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HS2

High Speed Rail (Crewe – Manchester) Environmental Statement

Volume 5: Appendix WR-006-00002

Water resources and flood risk

MA04: Broomedge to Glazebrook

Hydraulic modelling report - Manchester Ship Canal

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Department for Transport

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High Speed Two (HS2) Limited
Two Snowhill
Snow Hill Queensway
Birmingham B4 6GA

Telephone: 08081 434 434

General email enquiries: HS2enquiries@hs2.org.uk

Website: www.hs2.org.uk

A report prepared for High Speed Two (HS2) Limited:

ARUP+ ERM | FOSTER + PARTNERS | JACOBS
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MWJV
Mott MacDonald | WSP

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1 Introduction

1.1 Background

1.1.1 This appendix presents the results of the hydraulic modelling carried out for the Manchester Ship Canal, a tributary of the Mersey Estuary. The Manchester Ship Canal runs through the Broomedge to Glazebrook (MA04) area.

1.1.2 The hydraulic modelling has been used to inform the flood risk assessment (Volume 5: Appendix WR-005-0MA04) which includes the Broomedge to Glazebrook area.

1.1.3 There are no other hydraulic modelling reports relevant to this area.

1.1.4 The water resources and flood risk assessments include both route-wide and community area specific appendices. The route-wide appendices comprise:

- a Water Framework Directive (WFD) compliance assessment (Volume 5: Appendix WR-001-00000); and
- a Draft water resources and flood risk operation and maintenance plan (Volume 5: Appendix WR-007-00000).

1.1.5 For the Broomedge to Glazebrook area the Water resources assessment (Volume 5: Appendix WR-003-0MA04) should also be referred to.

1.1.6 Additional information is included in Background Information and Data (BID):

- Water resources assessment baseline data (BID WR-004-0MA04)[1]; and
- Water Framework Directive compliance assessment baseline data for the Proposed Scheme (BID WR-002-00001)[2].

1.2 Aims

1.2.1 The aim of this study was to develop a hydraulic model of a section of the Manchester Ship Canal around the proposed crossing location to simulate peak flood levels, with and without the Proposed Scheme. This report also aims to document the methods used, the results, assumptions and limitations.

1.2.2 The outputs from the study have been used to inform in particular the flood risk assessment for the Broomedge to Glazebrook area, which is reported in Volume 5 of the Environmental Statement. The hydraulic model has also informed the preliminary design of the Proposed

[1] High Speed Two Ltd (2022), High Speed Rail (Crewe – Manchester), *Background Information and Data, Water resources assessment baseline data,* BID WR-004-0MA04. Available online at: http://www.gov.uk/government/collections/hs2-phase-2b-crewe-manchester-environmental-statement.

[2] High Speed Two Ltd (2022), High Speed Rail (Crewe – Manchester), *Background Information and Data, Water Framework Directive compliance assessment data,* BID WR-002-00001. Available online at: http://www.gov.uk/government/collections/hs2-phase-2b-crewe-manchester-environmental-statement.

Scheme, with the specific objectives of ensuring that the design of the viaduct takes account of flood risk issues, as detailed in the Environmental Impact Assessment Scope and Methodology Report (SMR) Technical Note: Flood risk (see Volume 5: Appendix CT-001-00001).

1.3 Objectives

1.3.1 The objectives of this study were to:

- develop an understanding of existing hydraulic conditions at the proposed watercourse crossing, including channel and floodplain characteristics, hydraulic structures and flow paths, through desk study and, where possible, by conducting a site visit;
- estimate peak flows, and hydrographs, at the Manchester Ship Canal viaduct location, associated with the following Annual Exceedance Probabilities (AEP): 5.0% AEP, 1.0% AEP, 1.0% + climate change (CC), and 0.1% AEP; and
- develop a hydraulic model, using the information available at this stage, to estimate the flood levels associated with these peak flows along the study reach, both before and after construction of the Proposed Scheme.

1.4 Justification of approach

1.4.1 A risk-based approach has been adopted, whereby the level of modelling detail supporting the flood risk assessment at a specific site reflects the magnitude of the likely impacts of the Proposed Scheme on peak flood levels and the sensitivity of nearby receptors to flooding.

1.4.2 The Manchester Ship Canal is a canalised river and it is managed by Peel Holdings. Flood zone information is available for the Manchester Ship Canal and specifically at the Manchester Ship Canal viaduct. There are many local receptors, including vulnerable receptors, within the flood zones upstream and downstream of the Manchester Ship Canal viaduct.

1.4.3 An Environment Agency 2010 Flood Modeller Pro (FMP) model[3] of the full extent of the Manchester Ship Canal is available. Input hydrographs in the Environment Agency model were derived using the Revitalised Flood Hydrograph (ReFH) method within the FMP software, with an adjustment factor to match the peak flows derived from the Flood Estimation Handbook (FEH) statistical method. This model is extensive, therefore only its relevant water level and flow estimates have been used as boundary conditions in a new shorter 2D model of the relevant section of the canal. The 2D model uses the Infoworks ICM (Integrated Catchment Modelling) software and covers a sufficient distance upstream and downstream of the crossing, to give confidence that modelled results at the Manchester Ship Canal viaduct would not be affected by the model boundary conditions.

[3] JBA Consulting (2009), *The Environment Agency NW Region (South Area) Manchester Ship Canal model.*

1.5 Scope

1.5.1 This hydraulic modelling aimed to be detailed enough to allow assessment of the crossing location, to allow the management of flood risk.

1.5.2 This report focuses on a 6.6km reach of the Manchester Ship Canal extending upstream and downstream of the crossing of the Proposed Scheme. The Proposed Scheme crossing of the Manchester Ship Canal comprises the Manchester Ship Canal viaduct. A description of the crossing is provided in Section 2.

1.5.3 The scope of the report includes:

- discussion of all relevant datasets, in terms of their quality and gaps;
- details of the hydrological analysis undertaken, the approach used and the calculation steps;
- details of how the hydrological analysis has been integrated with the hydraulic modelling;
- identification and justification of the hydraulic modelling methodology selected; and
- a description of the hydraulic modelling parameters, assumptions, limitations and uncertainty.

2 Qualitative description of flood response

2.1 Sources of information

2.1.1 The following sources of information were obtained from the Environment Agency:

- Environment Agency hydraulic model of the Manchester Ship Canal (2010)[3];
- flood map for planning (rivers and sea)[4];
- risk of flooding from surface water (RoFSW)[5] map; and
- flood defence asset information.

2.1.2 Additional information from the lead local flood authorities (LLFA) and publicly available sources included:

- Manchester City, Salford City and Trafford Councils Level 2 Hybrid Strategic Flood Risk Assessment (SFRA), Final March 2011[6];
- Warrington Borough Council (WBC) Preliminary Flood Risk Assessment (2017)[7];
- Trafford Local Flood Risk Management Strategy (LFRMS)[8]; and
- WBC LFRMS (2017)[9].

2.2 Description of the study area

Study area

2.2.1 Figure 1 shows the Manchester Ship Canal within the study area and the Environment Agency flood maps. The upstream boundary of the model is located at Irlam, just downstream from the railway crossing between Irlam and Flixton Stations, which is approximately 3.8km upstream from the Proposed Scheme. The downstream boundary is

[4] Environment Agency (2021), Flood map for planning. Available online at: https://flood-map-for-planning.service.gov.uk.

[5] Environment Agency (2021), Long-term flood risk information. Available online at: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map.

[6] JBA Consulting (2011), *Manchester City, Salford City and Trafford Councils Level 2 Hybrid SFRA*. Available online at: https://www.trafford.gov.uk/planning/strategic-planning/docs/manchester-salford-and-trafford-councils-level-2-hybrid-sfra-level-1-sfra-march-2011.pdf.

[7] Warrington Borough Council (2017), *Warrington Preliminary Flood Risk Assessment.* Available online at: https://www.warrington.gov.uk/sites/default/files/2019-10/preliminary_flood_risk_assessment_pfra_2017_-_2023.pdf.

[8] Trafford Council (2014), *Trafford Local Flood Risk Management Strategy.* Available online at: https://www.trafford.gov.uk/planning/strategic-planning/docs/lfrms-trafford-final-2014.pdf.

[9] Warrington Borough Council (2017), *Warrington Local Flood Risk Management Strategy.* Available online at: https://www.warrington.gov.uk/sites/default/files/2019-10/local_flood_risk_management_strategy_2017_v7_af_approved.pdf.

located at Biffa Rixton before the confluence with the River Bolin, 2.8km downstream of the Proposed Scheme.

2.2.2 The primary hydraulic controls of the Manchester Ship Canal in the modelled reach are two crossings of the canal. The first crossing is of a dismantled railway bridge which is located 1.9km upstream of the Proposed Scheme. The second crossing is the Warburton Bridge Road crossing which is located 0.9km downstream of the Proposed Scheme.

Hydrological description

2.2.3 The Manchester Ship Canal is a canalised section of the River Mersey. The catchment consists of the area between Woden Street Bridge and the Mersey estuary which drain into the canal. This is an area of approximately 3,000km² stretching from the Pennine Hills to the Cheshire Plain. The catchment is characterised by the heavily urbanised Greater Manchester conurbation and the towns of Rochdale, Bury, Warrington and Runcorn. Along the canal itself, the steep upper (Pennine) reaches of the Rivers Irwell, Irk, Medlock and Mersey give way to a more low-lying and gently sloping built up landscape where industrial, commercial and residential development has encroached as far as (and shares land boundaries with) the river's edge. Glaze Brook enters Manchester Ship Canal, upstream of the Proposed Scheme Manchester Ship Canal viaduct. The local catchment area is shown in Figure 2.

2.2.4 There is only one Environment Agency operated river gauge (Latchford Cantilever Gauging Station (GS)) in the canal itself. It is understood however, that the canal operation has ultrasonic level monitors at the locks/sluices and at Rixton Junction, as part of the canal water level control arrangements. Thus, with the Latchford Cantilever and level monitors at Mode Wheel, Barton, Irlam, Latchford and Eastham Locks/Sluices and at Rixton Junction, there are effectively seven gauging stations on the canal.

Proposed Scheme

2.2.5 The Proposed Scheme crossing is a 1.9km long viaduct over the Manchester Ship Canal. An overview of the Manchester Ship Canal viaduct can be seen in Figure 3 below. Further details of the Proposed Scheme can be found in Volume 2, MA04 Map Book: map CT-06-325.

Features of note

2.2.6 For the Manchester Ship Canal viaduct piers and their foundations encroach into the edge of the canal, one on the north bank and one on the south bank. To protect these viaduct piers from ship collision, retaining walls are proposed on both banks of the canal. The wall along to the north bank of the canal is approximately 197m long, whilst the wall on the south bank is approximately 148m long. These walls result in a localised narrowing of the Manchester Ship Canal.

Figure 1: Environment Agency flood zones and RoFSW at the Manchester Ship Canal

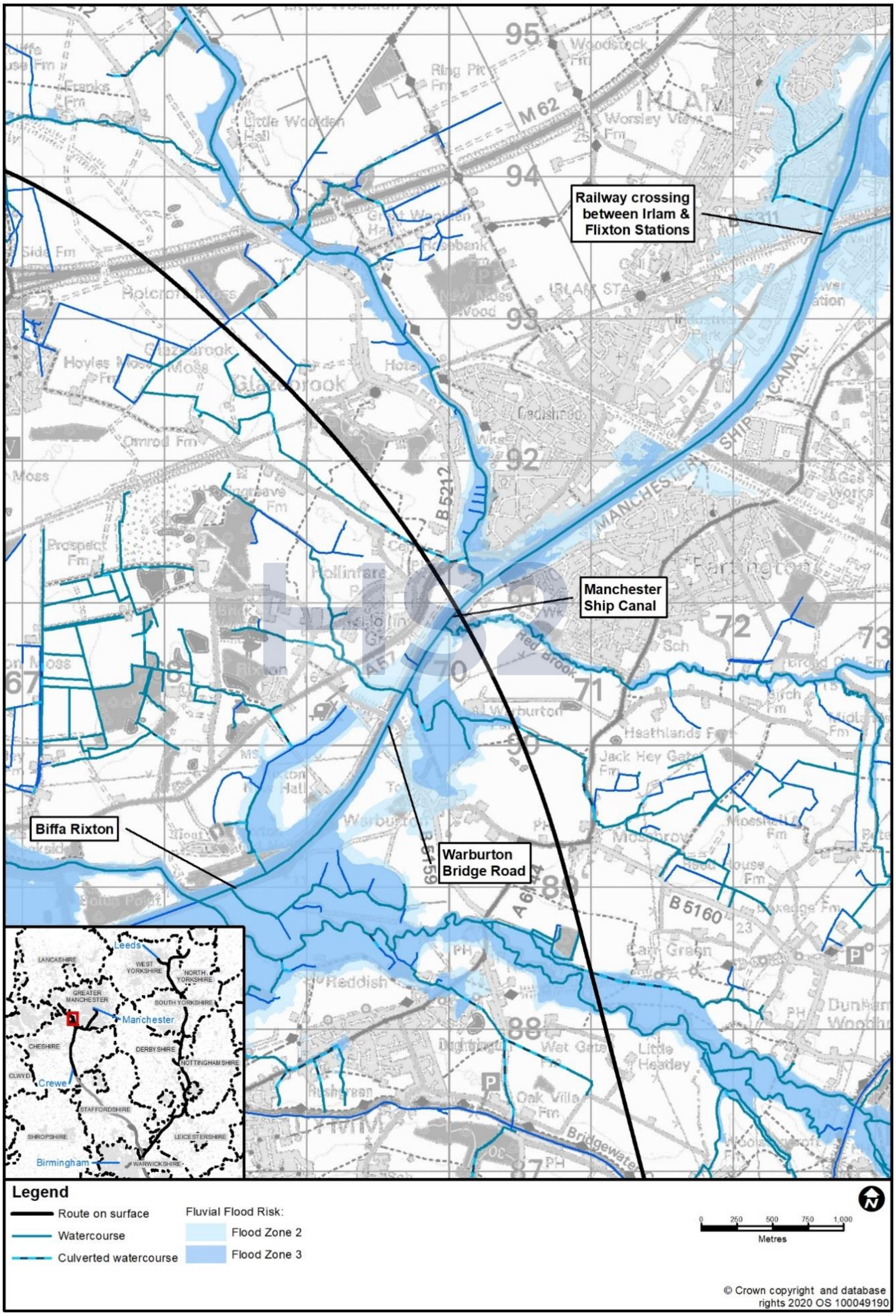


Figure 2: Manchester Ship Canal local catchment area

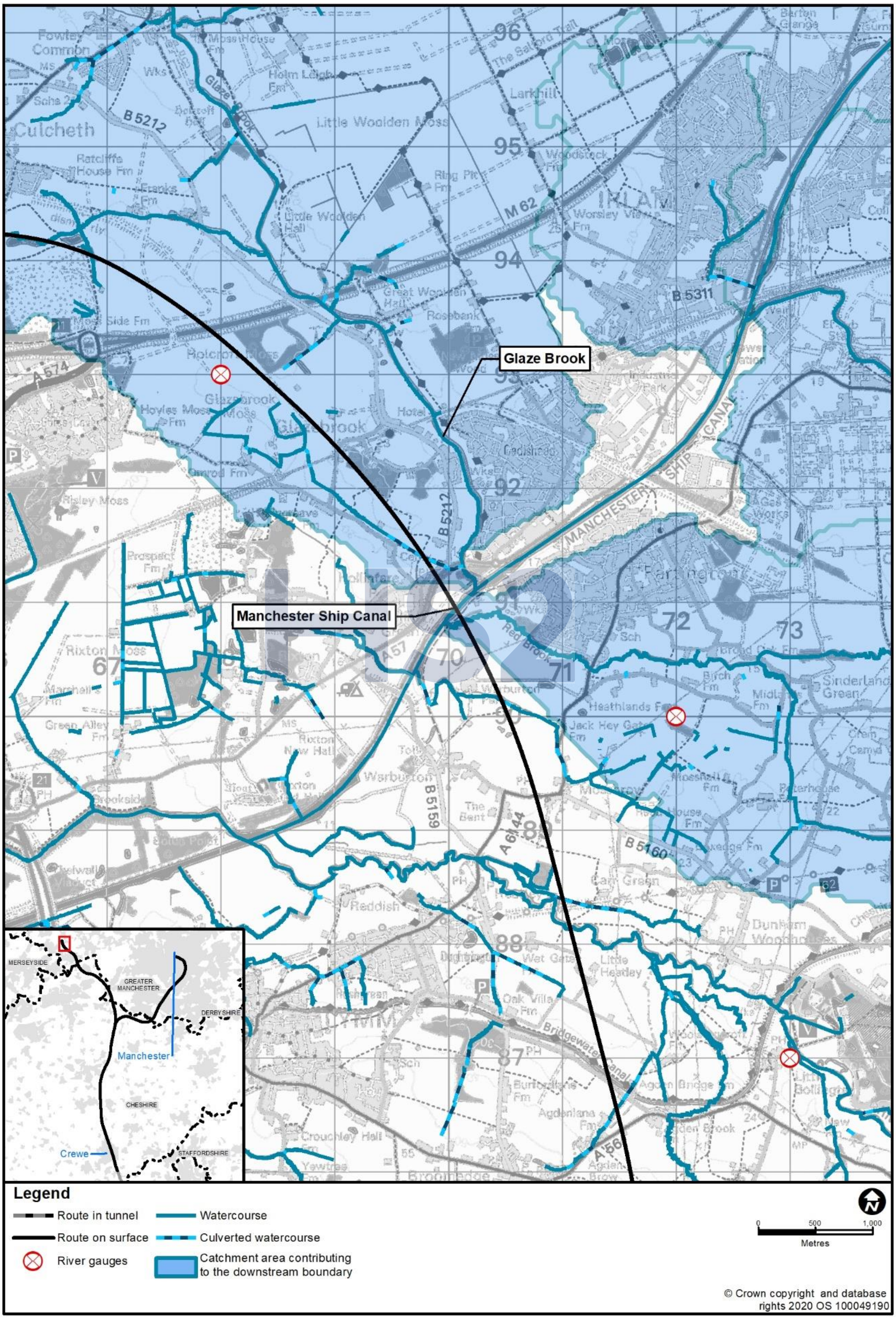
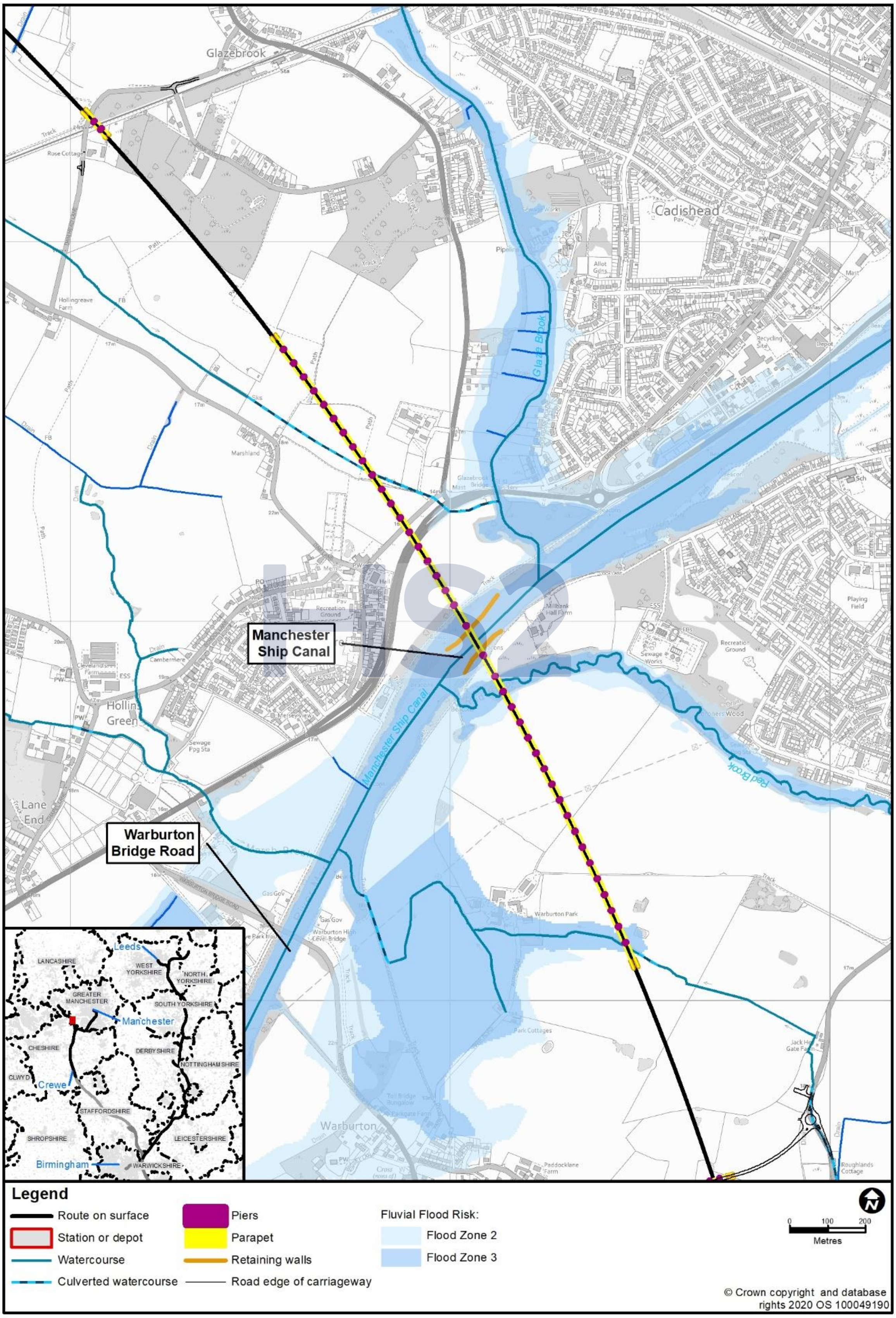


Figure 3: Manchester Ship Canal viaduct Proposed Scheme design



2.3 Existing understanding of flood risk

Flood mechanisms

2.3.1 The Proposed Manchester Ship Canal viaduct crosses over the Environment Agency Flood Zones 2 (0.1%AEP) and 3 (1.0% AEP), as shown in Figure 1. The inspection of the flood zones in the vicinity to the Manchester Ship Canal viaduct indicate that Flood Zone 3 remains within the canal banks.

2.3.2 Informal defences are in place along parts of the Manchester Ship Canal in the form of raised embankments around the surrounding ground or raised roads. These have been confirmed from the river cross sections (surveyed in the 1990s) that were utilised in the previous Environment Agency 2010 FMP model[3]. For extreme flood events, overtopping of the canal is anticipated at low points in the informal defences along both sides of the canal.

2.3.3 Downstream of the proposed crossing Flood Zone 2 covers an extensive area. This area is defined using the results of hydraulic modelling assuming the flood defences are not present and historical records.

Analysis of historical flooding

2.3.4 Historical flooding records[10] indicate that since the completion of the canal in 1894, no major flooding incidents have been recorded along the canal. However, flooding has been recorded on a number of its tributaries, specifically in 1946 and 1958. There are no records of overtopping of the Manchester Ship Canal in recent years including the January 2021 flood event.

Availability of existing hydraulic models

2.3.5 An existing Environment Agency 2010 FMP model[3] was available for the Manchester Ship Canal and relevant elements from that model (mainly river cross section data and hydrological estimates) have been used to inform a 2D Infoworks ICM model for this study. A digital terrain model was created using the river cross section data points.

2.4 Site visit

2.4.1 At this stage no topographic survey or site visit were undertaken to inform the proposed hydraulic analysis. The hydraulic model will be updated at the detailed design stage, in

[10] Section 19 of the Flood and Water Management Act 2010 sets out the requirement for that on becoming aware of a flood in its area, a LLFA must investigate and report on which risk management authorities have relevant flood risk management functions and whether each authority has exercised those functions in response to the flood.

accordance with the HS2 Ltd requirements, and a site visit will be undertaken by a hydraulic modeller to develop a site-specific topographic survey brief.

3 Model approach and justification

3.1 Model conceptualisation

3.1.1 The narrowing of the Manchester Ship Canal at the Manchester Ship Canal viaduct may result in increased flow velocities within the channel and potential scour of the canal. Therefore, a 2D model of the canal is considered to be appropriate, as it will allow for the analysis of any increases in velocity within the canal (both along its length and across the watercourse from one bank to the other) due to the proposed narrowing of the canal at the crossing.

3.1.2 The 2D model uses the Infoworks ICM software and has been created from the geo-referenced cross section data within the Environment Agency 2010 FMP model[3]. These cross sections were undertaken in the 1990s. This is considered appropriate as the river does not change shape significantly between cross sections or over time. The distance between cross sections vary between 50m where some change in cross section shape is visible and up to 400m where the change in shape is relatively small.

3.1.3 The 2D model covers a total length of 6.6km. The model has been extended sufficiently upstream and downstream of the Proposed Scheme to ensure that the boundaries have no impact on peak water levels at the location of the Proposed Scheme.

3.1.4 A review of the hydrology used in the Environment Agency 2010 FMP model[3] was carried out. This review concluded that the hydrology assessment was comprehensive and based on data from numerous gauging stations and a long period of record. Therefore, the same hydrological approach has been adopted for this study (ReFH hydrographs with the peak adjusted based on the statistical method).

3.1.5 The adoption of the same hydrological approach allows the relevant flow hydrographs to be abstracted from the Environment Agency 2010 FMP model[3] results and used as the inflow boundaries for this Infoworks ICM model. The Environment Agency model only contains model flows for the 1% AEP plus 20% event. To obtain the required 70% climate change allowance flow, a multiplying factor was applied. It was possible to run the Environment Agency 2010 FMP model[3] for the 1% AEP plus 70% climate change allowance without model instability issues.

3.1.6 The downstream boundary of the 2D Infoworks ICM model was obtained from the results taken from the Environment Agency 2010 FMP model[3].

3.2 Software

3.2.1 Version 9.5 of the Infoworks ICM software has been used for the development of the 2D model.

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 floodplain has been created from the geo-referenced cross section data, utilised in the Environment Agency 2010 FMP model[3] and undertaken in 1990s, since these cross sections extended beyond the canal into the full extent of the floodplain.

3.4.2 The boundary inflow hydrographs and the downstream water level hydrograph are input data that have been obtained from the results of the Environment Agency model at the relevant model locations.

4 Technical method and implementation

4.1 Hydrological assessment

4.1.1 A comprehensive review of previous studies within the catchment was undertaken for the development of the Environment Agency 2010 FMP model[3]. The various hydrological methods were investigated and the FEH statistical method was identified as the preferred method for the estimate of peak flows applied in the Environment Agency 2010 FMP model[3]. For the shape of the hydrograph, the ReFH shape was adopted following an extensive comparison against observed hydrograph shapes at flow gauges.

4.1.2 It was not considered necessary to update the estimate of peak flows, for this study. This is due to the fact that the data available for the development of peak flows for the Environment Agency 2010 FMP model[3] was already extensive and consistent at various locations along the watercourse. Sensitivity tests carried out using the additional data available since 2010 indicate that if the same pooling groups and donor sites are used in the vicinity of the Proposed Scheme, the results do not change more than 10%.

4.1.3 The inflow boundaries into the Infoworks ICM 2D model have been obtained from the estimates of the larger Environment Agency 2010 FMP model[3].

4.1.4 Table 1 shows the peak flows derived from the Infoworks ICM 2D model at the Proposed Scheme and, as anticipated, these are similar to those obtained by re-running the Environment Agency 2010 FMP model[3] with the latest version of the software 4.5. The original Environment Agency model used Version 3. No other return periods could be investigated as the Environment Agency model only had catchment inflow hydrographs for the 1.0% AEP event.

Table 1: Modelled peak flows at the Manchester Ship Canal crossing

AEP	Return period	Modelled peak flow (m^3/s)	Modelled peak flow (m^3/s)
		Environment Agency 2010 FMP model[3]	Infoworks ICM 2D model
1.0%	100 year	1,020.3	1,051.2
1.0% + 20%	100 year + 20% CC	1,195.5	1,218.7
1.0% + 70%	100 year + 70% CC	1,506.1	1,452.6

4.2 Hydraulic model build – baseline model

4.2.1 Figure 4 shows the baseline model schematic showing the 2D model extents and the main model inflows.

1D representation

4.2.2 No 1D representation has been used for the development of the 2D Infoworks ICM model.

2D representation

4.2.3 A 2D model was built using a variable triangle mesh area in Infoworks ICM. The minimum and the maximum areas of the triangles are the key parameters used in the model build, to control the meshing process. An irregular mesh was generated within the extents of the 2D model, using a minimum and a maximum area of 25m^2 and 100m^2 respectively. A finer mesh resolution was adopted in the vicinity of the Proposed Scheme, based on a minimum and a maximum area of 5m^2 and 20m^2 respectively. These small areas allow a better understanding of the changes in velocities within the canal due to the proposed narrowing, which could result in scouring of the banks.

Inflow boundaries

4.2.4 The model inflow boundaries are those extracted from the Environment Agency 2010 FMP model[3], as the same hydrology approach and estimates have been adopted.

Downstream boundary

4.2.5 The model downstream boundary is much higher than a normal depth condition as it takes account of a downstream sluice. This boundary has been obtained from the results provided by the Environment Agency 2010 FMP model[3].

Key structures

4.2.6 The two existing crossings within the 2D domain have been modelled as 2D bridge crossings as shown in Figure 4. Details of these structures are provided in Table 2. All structures, including key hydraulic controls, are shown in Figure 4.

Table 2: Key structures in the vicinity of the Proposed Scheme – Manchester Ship Canal

Structure reference	Structure description	Modelling representation and justification
Bridge beneath the dismantled railway line at Cadishead	The bridge formed of five openings in total, spanning the in-bank section of the Manchester Ship Canal. The central opening has a rectangular shape; the four lateral bridge openings are of arch shape. Opening dimensions are: • the central opening is rectangular, with a width of 41.0m and a height of 31.6m; • the four lateral openings are of arch shape, with a total height of 18.0m and a springing height of 15.1m (note that height values are calculated from the cross section modelled at bridge unit 'LAT_9493m' in the original Environment Agency model); and	Modelled using Bridge Linear Structure (2D) feature in Infoworks ICM. Dimensions for bridge openings were obtained from the Environment Agency model. Despite having an arch shape in nature, the four lateral bridge openings have been modelled as rectangular (with soffit level set to springing level) to avoid complexities during model build. This simplification has no impact on model results, given the bridge springing level (and subsequently the arch crown) is 10.6m higher than the predicted maximum water level for the 1 in 100 year plus 70% climate change event. A fixed bridge headloss value of 0.2 was adopted at all bridge openings. Sensitivity analysis was undertaken on bridge headlosses, whilst adopting an inlet headloss coefficient of 0.5 and an outlet headloss

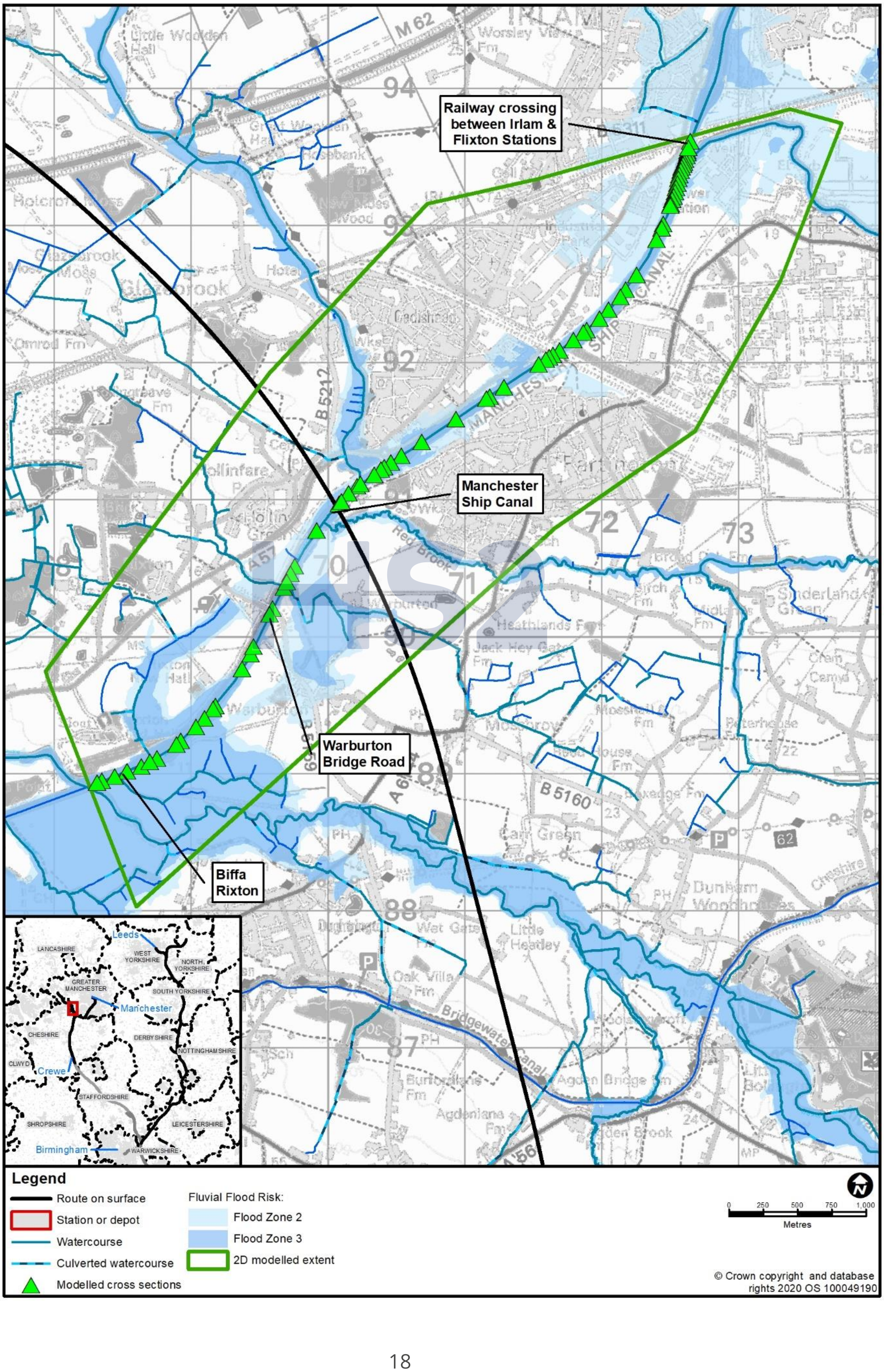
Structure reference	Structure description	Modelling representation and justification
	• the two outer openings have a width of 9.2m, whilst the two inner openings have a width of 10.3m.	coefficient of 1.0; these values are in accordance with those recommended from the literature. Model results from sensitivity analysis show that varying bridge headloss coefficients have no significant impact on results within the extent of the Proposed Scheme.
Warburton Bridge	The bridge formed of three openings in total, spanning the in-bank section of the Manchester Ship Canal. All bridge openings are of arch shape; opening dimensions are detailed below: • the central opening has a width of 64.6m and a height of 31.2m; • the opening on the left-hand side has a width of 12.9m, a total height of 14.2m and a springing height of 13.6m; and • the opening on the right-hand side has a width of 12.9m, a total height of 13.8m and a springing height of 13.1m. Note that height values above are calculated from the cross section modelled at bridge unit 'LAT_6589m' in the original Environment Agency model.	Modelled using Bridge Linear Structure (2D) feature in Infoworks ICM. Dimensions for bridge openings were obtained from the Environment Agency model. Despite having an arch shape in nature, bridge openings have been modelled as rectangular to avoid complexities during model build. This simplification has no impact on model results, given bridge springing level (and subsequently the arch crown) is 15.4m higher than the predicted maximum water level for the 1 in 100 year plus 70% climate change event. A fixed bridge headloss value of 0.2 was adopted at all bridge openings. Sensitivity analysis was undertaken on bridge headlosses, whilst adopting an inlet headloss coefficient of 0.5 and an outlet headloss coefficient of 1.0; these values are in accordance with those recommended from the literature. Model results from sensitivity analysis show that varying bridge headloss coefficients have no significant impact on results within the extent of the Proposed Scheme.

Roughness

4.2.7 Roughness is represented by Manning's n and the same model roughness of 0.033 has been adopted for the river sections, as for the Environment Agency 2010 FMP model[3]. This value is reasonable as it is known that the canal is dredged frequently[11]. Higher values are used for the floodplain and these vary depending on the land use.

[11] Smit marketing material (2014), *Peel Ports Maintenance Dredging.* Available online at: https://www.smit.com/projects/detail/peel-ports-maintenance-dredging.html.

Figure 4: Baseline model schematic



4.3 Hydraulic model build – Proposed Scheme

4.3.1 Figure 3 shows the Proposed Scheme model schematic. The Proposed Scheme model has been edited from the baseline to include the following design elements.

Viaduct piers

4.3.2 The narrowing of the canal has been modelled as 2D curved wall. Piers have been modelled outside of the canal and behind the retaining walls as these are located in the floodplain and will provide a local obstruction to flood flows.

Topographic changes

4.3.3 There have been no changes to the topography (imported from the Environment Agency 2010 FMP model[3]) as the data is based on an actual survey. LiDAR[12] has not been used and a comparison against this dataset indicates, as anticipated, large variations in wooded areas of up to 1.3m.

Replacement floodplain storage areas

4.3.4 Although the Manchester Ship Canal is not a main river, flood zones are available. Some replacement flood storage has been allowed in the design however it has not been modelled at this stage.

Channel realignments and diversions

4.3.5 The Manchester Ship Canal viaduct includes the viaduct piers and the narrowing of the canal on both the north and south banks with retaining walls. The current design does not include any channel realignments or diversions.

Production of flood extents

4.3.6 Flood extents have been derived using the direct output option available in Infoworks ICM, producing maximum flood depth and stage.

Modelling assumptions made

4.3.7 It is assumed that the topographic survey of cross sections undertaken in the 1990s is still valid. This assumption is reasonable as regular dredging takes place in the canal to maintain its shape despite heavy sediment transfer into the canal. The latest Environment Agency

[12] Light Detection and Ranging

LiDAR data was used to adjust ground levels where ground raising or informal defences were identified outside the dredging area.

4.3.8 A 2D modelling approach is assumed to be sufficient for estimating the 1.0% AEP plus climate change 20% and 70% events.

4.4 Climate change

4.4.1 The climate change allowance for the Manchester Ship Canal is a 70% (upper end) increase in peak river flows due to the presence of more vulnerable flood sensitive receptors in Flood Zone 3 upstream of the Manchester Ship Canal viaduct.

5 Model results

5.1.1 The model has been run for the 1.0%, 1.0% + CC with 20% and 70% increases in peak river flows for the Proposed Scheme.

5.1.2 The modelled flood extents for Proposed Scheme for the 1.0% AEP and 1.0% AEP + CC events are presented in the Volume 5, Water resources and flood risk Map Book: maps WR-05-314a and WR-06-314a respectively and are presented in Annex A.

5.1.3 The modelled impact of the Proposed Scheme on peak flood levels without mitigation for the 1.0% AEP + CC indicates a major impact on upstream vulnerable receptors; with peak water level increases of more than 100mm on receptors along Glaze Brook. With the bypass channel mitigation in place, these are reduced to minor impacts on peak water levels.

5.1.4 As there are no model results available for the 0.1% AEP event, this has been estimated from Flood Zone 2 and the ground terrain at the boundary of this flood zone.

5.1.5 Results show peak water level for the 1.0%+70%CC is 14.26mAOD. This result indicates that the current proposed design achieves more than 3m freeboard beneath the viaduct.

5.1.6 The flow velocities in the area of the Manchester Ship Canal viaduct increase from 1.8m/s for the baseline to 2.5m/s in the constricted section of the Proposed Scheme scenario. Therefore, localised scour protection of the bed and the banks will be required and in particular at the edge of the wall and the soft banks.

6 Model proving

6.1 Run performance

6.1.1 The 2D solver uses adaptive time steps which applies a varying timestep during the run simulation to achieve numerical stability. Final cumulative mass balance error is within +/- 1.0% for all model runs undertaken.

6.2 Calibration and verification

6.2.1 The Environment Agency 2010 FMP model hydraulic model[3] was used to provide the boundary conditions for the model. No additional calibration and verification has been carried out at this stage. Updated gauge data and a review of the statistical peaks for the Manchester Ship Canal should be used at a future stage supported by detailed cross section survey data across the canal and floodplain.

6.3 Validation

6.3.1 The longitudinal profile of the Infoworks ICM 2D model along the canal provides higher peak water levels than the Environment Agency 2010 FMP model[3]. This difference is 0.31m at the Manchester Ship Canal viaduct, however at the upstream end of this model (the confluence with the River Mersey) this difference is 0.74m. This is due to a detailed 2D modelling technique which fully takes account of the effects of informal defences and due to ground raising that have taken place since the surveys used in the Environment Agency 2010 FMP model[3].

6.4 Sensitivity analysis

6.4.1 Analysis was undertaken to assess the sensitivity of the 1.0% AEP + CC baseline model outputs to the following scenarios:

- compare the 1.0% event for the 20% and 70% climate change allowance to assess the sensitivity of the model to changes in flows;
- increase in roughness (channel, structures and floodplain) (Manning's n) by 20%; and
- decrease in roughness (channel, structures and floodplain) (Manning's n) by 20%.

6.4.2 No further sensitivity analysis was undertaken on the downstream boundary condition apart during the model construction phase, given this was based on the high water levels that are maintained to allow for navigation.

6.4.3 Sensitivity tests indicate that the current Proposed Scheme hydraulic design is sensitive to changes in flows but not roughness. The increase in peak water level at the Manchester Ship

Canal viaduct is 0.62m for the 1.0% AEP +20%CC and 1.69m for the 1.0% AEP +70%CC events.

6.5 Blockage analysis

6.5.1 No blockage has been considered at this stage, as the large openings at the two existing crossings are unlikely to block during a flood event. However, blockage should be considered during design progression at all crossings, to assess the impact of ships blocking the canal during a flood event.

6.6 Run parameters

6.6.1 The standard run parameters have been used in the Infoworks ICM 2D model.

7 Limitations

7.1.1 Land access for new topographic survey was not possible and so the model was run using available information based on the supplied Environment Agency 2010 FMP model[3]. The regular dredging of the canal suggests that the capacity of the canal varies depending on the extent of dredging which could imply that the survey undertaken in the 1990s may not be a true representation of the existing canal. In addition, there have been changes in the floodplain levels due to land use changes since these surveys were undertaken.

8 Conclusions and recommendations

8.1.1 The modelled impact of the Proposed Scheme without mitigation on peak flood levels for the 1.0% AEP + CC indicates a major impact of greater than 100mm just upstream of the Manchester Ship Canal viaduct on receptors along Glaze Brook.

8.1.2 With the bypass channel mitigation in place this is reduced to a minor impact on upstream vulnerable receptors.

8.1.3 Although it has not been modelled, a wider and deeper bypass channel will ensure that there is no increase in upstream flood risk to vulnerable property, as the modelling of the bypass channel has been proved to effectively reduce upstream flood risk. The final configuration of the bypass channel will be undertaken as part of the detailed design of the scheme.

8.1.4 Sensitivity analyses indicate that the baseline model is sensitive to flows with an increase in peak water level at the Manchester Ship Canal viaduct of 0.62m for the 1.0% AEP +20%CC and 1.69m for the 1.0% AEP +70%CC events. However, modelling results show peak water level without mitigation for the 1.0%+70%CC is 14.26mAOD. These results indicate that the current proposed design achieves more than 3m freeboard beneath the viaduct, which is at approximately 21mAOD.

8.1.5 At detailed design stage, the hydraulic modelling of the watercourse should be refined with updated hydrology and should be further verified against the recent January 2021 high flow event and updated topographic survey data for the canal and floodplain, in particular to reflect any widening of the channel due to erosion.

8.1.6 The flow velocities in the constricted area for the Manchester Ship Canal viaduct are approximately 2.5m/s and therefore localised scour protection of the bed and the banks will be required and in particular at the edge of the wall and the soft banks.

8.1.7 Blockage should be considered during design progression at all crossings, to assess the impact of ships blocking the canal during a flood event.

Annex A: Flood level impact maps

The water level difference has been mapped for the 1.0% AEP and 1.0% AEP + CC events as described in Section 5 of this report, and Figure A 1 and Figure A 2.

Figure A 1: Manchester Ship Canal impact map for 1.0% AEP (1 in 100 year)

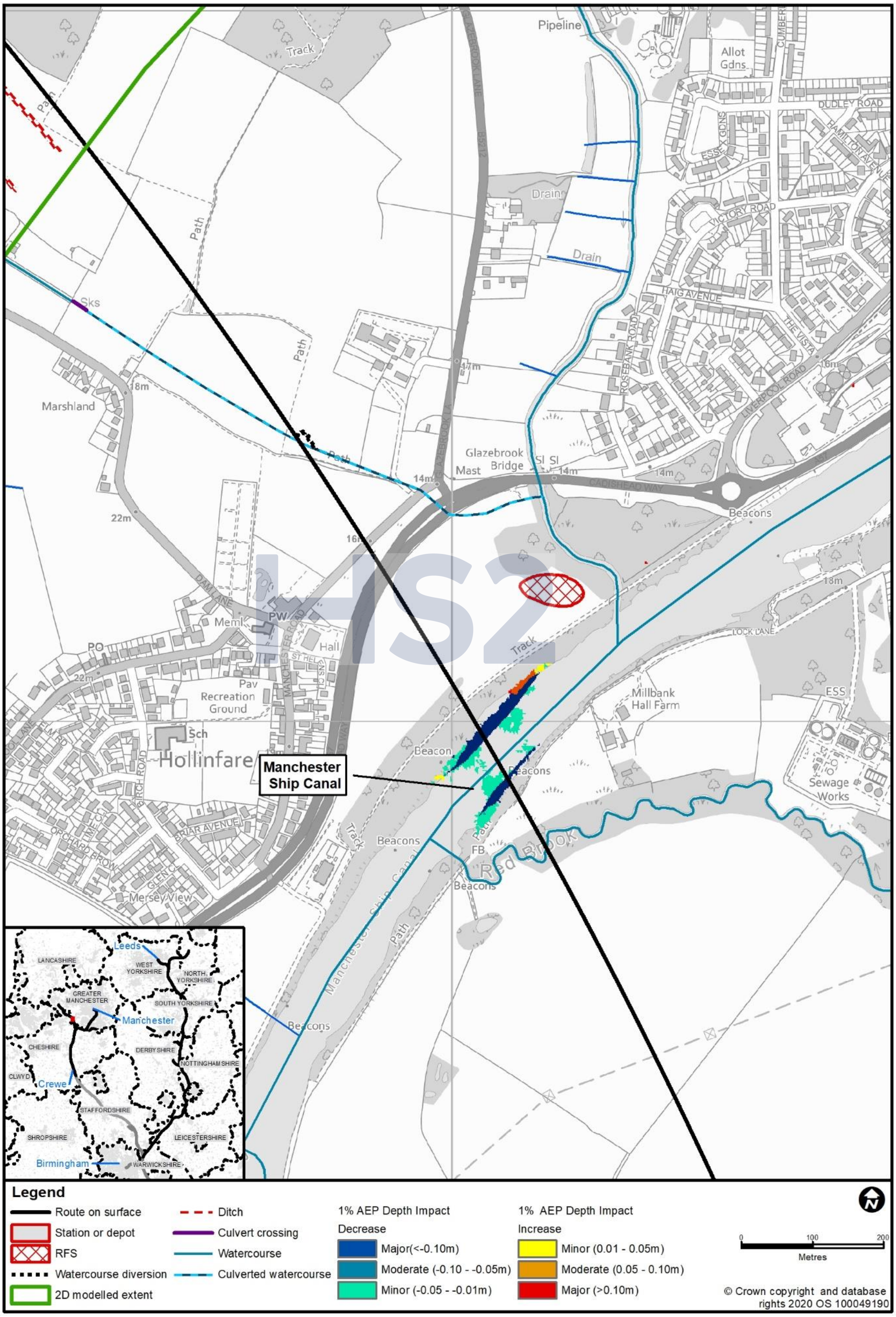
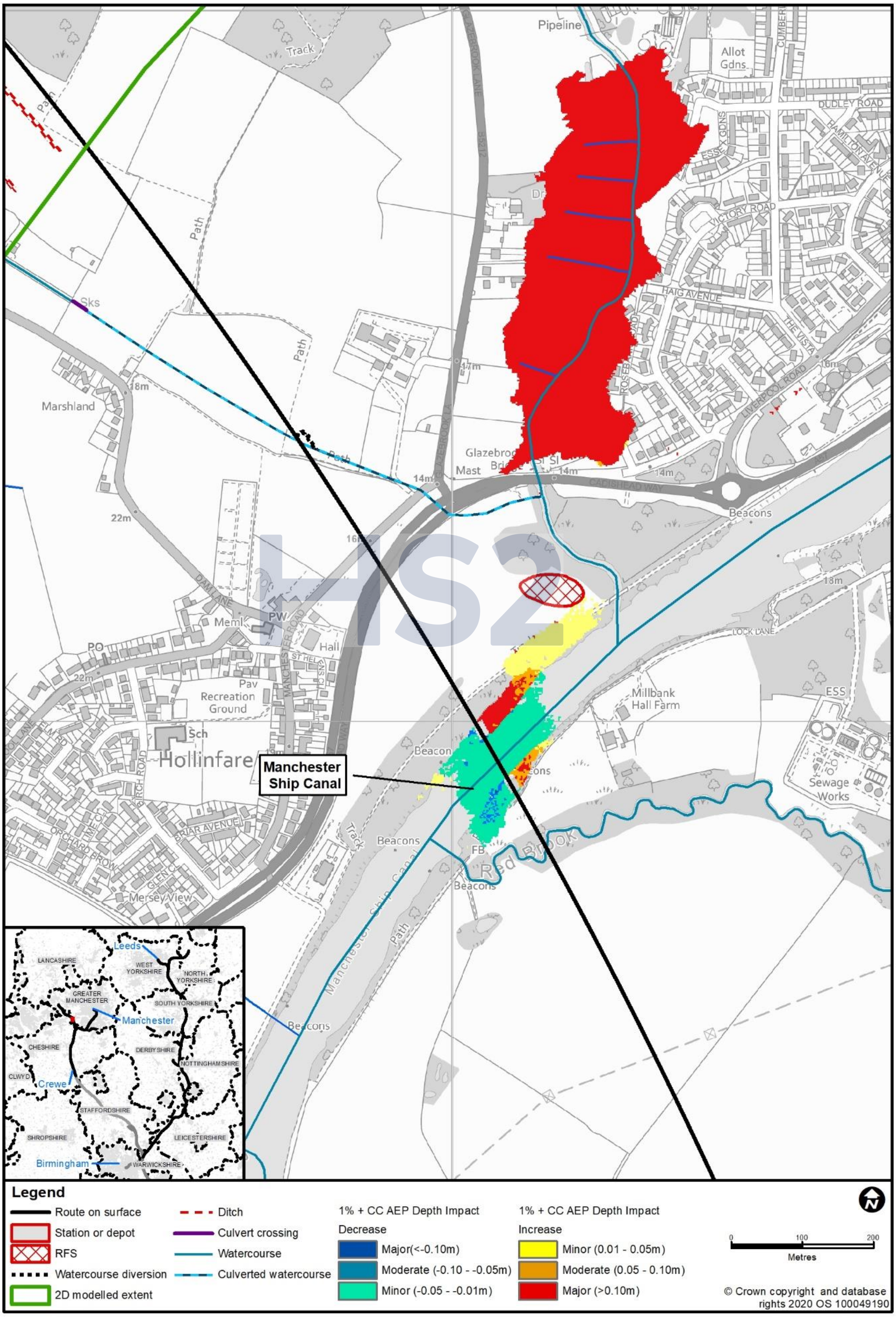


Figure A 2: Manchester Ship Canal impact map for 1.0% AEP (1 in 100 year plus climate change)



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High Speed Two (HS2) Limited
Two Snowhill
Snow Hill Queensway
Birmingham B4 6GA
Freephone: 08081 434 434
Minicom: 08081 456 472
Email: HS2enquiries@hs2.org.uk