E137

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

Background Information and Data

CA3: Stone and Swynnerton

Hydraulic modelling report - Filly Brook (BID-WR-004-007)

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 Stone and Swynnerton area (CA3) relevant to High Speed Rail (West Midlands - Crewe).

1.1.2 In addition, the Hydraulic modelling report – Meece Brook (Background Information and Data 004: BID-WR-004-008) sits across both the Stone and Swynnerton area and the Whitmore Heath and Madeley 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 Stone and Swynnerton area:

- a route-wide Water Framework Directive compliance assessment (Volume 5: Appendix WR-001-000);
- a water resources assessment (Volume 5: WR-002-003);
- a flood risk assessment (Volume 5: WR-003-003); 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 will cross watercourses and their floodplains. The 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 Filly Brook on the proposed Filly Brook viaduct and the M6 motorway and an unnamed watercourse on the proposed M6 Meaford viaduct.

1.2.3 A hydraulic model of Filly Brook was created to simulate the risk of flooding in this location for an approximate 3.9km stretch of the brook, also incorporating four unnamed drains and Yarnfield Brook downstream. 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 2D hydraulic model was selected for this study as detailed 1D channel information was not available at the time of study and the Light Detection and Ranging (LiDAR) survey adequately portrayed the existing channels and features. Using a 2D approach allows for structures to be represented using the ESTRY solver within Two-dimensional Unsteady FLOW (TUFLOW).

1.4.3 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 was 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 Filly Brook being modelled is situated between Yarnfield to the west, Stone to the east and the M6 which bisects the catchment. Figure 1 shows the modelled extent. The model upstream boundary is situated approximately 300m upstream and east of the M6 crossing and the downstream boundary is located approximately 320m downstream of the Norton Bridge to Stone Railway crossing. Approximately 3.9km of Filly Brook has been modelled.

2.1.2 Filly Brook flows south, running parallel to the east of the M6 before crossing to the west through a culvert underneath the M6 continuing in a southerly direction. The watercourse then turns east to cross the M6 again via a culvert to flow parallel to the Norton Bridge to Stone Railway, eventually passing beneath the railway and through Stone to its confluence with the River Trent.

2.1.3 There are no major tributaries of Filly Brook within the proposed model extent although there are a number drains that converge with Filly Brook either side of the Norton Bridge to Stone Railway.

2.1.4 The area is predominantly rural with isolated properties throughout. Stone Golf Course is to the north-east.

Hydrological description

2.1.5 Filly Brook originates north of the M6, to the west of Meaford.

2.1.6 The catchment area contributing to the downstream boundary of the proposed hydraulic model is 5.0km^2, and is predominantly rural.

2.1.7 There are no gauging stations present within the Filly Brook catchment.

2.1.8 Standard Annual Average Rainfall for the catchment at the model downstream boundary is 766mm.

Railway alignment

2.1.9 The route of the Proposed Scheme crosses the study area from the south-east heading in a north-west direction, crossing the Norton Bridge to Stone Railway and Filly Brook via the proposed Filly Brook viaduct. It continues heading north-west crossing a realigned Yarnfield Lane and eventually the M6 and Filly Brook for a second time on the proposed M6 Meaford viaduct. Further detail on the Proposed Scheme can be found in Maps CT-06-222, CT-06-222-R1, CT-06-223 and CT-06-223-L1 in the Volume 2 Map Book.

2.1.10 The route crosses Filly Brook on two structures, the Filly Brook West underbridge for the Infrastructure and Maintenance Base – Rail (IMB-R) tracks and the Filly Brook viaduct for the mainline.

2.1.11 Additionally, the reception sidings for the IMB-R run adjacent to the Norton Bridge to Stone Railway to the east.

Flood mechanisms

2.1.12 The updated Flood Map for Surface Water (uFMfSW) shows a connection between the Filly Brook and Yarnfield Brook catchments. The Yarnfield Brook catchment enters Meece Brook eventually reaching the River Sow therefore it does not pass beneath the Proposed Scheme until it reaches the River Trent viaduct significantly downstream.

2.1.13 The uFMfSW shows a significant flow path along the existing Norton Bridge to Stone Railway.

2.1.14 The eastern most culvert that passes under the Norton Bridge to Stone Railway, within the modelled extent, acts as a throttle at the downstream end of the catchment.

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 Filly Brook 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 1.

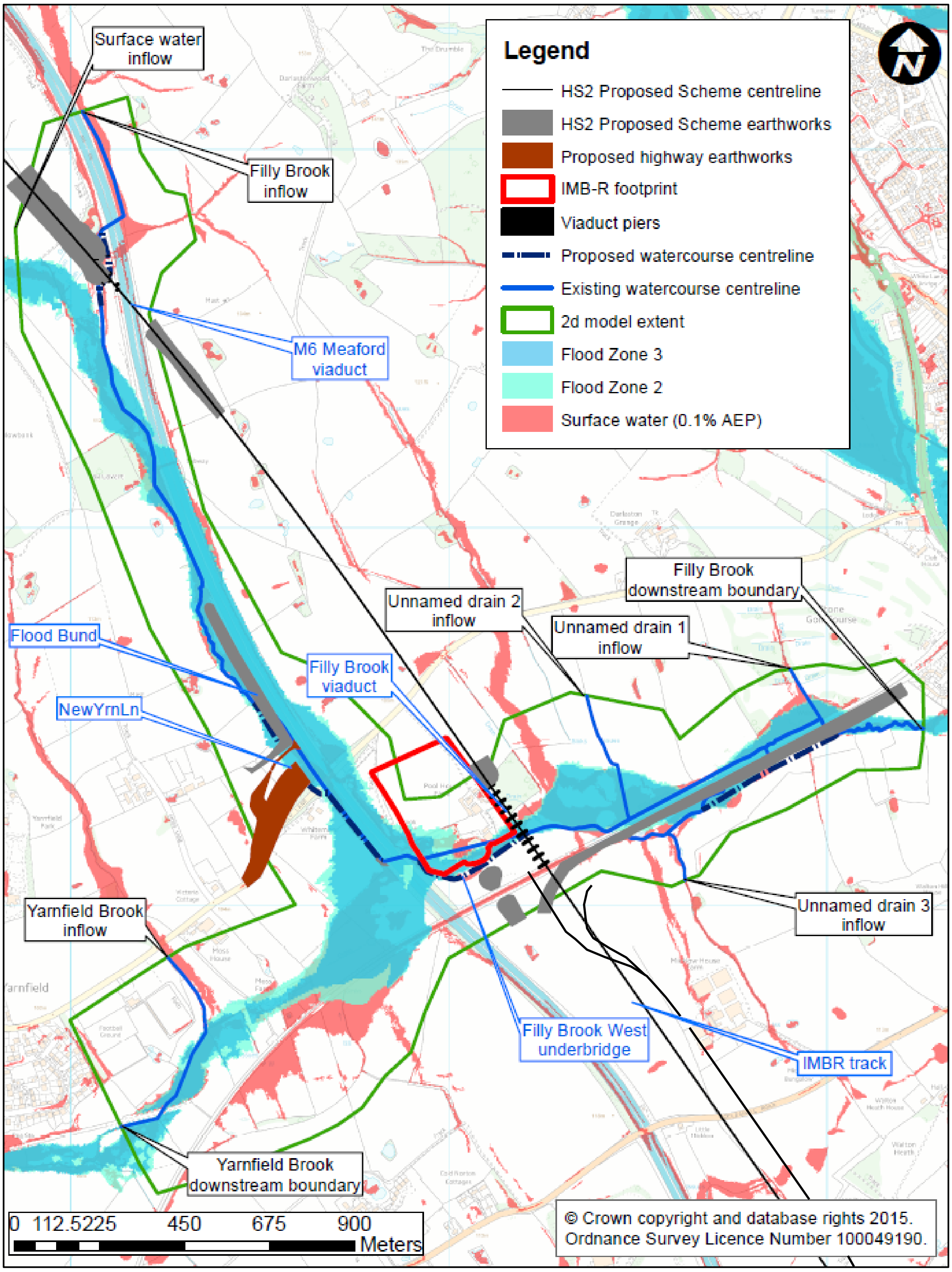
2.2.3 The uFMfSW shows multiple flow paths exist. Four prominent flow paths east of the Proposed Scheme, two either side of the Norton Bridge to Stone Railway and one west of the Proposed Scheme where Yarnfield Brook joins the flow from Filly Brook. In addition, a flow path can be seen along the centreline of the Norton Bridge to Stone Railway.

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

2.2.5 The Environment Agency flood maps are believed to be derived by 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 1: Environment Agency Flood Zones 2 and 3 and uFMfSW (0.1%AEP) at Filly Brook



2.3 Availability of existing hydraulic models

2.3.1 There were no existing models for Filly Brook identified for this study.

2.4 Site visit

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

2.4.2 Several structures were visited along Filly Brook 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 From aerial photography, a millstream was believed to exist parallel to the M6 immediately west of the proposed Filly Brook viaduct. However, the site visit determined that this stream does not exist at any point where aerial photography suggests.

2.4.4 A 1.2m diameter field drainage culvert exists approximately 100m south-west of Pool House Farm.

2.4.5 A 0.3m diameter culvert crosses the Norton Bridge to Stone Railway approximately 410m east from the M6 crossing.

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 2D approach is appropriate for this area as there was no survey data available for the watercourse extent. Using 2D allows more confidence in the flood extent under the proposed Filly Brook viaduct which is important in this area as it defines the abutment positions and viaduct width.

3.2 Software

3.2.1 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 TUFLOW is industry standard software.

3.3 Topographic survey

3.3.1 No additional topographic survey was commissioned for this study.

3.4 Input data

3.4.1 The elevation data for the domain was produced using 200mm LiDAR flown specifically for HS2 Ltd and covers 500m either side of the route centreline. In addition, 1m LiDAR, provided by the Environment Agency, was used for the remainder of the modelled extent

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. No gauged flows were available in the study area so the FEH Pooling Group methodology was adopted. This 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 undertaking the calculations. The data was obtained from the National River Flow Archive and/or HiFlowsUK.

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, in the case of the Filly Brook catchment it was ReFH2.

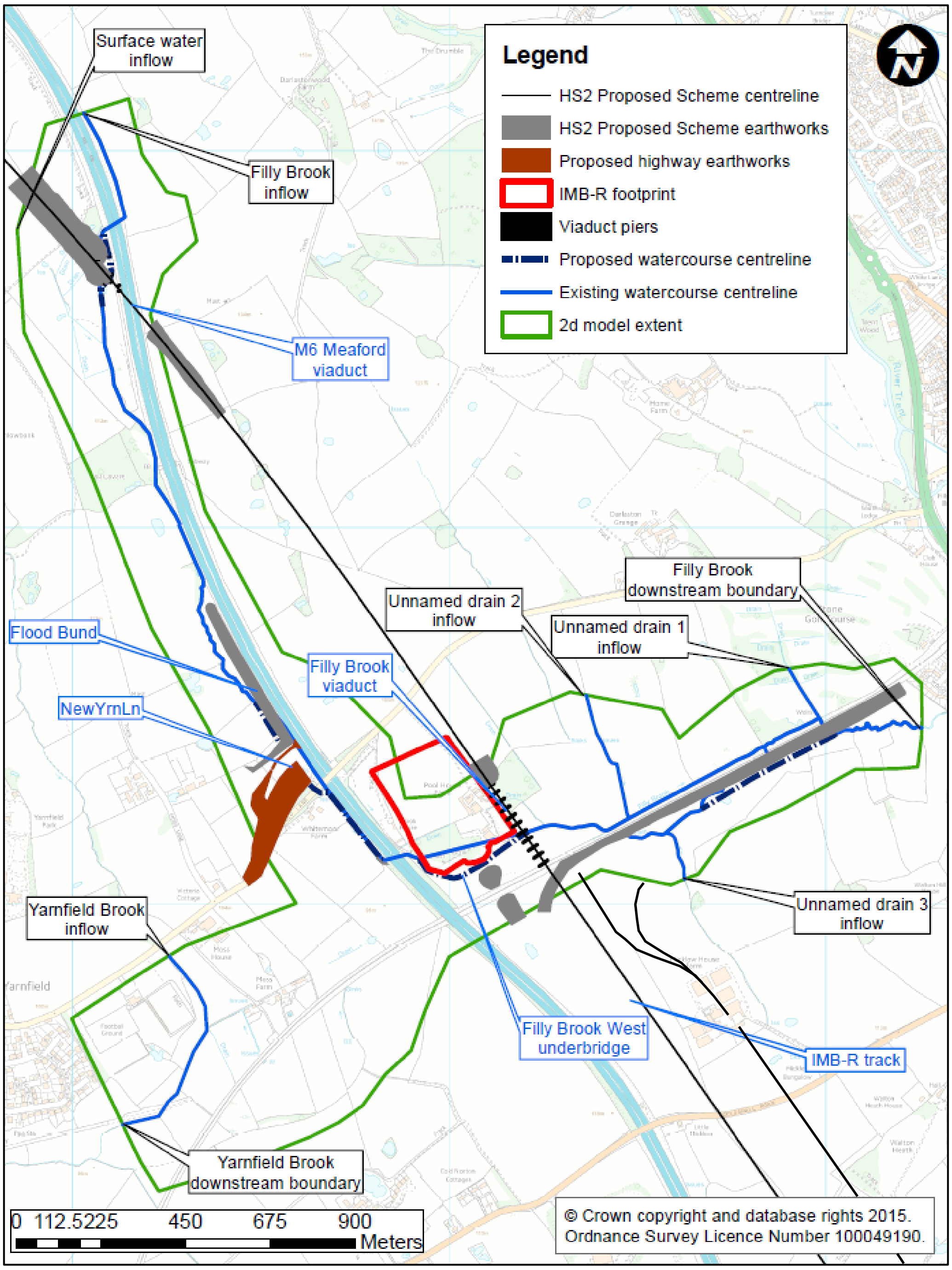
4.1.5 The design hydrographs used for the hydraulic modelling stage were generated using ReFH2 as the FEH Statistical method does not produce time series, just peak flows. The values were scaled so the peak flow for each return period matched that selected as the design value.

4.1.6 Table 1 shows the peak flows used for the computational hydraulic modelling work. Figure 2 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					
			Filly Brook Inflow	**Surface water inflow**	**Unnamed drain 1**	**Unnamed drain 2**	**Unnamed drain 3**	**Yarnfield Brook inflow**
Flood peak (m^3/s)	50%	2yr	0.32	0.65	0.12	0.30	0.39	0.86
	20%	5yr	0.44	0.88	0.17	0.40	0.53	0.86
	5.0%	20yr	0.63	1.25	0.24	0.57	0.75	1.26
	1.33%	75yr	0.90	1.75	0.34	0.80	1.05	1.60
	1.0%	100yr	0.97	1.89	0.36	0.87	1.13	1.71
	1.0% + CC	100yr +CC	1.46	2.84	0.54	1.31	1.70	2.57
	0.5%	200yr	1.19	2.30	0.44	1.05	1.38	2.02
	0.1%	1000yr	1.86	3.52	0.68	1.60	2.09	3.05

Figure 2: Schematic of inflows and modelled river network



4.2 Hydraulic model build - baseline model

1D Representation

4.2.1 Culverts were included in the ESTRY component of TUFLOW. The sizes of these culverts were based off site visit observations, information from Network Rail, the Highways Agency Geotechnical Data Management System (HA GDMS)[4] and the inverts from available LiDAR information.

[4] Highways England, *Geotechnical Data Management System v5.12.0*, http://www.hagdms.com/

2D Representation

4.2.2 The cell size of the model was set as 2m. 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.

4.2.3 Sections of Filly Brook downstream and east of the M6 and Yarnfield Brook west of the M6 have been modified in the 2D as the 1m Environment Agency LiDAR used did not adequately pick up the features of existing channel.

Inflow boundaries

4.2.4 The study area has six inflows. The main inflow, Filly Brook, is located at the upstream extent of the model, east of the M6. A surface water inflow is also located at the upstream extent of the model on the opposite side of the M6. Three more inflows join Filly Brook once it runs parallel with the Norton Bridge to Stone Railway, two from the north and one from the south. The Yarnfield Brook inflow has been introduced approximately 30m downstream of where Yarnfield Lane crosses Yarnfield Brook. These are shown in Figure 2.

Downstream boundary

4.2.5 A normal depth boundary was used at the downstream extent of Filly and Yarnfield Brooks, 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.

4.2.6 A normal depth slope of 0.0078 m/m (1 in 128) was used within the Filly Brook channel and slopes of the floodplain. A slope of 0.0023 m/m (1 in 435) was used for the Yarnfield Brook downstream boundary. These were derived from LiDAR.

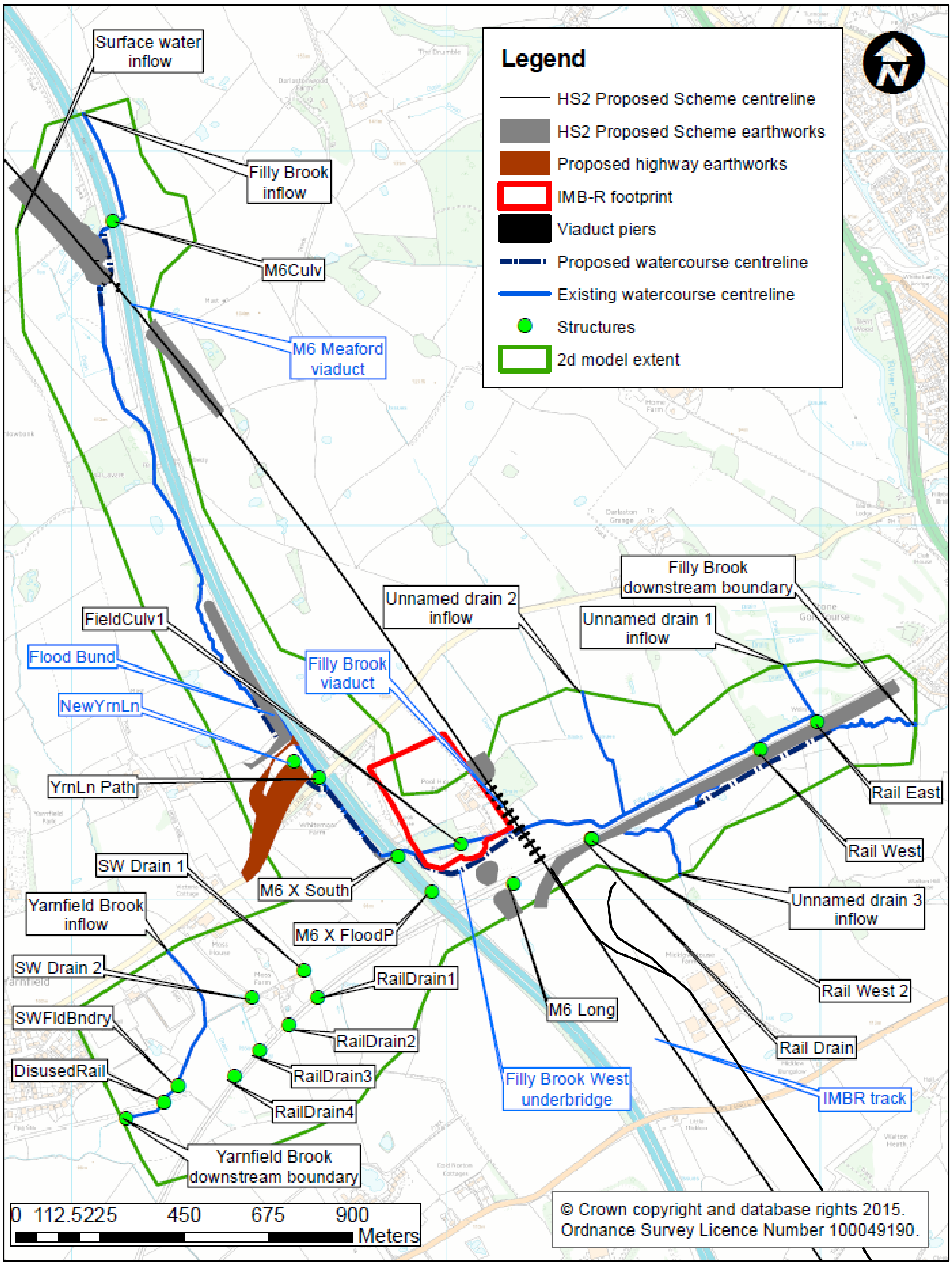
Key structures

4.2.7 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. All structures, including key hydraulic controls, are shown in Figure 3.

Table 2: Key structures present within the modelled extent of Filly Brook.

Structure reference	Structure description	Modelling representation and justification
M6 X South	M6 Crossing adjacent to Pool House Farm. 82.0m (L) x 2.2m (W) x 1.5m (H)	ESTRY rectangular culvert – dimensions taken from HA GDMS.
Rail East	Norton Bridge to Stone Railway crossing approx. 250m from the northern downstream extent. 20.0m (L) x 1.68m (W) x 1.5m (H)	ESTRY rectangular culvert – dimensions from Network Rail 5-mile diagram.
M6Culv	M6 crossing at upstream extent of model. 62.48m (L) x 0.525m (D)	ESTRY circular culvert – dimensions taken from HA GDMS.

Figure 3: Existing and proposed structures within the model extent



Roughness

4.2.8 Roughness values utilised are in line with the recommended values stated within Chow, 1959[5].

4.2.9 The 2D domain roughness values have been informed by the land use classifications within the current Ordnance Survey (OS) Mastermap data

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

together with information derived from aerial and site visit photography for specific features.

4.2.10 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 Filly Brook viaduct spans approximately 449m and will be supported by eleven piers north of the Norton to Stone Railway line, spaced approximately 15-25m apart. Eight piers will be south of the railway line however they would not be within the modelled floodplain and have not been represented.

4.3.3 The proposed M6 Meaford viaduct spans approximately 174m and would be supported by two piers west of the M6, spaced approximately 35-52m apart. Two piers will be south of the motorway however they would not be within the modelled floodplain and have not been represented.

4.3.4 A deactivated code layer was used to represent the piers at both the proposed M6 Meaford and the Filly Brook viaducts. The modelled dimensions of each pier constitute a deactivated area of the model of $56m^2$ per pier, for a pier size of 28m x 2m ($56m^2$).

Topographic changes

4.3.5 The Proposed Scheme embankments (Yarnfield North and South and Meaford North and South), the Stone IMB-R, the realignment of Yarnfield Lane and its associated access path and the flood bunds designed to alleviate flooding at the Proposed Scheme site have been included using the relevant heights for embankment crest and road alignment.

4.3.6 The flood bunds noted have been implemented to alleviate the impact on dwellings in the area caused by the Yarnfield Lane realignment and to stop the existing flow path along the Norton Bridge to Stone Railway, shown in Figure 1. This flow path would likely flood the Proposed Scheme reception tracks that are in cut and south of the existing rail line. This proposed design consists of a 3m high bund created to hold water back from Yarnfield lane with a culvert to pass flow and a small 0.5m head wall bund at the southern M6 crossing to direct flow downstream. This will stop water breaking bank and heading south to join the Yarnfield Brook catchment and further inundating Moss Farm and surrounding dwellings that exist between Filly Brook and Yarnfield Brook. In addition, this will stop flow propagating down the existing rail.

4.3.7 All the topographic changes noted are based on the design as shown in Maps CT-06-222, CT-06-222-R1, CT-06-223 and CT-06-223-L1 in the Volume 2 Map Book.

4.3.8 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

4.3.9 The replacement floodplain storage area north of Yarnfield Lane has been included within the model. This area is shown as replacement floodplain storage as it is an area of additional flooding due to the solution implemented for the Proposed Scheme.

4.3.10 The two replacement floodplain storage areas between the Stone IMB-R and the Norton Bridge to Stone Railway have been provided to allow space for a sinuous channel following the removal of the long culvert that currently exists in this location. However, they have not been included in the modelling at this stage. These have not been derived on a level for level and volume for volume basis.

4.3.11 All replacement floodplain storage areas are shown on CT06 design drawings.

Channel realignments and diversions

4.3.12 A channel realignment was required where the existing channel will be displaced by the Yarnfield Lane realignment and surrounding landscape mitigation embankments. This is also true at the proposed Meaford North embankment where the channel has been realigned to pass around the edge of the new embankment. It is also assumed that an existing culvert approximately 90m south of Pool House Farm that passes under the proposed Filly Brook viaduct will be removed and replaced with an open channel. No diversions of the river channel have been proposed.

Production of flood extents

4.3.13 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

4.3.14 Existing LiDAR is assumed to be correct as no other information is available.

4.3.15 Culvert sizes have been assumed in a number of places 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.

4.3.16 Channel widths have been assumed based off LiDAR and site specific photos at crossing points. Channels have been defined on this basis in a number of locations.

4.4 Climate change

4.4.1 The climate change allowance for the Filly Brook is 50% based on the new climate change approach developed by the Environment Agency and published in February 2016.[6]

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[7]), the upper end value for the longest duration was chosen.

4.4.3 The new climate change guidance recommends consideration of the H++ scenario[8]. While these percentages have not been explicitly assessed, the sensitivity for the 20% increase in flow on the 1.0% AEP + CC event is assumed to be representative of an event greater than the H++ scenario.

[6] Environment Agency, *Flood risk assessments: climate change allowances*, https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances
[7] Gov.uk, *Flood Zone and flood risk tables*, https://www.gov.uk/guidance/flood-risk-and-coastal-change#flood-zone-and-flood-risk-tables
[8] 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, an average impact of 10mm is observed across the model extent with a number of locations indicating no impact apart from where the channel has been realigned and the flood bund proposed. Here, an impact of greater than 100mm is observed.

5.1.4 The flood bund activates at higher return periods (1.33% AEP and greater). This causes a significant increase in extent within an area designated as replacement floodplain storage.

5.1.5 The provision of the flood bunds is to prevent flooding of the existing Network Rail infrastructure, observed in the uFMfSW and verified using the hydraulic modelling undertaken for this study.

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 assessed across all open channel and model structures to assess model stability and overall model performance.

6.2.2 Final cumulative mass balance error is within +/-1.0% for all return periods and blockage and sensitivity cases simulated except for the 0.1%AEP which saw cumulative mass balance error of 3.0%. Attempts to rectify this resulted in further model instabilities. As the 0.1%AEP extent does not drive the design of the Proposed Scheme, this has been deemed acceptable at this stage.

6.3 Calibration and validation

6.3.1 There is no gauge situated within an appropriate distance of this location to provide calibration or validation data.

6.3.2 There is no additional anecdotal evidence available for any effective model validation exercise.

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 and uFMfSW.

6.4.2 Flood extents generated closely match the uFMfSW, however, they do not match the Environment Agency Flood Map for Planning as this does not take into account floodplain features such as the existing Norton Bridge to Stone Railway and the M6.

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 in some locations. The effect of increase has greater impact further upstream of the Proposed Scheme at the Yarnfield Lane realignment and flood bund.

6.5.3 Decreasing the roughness by 20% results in a decrease in peak water level throughout the model of approximately 250mm in some locations. The effect of the decrease in roughness is localised to immediately upstream of the Yarnfield Lane realignment and flood bund.

Inflows

6.5.4 An increase in inflow of 20% results in a maximum increase of greater than 100mm upstream of the proposed M6 Meaford viaduct. Increases between 50mm and 100mm are observed at the Filly Brook downstream extent of the model and do not affect the Proposed Scheme. The proposed flood bunds remain functional and are not overtopped.

Downstream boundary

6.5.5 There was no impact in the vicinity of the Proposed Scheme crossing when the downstream boundary was reduced and increased by 20%, with negligible impact of less than 50mm at the Filly Brook downstream boundary. No impact is seen greater than 20m from the downstream extent.

Summary

6.5.6 The sensitivity analysis shows the model is moderately sensitive to changes in flows and roughness values at the proposed Filly Brook viaduct. The changes in the downstream boundary gradient had no impact at the proposed Filly Brook viaduct with minimal impact at the downstream boundary of the model.

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 for all scenarios.

6.6 Blockage analysis

6.6.1 Two blockage scenarios were assessed:

- blockage scenario 1 – 2% blockage at the proposed Filly Brook viaduct; and
- blockage scenario 2 – 50% blockage of the easternmost culvert under the Norton Bridge to Stone Railway (Rail East).

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 Filly Brook 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 Norton Bridge to Stone Railway culvert was represented by reducing the width of the culvert by 50%.

6.6.5 The results of blockage scenario 1 show zero impact to flood levels as the enlarged pier did not enter the floodplain.

6.6.6 The results for blockage scenario 2 indicate that local to the blockage, increases in flood depth up to 1m would be observed. However, this is local to the structure and causes no impact at the proposed Filly Brook viaduct.

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 0.5 seconds for ESTRY and 1 second for the 2D model. This is the suggested approach for a grid size of 2m.

7 Limitations

7.1.1 Land access for new topographic survey was not possible and therefore all channels have been represented in 2D, meaning channel conveyance will not be fully represented in the model; however, this will lead to a conservative estimation of flood risk for the purposes of the Environmental Impact Assessment. Onsite observations have been used to reduce the number of assumptions. 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 No survey data was available for the watercourse and the model has been developed based on the LiDAR provided.

7.1.3 The two flood replacement storage areas between the Stone IMB-R and the Norton Bridge to Stone Railway have not been modelled but instead put in the design to safeguard a future design of the IMB-R. However, the culvert under the M6 throttles at this location so the potential benefit of these areas is not confirmed at this stage.

7.1.4 The small catchment west of the M6 and south of the Norton Bridge to Stone Railway has not been included in the hydrological analysis of this model. Due to the relatively small size of the catchment it is not believed this will have a significant impact.

7.1.5 In both baseline and proposed scenarios, channels that are not clearly defined in the LiDAR have been carved out using appropriate modelling methods. Due to instabilities in the model, the width of these channels had to be set to 4m.

7.1.6 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 Filly Brook to simulate the baseline and Proposed Scheme scenarios and to determine the peak water levels and flows throughout the catchment has been met.

8.1.2 Increases in water level are observed due to the Proposed Scheme reach a maximum of up to 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 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.

8.1.4 At detailed design stage, the hydraulic modelling of the watercourse should be revisited. Topographic survey data of the channel and associated structures should be collected and if preliminary results deem it necessary, this model should then be converted into a linked 1D-2D model. This will provide better representation of the channel conveyance processes and refine the model outputs, allowing the model to be used to confirm flood risk from the Phase 2a scheme.

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: Filly Brook at Yarnfield Impact Map for 5% AEP (1 in 20 year)

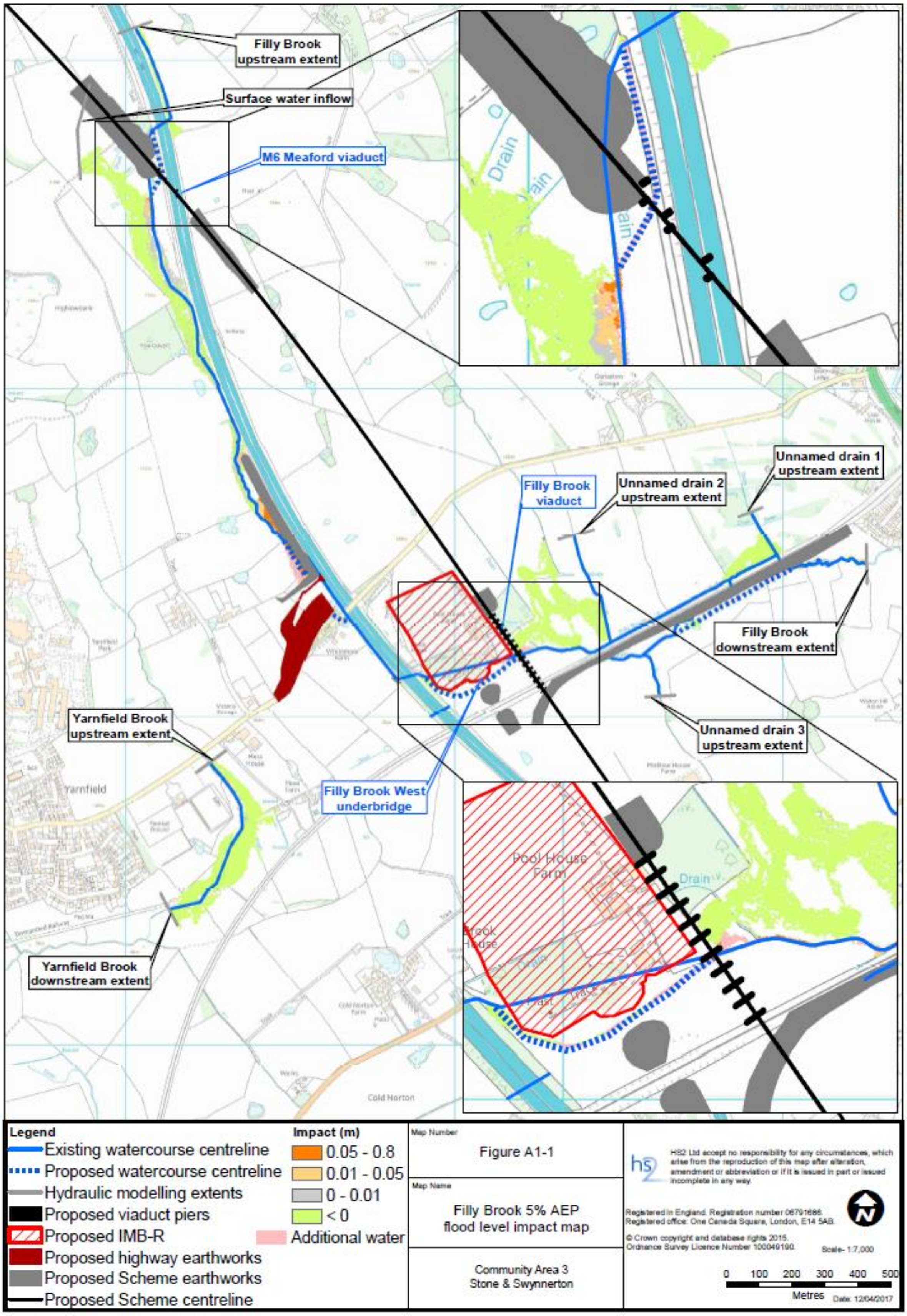
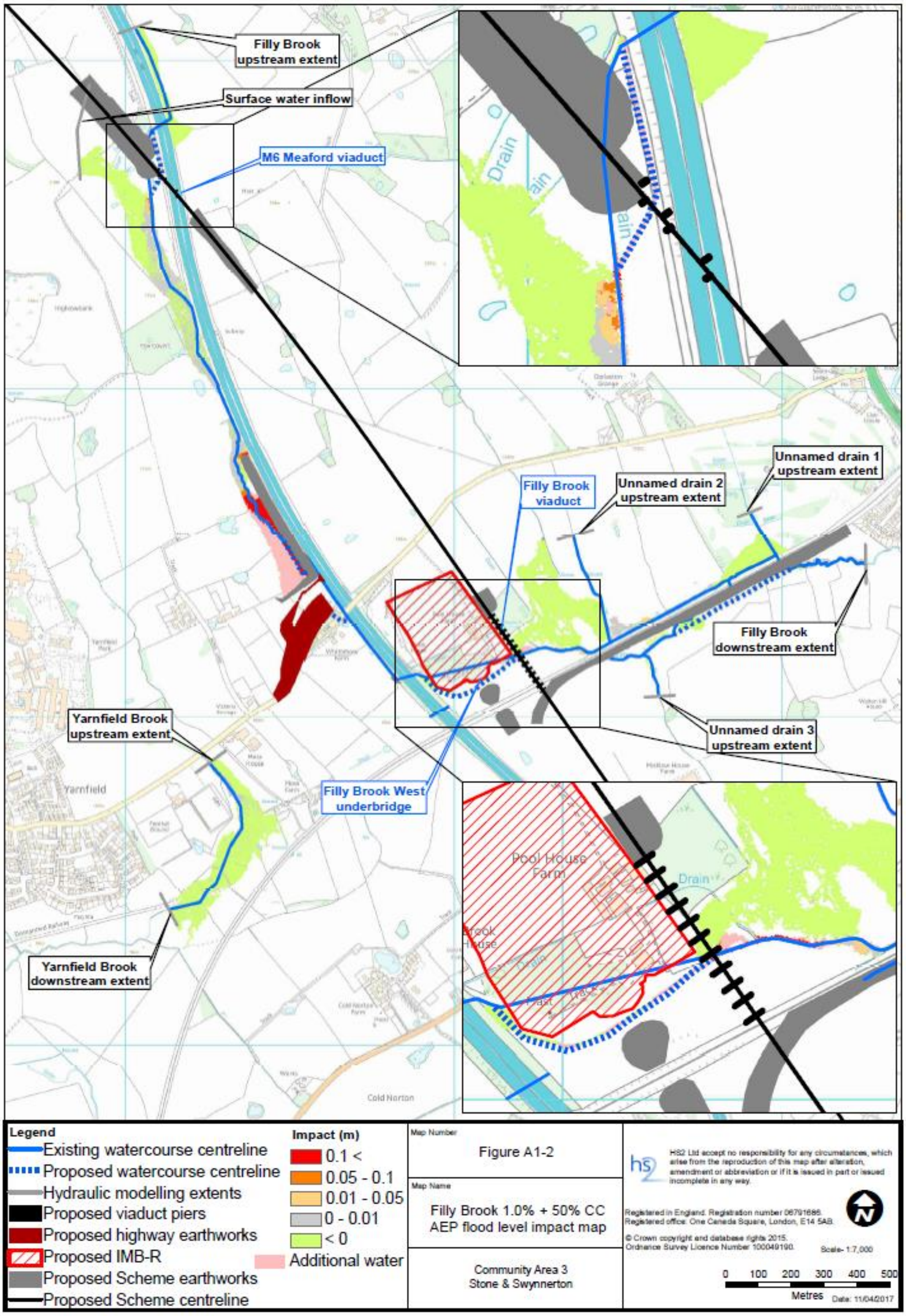


Figure A-2: Filly Brook at Yarnfield Impact Map for 1% AEP + CC (1 in 100 year) plus 50% climate change allowance



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