E100

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

## Background Information and Data

CA1: Fradley to Colton

Hydraulic modelling report - Stockwell Heath (BID-WR-004-004)

July 2017

BID

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High Speed Two (HS2) Limited has been tasked by the Department for Transport (DfT) with managing the delivery of a new national high speed rail network. It is a non-departmental public body wholly owned by the DfT.

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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 Fradley to Colton (CA1) relevant to High Speed Rail (West Midlands - Crewe). The following hydraulic modelling reports are also relevant to the Fradley to Colton area:

- Hydraulic modelling report - Pyford Brook (Background Information and Data 004: BID-WR-004-001);
- Hydraulic modelling report - River Trent and Bourne Brook (Background Information and Data 004: BID-WR-004-002); and
- Hydraulic modelling report - Moreton Brook (Background Information and Data 004: BID-WR-004-003).

1.1.2 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 Fradley to Colton 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 an unnamed watercourse on the Stockwell Heath embankment.

1.2.3 A hydraulic model of the unnamed watercourse was created to simulate the risk of flooding in this location for an approximate 1.2km stretch of the watercourse. This report documents the methods used and discusses the results, assumptions and limitations imposed by them.

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

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 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 an embankment and thus causing a medium level of risk for the design of the project and its impact on the environment, it was proposed that hydrological calculations be undertaken using Revitalised Flood Hydrograph 2 (ReFH2).

## 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 watercourse being modelled is located in the village of Stockwell Heath. Figure 1 shows the modelled extent, with the model upstream boundary situated approximately 250m upstream of Pool Farm and the downstream boundary located approximately 650m downstream of Newlands Lane. Approximately 1.1km of the watercourse has been modelled.

### Hydrological description

2.1.2 The unnamed watercourse originates north of the village of Stockwell Heath, a short distance upstream of the model extent. The watercourse drains from north-east to south-west into Moreton Brook, eventually reaching the River Trent.

2.1.3 The catchment area contributing to the downstream boundary of the hydraulic model is $2.0km^2$ and is predominantly rural.

2.1.4 There are no gauging stations present within the Stockwell Heath catchment.

2.1.5 Standard annual average rainfall for the catchment at the model downstream boundary is 703mm.

### Railway alignment

2.1.6 The route of the Proposed Scheme crosses the study area from east to west, passing over the unnamed watercourse on the Stockwell Heath embankment. Further detail on this structure can be found in Map CT-06-208 in the Volume 2 Map Book.

### Flood mechanisms

2.1.7 There is no existing Environment Agency flood zone map for this catchment. While the Environment Agency updated Flood Map for Surface Water (uFMfSW) shows a number of surface water flow paths, it does not indicate that any property within Stockwell Heath is in the flood extent.

2.1.8 There are a number of culverts where farm tracks and roads cross the watercourse. Newlands Lane Bridge is shown to flood in the uFMfSW extents but this mapping may not take account of fluvial structures such as small culverts.

2.1.9 Surface water flow paths shown in Figure 1 have been used to identify the three major flow paths into the catchment.

## 2.2 Existing understanding of flood risk

### Sources of information

2.2.1 Sources of Environment Agency data were assessed as below:

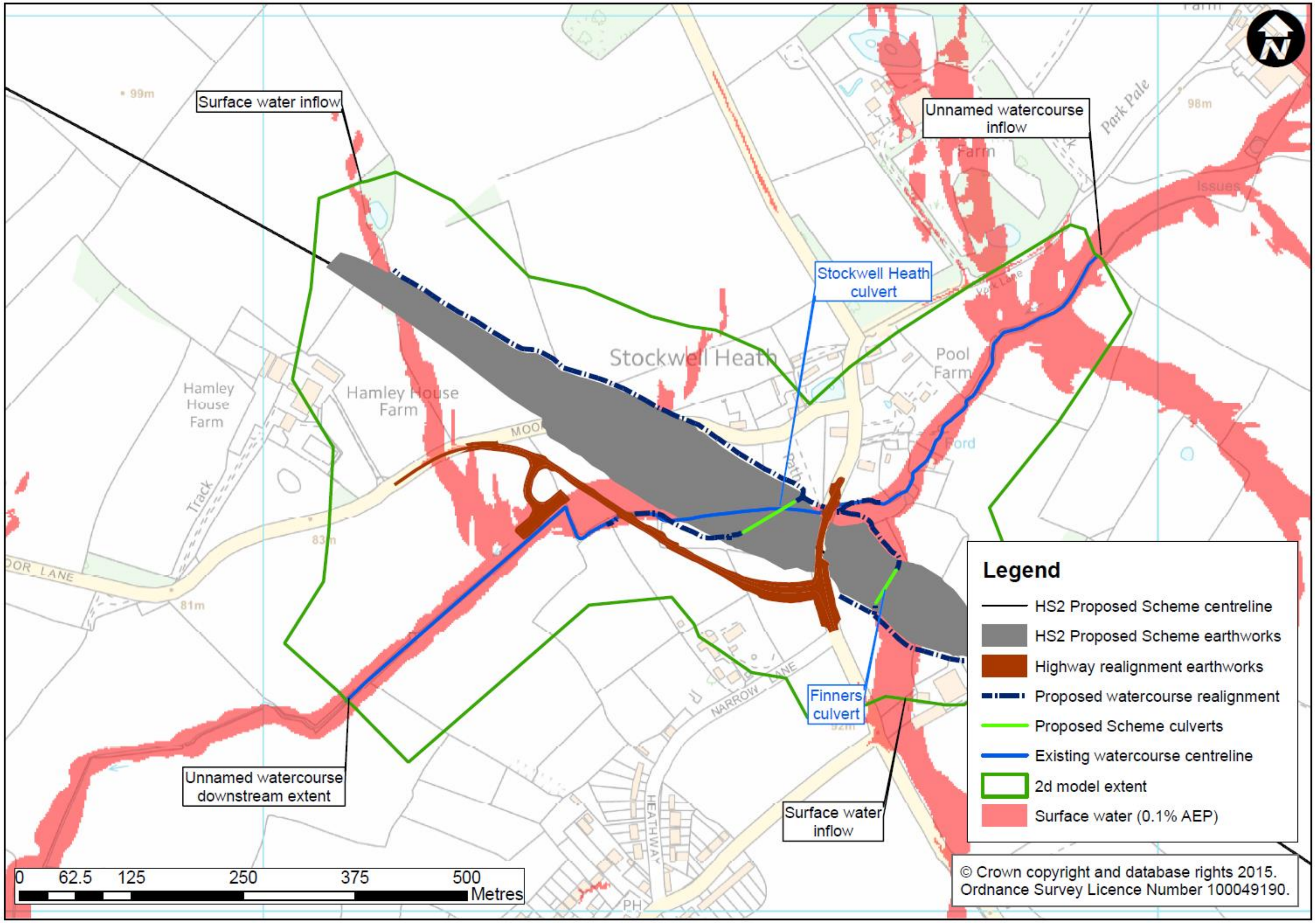
- Flood Map for Planning (Rivers and Sea)[2]; and
- updated Flood Map for Surface Water (uFMfSW)[3].

2.2.2 The uFMfSW shows that the main flow paths are confined largely to the channel with additional flow paths to the north-west and to the south-east, both of which are intersected by the Proposed Scheme as shown in Figure 1.

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

[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 uFMfSW (0.1%AEP) at Stockwell Heath



## 2.3 Availability of existing hydraulic models

2.3.1 There were no existing models for the unnamed watercourse at Stockwell Heath identified for this study.

## 2.4 Site visit

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

2.4.2 Several structures were visited along the unnamed watercourse 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.

# 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 around the Stockwell Heath embankment.

## 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 study area was produced using 200mm LiDAR flown specifically for HS2 Ltd and covers 500m either side of the route centreline.

# 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 Given the very small size of the catchments (under $2km^2$) and the absence of recorded flows within the catchment or in its vicinity, FEH Revitalised Rainfall Runoff Method, version 2 (part of ReFH2) was used to produce a 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.

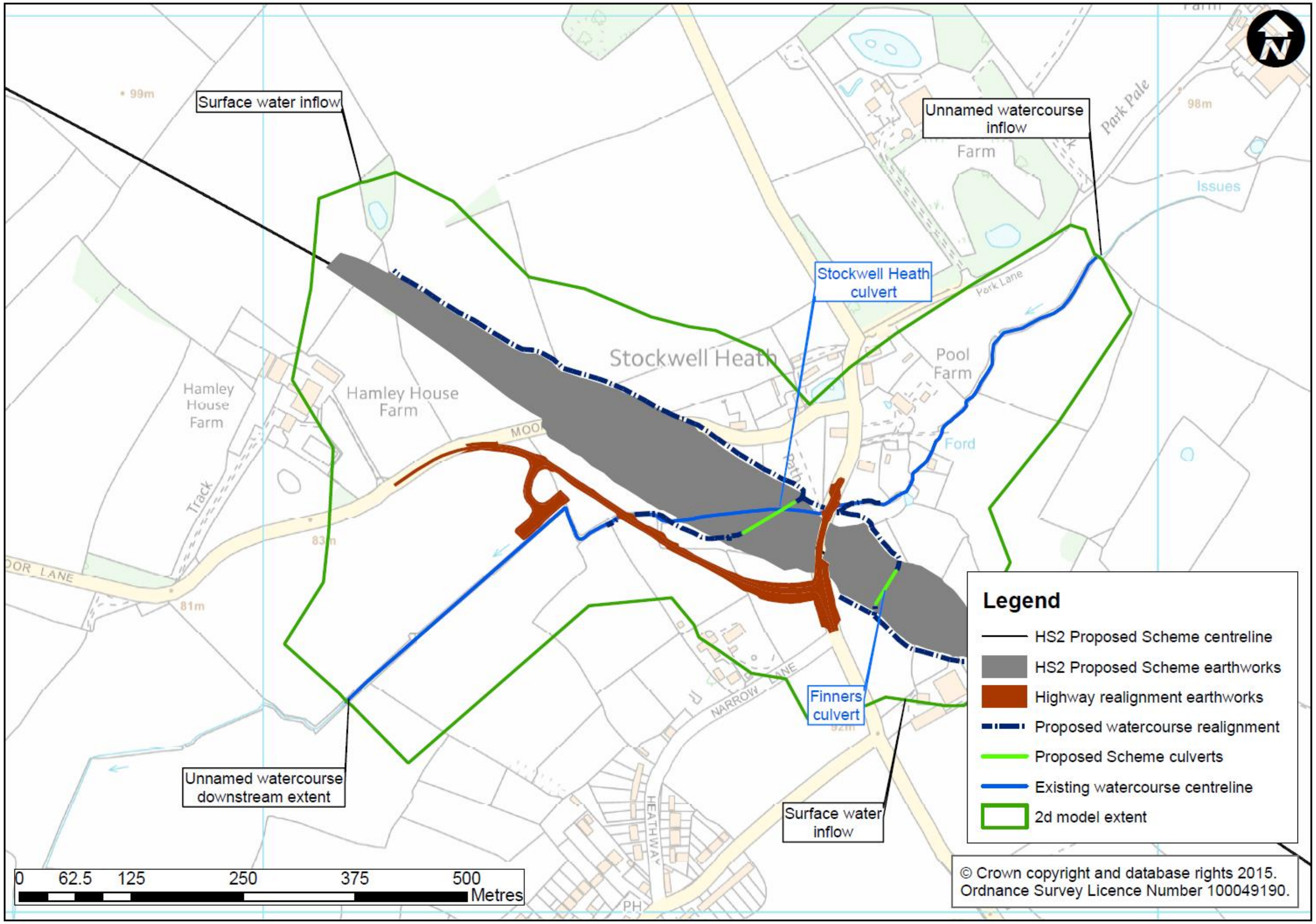
4.1.3 The design hydrographs used for the hydraulic modelling stage were generated using ReFH2 as the FEH Statistical method does not produce time series, just peak flows. The values were scaled so the peak flow for each return period matched that selected as the design value.

4.1.4 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 | | |
|---|---|---|---|---|---|
| | | | Unnamed watercourse inflow | Surface water inflow (east) | Surface water inflow (west) |
| Flood peak ($m^3/s$) | 50% | 2yr | 0.60 | 0.16 | 0.13 |
| | 20% | 5yr | 0.84 | 0.23 | 0.18 |
| | 5.0% | 20yr | 1.27 | 0.35 | 0.27 |
| | 1.33% | 75yr | 1.85 | 0.51 | 0.40 |
| | 1.0% | 100yr | 2.00 | 0.55 | 0.43 |
| | 1.0% + CC | 100yr + CC | 3.00 | 0.77 | 0.60 |
| | 0.5% | 200yr | 3.00 | 0.77 | 0.60 |
| | 0.1% | 1000yr | 2.41 | 0.67 | 0.52 |

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 and the inverts were taken from available LiDAR information.

### 2D Representation

4.2.2 The cell size of the model was set as 2m. Cell size for the 2D model grid was optimised to ensure appropriate representation of the flow pathways whilst maintaining reasonable run times.

### Inflow boundaries

4.2.3 The study area has three inflows. Of these three inflows, one is for a fluvial source and the other two are for mapped surface water flow paths. These are shown in Figure 2.

### Downstream boundary

4.2.4 A normal depth boundary was used at the downstream extent of the unnamed watercourse, 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.

4.2.5 A normal depth slope of 0.0125 m/m (1 in 80) was used for both boundaries. This was derived from LiDAR.

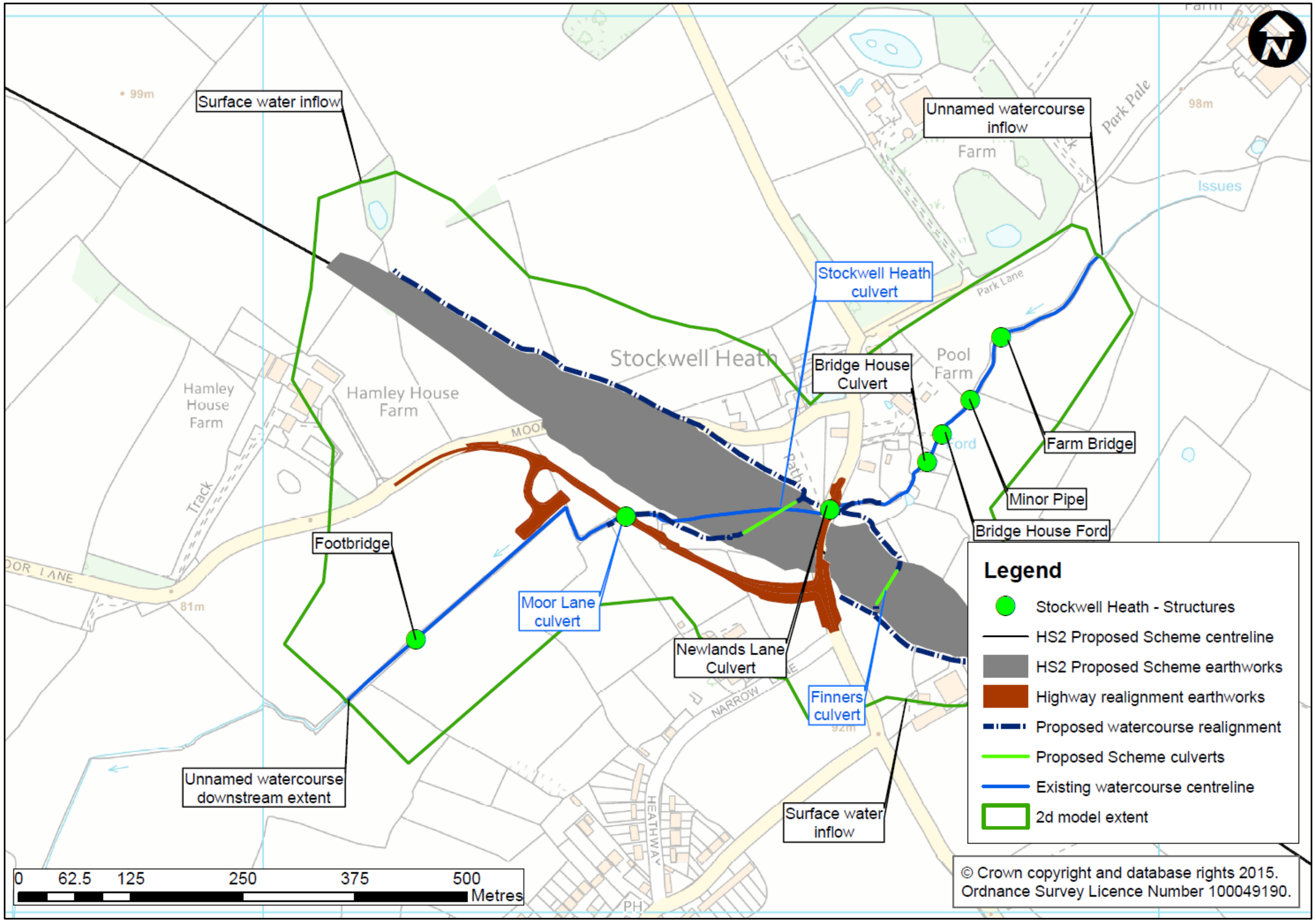
### Key structures

4.2.6 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 the unnamed watercourse at Stockwell Heath

| Structure reference | Structure description | Modelling representation and justification |
|---|---|---|
| Bridge House culvert | Small circular culvert.<br><br>10.0m (L) x 0.6m (D) | ESTRY circular culvert. Dimensions obtained from site visits. |
| Newlands Lane culvert | Small road bridge with circular culvert.<br><br>7.0m (L) x 0.9m (D) | ESTRY circular culvert. Dimensions obtained from site visits. |

Figure 3: Existing and proposed structures within the model extent



### Roughness

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

4.2.8 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.

4.2.9 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:

### Topographic changes

4.3.2 The Proposed Scheme Stockwell Heath embankment, Moor Lane diversion, Newlands Lane regrading and all drainage channels and the watercourse realignment have been included using the relevant heights for embankment crest and road alignment. These are based on the design as shown in Map CT-06-208 in the Volume 2 Map Book.

4.3.3 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

4.3.4 Replacement floodplain storage has not been included in the design at this location due to the negligible impacts at this stage.

### Proposed Structures

4.3.5 Three structures were included in the Proposed Scheme model, as outlined in Table 3 and presented in Figure 3.

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

Table 3: Proposed Scheme structures

| Structure reference | Structure description | Modelling representation and justification |
|---|---|---|
| Stockwell Heath culvert (SH_199n269) | Rectangular culvert under the Proposed Scheme.<br><br>69.0m (L) x 3.7m (W) x 1.05m (H) | 1D culvert structure. |
| Finners culvert (Fnrs_199n094) | Rectangular culvert under the Proposed Scheme.<br><br>44.0m (L) x 1.75m (W) x 1.05m (H) | 1D culvert structure. |
| Moor Lane culvert (MOOR_LANE) | Rectangular culvert under the Proposed Scheme.<br><br>19.0m (L) x 3.0m (W) x 1.2m (H) | 1D culvert structure. |

### Channel realignments and diversions

4.3.6 In the Proposed Scheme the Stockwell Heath embankment will cross the unnamed watercourse over an area that includes the existing Newlands Lane culvert. The watercourse is to be realigned, with the Newlands Lane culvert being moved 5m to the north-east. From this point the watercourse is to take a north-westerly course before passing south-west beneath the Stockwell Heath embankment via the Stockwell Heath culvert. Downstream of the culvert, the watercourse flows westwards before re-joining the existing channel and passing beneath the diverted Moor Lane. No diversions of the channel have been proposed.

### Production of flood extents

4.3.7 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

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

4.3.9 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 this catchment 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 5.0% AEP and 1.0% + CC AEP. These flood maps are reported in Appendix A.

5.1.3 Increased levels are observed within a proposed perimeter drain near agricultural buildings at Finners Hill on the south side of the Stockwell Heath embankment, upstream of the proposed Finners culvert. This results in an increased flood level of up to 300mm for this location within 10m of the embankment edge. This is contained within the perimeter drain.

5.1.4 Additional impacts were observed upstream of Newlands Lane realignment and relocated culvert in 1.0% + CC and 0.1% AEP events. This impact is greater than 100mm. The watercourse has been realigned through this area to pass beneath the Proposed Scheme in a more perpendicular manner. Channelisation of dispersed surface flows through Finners Culvert contributes to this impact. The increased levels are absolute height levels, in metres above Ordnance Datum (mAOD) and because the proposed Newlands Lane realignment is at a greater elevation than the existing road absolute levels appear higher than those of the existing conditions. It is important to note that the peak water depth on Newlands Lane has decreased in the Proposed Scheme due to the raising of the road, and consequently hazard on Newlands Lane has also been reduced under the Proposed Scheme.

5.1.5 For return periods of a greater magnitude than the 5% AEP, increased flood levels were observed downstream of the Moor Lane diversion. A diversion of dispersed surface flows along the northern edge of the Stockwell Heath embankment results in an increased flood level of up to 180mm for this location due to channelisation of these surface flows.

5.1.6 Additional impacts were observed for the 1.0% + CC AEP event directly upstream of the Moor Lane diversion. This impact is greater than 100mm. The watercourse here is the same as in existing conditions, but conveys slightly higher flows due to the surface water flows being channelised as discussed in 5.1.5. Flood water fills the floodplain between the Stockwell Heath embankment and the Moor Lane road realignment on the right bank at this location however this land is designated as planting in the Proposed Scheme.

5.1.7 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 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% for all return periods and blockage and sensitivity cases simulated.

## 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 the uFMfSW.

6.4.2 Flood extents generated for this study are similar to the uFMfSW.

## 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

6.5.3 The model is sensitive to increases in roughness, with a 20% increase resulting in increases in water level of 50-100mm in localised locations. The general increase is 10-50mm.

6.5.4 Decreasing the roughness by 20% results in a decrease in water level of approximately 10-50mm in some localised locations. A negligible change in extent is observed.

### Inflows

6.5.5 An increase in inflow of 20% results in an increase of greater than 100mm downstream of the proposed Stockwell Heath culvert. The general increase across the model extent is 10-50mm with areas of 50-100mm impact.

### Downstream boundary

6.5.6 There was no impact to the proposed Stockwell Heath culvert when the downstream boundary was reduced and increased by 20%, with negligible impact of 10-50mm at the downstream boundary. No impact is seen greater than 5m from the downstream extent.

### Summary

6.5.7 The sensitivity analysis shows the model is fairly insensitive to changes in flows and roughness values at the proposed Stockwell Heath embankment. The changes in the downstream boundary gradient had no impact at the Stockwell Heath embankment with minimal impact at the downstream boundary of the model.

6.5.8 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 Four blockage scenarios were assessed:

- blockage scenario 1 – 50% blockage of realigned culvert (Moor Lane culvert);
- blockage scenario 2 – 50% blockage of the Proposed Scheme culvert (Stockwell Heath culvert);
- blockage scenario 3 – 50% blockage of the Proposed Scheme culvert (Finners culvert); and
- blockage scenario 4 – 50% blockage at the realigned culvert (Newlands Lane 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 blockages of Moor Lane culvert, the Proposed Scheme Stockwell Heath culvert, the Proposed Scheme Finners culvert and the realigned Newlands Lane culvert were represented by reducing the width of the culvert by 50%.

6.6.4 The results for blockage scenario 1 show localised increases of in peak water level of up to 300mm upstream of Moor Lane and overtopping of the road. Impacts of 0-10mm are observed at the downstream model extent.

6.6.5 The results for blockage scenario 2 indicate that local to the blockage, increases in peak water level up to 1.3m would be expected. This increase is observed on the realigned Newlands Lane and for 60m upstream before returning to existing conditions.

6.6.6 The results for blockage scenario 3 show localised increases in peak water level of up to 300mm upstream of Finners culvert. These increases are largely confined to the perimeter drain.

6.6.7 The results for blockage scenario 4 indicate that local to the blockage, increases in peak water level of up to 50-100mm would be expected, with a very localised increase of 800mm. This increase is observed on the realigned Newlands Lane. The Stockwell Heath culvert is affected on its upstream face.

6.6.8 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 extent of the model is slightly limited upstream due to LiDAR availability. Only 5m LiDAR was available in this area but it was unsuitable due to its poor accuracy. Therefore, the upstream boundary was restricted to the boundary of the 200mm LiDAR.

7.1.4 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 Stockwell Heath to simulate the baseline and Proposed Scheme scenarios; to determine the peak water levels and flows throughout the catchment has been met.

8.1.2 Increases in water level caused by the Proposed Scheme are in excess of 100mm upstream of the Newlands Lane realignment however the hazard on the road has reduced.

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: Unnamed watercourse at Stockwell Heath Impact Map for 5%AEP (1 in 20 year)

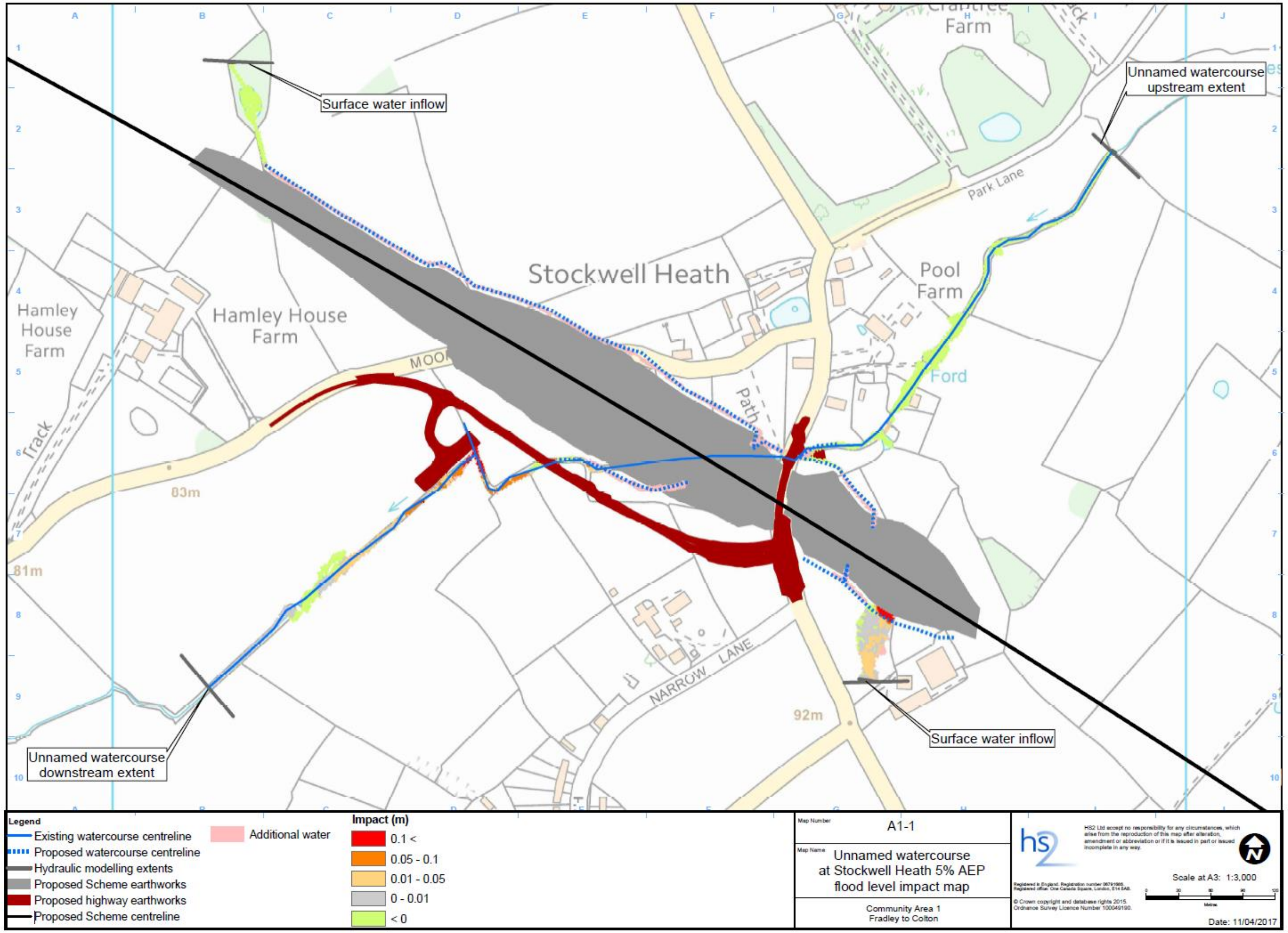
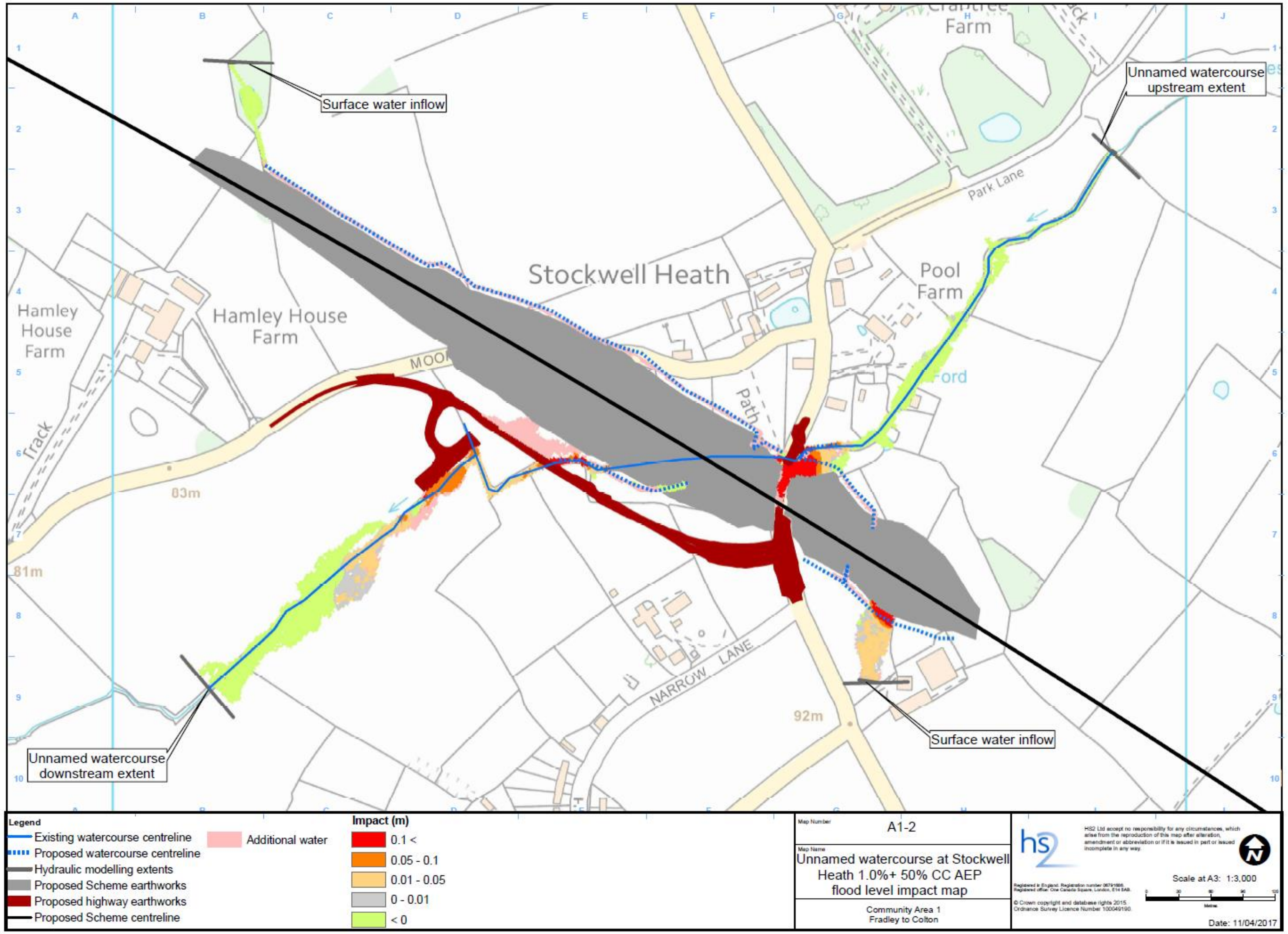


Figure A-2: Unnamed watercourse at Stockwell Heath Impact Map for 1%AEP (1 in 100 year) plus 50% climate change allowance



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