hydrologically similar catchments to estimate flows at the subject location. The calculations were based on the most up-to-date national database available at the time of the undertaking the calculations. The data was obtained from the National River Flow Archive and/or HiFlowsUK. The gauging station at Darlaston was used to correct the value of the median flow for the River Trent.

4.1.3 In addition, the FEH Revitalised Rainfall Runoff Method, version 2 (part of ReFH2) was used to produce an alternative set of design peak flows and event probability. ReFH2 uses the recently updated FEH13 rainfall database and parameters. The calculations are based on relevant catchment descriptors of each catchment, which were obtained from the FEH Web Service database.

4.1.4 The two sets of design peak flows (from FEH Statistical Method and ReFH2) were analysed and compared, selecting the methodology that produced the most conservative river flows. The FEH Statistical Method was therefore selected.

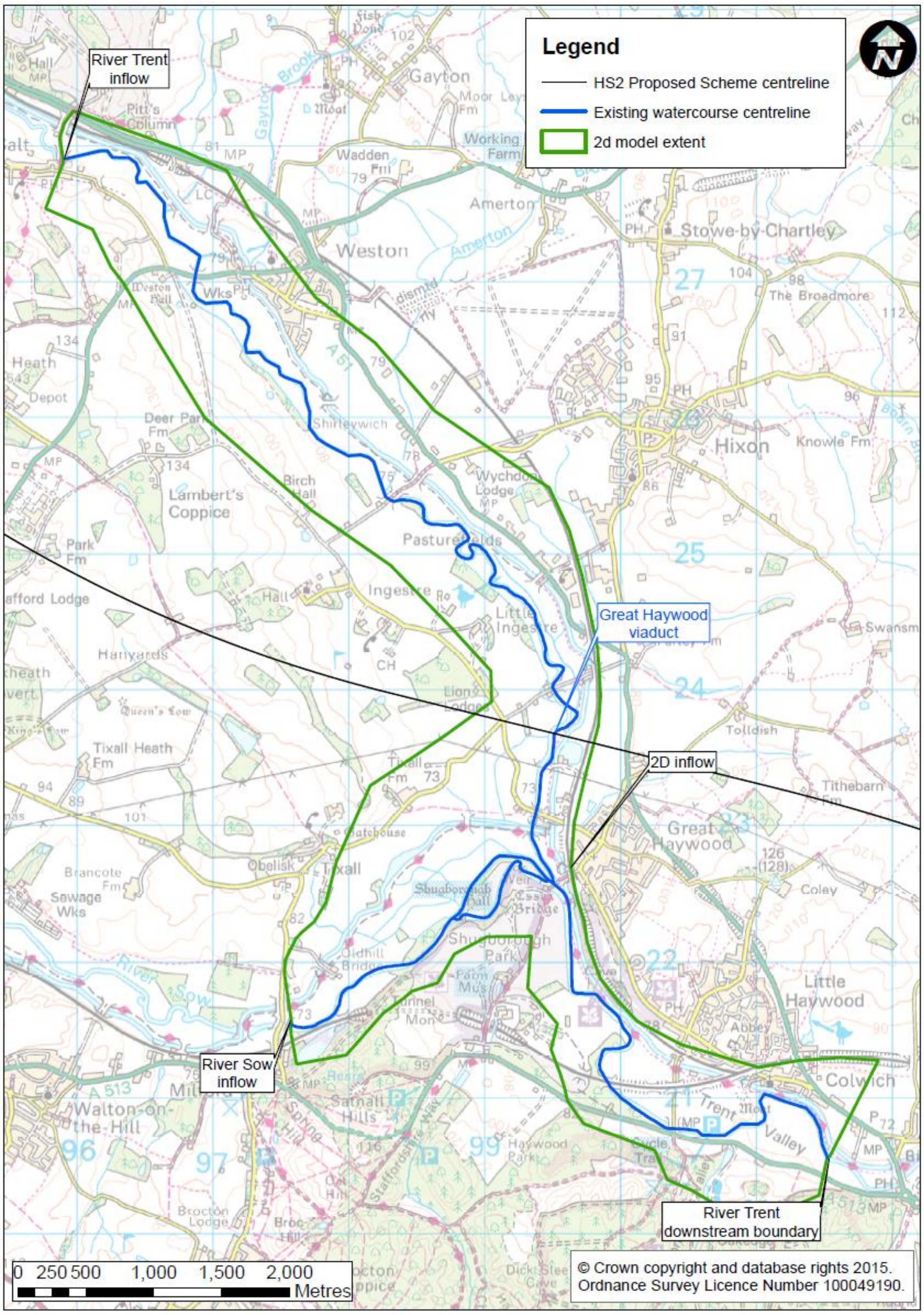
4.1.5 The design hydrographs used for the hydraulic modelling stage were generated using ReFH2 as the FEH Statistical method does not produce time series, just peak flows. The values were scaled so the peak flow for each return period matched that selected as the design value.

4.1.6 Table 1 shows the peak flows used for the computational hydraulic modelling work. Figure 4 highlights the inflow locations and the associated river networks assessed as part of this study.

Table 1: Peak flows used for hydraulic analysis

	AEP	Return period	Site code		
			River Trent inflow	River Sow inflow	2D inflow
Flood peak (m^3/s)	50%	2yr	29.38	30.20	0.92
	20%	5yr	40.11	40.46	1.25
	5.0%	20yr	57.56	55.60	1.81
	1.33%	75yr	79.51	72.88	2.55
	1.0%	100yr	85.27	77.18	2.74
	1.0% + CC	100yr + CC	127.9	115.8	4.1
	0.5%	200yr	100.93	88.48	3.28
	0.1%	1000yr	149.61	120.90	5.01

Figure 4: Schematic of inflows and modelled river network



4.2 Hydraulic model build - baseline model

1D Representation

4.2.1 The accuracy of distances between model cross-sections was checked for accuracy, and some sections were relocated, or the stated distance between them increased or decreased. This was based on latest LiDAR information and known positions of structures referenced in the model. All structures that have a deck which is less than three 2D cells wide have had an overspill included in the

1D model. All structures represented in the 1D model are marked with comments stating the location and the source of the data.

4.2.2 Defined flow paths through culverts observed within the 2D domain but not represented within the 1D river channel model have been included as ESTRY components connected using standard methods.

2D Representation

4.2.3 The cell size of the model was set as 4m. Cell size and alignment for the 2D model grid was optimised to ensure appropriate representation of the flow pathways whilst maintaining reasonable run times. The alignment for the 2D model grid follows the rotation of the Proposed Scheme piers.

4.2.4 Bank line heights were sampled from the 200mm, 1m and 2m LiDAR data, and integrated with the 1D bank heights at the cross-section locations.

Inflow boundaries

4.2.5 The study area has three inflows. Inflows into the 1D model for the River Trent and River Sow have been applied. A minor tributary (unnamed) feeds into the 2D model at Great Haywood, indicated as '2D Inflow' in Figure 4.

Downstream boundary

4.2.6 A normal depth boundary was used at the downstream cross-section of the River Trent and also in the floodplain at the downstream extent. This generates a stage-discharge curve based on the bed slope which varies across the floodplain.

4.2.7 A normal depth slope of 0.03 m/m (1 in 33) was used within the channel and slopes of 0.002 m/m (1 in 500) was used for the left bank floodplain and a slope of 0.0043 m/m (1 in 232) was used for the right bank floodplain. These were derived from LiDAR.

Key structures

4.2.8 There are a number of structures within the model extent that were modelled in a variety of ways. Additionally, there are a number of structures which are not modelled as no information is available. Those included in the model and deemed to be key hydraulic controls are detailed in Table 2 and shown in Figure 1.

Table 2: Key structures present within the modelled extent of the River Trent at Great Haywood

Structure reference	Node reference	Structure description	Modelling representation and justification
Culvert (7)	Haywoodbridg	Large dry aperture throughway passing beneath the Staffordshire and Worcestershire Canal. 17.0m (L) x 8.0m (W) x 0.8m (H)	Single channel, ESTRY Rectangular culvert observed on aerial photography
Hoomill Bridge	HOOMIL_US	Single arch road bridge. 8.2m (W), Soffit Height: 74.23 metres above Ordnance Datum (mAOD)	Arch Bridge as represented in existing model and onsite
Weir 1	3161401674wu	In line spill representation of the weir in close proximity beneath Hoomill Bridge. 7.65m (W), Spill level: 72.01mAOD,	In line spill unit, observed on site
Great Haywood Bridge	GHAY_US	Single arch road bridge. 11.47m (W), Soffit Height: 73.33mAOD.	Arch Bridge as represented in existing model and observed on site
Haywood Bridge Aqueduct	GHAY_AQ_US	Four arch bridge carrying the Staffordshire and Worcestershire Canal spanning a 31m channel. 6.66m (W), Soffit Height: 71.49mAOD; 6.15m (W), Soffit Height: 71.51mAOD; 6.46m (W), Soffit Height: 71.49mAOD; 5.09m (W), Soffit Height: 71.57mAOD.	Arch Bridge as represented in existing model and observed on site

4.2.9 Additionally, a number of other culverts and bridges are included within the hydraulic modelling, however these are not deemed to be critical to determining the flood risk to the Proposed Scheme. This includes, but is not limited to, the road crossings of the A518 (Weston Bank), Sandy Lane and Meadow Lane as well as a number of footbridges including Essex Bridge. The Colwich Junction to Macclesfield Line crosses the river channel close to the downstream extent of the model and there are several culverts representing minor flow routes through obstacles within the floodplain.

4.2.10 Weir 1 has been included in the 1D model as a weir structure, replacing the sharp gradient between the upstream and downstream cross-sections that were used in the previous modelling.

Roughness

4.2.11 Roughness values utilised are in line with the recommended values stated within Chow, 1959[4].

[4] Chow, V.T (1959), *Open-channel hydraulics*, McGraw-Hill, New York

4.2.12 The 2D domain roughness values have been informed by the land use classifications within the current Ordnance Survey (OS) Mastermap data together with information derived from aerial and site visit photography for specific features.

4.2.13 In some locations the OS Mastermap data has been modified to suit the cell size of the hydraulic model, to ensure that key features such as woodland, roads and the channel itself are represented.

4.3 Hydraulic model build - Proposed Scheme

4.3.1 The Proposed Scheme model has been edited from the baseline to include the following:

Viaduct piers

4.3.2 The proposed Great Haywood viaduct spans approximately 780m and will be supported by 17 piers, spaced approximately 45m apart.

4.3.3 A deactivated code layer was used to represent the piers. The modelled dimensions of each pier constitute a deactivated area of the model of $48m^2$ per pier, for a pier size of 14.5m x 2m ($29m^2$).

Topographic changes

4.3.4 No additional features were applied to the model to represent the Proposed Scheme due to the wide span of the proposed Great Haywood viaduct across the floodplain, the embankments (Trent south embankment and Trent north embankment) either side of the floodplain were not close enough to the flooded extent to be required for representation in the model. The footprints of these embankments are based on the design as shown in Map CT-06-212 in the Volume 2 Map Book.

4.3.5 The OS Mastermap layer was modified to correctly represent any changes to the roughness and planting associated with the Proposed Scheme.

Replacement floodplain storage areas

4.3.6 Although there are only localised changes between baseline and post-development, provision for replacement floodplain storage has been made based on the 1.0% + CC AEP levels, on a level for level, volume for volume basis. This has not been included within the hydraulic modelling.

Channel realignment or diversions

4.3.7 A realignment has been proposed for a minor field drain beneath the Great Haywood viaduct to avoid a pier. This has not been modelled.

4.3.8 No diversions of the river channel have been proposed.

Production of flood extents

4.3.9 Flood extents have been derived using the direct output options now available in TUFLOW to produce ASCII output for the maximum depth and height. This has then been converted into a polygon and cleaned to remove all bow ties (where two polygons overlap) as well as any dry islands less than $48m^2$.

Modelling assumptions made

4.3.10 Existing topographic survey is assumed to be correct as no other information is available. This covers all the existing cross-section data for the Rivers Trent and Sow. It is noted that the River Trent survey is up to 18 years old.

4.3.11 Culvert sizes have been assumed in a number of locations within the model. Where a site visit to provide photos or measurements was not possible, they have been approximated based on LiDAR information. This provided road levels and ground levels and the measured width of the top of structures from aerial photography.

4.4 Climate change

4.4.1 The climate change allowance for the River Trent is 50% based on the new climate change approach developed by the Environment Agency and published in February 2016[5].

4.4.2 This climate change percentage considers the design life of the Proposed Scheme (120 years), the River Basin District (Humber) and the receptors within the existing Flood Map for Planning. Due to the presence of more vulnerable receptors (National Planning Policy Framework Table 2[6]), the upper end value for the longest duration was chosen.

4.4.3 The new climate change guidance recommends consideration of the H++ scenario[7]. While these percentages have not been explicitly assessed, the sensitivity for the 20% increase in flow on the 1.0% + CC AEP event is assumed to be representative of an event greater than the H++ scenario.

[5] Environment Agency, *Flood risk assessments: climate change allowances*, https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

[6] Gov.uk, *Flood Zone and flood risk tables*, https://www.gov.uk/guidance/flood-risk-and-coastal-change#flood-zone-and-flood-risk-tables

[7] Environment Agency, *Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/571572/LIT_5707.pdf

5 Model results

5.1.1 The model has been run for the 50%, 20%, 5.0%, 1.33%, 1.0%, 1.0%+CC, 0.5% and 0.1% AEPs. The 1.0% +CC simulation is based on a 50% increase in flows.

5.1.2 The water level difference has been mapped for the 1.0%+CC and 5.0% AEPs. These flood maps are reported in Appendix A.

5.1.3 In all return periods modelled, impacts are observed at the location of the proposed Great Haywood viaduct and in isolated areas of the floodplain, of less than 10mm. There is no change to the flood extent.

5.1.4 Model results conclude that the current proposed design ensures a freeboard of a minimum of 1m to the rail track in a 0.1%AEP event and a minimum of 0.6m to the viaduct soffit in a 1.0%AEP + CC (50%) event for all scenarios.

6 Model proving

6.1 Introduction

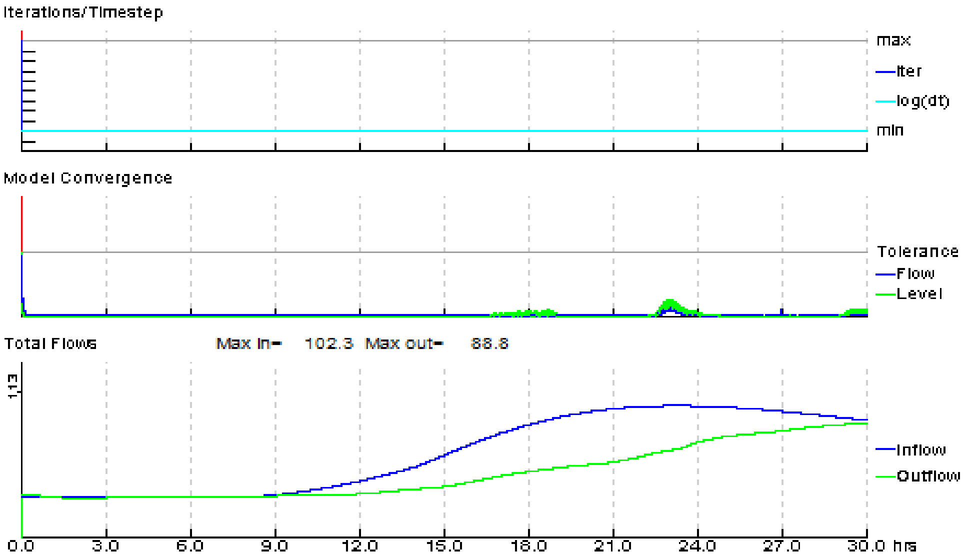
6.1.1 This section of the report presents the analysis of the model undertaken to ensure confidence in the stability of the model build, its response to input values and consistency with previous modelling.

6.2 Run performance

6.2.1 Model output has been reviewed across all open channel and model structures to assess model stability and overall model performance. In all events the model shows convergent situations.

6.2.2 Figure 5 shows the convergence plots for the Proposed Scheme 5.0% and 0.1%AEP simulations.

Figure 5: Model convergence plot for the 5.0%AEP (top) and 0.1%AEP (bottom) simulations on the HS2 Proposed Scheme model.



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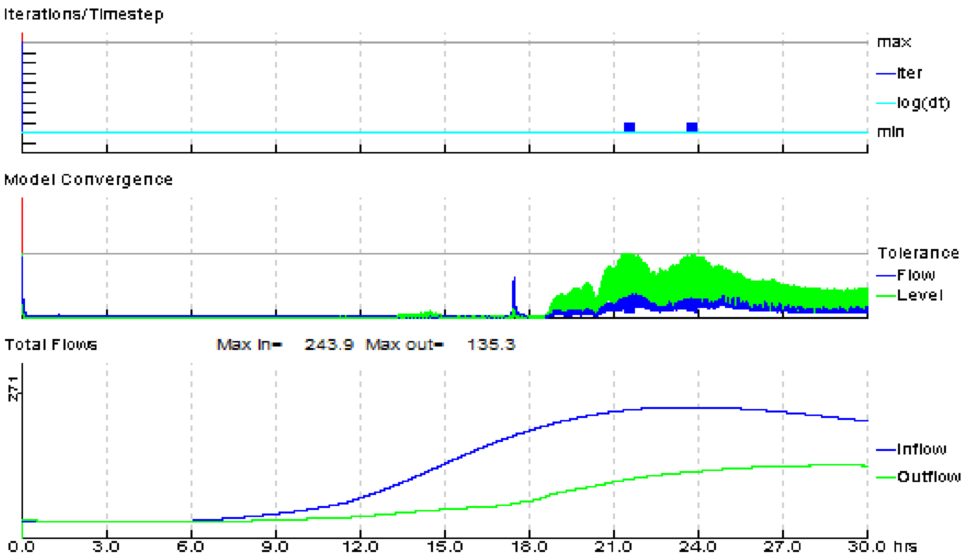
Ran at 09:46:27 on 23/01/2017
Ended at 20:16:13 on 23/01/2017
Start Time: 0.000 hrs
End Time: 30.000 hrs
Timestep: 1.0 secs

Current Model Time: 30.00 hrs
Percent Complete: 100 %



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Ended at 09:17:34 on 08/02/2017
Start Time: 0.000 hrs
End Time: 30.000 hrs
Timestep: 1.0 secs

Current Model Time: 30.00 hrs
Percent Complete: 100 %

6.2.3 Modelled event duration ends at 30 hours which is before the downstream water levels have peaked, however the water levels at the proposed Great Haywood viaduct reach their peak at 25 hours and are in recession after 26 hours.

6.2.4 Final cumulative mass balance error is within +/-1.0% for all return periods and blockage and sensitivity cases simulated.

6.3 Calibration and validation

6.3.1 The Great Haywood river gauge is located within 1.3km downstream of the Proposed Scheme but is not suitable for calibration as it measures water levels only.

6.3.2 Calibration has not been carried out due to no available historic or recorded flood mapping and the available rainfall information is spatially variable to an extent where gauges either record significant events, or record no rainfall at all. Additionally, the only gauge in this area – Great Haywood – is level only and significantly bypassed.

6.4 Verification

6.4.1 Model outputs have been compared with other readily available flood risk data such as Environment Agency Flood Maps for Planning.

6.4.2 Flood extents generated for this study show a smaller flooded extent across the floodplain when compared to the Environment Agency Flood Maps for Planning.

6.5 Sensitivity analysis

6.5.1 Sensitivity scenarios were undertaken as below:

- increase in flow by 20% (compared to 1.0%AEP+CC Proposed Scheme);
- increase in roughness (channel, structures and floodplain) (Manning's n) by 20% (compared to 1.0%AEP+CC Proposed Scheme);
- decrease in roughness (channel, structures and floodplain) (Manning's n) by 20% (compared to 1.0%AEP+CC Proposed Scheme);
- increase in downstream boundary gradient by 20% (compared to 1.0%AEP+CC Proposed Scheme); and
- decrease in downstream boundary gradient by 20% (compared to 1.0%AEP+CC Proposed Scheme).

Roughness

6.5.2 The model is sensitive to increases in roughness with a 20% increase resulting in increases in water level of greater than 100mm throughout the majority of the model. A minor increase in flood extent is observed, however this does not affect the Proposed Scheme.

6.5.3 Decreasing the roughness by 20% results in a general decrease in peak water level throughout the majority of the model of greater than 100mm, with a localised increase upstream of Weston Bridge of greater than 100mm.

Inflows

6.5.4 An increase in inflow of 20% results in an increase of greater than 400mm at the proposed Great Haywood viaduct. An increase in the flood extent is observed however this does not affect the Proposed Scheme.

Downstream boundary

6.5.5 There was no impact to the proposed Great Haywood viaduct when the downstream boundary gradient was increased or decreased by 20%, with a maximum impact of 100mm at the downstream boundary. No impact is seen greater than 1.4km from the downstream extent.

Summary

6.5.6 The sensitivity analysis shows the model is sensitive to changes in flows and roughness values at the proposed Great Haywood viaduct. The changes to the downstream boundary gradient had no impact at the proposed Great Haywood viaduct with minimal impact at the downstream boundary of the model. However, while levels are shown to be sensitive, extents are not; the small increases do not affect the Proposed Scheme.

6.5.7 Sensitivity tests conclude that the current proposed design ensures a freeboard of a minimum of 0.6m to the viaduct soffit in a 1.0%AEP +CC (50%) event.

6.6 Blockage analysis

6.6.1 Two blockage scenarios were assessed:

- blockage scenario 1 – 2% blockage at the proposed Great Haywood viaduct; and
- blockage scenario 2 – 50% blockage of the Haywood Bridge Aqueduct and associated culvert.

6.6.2 These blockage scenario results were compared to the 0.1%AEP results for the Proposed Scheme model.

6.6.3 The viaduct blockage of 2% was represented for the proposed Great Haywood viaduct by expanding the size of the pier standing nearest to the main channel by 2% of the length of the viaduct.

6.6.4 The blockage of the aqueduct and adjacent culvert beneath the Staffordshire and Worcestershire Canal was represented by use of a blockage unit for the aqueduct, and through reducing the width of the culvert by 50%.

6.6.5 The results for the blockage scenario 1 show negligible impact to peak flood levels with an impact of less than 10mm around the proposed Great Haywood viaduct.

6.6.6 The results for the blockage scenario 2 indicate an increase to peak flood levels around the viaduct of greater than 100mm.

6.6.7 Blockage tests conclude that the current proposed design ensures a freeboard of a minimum of 1m to the rail track in a 0.1%AEP event for all scenarios.

6.7 Run parameters

6.7.1 There is no deviation from default run parameters for all model runs.

6.7.2 The time step parameters used were 1 second for the 1D model river, 0.2 seconds for ESTRY and 2 seconds for the 2D model. This is the suggested approach for a grid size of 4m, with the exception of the ESTRY time step which was selected to improve stability within the culverts.

7 Limitations

7.1.1 Land access for new topographic survey was not possible, and therefore the existing survey within the hydraulic models provided by the Environment Agency for the River Trent and River Sow is assumed to be correct. Site observations have been used to reduce the number of assumptions. Some culvert dimensions have been estimated based upon ground levels and watercourse size, which may impact flood extent and level predictions if these were to change.

7.1.2 Small flow paths and a number of drains may not be fully represented at the 4m grid resolution but all major flow paths are represented.

7.1.3 Calibration has not been able to be carried out due to a lack of available data.

8 Conclusions and recommendations

8.1.1 The aim of developing a hydraulic model of the River Trent at Great Haywood to simulate the baseline and Proposed Scheme and to determine the peak water levels and flows throughout the catchment has been met.

8.1.2 Increases in water level observed due to the Proposed Scheme reach less than 10mm over a localised area close to the viaduct. These are detailed for a range of AEP and flood maps provided in Appendix A.

8.1.3 Water levels are shown to increase in the Trent and Mersey Canal and Great Haywood Marina but by less than 10mm.

8.1.4 Blockage and sensitivity analyses have demonstrated that changes in key variables such as roughness, model inflows and downstream boundary location and gradient result in modelled water levels that remain below the critical freeboard requirements.

8.1.5 Further topographical survey of the channel to verify modelled cross-sections and to identify and provide detail for culverts and drains within the floodplain would improve the representation of important flow dynamics in the modelling of the catchment.

9 References

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Appendix A: Flood level impact maps

1.1.1 The water level difference has been mapped for 5.0%AEP and 1.0%+CC AEP as described in Section 5, see Figures A-1 and A-2.

Figure A-1: River Trent at Great Haywood Impact Map for 5%AEP (1 in 20 year)

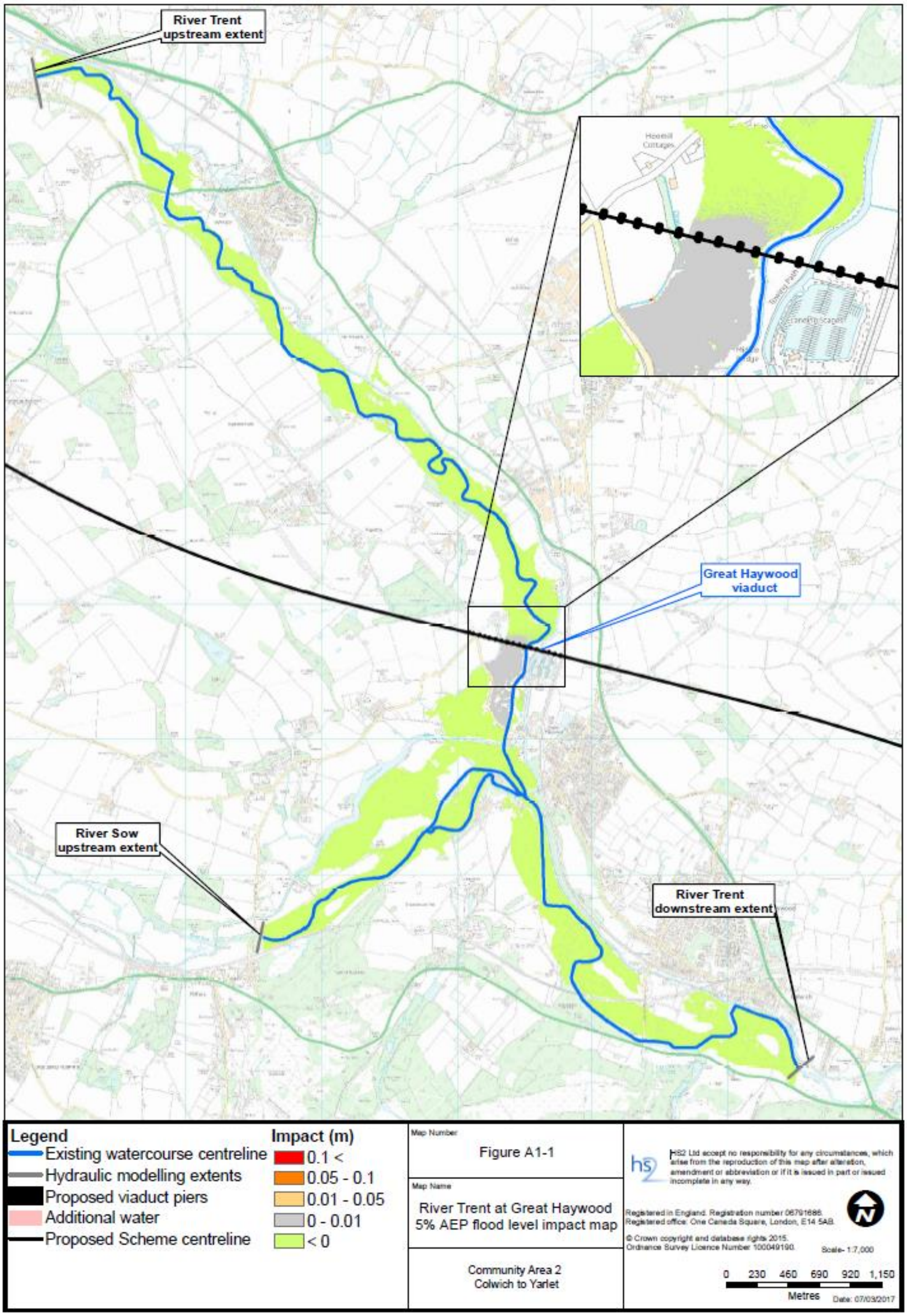
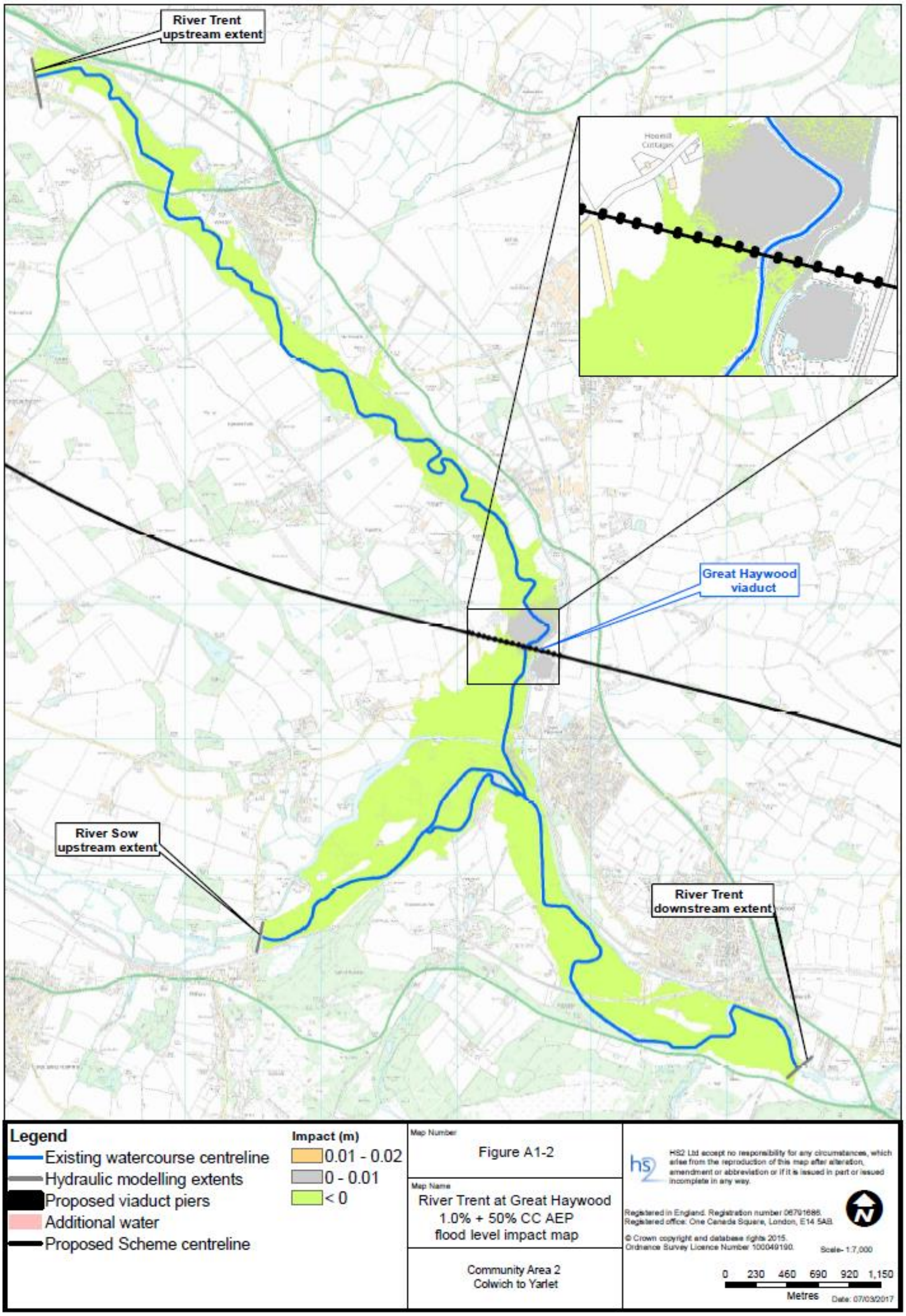


Figure A-2: River Trent at Great Haywood Impact Map for 1%AEP (1 in 100 year) plus 50% climate change allowance



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