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HS2

High Speed Rail (Crewe – Manchester) Environmental Statement

Volume 5: Appendix WR-006-00009

Water resources and flood risk

MA07: Davenport Green to Ardwick

Hydraulic modelling report - River Mersey

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Department for Transport

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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 River Mersey. The River Mersey runs through the Davenport Green to Ardwick area (MA07).

1.1.2 The hydraulic modelling has been used to inform the Flood risk assessment (Volume 5: Appendix WR-005-0MA07) for this area.

1.1.3 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).

1.1.4 For each community area the water resources assessments (Volume 5: Appendix WR-003) should also be referred to.

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

- Water resources assessment baseline data (BID WR-004-0MA07)[1]; and
- Water Framework Directive compliance assessment baseline data for the Proposed Scheme (BID WR-002-00000)[2].

1.2 Proposed Scheme

1.2.1 The route of the Proposed Scheme runs in tunnel beneath the floodplain of the River Mersey at Northenden and Didsbury. The only elements of the Proposed Scheme that encroach into the floodplain are the Palatine Road vent shaft and its associated raised compound, which are required to provide a working platform during construction and ventilation and access for emergency services during operation. The proposed shaft and its associated raised compound cover an area of approximately 14,000m^2 and are located at Withington Golf Course within the Didsbury flood storage basin. The Didsbury flood storage basin is a statutory flood storage reservoir operated by the Environment Agency.

1.2.2 An overview of these design components can be seen in Figure 1. Further details on the Proposed Scheme can be found in Volume 2, MA07 Map Book: map CT-06-360.

1.3 Aims

1.3.1 The aims of this study are to:

- develop a hydraulic model for the River Mersey in the vicinity of the Palatine Road vent shaft and associated compound to simulate peak flood levels, with and without the Proposed Scheme;
- develop a model which could assess the impact/interaction of the scheme on the operation of the flood storage basin; and
- document the methods used, the results, assumptions and limitations.

1.3.2 The hydraulic model has been used to inform the flood protection level required for the vent shaft compound and to calculate the volume of replacement floodplain storage (RFS) required, as detailed in the Environmental Impact Assessment Scope and Methodology Report (SMR): Technical Note: Flood risk.

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[1] High Speed Two Ltd (2022), High Speed Rail (Crewe – Manchester), *Background Information and Data, Water resources assessment baseline data,* BID WR-004-0MA07. 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 baseline data,* BID WR-002-00001. Available online at: http://www.gov.uk/government/collections/hs2-phase-2b-crewe-manchester-environmental-statement.

1.4 Objectives

1.4.1 The objectives of this study were to:

- develop an understanding of existing hydraulic conditions at the proposed vent shaft and associated compound on Palatine Road, including channel and floodplain interaction, hydraulic structures and flow paths, including the operation of inlet and main outlet gates that control water levels within Didsbury flood storage basin, through desk study, engagement with the Environment Agency local area team and, where possible, by conducting a site visit;
- calibrate the model to the Storm Christoph event (January 2021);
- estimate catchment peak flows and hydrographs associated with the following Annual Exceedance Probabilities (AEP): 5.0% AEP, 1.0% AEP, 1.0% AEP + climate change (CC)[3], and 0.1% AEP; and
- using the catchment hydrographs as inflow boundaries and other information available at this stage, develop a hydraulic model to estimate flood levels along the study reach both before and after construction of the Proposed Scheme.

1.5 Justification of approach

1.5.1 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. The Palatine Road vent shaft and its associated compound (which will be raised above flood levels) are proposed to be partially located within the Didsbury flood storage basin, a flood risk management asset used by the Environment Agency to regulate flows within the River Mersey during flood events.

1.5.2 A preliminary Proposed Scheme hydraulic model built in 2020 indicated that the shaft and its associated compound would not only affect floodplain storage volumes; but it could potentially amend flow conveyance routes towards vulnerable properties during an extreme flood event, when the storage capacity of the Didsbury flood storage basin is exceeded. The preliminary Proposed Scheme model was based on the 2012 Environment Agency 1D Flood Modeller Pro model[4]. It was updated to include a linked 2D extent of a small 1km area around Palatine Road, including the Didsbury flood storage basin. This preliminary Proposed Scheme 1D-2D model provided an improved understanding of the local effect of the vent shaft and compound on flow conveyance routes.

1.5.3 Storm Christoph hit the UK in late January 2021 and caused extensive flooding in the River Mersey area, which reached a peak on 21 January 2021. A review of the flooding which occurred during Storm Christoph, showed that the preliminary Proposed Scheme 1D-2D hydraulic model did not provide enough detail of the mechanisms of flooding in this complex area, and did not accurately represent the flooding that occurred during that event. Some anomalies in the level of flood defences were also highlighted.

1.5.4 Following Storm Christoph further detailed engagement with the Environment Agency local area team was undertaken, with the aim of understanding these anomalies in the Proposed Scheme model and to ensure the best available flood event data was incorporated into the modelling assessment. As part of this engagement, the Environment Agency provided the 2018 1D-2D model of the Upper River Mersey[5], which contained a 2D representation of the entire Upper Mersey floodplain (including modelled tributaries) with a cell size of 8m. The defence data in this Environment Agency 2018 model was based on a 2017 flood defence survey for the River Mersey. The defence data and hydrological inflows of this Environment Agency 2018 model were used to update the preliminary 1D-2D hydraulic model. The outputs of the updated 1D-2D hydraulic model (defined in this study as the Proposed Scheme model) are presented in this report.

1.5.5 The Proposed Scheme model, developed from the 2018 Environment Agency model, covers a much larger 8.4km^2 2D extent when compared to the 1km^2 2D extent of the preliminary Proposed Scheme model. This larger area extends from the upstream Brinksway GS (located approximately 5km east of the Proposed Scheme) to the Riverside Avenue recreation ground (located approximately 1.2km west of the Proposed Scheme).

1.5.6 In summary, the Proposed Scheme model uses the best available data and has been improved as a result of internal and external reviews. It incorporates:

- the 1D in-bank cross sections and 1D hydraulic structures from the 2012 Environment Agency 1D Flood Modeller Pro model[4], however with improved structure parameters and a better representation of bank levels (based on the defence data from the 2018 Environment Agency model);

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[3] Climate change allowance is based on the allowances as set out in the SMR (see Volume 5: Appendix CT-001-00001).

[4] Environment Agency (2012), *Upper Mersey Model update 2011/12*.

[5] JBA Consulting Ltd (2018), *Upper Mersey Model update.*

- a recent 2020 LiDAR data survey for the representation of the 2D extents;
- the catchment flow hydrographs from the Environment Agency 2018 model which have been verified; and
- calibrated parameters based on the January 2021 Storm Christoph event, as described below.

1.5.7 The Environment Agency flow and level gauging data has been used to calibrate the Proposed Scheme model against the Storm Christoph event. Various model parameters were adjusted in order to match the flood levels observed at the Northenden weir (River Mersey level), Stenner Lane (Didsbury flood storage basin level) and Withington Golf Course (Didsbury flood storage basin level) gauges.

1.6 Scope

1.6.1 The scope of the study was to undertake detailed hydraulic modelling to enable assessment of the impact of the Proposed Scheme on the local environment. The Proposed Scheme model aimed to be detailed enough to allow a robust assessment of impacts that have the potential to lead to significant adverse effects on peak flood levels. The Proposed Scheme model also allowed the identification and preliminary testing of appropriate mitigation measures.

1.6.2 This report focuses on an 8.4km^2 floodplain area which is covered by a 11.5km reach of the River Mersey, extending upstream and downstream of the crossing of the Proposed Scheme. The Proposed Scheme crossing comprises of a vent shaft and associated compound which encroach on the floodplain of the River Mersey. A description of the location and type of Proposed Scheme is provided in Section 2.

1.6.3 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:

- flood map for planning (rivers and sea)[6];
- risk of flooding from surface water (RoFSW)[7] map;
- flood defence asset information;
- operational data for the Didsbury flood storage basin and Sale Ees flood storage basin;
- Environment Agency Operational Action Plans for Phase 1 (OAP1), Phase 2 (OAP2) and Phase 3 (OAP3) of the Sales Ees and Didsbury flood storage basins;
- a site location plan for the Didsbury flood storage basin;
- river gauging data for the River Mersey at Brinksway, Northenden Weir, and within the Didsbury flood storage basin for the January 2021 Storm Christoph event;
- gate operation at the inlet to the Didsbury flood storage basin during the Storm Christoph event;
- 2012 Environment Agency 1D model[4]; and
- 2018 Environment Agency 1D-2D model[5].

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

- Manchester City, Salford City and Trafford Councils Level 2 Hybrid Strategic Flood Risk Assessment (SFRA), Final March 2011[8];
- Manchester City Council Preliminary Flood Risk Assessment (2011)[9]; and
- Manchester City Council Local Flood Risk Management Strategy (2014)[10].

2.2 Description of the study area

Study area

2.2.1 Figure 1 shows the River Mersey within the study area and the Environment Agency flood maps. The upstream extent of the modelled River Mersey is located at Brinksway GS which is situated approximately 8km upstream from the Proposed Scheme vent shaft and associated compound. The downstream extent of the modelled River Mersey located 19.6km further downstream from the shaft, at the confluence with the Manchester Ship Canal. The upstream and downstream boundaries are sufficiently far upstream and downstream, in order not to impact on peak water levels at the location of the Proposed Scheme vent shaft.

2.2.2 The Proposed Scheme model also includes a 2.8km reach of the Fielden Park Brook, a 1.2km reach of the Chorlton Brook, a 1.3km reach of the Old Eea Brook and 2.2km of an overflow channel from the River Mersey just off Stretford Ees.

2.2.3 The proposed vent shaft and associated compound are located at Withington Golf Course within the Didsbury flood storage basin (see Figure 3). The primary hydraulic mechanisms that can affect the peak water levels at receptors in the vicinity of the proposed vent shaft and associated compound are:

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

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

[8] JBA Consulting (2011), *Manchester City, Salford City and Trafford Councils Level 2 Hybrid SFRA*. Available online at: https://secure.manchester.gov.uk/download/downloads/id/26463/final_mst_level_2_sfra_mar_2011.pdf/.

[9] JBA Consulting (2011), *Manchester City Council Preliminary Flood Risk Assessment*. Available online at: http://webarchive.nationalarchives.gov.uk/20140328165058/http:/cdn.environment-agency.gov.uk/flho1211bvmm-e-e.pdf/.

[10] Manchester City Council (2014), *Local Flood Risk Management Strategy*. Available online at: https://secure.manchester.gov.uk/download/downloads/id/21915/1_local_flood_risk_management_strategy_nt.pdf/.

- the release of water from the River Mersey into the Didsbury flood storage basin through the inlet control gates at Milgate Lane;
- the release of water back into the River Mersey through the outlet control gates beneath the M60 viaduct downstream of Northenden Weir;
- the twin flap valves at the outlet of the Fielden Park Brook into the River Mersey;
- overtopping of the River Mersey flood defences at various locations including Didsbury Golf Club, Withington Golf Course, Northenden, West Didsbury and Northenden Golf Club; and
- spilling of floodwater from Didsbury flood storage basin across Palatine Road in an extreme event, when the basin reaches maximum storage capacity.

Hydrological description

2.2.4 The River Mersey at Didsbury receives runoff from an approximately 600km^2 catchment. It generates flows from east to west and drops from a bed level of around 34.5mAOD at its source at the confluence of the Rivers Tame and Goyt, to around 6.3mAOD at its confluence with the Manchester Ship Canal (see Figure 2).

2.2.5 Upstream of Didsbury, the Upper Mersey floodplain at Stockport is narrow. However, for much of its length at and downstream of Didsbury the river is accompanied by a wide floodplain. Much of this floodplain is rural (either undeveloped, agricultural or recreational) but, due to the large size of the catchment and proximity to the large urban hub of Manchester, there are a significant number of properties potentially at flood risk from the River Mersey. The main at-risk communities being Stockport, Didsbury, Northenden, Stretford, Ashton and Flixton.

2.2.6 The catchment geology comprises mostly peat-covered Millstone Grit in the headwaters; Coal Measures, Sherwood Sandstone (around Didsbury) and Boulder Clay in the lower catchment. The catchment is therefore fairly impermeable (the Flood Estimation Handbook (FEH) SPRHOST[11] value is 40%) and the groundwater contribution to streamflow is modest.

2.2.7 An extensive system of raised flood defences (primarily earth embankments but also some walls), have been built alongside the Upper Mersey and some of its tributaries. In addition, there are flood storage basins at Didsbury and Sale Ees, where sluices allow floodwater to be stored more efficiently than under natural conditions.

2.2.8 The FEH standard annual average rainfall for the catchment is 1152mm[12].

Features of note

2.2.9 The Didsbury and Sale Ees flood storage basins protect floodplain communities along the River Mersey. The Didsbury and Sale Ees flood storage basins are operated with a set of detailed control rules. These two flood storage basins have statutory designations under the 1975 Reservoirs Act, and as such have detailed operational and maintenance requirements. The manual opening and closing of the inlet and outlet control structures are based on a set of river and floodplain water levels, which are monitored by sensors located both inside and outside the storage basins.

2.2.10 The Didsbury flood storage basin inlet gates only come into operation when the downstream Sale Ees flood storage basin is in operation (i.e. its inlet gate is open) and the water level in the River Mersey at Milgate Lane has exceeded a pre-determined threshold level. The outlet of the Didsbury flood storage basin is operated in accordance with a set of rules designed to keep water levels within the Withington Golf Course below the predetermined water level of 28.65mAOD. This allows for a sufficient freeboard prior to spilling of the Didsbury flood storage basin over Palatine Road at approximately 29.3mAOD, at which point properties along Palatine Road are potentially at risk of flooding. If water levels continue to rise in the River Mersey, then the river defences will overtop into the storage basin.

2.2.11 During flood events, gates are manually operated at Stenner Lane to protect isolated properties within the Didsbury flood storage basin (Environment Agency, Operational Action Plans for Phase 1 (OAP1), Phase 2 (OAP2) and Phase 3 (OAP3)). The Fielden Park Brook rises within the Didsbury flood storage basin. It crosses under Palatine Road and 120m downstream, it discharges into the River Mersey. Fielden Park Brook, therefore, operates as a small secondary high-level outlet from the Didsbury flood storage basin, into the River Mersey. This discharge is not controlled by any rules or remote sensors, but flap valves are in place to prevent backflow from the River Mersey.

2.2.12 Northenden weir on the River Mersey is located between the main inlet and outlet structures of the Didsbury flood storage basin. Water levels are recorded just upstream of the weir as well as at the inlet into the Didsbury flood storage basin, at Stenner Lane and at Withington Golf Course.

[11] Standard percentage runoff (%) associated with each HOST soil class (SPRHOST).

[12] Centre for Ecology and Hydrology (2021), *Flood estimation handbook web service.* Available online at: http://fehweb.ceh.ac.uk.

Figure 1: Environment Agency Flood zones at the River Mersey

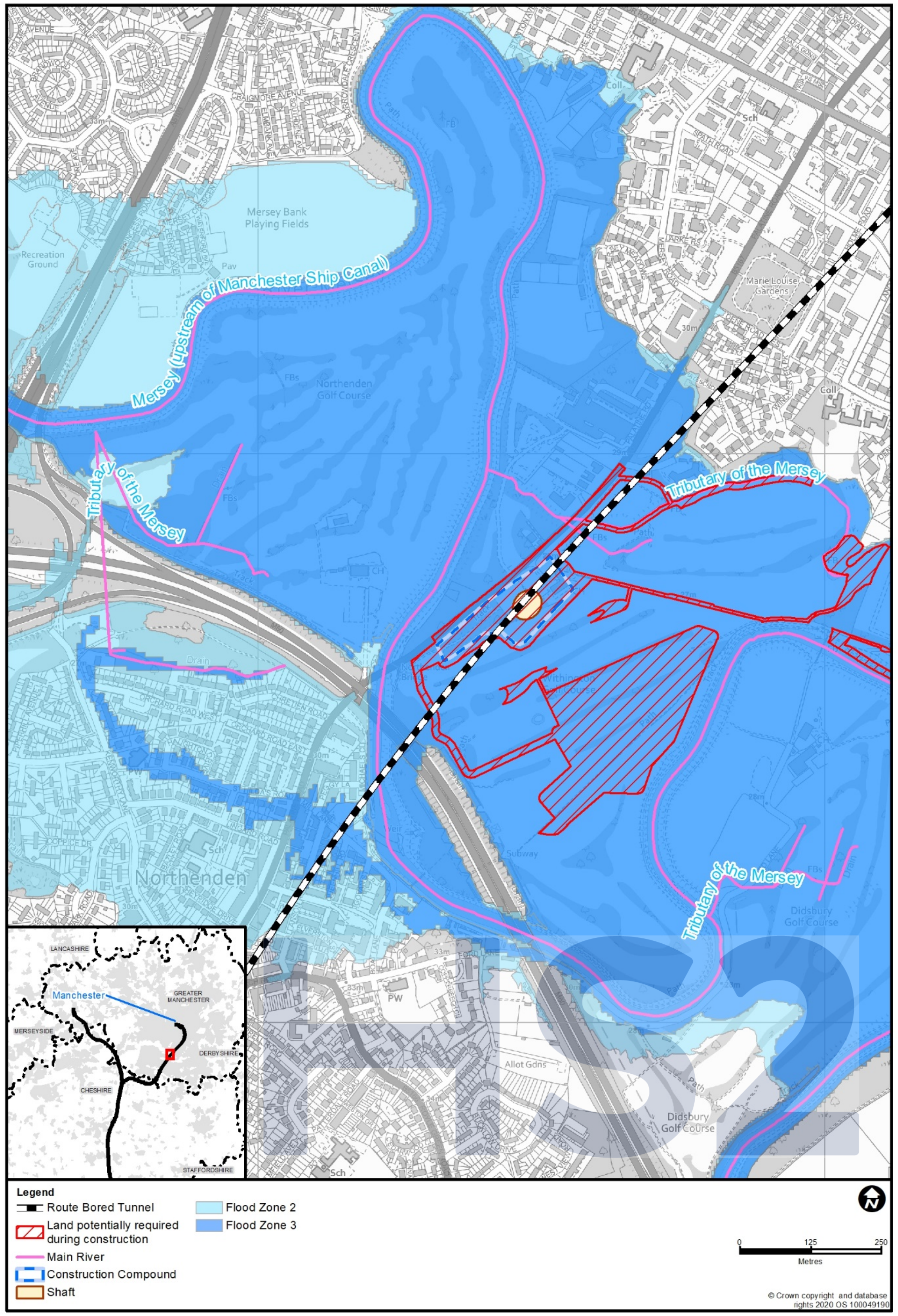
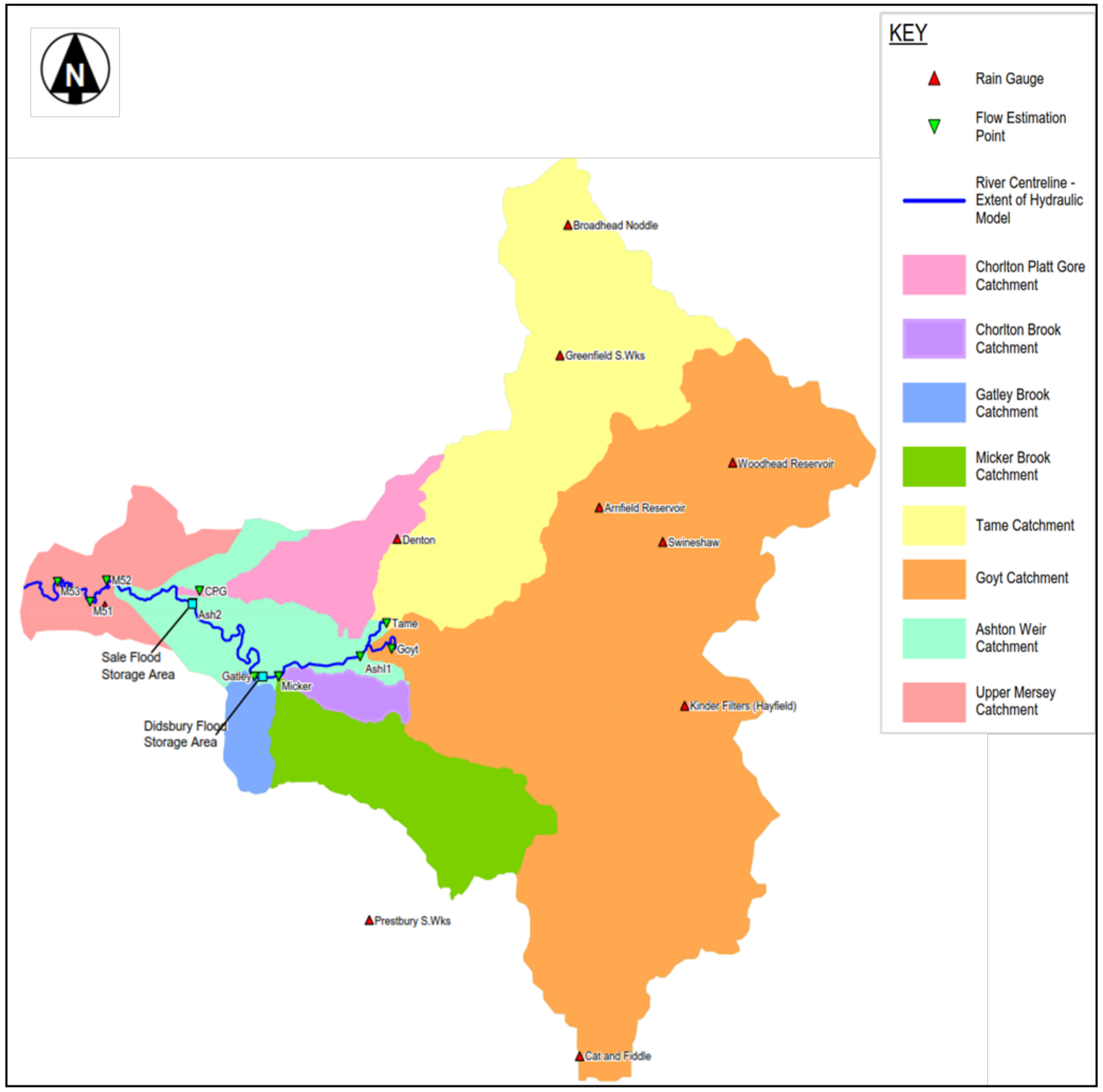
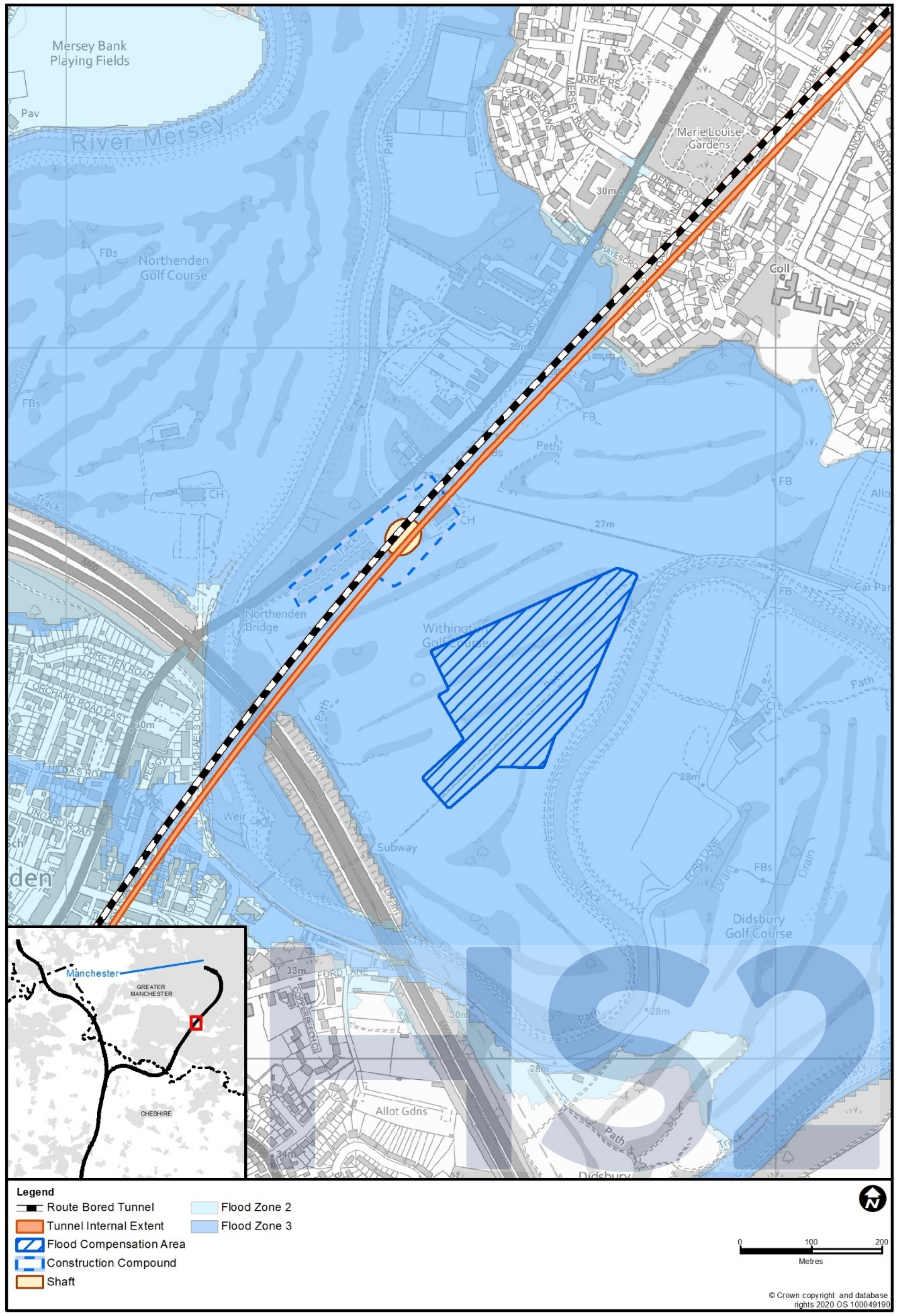


Figure 2: River Mersey catchment area



Source: Environment Agency (Mar 2012), Upper Mersey Model update 2011/12

Figure 3: River Mersey Proposed Scheme design with Environment Agency flood zones



2.3 Existing understanding of flood risk

Flood mechanisms

2.3.1 The flooding of the Didsbury flood storage basin is controlled by a set of clearly defined rules at its inlet and main outlet respectively. For events within its design capacity (which is for the 1 in 50 year event), it will store flood water in order to protect downstream properties without adversely affecting any property within the local area.

2.3.2 During operation, water levels within the Didsbury flood storage basin increase rapidly. Flooding begins within the area of the reservoir at Stenner Lane and Withington Golf Course. When water levels reach the top of the reservoir, in excess of its design standard, flood water starts to spill over Palatine Road and into the surrounding areas, and the River Mersey overtops its defences along long reaches of the river. For these events, where overtopping occurs along Palatine Road (approximately the 1 in 100 year event), the Proposed Scheme model predicts that the predominant flow pathway into the Didsbury flood storage basin is the overtopping of the flood defence embankments as opposed to via the basin inlet structure. The predominant flow pathway out of the Didsbury flood storage basin is the spilling over Palatine Road as opposed to via the main outflow structure. In these extreme events, the 430m long stretch of Palatine Road adjacent to the Withington Golf Course behaves therefore like a dam spillway.

Analysis of historical flooding

2.3.3 Prior to the construction of the present flood alleviation scheme in the 1970s, which included the construction of the Didsbury flood storage basin in 1978, there were numerous flood events associated with the River Mersey.

2.3.4 There is anecdotal evidence of flooding in the Palatine Road area, and in 1991 the Britannia Hotel car park flooded by up to 1m[13]. The Didsbury flood storage basin has been operated many times over the last 40 years and most recently in November 2019 and during Storm Christoph in January 2021.

Availability of existing hydraulic models

2.3.5 The Environment Agency 2012 Flood Modeller Pro (FMP)[4] and 2018 FMP-TUFLOW hydraulic models[5] were available for the River Mersey. Selected data from these two Environment Agency models were used to build the Proposed Scheme model for this study.

2.4 Site visit

2.4.1 No additional topographic survey or site visits were required to inform the hydraulic analysis as the existing data available from the Environment Agency was considered sufficient for this stage of the design process. The hydraulic Proposed Scheme model will be updated during design development, in accordance with the HS2 Ltd requirements, and a site visit will be undertaken by a hydraulic modeller, if required, to develop a site-specific topographic survey brief.

[13] Photograph of flooding at the Britannia Hotel car park in December 1991. Available online at: https://www.researchgate.net/figure/Photograph-of-the-Britannia-Hotel-car-park-after-the-flood-of-27-December-1991_fig3_265224458.

3 Model approach and justification

3.1 Model conceptualisation

3.1.1 A 1D-2D Proposed Scheme modelling approach has been selected to effectively model the flood mechanisms in the Didsbury area and more specifically in the vicinity of the proposed vent shaft and associated compound. The 1D and 2D Proposed Scheme model extents are shown in Figure 4.

3.1.2 The 2D domain comprises the Didsbury flood storage basin and a sufficiently large area upstream and downstream from the basin, to ensure that the impact of the vent shaft and potential mitigation measures can be assessed in a linked 1D-2D floodplain environment.

3.1.3 The upstream end of the 2D domain coincides with the 1D upstream end at the Environment Agency's Brinksway GS. Brinksway GS is located 4.4km upstream from the inlet gate into the Didsbury flood storage basin, at Milgate Lane. The downstream end of the 2D domain is located 510m downstream of the Bailey Bridge at Chorlton Water Park, which is itself located 2.3km downstream of the outlet of the Didsbury flood storage basin. The 2D domain includes representation of the Fielden Park Brook within the Didsbury flood storage basin, via a 2D channel in the 2D domain.

3.1.4 The Proposed Scheme model continues in 1D beyond the downstream extent of the 2D domain and up to the confluence of the River Mersey with the Manchester Ship Canal (SC). The 1D representation includes the River Mersey channel as cross section units and also the floodplain in the form of reservoir units which are hydraulically linked to the river and each other via spill units. This 1D representation downstream of the Bailey Bridge is taken from the Environment Agency 1D 2012 model.

3.2 Software

3.2.1 The latest Flood Modeller Pro[4] (FMP) version 4.5 has been used for modelling the 1D domain and the latest TUFLOW-2018-03-AD-iSP-w64[5] has been used for the modelling of the 2D domain.

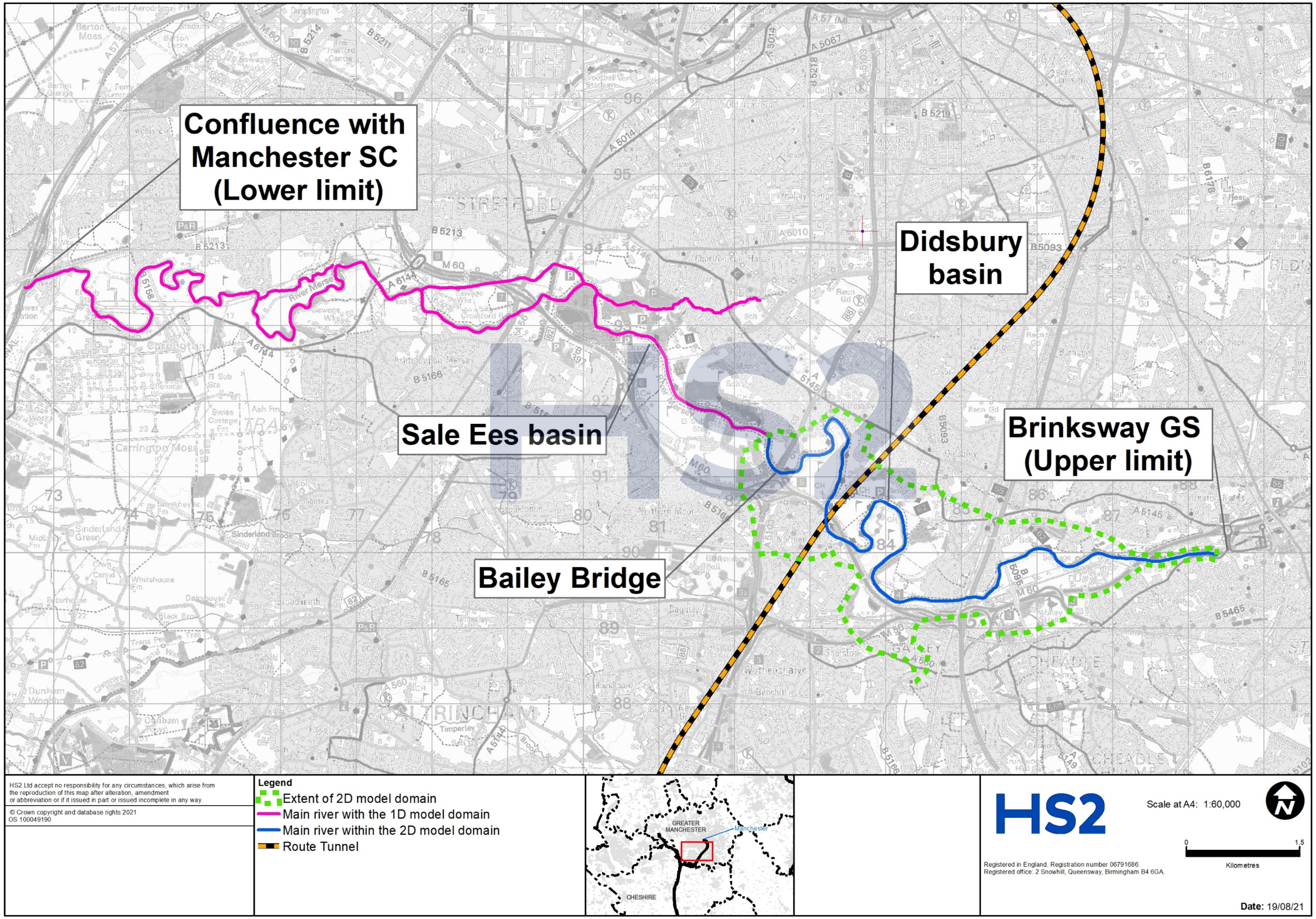
3.3 Topographic survey

3.3.1 No additional topographic survey was commissioned for this study as sufficient information has been made available from the Environment Agency, for this stage in the design process.

3.4 Input data

3.4.1 The 1D cross sections are based on the 2012 Environment Agency model however the riverbank levels have been modified based on a 2017 flood defence survey (this information was extracted directly from the 2018 Environment Agency model). The elevation data for the 2D floodplain has been obtained from 1m resolution 2020 Environment Agency LiDAR data. Inflows into the Proposed Scheme model are based on the 2018 Environment Agency model[5].

Figure 4: Baseline Proposed Scheme model schematic



4 Technical method and implementation

4.1 Hydrological assessment

4.1.1 The Proposed Scheme model uses the hydrology from 2018 Environment Agency model[5]. This data is based on the ReFH[14] method with the peak river flows adjusted using the FEH statistical method, based on gauge records for the period 1955 to 2012.

4.1.2 A verification of the hydrology has been undertaken by comparing peak river flows at a single location. FEH statistical analysis with records peak river flows at the inlet of the Didsbury flood storage basin up to 2018 have been compared against peak river flows from the Proposed Scheme model and those from the 2018 Environment Agency model. Table 1 indicates that the Proposed Scheme model estimates are conservative when compared to the FEH statistical method up to the 100 year return period (and therefore for the design 1% AEP + CC event). Therefore, these flows are considered acceptable for this stage in the design development.

4.1.3 The estimated flows in the Proposed Scheme model and the 2018 Environment Agency model are similar up to the 1% AEP event, however the Proposed Scheme model flow estimates are significantly lower for the 0.5% and 0.1% AEP events. This is because a larger volume of floodwater enters the floodplain upstream of Didsbury flood storage basin in the Proposed Scheme model due to increased roughness within the river channel. Higher roughness means higher water levels in the river channel and therefore more spilling into the floodplain. The Proposed Scheme model has higher roughness values as a result of its calibration to Storm Christoph as detailed in Section 4.3.

Table 1: River Mersey peak flow estimates at the inlet to the Didsbury flood storage basin

AEP	Return period	FEH statistical method (m^3/s)	2018 Environment Agency 1D–2D model - defended scenario (m^3/s)	Proposed Scheme 1D–2D model - defended scenario (m^3/s)
50%	1 in 2 year	166	184	184
10%	1 in 10 year	245	271	274
5%	1 in 20 year	276	311	306
1.33%	1 in 75 year	338	383	355
1%	1 in 100 year	351	398	362
0.5%	1 in 200 year	384	423	373
0.1%	1 in 1,000 year	565	577	481

4.2 Hydraulic model build – baseline model

4.2.1 Figure 4 shows the Proposed Scheme baseline model schematic.

1D representation

4.2.2 The 1D cross sections used in the 2012[4] and 2018[5] Environment Agency models (both have the same data) have been used to represent the main channel and tributaries. However, some of the cross sections included points on the banks with elevations based on historical LiDAR data. This suggests that at some locations the original topographic survey was not extended sufficiently far from the watercourse.

4.2.3 Due to the model uncertainty with regards to bank levels, 64 cross sections within the 1D-2D linked area have been fully reviewed. Updates have been made to trim the sections to in-bank thus removing historical LiDAR data points. Defence levels have then been added manually using the latest Environment Agency flood defence asset data (from the layers included in the 2018 Environment Agency model) and checked against the 1m resolution 2020 Environment Agency LiDAR data.

[14] Wallingford HydroSolutions (2016), *Revitalised Flood Hydrograph Model ReFH2: Technical Guidance*.

4.2.4 Interpolated cross section units have been added where required to reduce large variations in distances between cross sections for model stability and to enable a smooth transition of channel properties between consecutive cross sections.

4.2.5 Outside the 1D-2D linked area, downstream of the Bailey Bridge at Chorlton Water Park, the Proposed Scheme model is unchanged from the Environment Agency 2012 model in 1D. The floodplain is modelled as a series of reservoir units including the Sale Ees flood storage basin. The hydraulic connectivity between adjacent reservoir units and with the river cross sections is achieved via spill units.

4.2.6 The operation of the Sale Ees flood storage basin is important for the Didsbury flood storage basin. This is because the opening of the inlet gates at the Didsbury flood storage depends on two conditions: a) reaching near bank full threshold level on the River Mersey at the inlet (of the Didsbury flood storage basin) and b) the Sale Ees flood storage basin is filling – its inlet gates are opened.

2D representation

4.2.7 The 2D representation is based on the 2020 1m resolution LiDAR data. At the downstream boundary of the 2D extents (just downstream Bailey Bridge), 2D outflow boundary units have been added to provide hydraulic connectivity of the floodplain between the 2D domain and the downstream 1D floodplain representation – a reservoir unit.

4.2.8 A LiDAR override patch has been applied to modify ground levels within a small area of dense vegetation adjacent to Palatine Road. During initial checks of the LiDAR data, this area was identified as having excessively high ground levels, likely due to poor filtering of trees/dense vegetation.

4.2.9 A building threshold level of 300mm higher than the base topography has been assumed for buildings in areas at risk of flooding. An increased Manning's n value of 0.3 has been adopted for all buildings located within the extents of the 2D Proposed Scheme model domain, to simulate the increased energy dissipation associated with water flowing through and around buildings.

4.2.10 The Fielden Park Brook has been modelled in 2D, with the insertion of 1D ESTRY[15] structures to represent the bridge at Palatine Road and the twin flap valves that release water at the downstream end of the brook into the River Mersey. This modelling approach is preferred over the 1D-2D representation of the Fielden Park Brook as it avoids model instabilities and because the system formed by the Fielden Park Brook and the Didsbury flood storage basin act as a single reservoir during a large flood event (with no difference in water levels between the brook and the surrounding floodplain area).

Inflow boundaries

4.2.11 As the same hydrology has been adopted for this Proposed Scheme model to that of the 2018 Environment Agency model[5], the inflow boundary at Brinksway has been obtained by extracting flow hydrographs from the 2018 Environment Agency model.

4.2.12 Other inflow boundaries into the Proposed Scheme model from tributaries of the River Mersey are the same as for the 2018 Environment Agency model.

Downstream boundary

4.2.13 The downstream boundary is a constant 8.42mAOD water level related to the normal operational level in the Manchester Ship Canal at the confluence with the River Mersey. This level has been selected because an increase in water levels in the Manchester Ship Canal would not affect the levels of the River Mersey at Sale Ees and Didsbury (peak water levels drop by approximately 10m between Sale Ees and the canal.

Key structures

4.2.14 All structures along the River Mersey that were present in the 2012[4] and 2018[5] Environment Agency models have been retained within the extents of the Proposed Scheme model , with small dimension updates if necessary and in some cases changing the type of unit for stability reasons, as shown in Table 2 below.

Table 2: Key structures

Structure name	Structure type modelled in FMP	Checked/adjusted
Heaton Mersey Bleachworks	General weir	Checked with no changes
Cheadle Bridge	Bernoulli loss	Checked with no changes

[15] ESTRY is the TUFLOW model software's 1D solver, which allows for the inclusion of 1D structure (such as culverts, weirs and bridges) into the 2D model.

Structure name	Structure type modelled in FMP	Checked/adjusted
Kingsway Railway Bridge	Arch bridge	This is same as in the 2018 Environment Agency model but enabling switch to orifice flow when bridge becomes surcharged.
Didsbury flood basin inlet	Vertical sluice	Checked with no changes
Northenden Weir	Crump weir	Changed to a spill unit to improve model stability. The banks of the weir have also been added as spill units.
Didsbury flood storage basin outlets	Vertical sluices	Checked with no changes
Didsbury flood storage basin floodplain sensor	(Dummy) vertical sluice	The dummy HT node is maintained but it's position is shifted to be on the Fielden Park Brook, upstream of Palatine Road bridge crossing to match the location of the water level sensor (i.e. pressure transducer) that was informed by the Environment Agency.
Palatine Road Bridge	US BPR 1978 Bridge[16]	This is retained with a skew angle applied and the bridge is set to switch to orifice flow conditions when surcharged.
Borrowdale Crescent Rubble Weir	Spill unit	Checked with no changes
Princess Parkway Bridge	Arch bridge	This is same as in the Environment Agency 2018 model but enabling switch to orifice flow when bridge becomes surcharged.
Princess Parkway downstream rubble weir	Spill unit	Checked with no changes
Chorlton Water Park Rubble Weir	Spill unit	Checked with no changes
Bailey Bridge	US BPR 1978 Bridge[16]	This is same as in the Environment Agency 2018 model but enabling switch to orifice flow when bridge becomes surcharged.
Sale Ees flood basin inlets	Vertical sluice	Checked with no changes
Sale Ees Rubble Weir	Spill unit	Checked with no changes
Rubble weir u/s Barfoot Aqueduct	Spill unit	Checked with no changes
Metrolink Rail Bridge	US BPR 1978 Bridge[16]	This is same as in the Environment Agency 2018 model but enabling switch to orifice flow when bridge becomes surcharged.
Barfoot Aqueduct	Benoulli loss	Checked with no changes
Sale Ees flapped outfall culvert	Circular conduit	Checked with no changes
Sale Ees flood basin outfall	Vertical sluice	Checked with no changes
M63 Bridge at Sale	US BPR 1978 Bridge[16]	This is same as in the Environment Agency 2018 model but enabling switch to orifice flow when bridge becomes surcharged.
Crossford Bridge	Arch bridge	This is same as in the Environment Agency 2018 model but enabling switch to orifice flow when bridge becomes surcharged.
Rubble Weir at New Manor Farm	Spill unit	Checked with no changes
Rubble Weir at Stretford Sewage Treatment Works	Spill unit	Checked with no changes
Rubble Weir at Ashton Cricket Club	Spill unit	Checked with no changes
Ashton Weir right side	Spill unit	Checked with no changes
Ashton Weir left side	General weir	Checked with no changes
Ashton Weir central weir	General weir	Checked with no changes
Flixton Bridge	Arch bridge	This is same as in the Environment Agency 2018 model but enabling switch to orifice flow when bridge becomes surcharged.
Irlam Weir	Spill unit	Checked with no changes
Ashton Weir central weir	General weir	Checked with no changes

[16] US BPR - US Bureau of Public Roads. The US BPR 1978 Bridge refers to a bridge which has been modelled using the methodology developed by the US Bureau of Public Roads (US BPR). The bridge afflux is calculated using the methods described in US BPR (1978), *Hydraulics of Bridge Waterways*. Available online at: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hds1.pdf.

Structure name	Structure type modelled in FMP	Checked/adjusted
Flixton Bridge	Arch bridge	This is same as in the Environment Agency 2018 model but enabling switch to orifice flow when bridge becomes surcharged.
Irlam Weir	Spill unit	Checked with no changes

Roughness

4.2.15 The Manning's n roughness values for the Proposed Scheme model, were set to between 0.029 and 0.032. These are largely consistent with those used in the 2018 Environment Agency model.

4.2.16 2D Manning's n values have been revised using Mastermap data and aerial views.

4.3 Storm Christoph model calibration

4.3.1 Following the validation of the Proposed Scheme baseline model (refer to the Validation Section 5.2), the Proposed Scheme baseline model has been calibrated using gauged data from the January 2021 Storm Christoph event.

4.3.2 The following data provided by the Environment Agency was used for the Proposed Scheme baseline model calibration:

- 15 minute water level data recorded at the following four water level gauges in the Mersey catchment:
  - Brinksway;
  - Didsbury Basin at Withington Golf Course;
  - Didsbury Basin at Stenner Lane; and
  - Northenden weir;
- 15 minute flow data and flow-stage rating curve for Brinksway; and
- operational data for the Didsbury flood storage basin and Sale Ees flood storage basin including: measured levels at the nearby gauging station; operational Action Plans for Phase 1 (AOP1), Phase 2 (OAP2) and Phase 3 (OAP3); and a site location plan for the Didsbury flood storage basin.

4.3.3 The main input data for the Proposed Scheme baseline model calibration is as follows:

- the estimated discharge hydrograph at Brinksway GS at the upstream end of the model. This discharge hydrograph has been obtained by converting recorded water levels to flows, via the flow-stage rating curve provided by the Environment Agency for this gauging station;
- the estimated flows at the modelled tributaries. As the total peak flow of these tributaries is estimated to be less than 5% of the peak flow in the River Mersey, it has been considered sufficient to use FEH flow hydrographs but reduced proportionally to fit the magnitude of the Storm Christoph event. The peak flow ratio of Storm Christoph and the 100 year FEH event was obtained at the Brinksway GS and this ratio was applied to the 100 year flow hydrographs of the tributaries; and
- the operation of the inlet to the Didsbury flood storage basin. Reasonable assumptions where made regarding the operation of the gates by inspecting the rising limb of the water level records within the Didsbury flood storage basin, at Stenner lane and Withington Golf Course.

4.3.4 During calibration inlet gate operation data was not available from the Environment Agency. The operation of the inlet to the Didsbury flood storage basin was estimated based on the water level response observed at Didsbury flood storage basin, as shown in Figure 5. The red profile in Figure 5 indicates the assumed opening of the inlet gate over time (refer to right hand y axis) and the blue profile provides the modelled flow through the inlet (refer to left hand y axis). This data has subsequently been provided, reviewed and was found to make no substantial difference to the model calibration or results.

4.3.5 The Manning's n roughness for the in-bank sections for the 1D-2D part of the Proposed Scheme baseline model, were increased were increased from 0.032 to 0.045 as part of the model calibration for the Storm Christoph event. Outside the 1D-2D area, manning's roughness values have been left unchanged from the preliminary Proposed Scheme model. In addition, the discharge coefficient of Northenden Weir (modelled as an on-line spillway unit) was reduced from its default value of 1.2 to 0.9.

4.3.6 The hydrographs for the calibration period at the Northenden Weir (River Mersey water level), Stenner Lane (reservoir water level) and Withington Golf Course (reservoir water level) are provided in Figure 6 to Figure 8.

4.3.7 Figure 6 provides the calibration at the Northenden weir. This graph shows that the recorded water levels (blue line) are well matched by the calibrated Proposed Scheme baseline model water levels (red line). The uncalibrated model flows are also presented (green line).

4.3.8 The water levels at the Stenner Lane gauge (shown in Figure 7) underestimates recorded levels however the overall temporal response matches the recorded changes in water level well.

4.3.9 For the gauge at Withington Golf Course (presented in Figure 8) the Proposed Scheme e baseline modelled peak water level is a close match to the recorded levels.

4.3.10 Following the completion of calibration, the 15 minute manual log records for the operation of the Sales Ees/Didsbury inlet gates during the Storm Christoph event were provided by the Environment Agency. These details were incorporated into the hydraulic Proposed Scheme baseline model to validate the model calibration. Based on the results of the validation runs, which continued to demonstrate a close match to observed water levels, and given that the modelling was well advanced, there was no further adjustment of Manning's n values.

Figure 5: Assumed gate operation at the Didsbury flood storage basin inlet and estimated flows

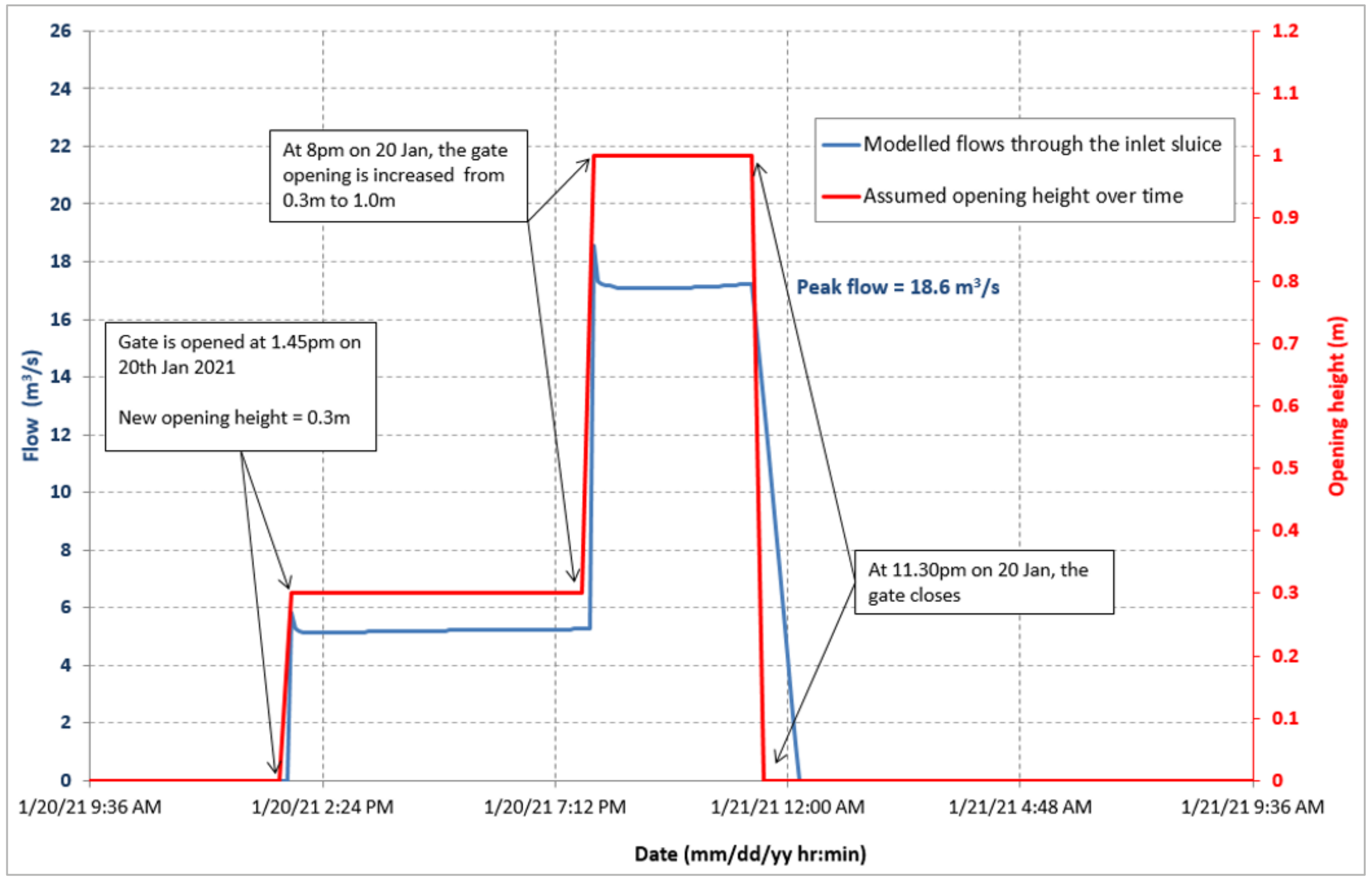


Figure 6: Northenden Weir hydrograph calibration

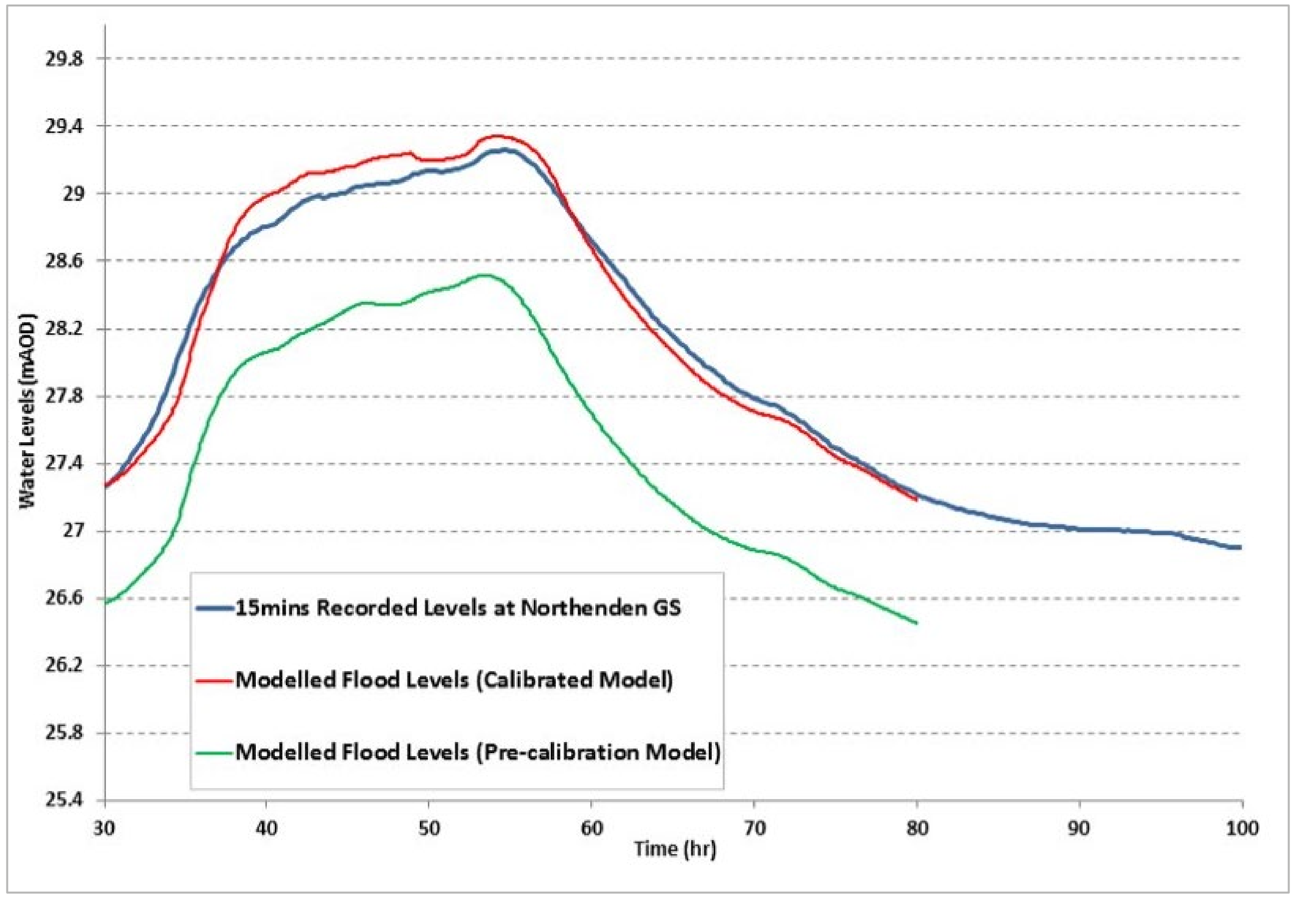


Figure 7: Stenner gauge hydrograph calibration

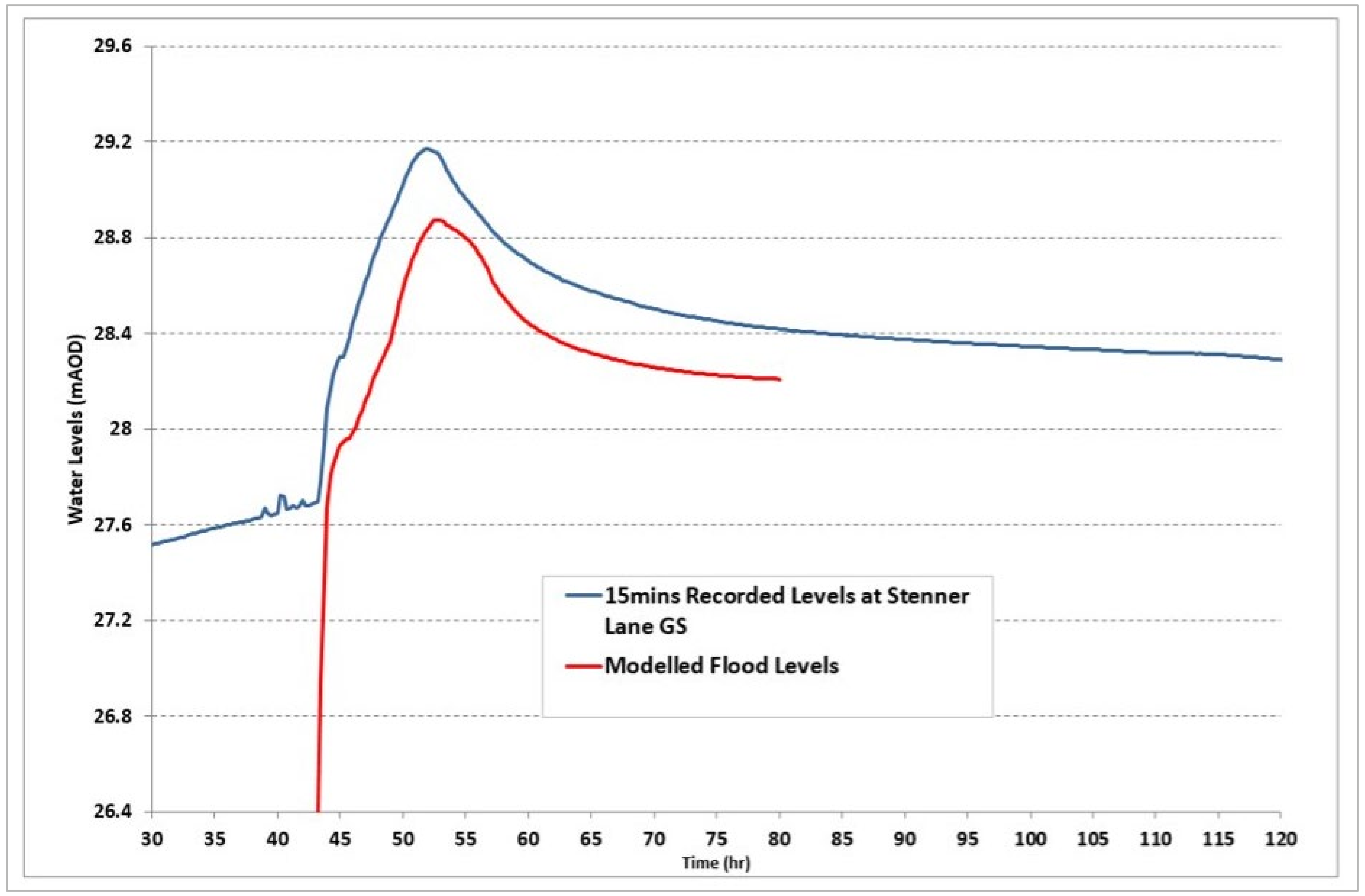
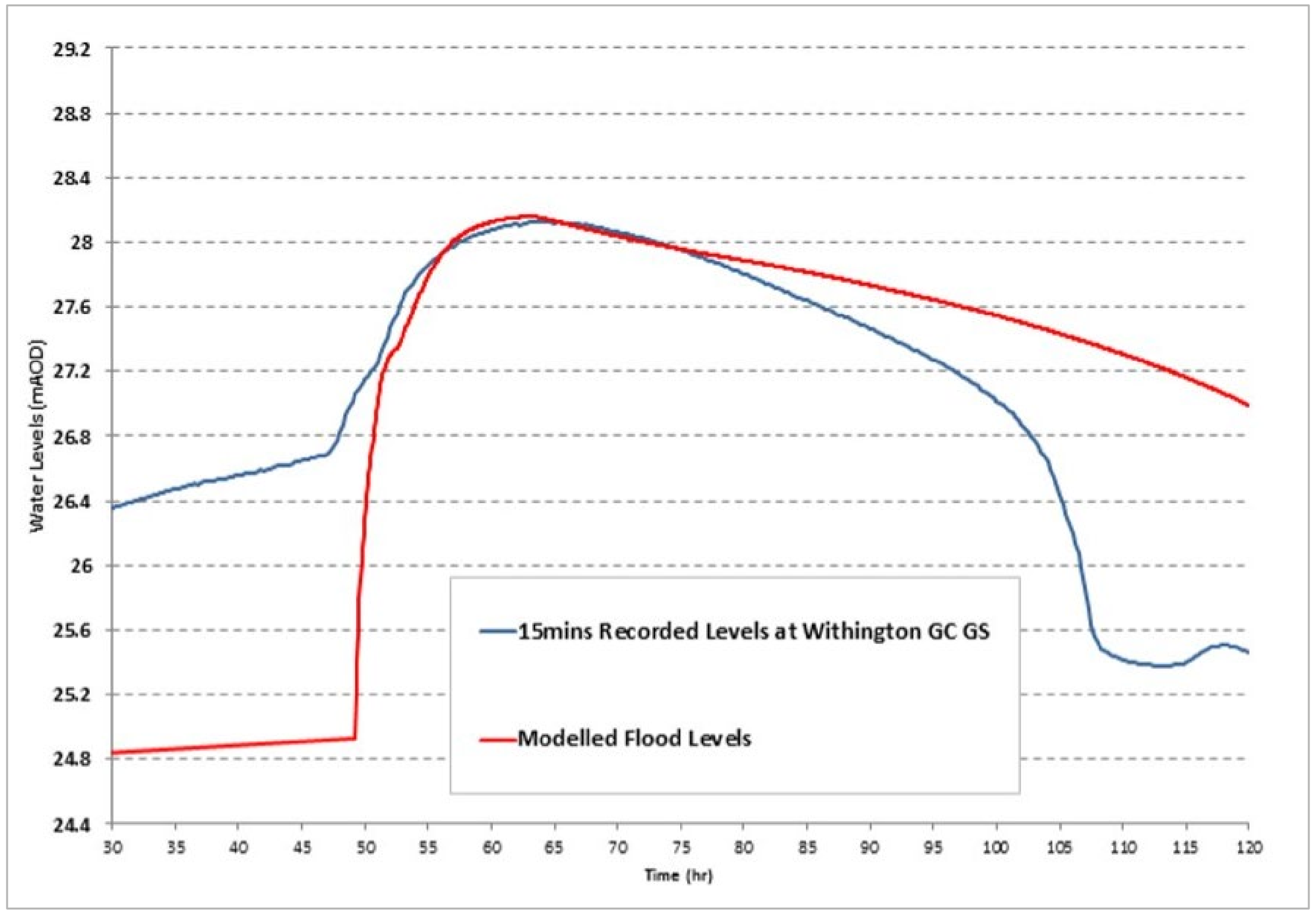


Figure 8: Withington Golf Course gauge hydrograph calibration



4.4 Hydraulic model build – Proposed Scheme

4.4.1 Figure 9 shows the Proposed Scheme model schematic. The Proposed Scheme model has been edited from the baseline to include the following design elements.

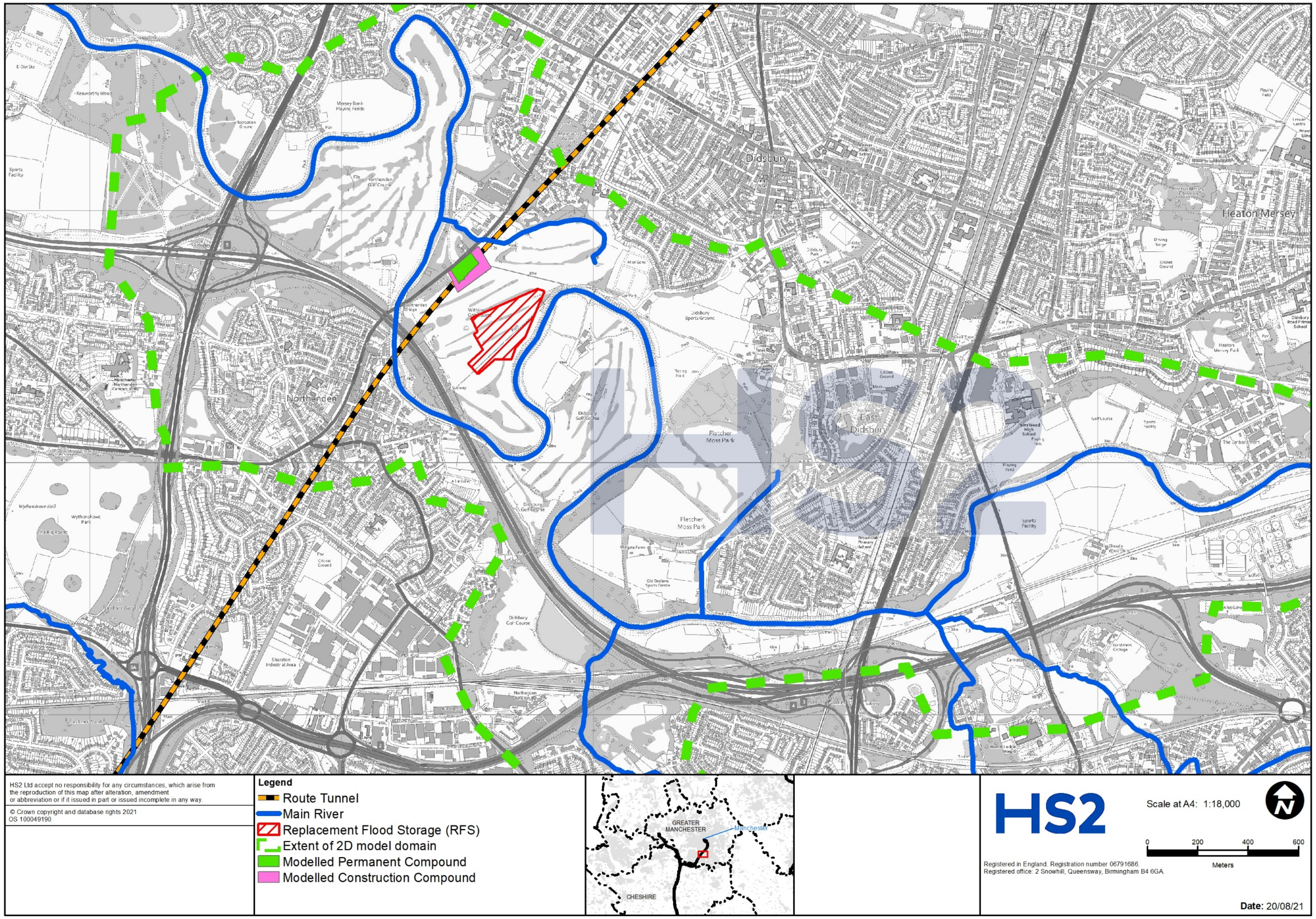
Topographic changes

4.4.2 The raised compound and the shaft have been modelled using 3D polygons to raise ground levels over the land required for the construction of the Proposed Scheme and land required for the Proposed Scheme.

4.4.3 Within the land required for the Proposed Scheme ground levels have been raised to a notional level of 33.5mAOD which is above the estimated 1.0% AEP + CC peak water level of 30.45mAOD at this location. Outside the land required for the Proposed Scheme, within the land required for the construction of the Proposed Scheme, ground levels have been raised to 30.1mAOD consistent with a 1 in 100 year standard of protection plus a relatively small freeboard of 0.15m.

4.4.4 The top of the vent shaft has been designed for the 1 in 1,000 year peak water level of 30.37mAOD plus freeboard of 0.6m, giving a top level of 30.97mAOD.

Figure 9: Proposed Scheme model schematic



Replacement floodplain storage areas

4.4.5 The proposed volume for volume compensation in the Withington Golf Course area has been modelled using a 3D polygon to lower the ground levels in the proposed flood compensation area to a minimum level of 27.34mAOD. This level has been chosen to ensure a gravity discharge via an existing ditch into the River Mersey via the main outlet structure. The excavated volume replaces the floodplain volume removed by the proposed vent shaft and its associated compound at the peak operating level of the Didsbury flood storage basin of 28.65mAOD. The replacement storage volume is embedded into the design and is included in the Proposed Scheme model.

Production of flood extents

4.4.6 Maximum flood depth grids have been extracted from the Proposed Scheme model outputs using a standard TUFLOW utility tool known as TUFLOW–to_GIS. The resulting flood depth grids have been post-processed using 'Raster to Vector' tool in QGIS to generate flood extent regions for the full range of design flood events.

Modelling assumptions made

4.4.7 Key structure sizes and river cross sections are based on the data available within the existing 2012 Environment Agency model which we have assumed for the purposes of this assessment to be correct. This is because the original survey data undertaken in the 1990s was not available.

4.5 Climate change

4.5.1 The climate change allowance for the River Mersey is a 70% (upper end) increase in peak river flows due to the presence of more vulnerable flood sensitive receptors in Flood Zone 3 in the vicinity of the proposed vent shaft and associated compound[3].

4.5.2 The H++ allowance for the River Mersey is a 95% increase in peak river flows for the purpose of sensitivity analysis.

5 Model proving

5.1 Run performance

5.1.1 The time step parameters used are 1 second for the 1D Proposed Scheme model element and 2 seconds for the 2D Proposed Scheme model element. Final cumulative mass balance error is within +/-2.0% for all model runs undertaken.

5.2 Validation

5.2.1 Following Proposed Scheme model build an independent review of the model was carried out following the HS2 technical standards. The findings of this review were discussed and subsequently, improvements were made to the Proposed Scheme model prior to calibration. The key elements that have been addressed are:

- left and right banks of Northenden weir were added to simulate flows bypassing the weir through the side bank slopes;
- the crest length of the Northenden weir has been adjusted to take account of the weir skew angle compared to the river flow direction; a value of 37m has been included;
- inclusion of an existing flood wall along Ford Lane;
- inclusion of a full barrier to flow to represent the M60 bridge abutment on the western bank of the River Mersey;
- removal of model instabilities for both low and high flows, by changing the Northenden crump weir to a general spill unit;
- inclusion of a 25 degrees skew angle on the USBPR Palatine Road bridge; and
- all bridges in the 1D FMP model have been set to switch to orifice flow conditions when surcharged; this is to enhance the accuracy of the model when simulating head losses at surcharging bridges.

5.2.2 Figure 10 presents the differences in modelled flood extent in the Northenden area between the Proposed Scheme model and the 2018 Environment Agency model[5]. The Proposed Scheme model indicates a smaller extent of flooding on the western side of the River Mersey in Northenden than shown in the 2018 Environment Agency model. This is due to the inclusion of the flood wall along Ford Lane and the M60 abutment in the Proposed Scheme model, which are incorrectly omitted from the 2018 Environment Agency model. These changes affect the overland flow path at Ford Lane, with flood water restricted to the road underpass of the M60 towards Northenden due to the solid M60 bridge abutment.

5.2.3 Differences between flood extents are also observed within the land located just off the M60 Junction 4, near Kingsway, as shown in Figure 11. This is due to the improvements in the modelling outlined above.

5.3 Sensitivity analysis

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

- use of H++ climate change scenario of 95% increase in peak river flow;
- increase in Manning's n roughness (channel, structures and floodplain) by 20%; and
- decrease in Manning's n roughness (channel, structures and floodplain) by 20%.

5.3.2 No sensitivity tests have been undertaken for the downstream boundary condition as the downstream boundary is 19.6km away from the Proposed Scheme vent shaft. This is considered sufficiently far downstream to ensure there is no effect at the Proposed Scheme vent shaft.

5.3.3 The results indicate that the Proposed Scheme model is sensitive to the manning's n parameter as well as the change in flows from a 70% to a 95% increase in peak river flow.

5.4 Blockage analysis

5.4.1 Blockage analysis has not been undertaken as there are no openings beneath the proposed vent shaft and associated compound.

5.5 Run parameters

5.5.1 Run parameters from the Environment Agency 2012 model have been retained in the Proposed Scheme model, with the following exceptions:

- MaxItr (the maximum number of iterations performed at each step) has been increased from 13 to 19 to enhance the likelihood of convergence during the iterative step process; and
- Theta has been increased from the value of 0.7 (default) to 1.0 to enhance computational efficiency via switching to a fully implicit numerical scheme.

5.5.2 All model runs have been performed using default run parameters in TUFLOW as recommended from the literature.

Figure 10: Comparison of flood extents generated from the Proposed Scheme model and the 2018 Environment Agency model at Northenden

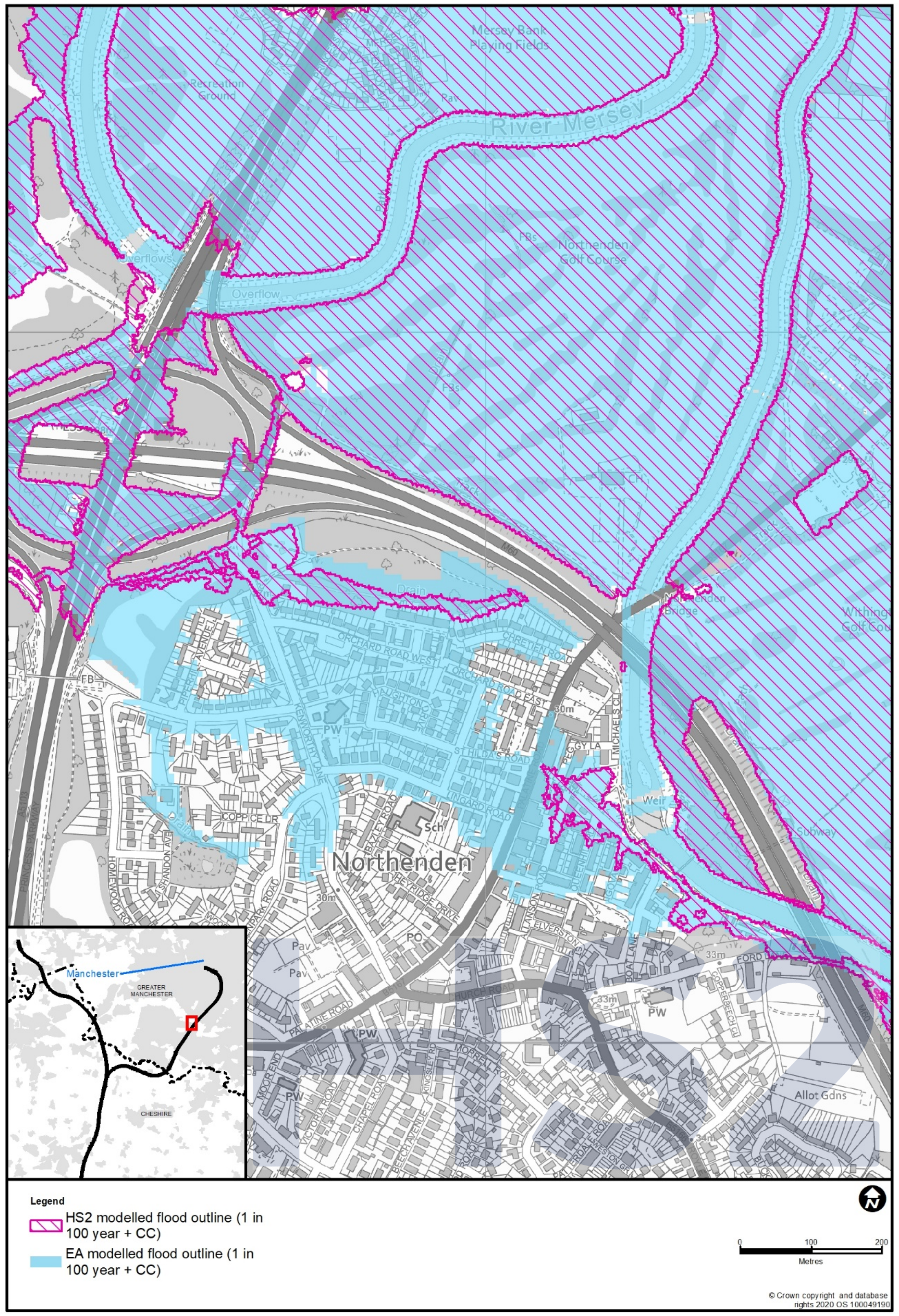
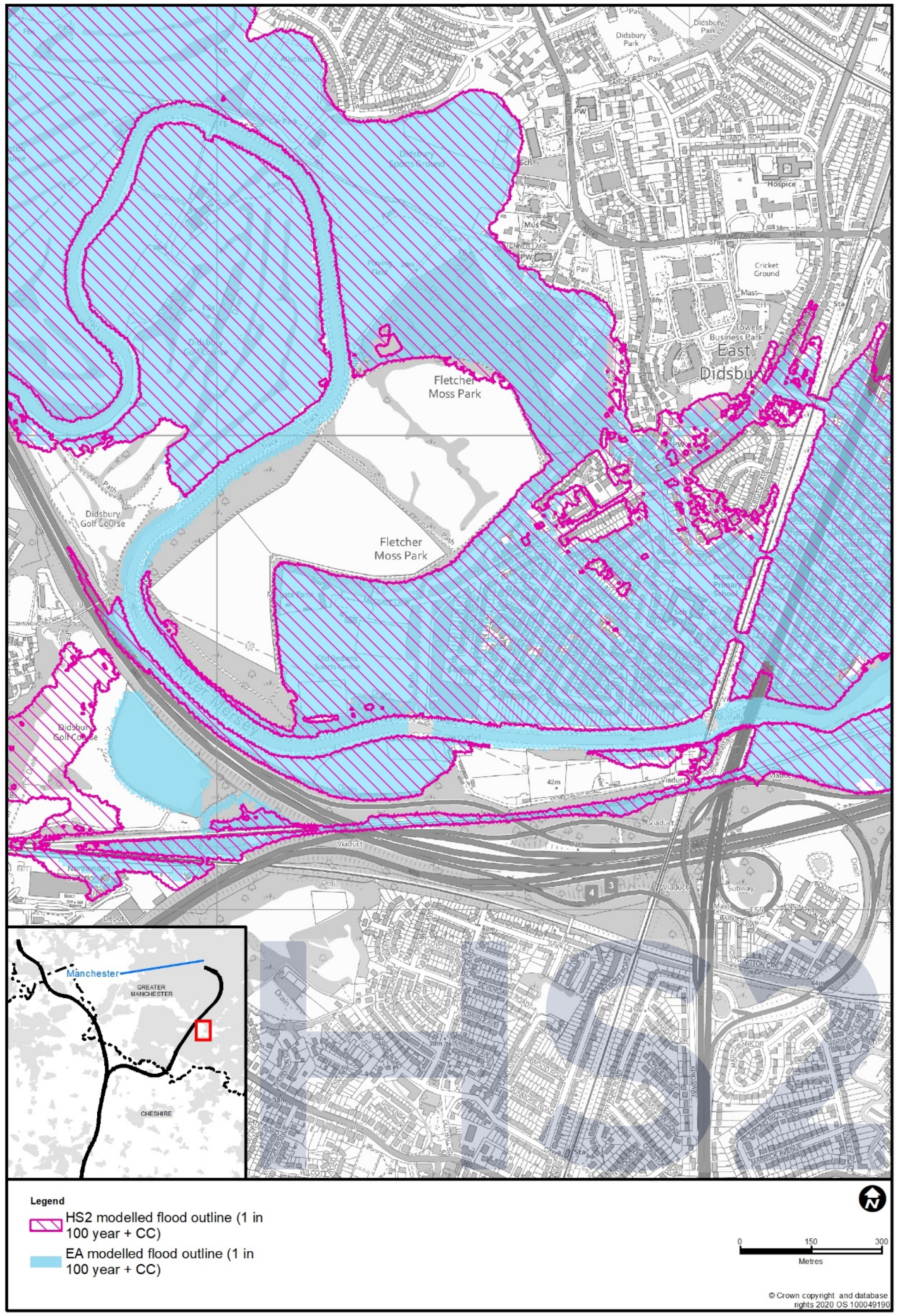


Figure 11: Comparison of flood extents generated from the Proposed Scheme model and the 2018 Environment Agency model at Kingsway



6 Model results

6.1 Baseline model results

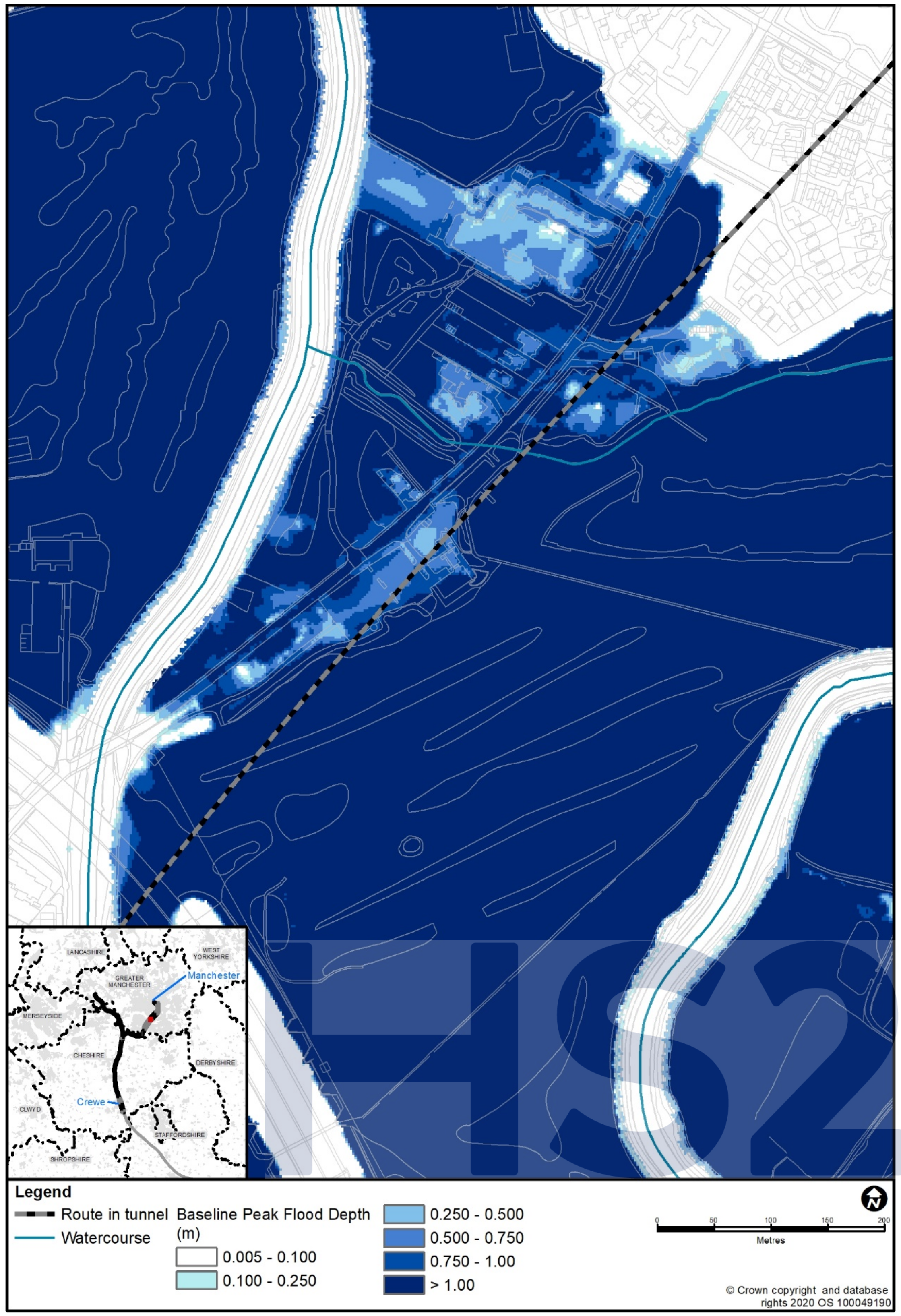
6.1.1 The Proposed Scheme model has been run for the 5.0%, 2%, 1.33% 1.0%, 0.5%, 0.1% and 1.0% AEP + CC AEP flood events. The 1.0% AEP + CC simulation is based on a 70% increase in peak river flows. Flood event probabilities and peak water levels at Withington Golf Course in the vicinity of the proposed shaft are provided in Table 3.

Table 3: Peak water levels at Withington Golf Course in the vicinity of the proposed shaft

Event probability (% AEP)	Return period (years)	Peak water level (mAOD)
5	20	29.59
2	50	29.85
1.33	75	29.90
1	100	29.93
0.5	200	30.00
0.1	1000	30.37
1+ CC	100 + CC	30.34

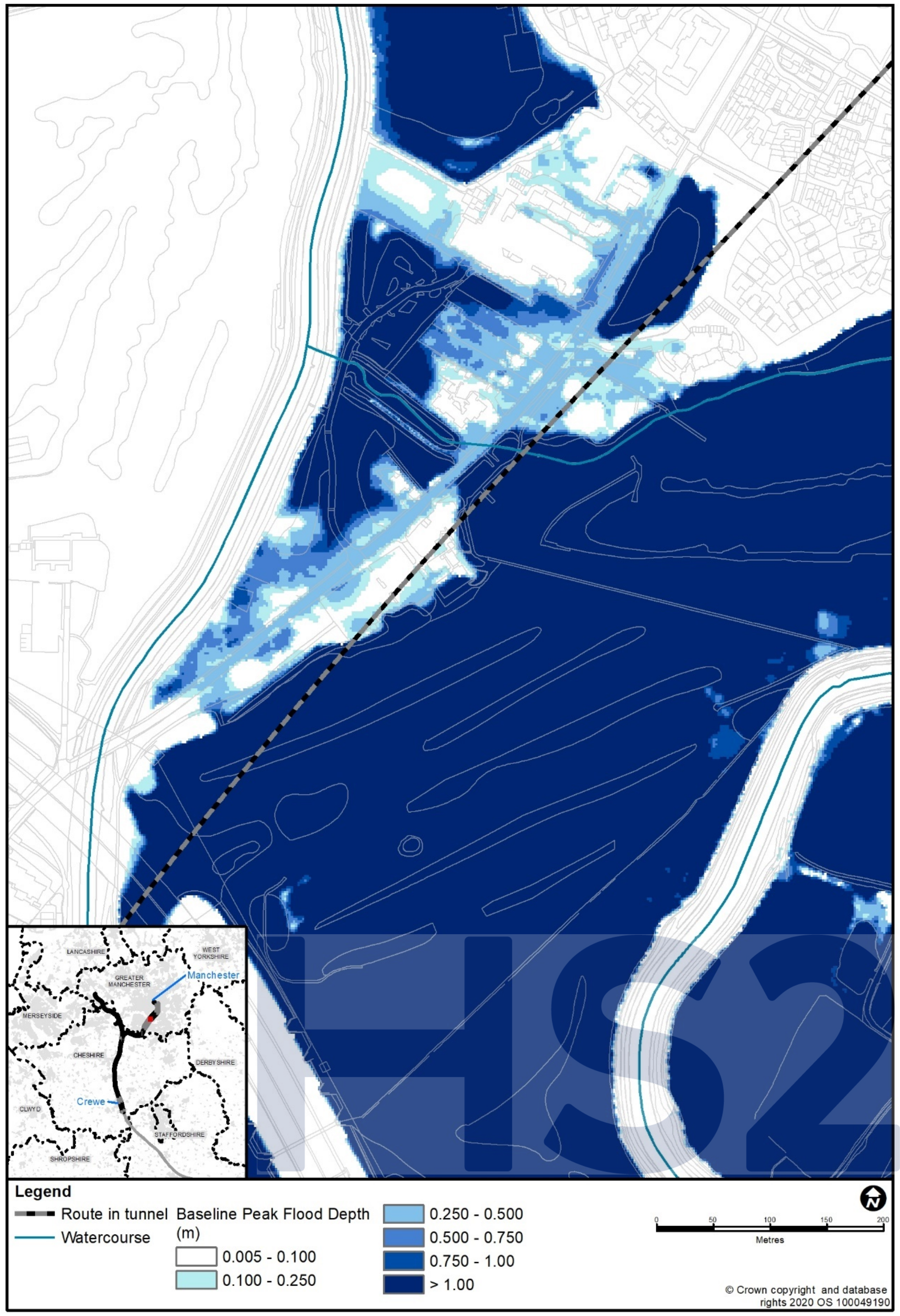
6.1.2 Peak flood depths are provided for the 5% and the 1.0% AEP + CC design event in Figure 12 to Figure 19, which include a brief description of the baseline flood risk in those areas.

Figure 12: Peak flood depth in Palatine Road area (1% AEP + CC)



Deep flooding above 1m covers the surrounding floodplain. Most receptors in the areas adjacent to Palatine Road are flooded to depths of between 0.01m and 1m.

Figure 13: Peak flood depth in Palatine Road area (5% AEP)

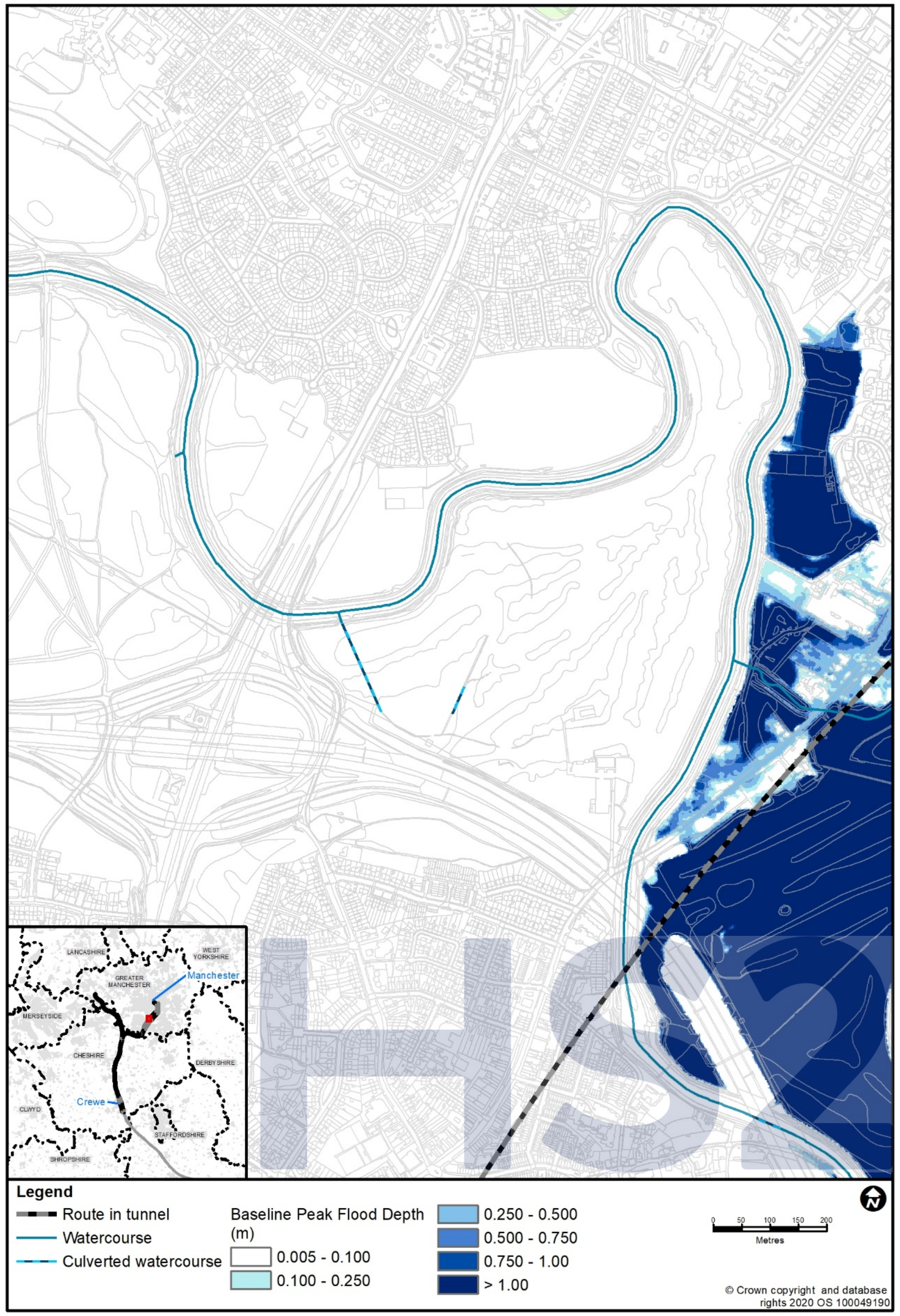


No commercial or residential receptors are flooded. There is shallow flooding of less than 0.25m along parts of Palatine Road.

Figure 14: Peak flood depth downstream of Palatine Road (1% AEP + CC)

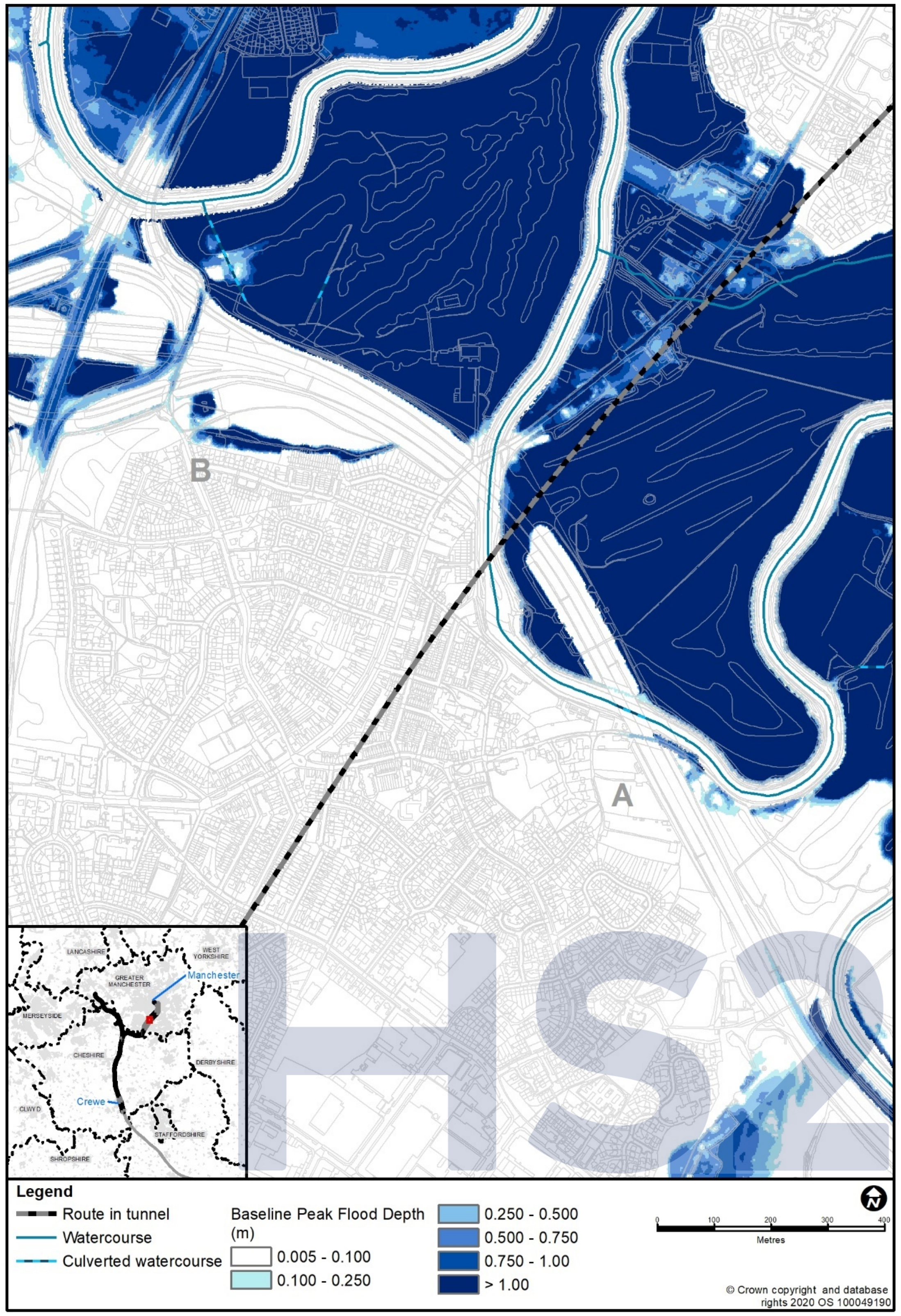
Deep flooding of Northenden golf course takes place (A) and there is risk of flooding of properties along the floodplain at locations B, C and D.

Figure 15: Peak flood depth downstream of Palatine Road (5% AEP)



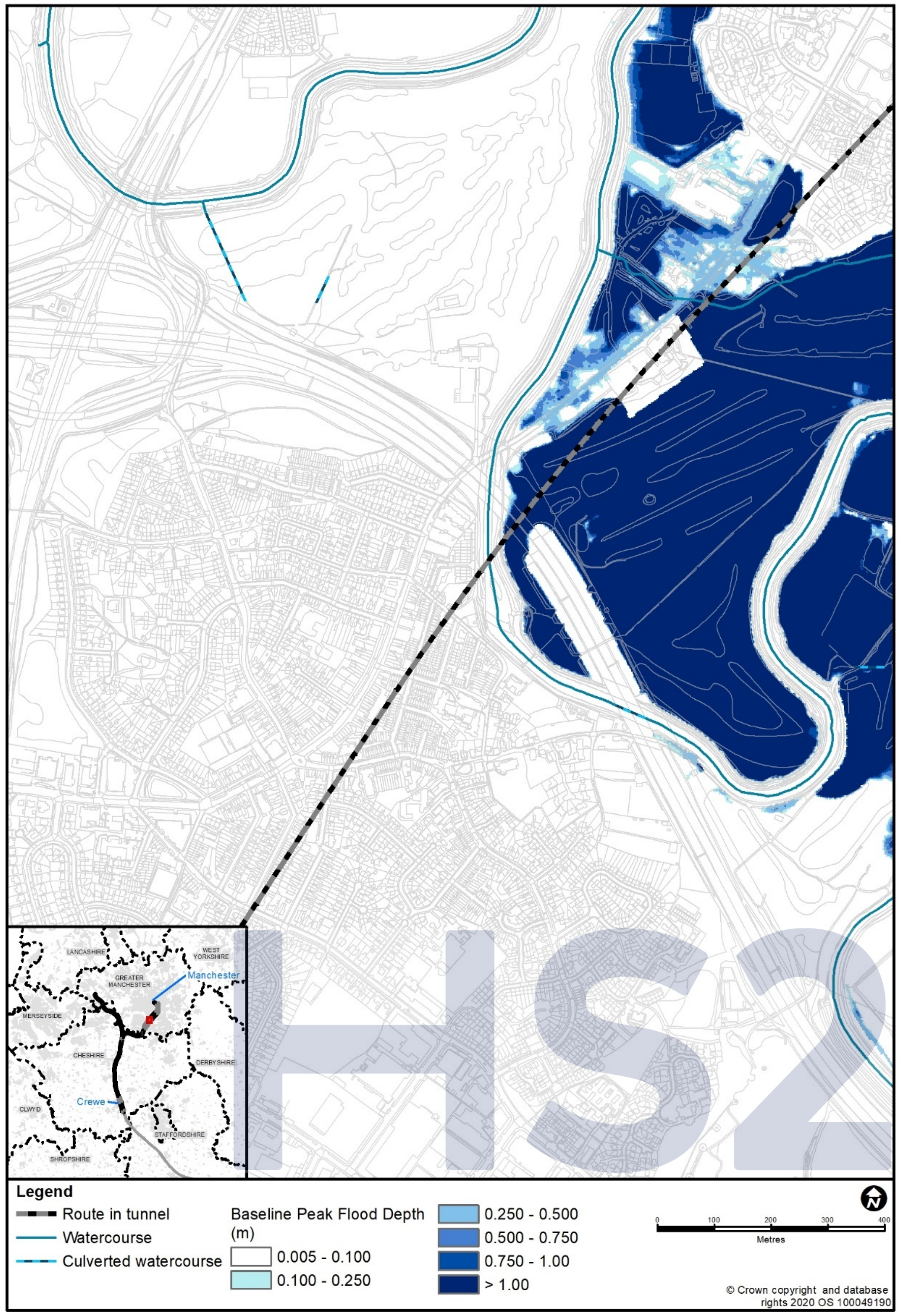
There is no flooding of Northenden golf course or property downstream of Palatine Road.

Figure 16: Peak flood depth in Northenden area (1% AEP + CC)



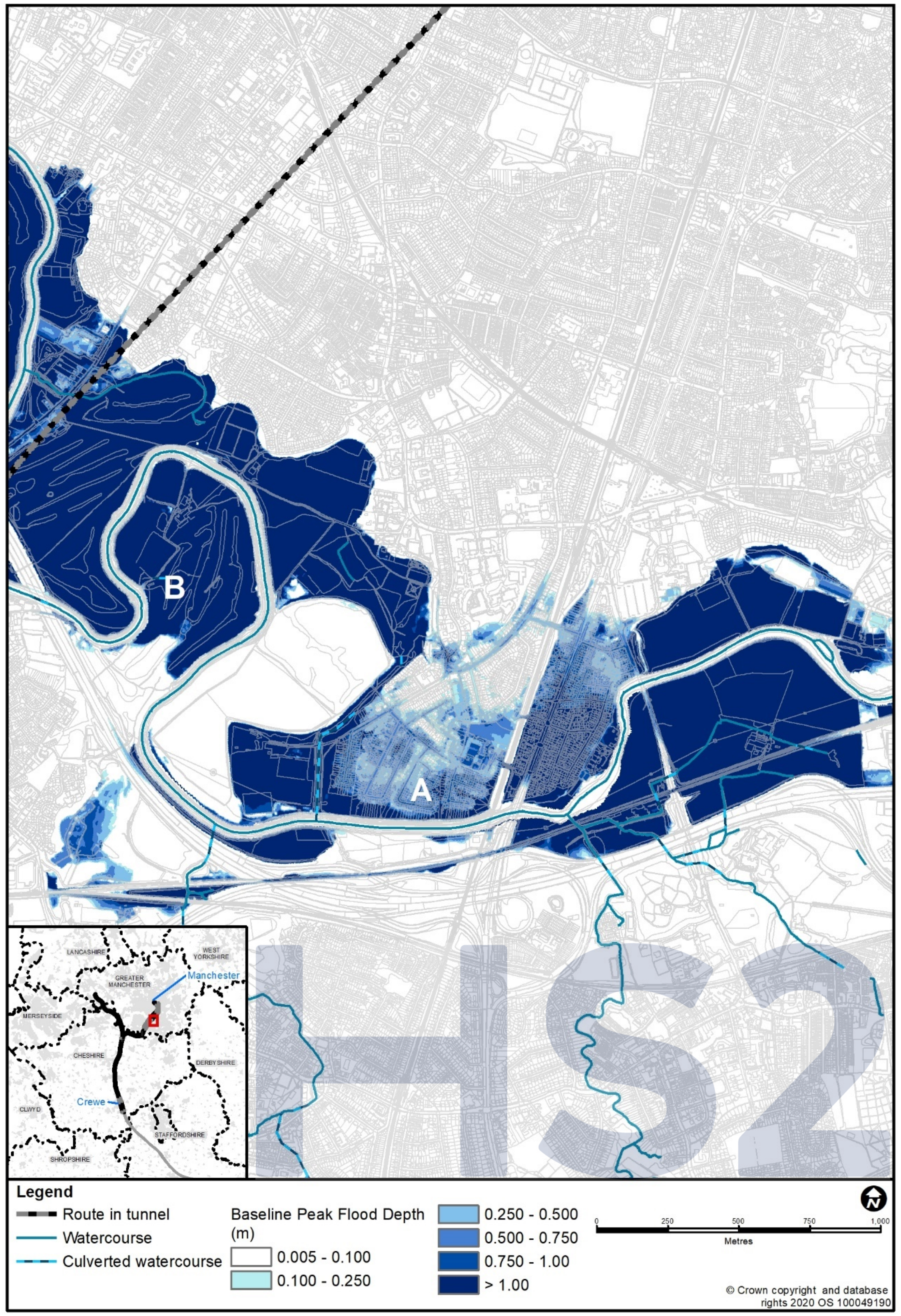
Flooding of static caravans and temporary accommodation along Ford Lane (A) and floodwater surrounds buildings but does not flood them at location B.

Figure 17: Peak flood depth in Northenden area (5% AEP)



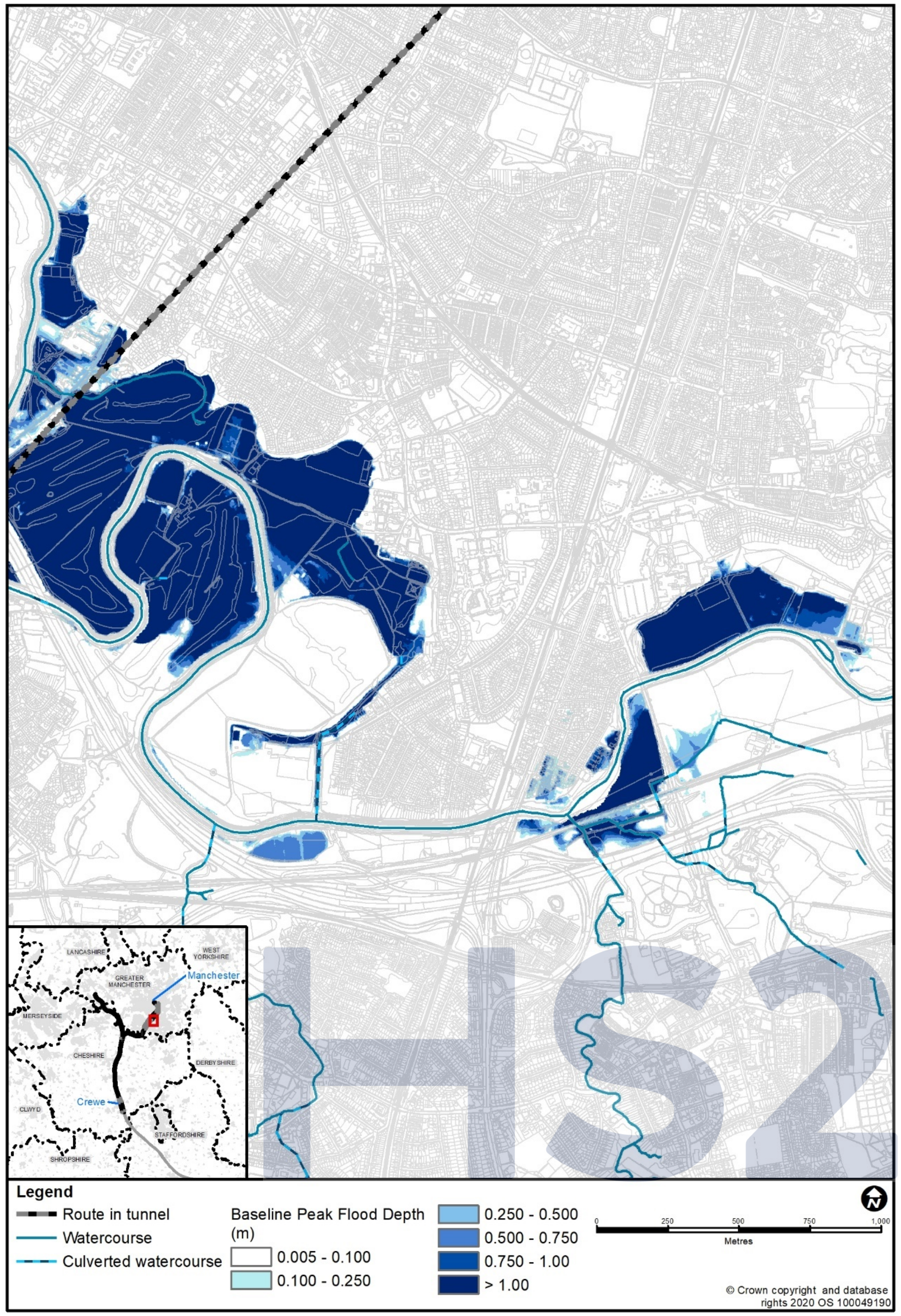
No flooding in the area of Northenden.

Figure 18: Peak flood depth in Didsbury and upstream (1% AEP + CC)



Large areas of open space are flooded to a depth of above 1m, with areas of shallow flooding surrounding receptors (A) upstream of the Didsbury flood storage basin (B).

Figure 19: Peak flood depth in Didsbury and upstream (5% AEP)



Limited flooding in open spaces, apart from within the Didsbury flood storage basin.

6.2 Proposed Scheme

6.2.1 The Proposed Scheme model has been run for the 5.0%, 1.0%, 1.0% AEP + CC, and 0.1% AEP design flood events. The 1.0% AEP + CC simulation is based on a 70% increase in peak river flows.

6.2.2 The modelled flood extents with the Proposed Scheme for the 5.0% AEP event are presented in the Volume 5, Water resources and flood risk Map Book: map WR-06-323 and WR-06-324. The modelled flood extents with the Proposed Scheme for the 1.0% AEP + CC event are presented in the Volume 5, Water resources and flood risk Map Book: map WR-05-323 and WR-05-324.

6.2.3 The impact of the proposed vent shaft and its associated raised compound on peak flood levels, taking into account the volume for volume compensation within Withington Golf Course, is presented as an overview within the 2D extents for the 5% AEP and the 1.0% AEP + CC events in Annex A (Figure A 1 and Figure A 2 respectively).

6.2.4 Detailed information for the 1% + CC AEP event is provided in the areas where there is an impact on properties in Figure 20 to Figure 29. These figures include the baseline peak flood depths as well as the impacts resulting from the Proposed Scheme. The figures have associated tables which provide flood risk information for those properties potentially affected as a result of the Proposed Scheme. These tables include peak water levels and peak depths above threshold for the baseline and the Proposed Scheme (including the volume for volume compensation storage). The difference in peak water levels at these properties provides an indication of the impact as a result of the scheme.

Figure 20: Change in peak flood level in the Palatine Road area

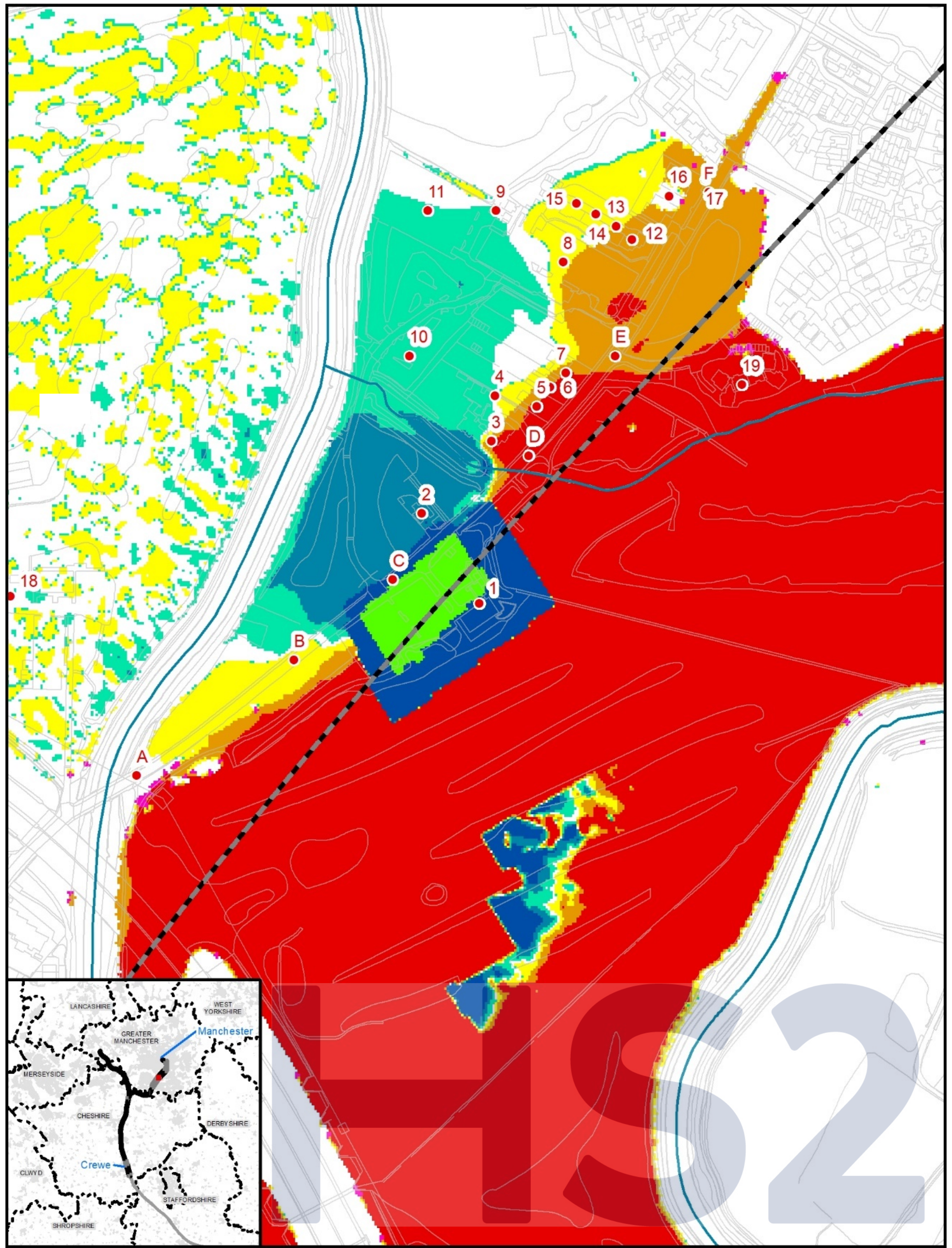


Figure 21: Baseline peak flood depth in the Palatine Road area

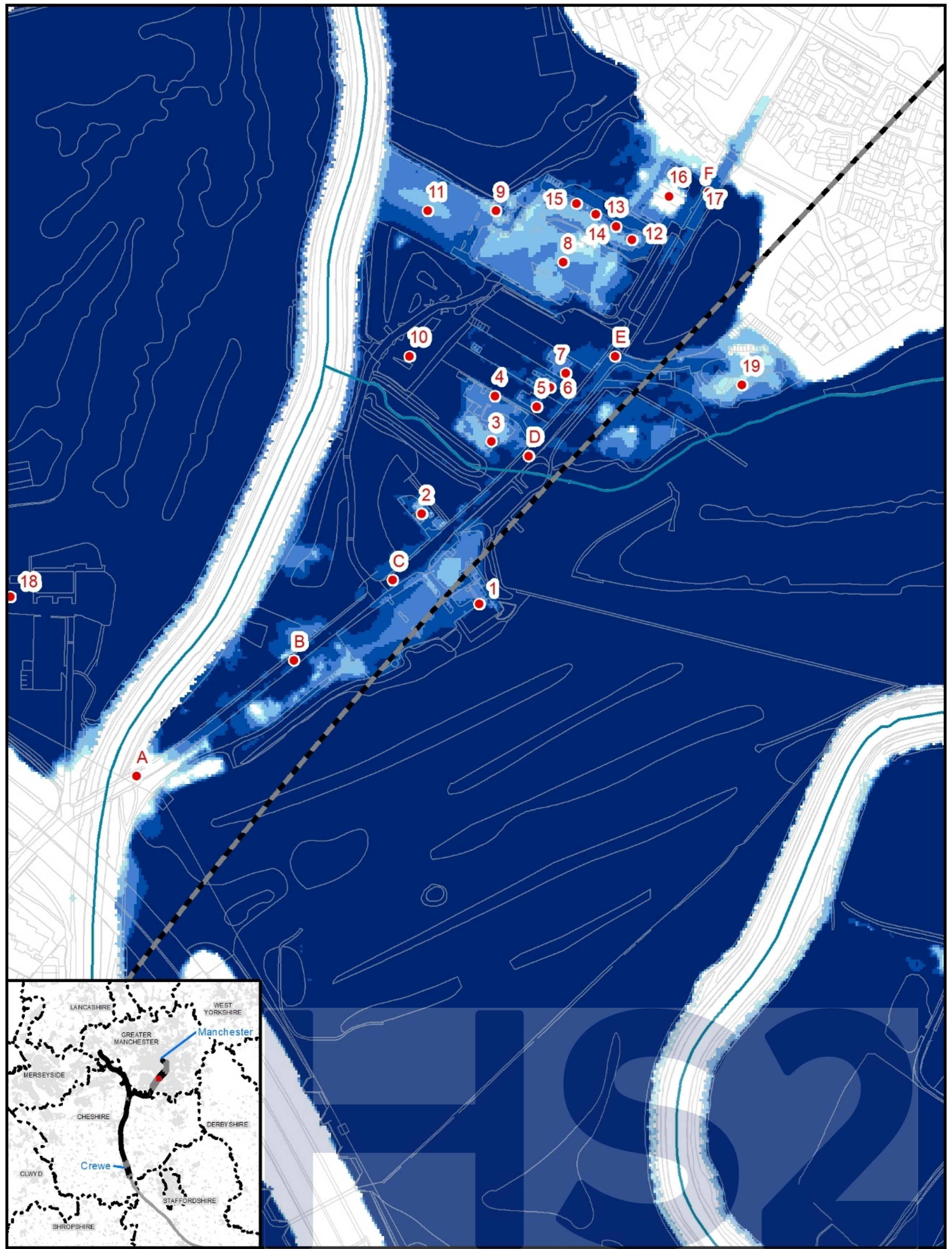


Table 4: Change in peak flood level in the Palatine Road area (see Figure 20)

Receptor details				Peak flood levels mAOD (depth above ground level (m))		Peak water level
ID	Receptor type	Ground level (mAOD)	Assumed threshold level (mAOD)	Baseline water level	Proposed Scheme (including compensation storage) scenario	Difference (m)
A	Road	30.754	30.754	Dry	Dry	N/A
B	Road	29.120	29.120	30.155 (1.035)	30.189 (1.069)	0.035
C	Road	29.141	29.141	30.147 (1.006)	30.034 (0.893)	-0.113
D	Road	29.188	29.188	30.289 (1.101)	30.406 (1.218)	0.117
E	Road	29.279	29.279	30.188 (0.909)	30.284 (1.005)	0.096
F	Road	29.346	29.346	30.184 (0.838)	30.281 (0.935)	0.096
1	Commercial	29.596	29.896	30.291 (0.695)	30.473 (0.877)	0.182
2	Residential	29.193	29.493	30.114 (0.921)	30.035 (0.842)	-0.079
3	Residential – multiple occupancy	29.440	29.740	30.185 (0.745)	30.267 (0.827)	0.082
4	Secondary electrical substation	29.261	29.561	30.107 (0.846)	30.117 (0.856)	0.010
5	Residential	29.297	29.597	30.265 (0.968)	30.379 (1.082)	0.114
6	Residential	29.273	29.573	30.251 (0.978)	30.363 (1.090)	0.112
7	Residential	29.129	29.429	30.212 (1.083)	30.314 (1.185)	0.102
8	Commercial property	29.125	29.425	30.082 (0.957)	30.119 (0.994)	0.037
9	Commercial property	28.996	29.296	29.825 (0.829)	29.821 (0.825)	-0.004
10	Car park	26.666	26.666	30.061 (3.395)	30.022 (3.356)	-0.039
11	Car park	29.355	29.355	29.893 (0.538)	29.874 (0.519)	-0.019
12	Residential – multiple occupancy	29.263	29.563	29.954 (0.691)	30.023 (0.760)	0.069
13	Residential – multiple occupancy	29.235	29.535	29.863 (0.628)	29.901 (0.666)	0.038
14	Residential – multiple occupancy	29.227	29.527	29.828 (0.601)	29.851 (0.624)	0.023
15	Residential – multiple occupancy	29.260	29.560	29.808 (0.548)	29.824 (0.564)	0.016
16	Residential – multiple occupancy	30.990	31.290	Dry	Dry	N/A
17	Secondary electrical substation	29.433	29.733	30.181 (0.748)	30.277 (0.844)	0.096
19	Residential – multiple occupancy	29.747	30.047	30.317 (0.570)	30.445 (0.698)	0.128

Figure 22: Change in peak flood level in Northenden South of Junction 5 of the M60

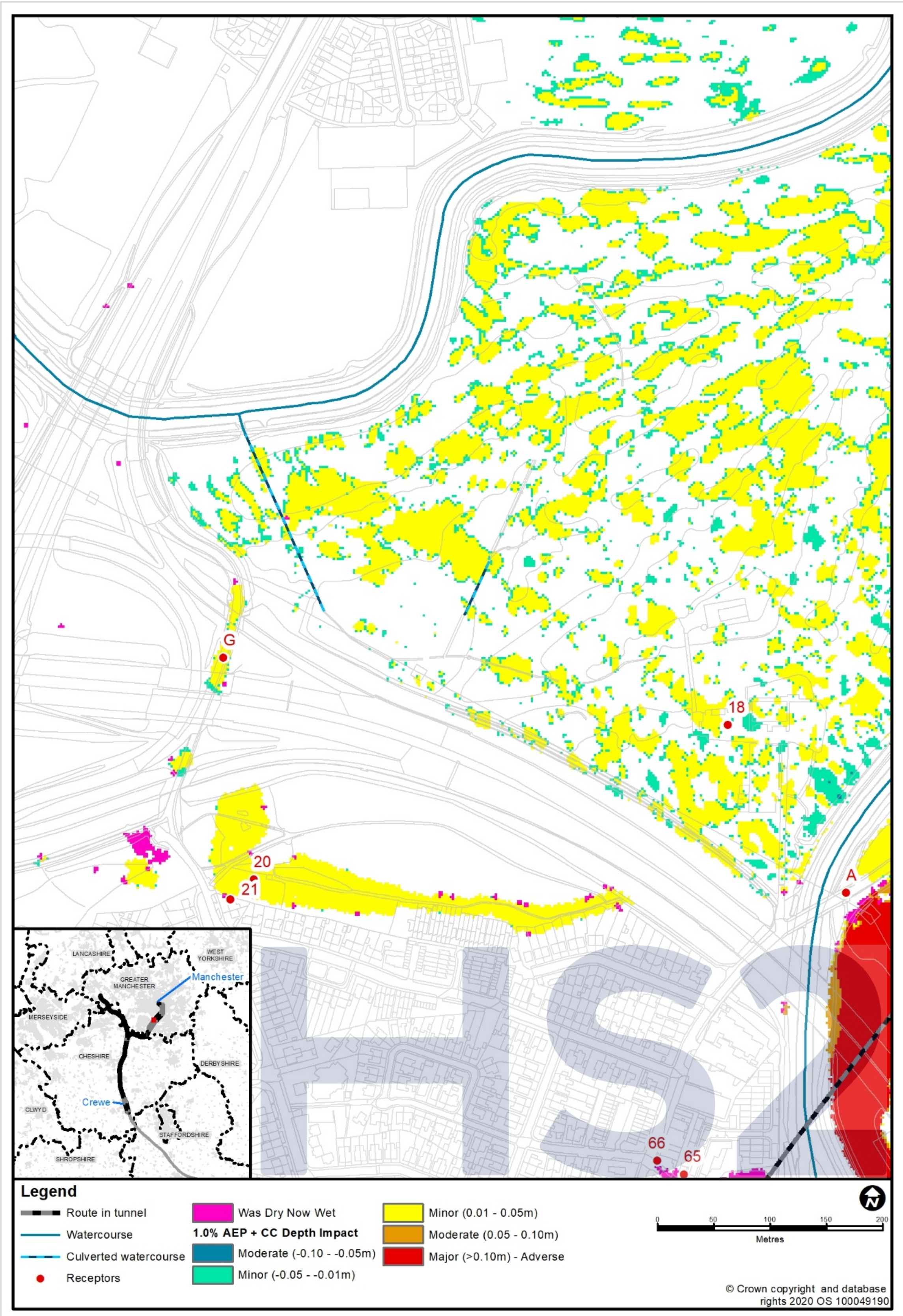


Figure 23: Baseline peak flood depth in Northenden South of Junction 5 of the M60

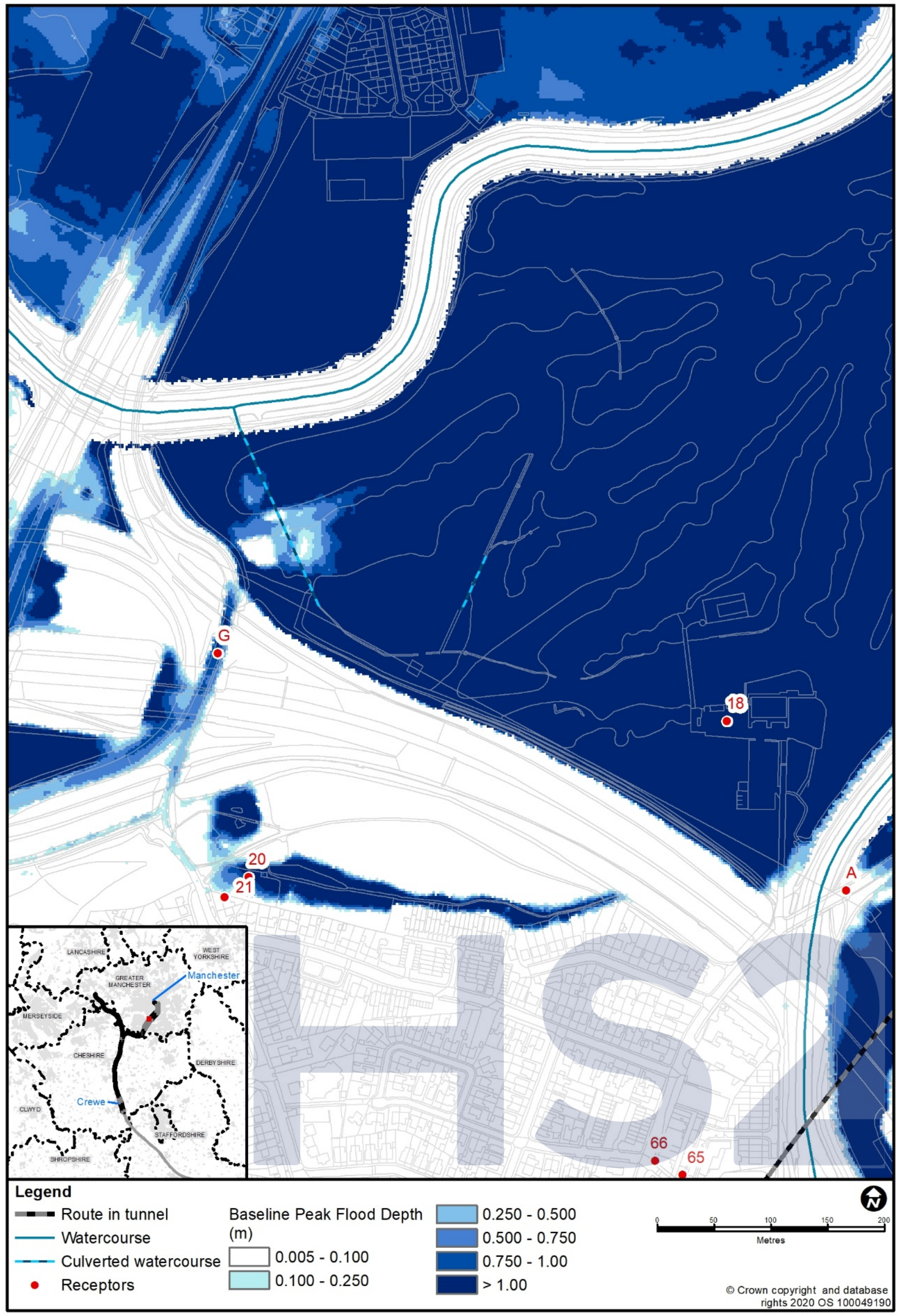


Table 5: Change in peak flood level in Northenden, south of Junction 5 of the M60 (see Figure 22)

Receptor details				Peak flood levels mAOD (depth above ground level (m))		Peak water level
ID	Receptor type	Ground level (mAOD)	Assumed threshold level (mAOD)	Baseline water level	Proposed Scheme (including compensation storage) scenario	Difference (m)
G	Cycle track	28.591	28.591	29.514 (0.923)	29.526 (0.935)	0.012
18	Commercial	25.729	26.029	29.797 (4.068)	29.798 (4.069)	0.001
20	Residential	26.419	26.719	Dry	Dry	N/A
21	Residential	26.772	27.072	Dry	Dry	N/A

Figure 24: Change in peak flood level in Northenden (Ford Lane)

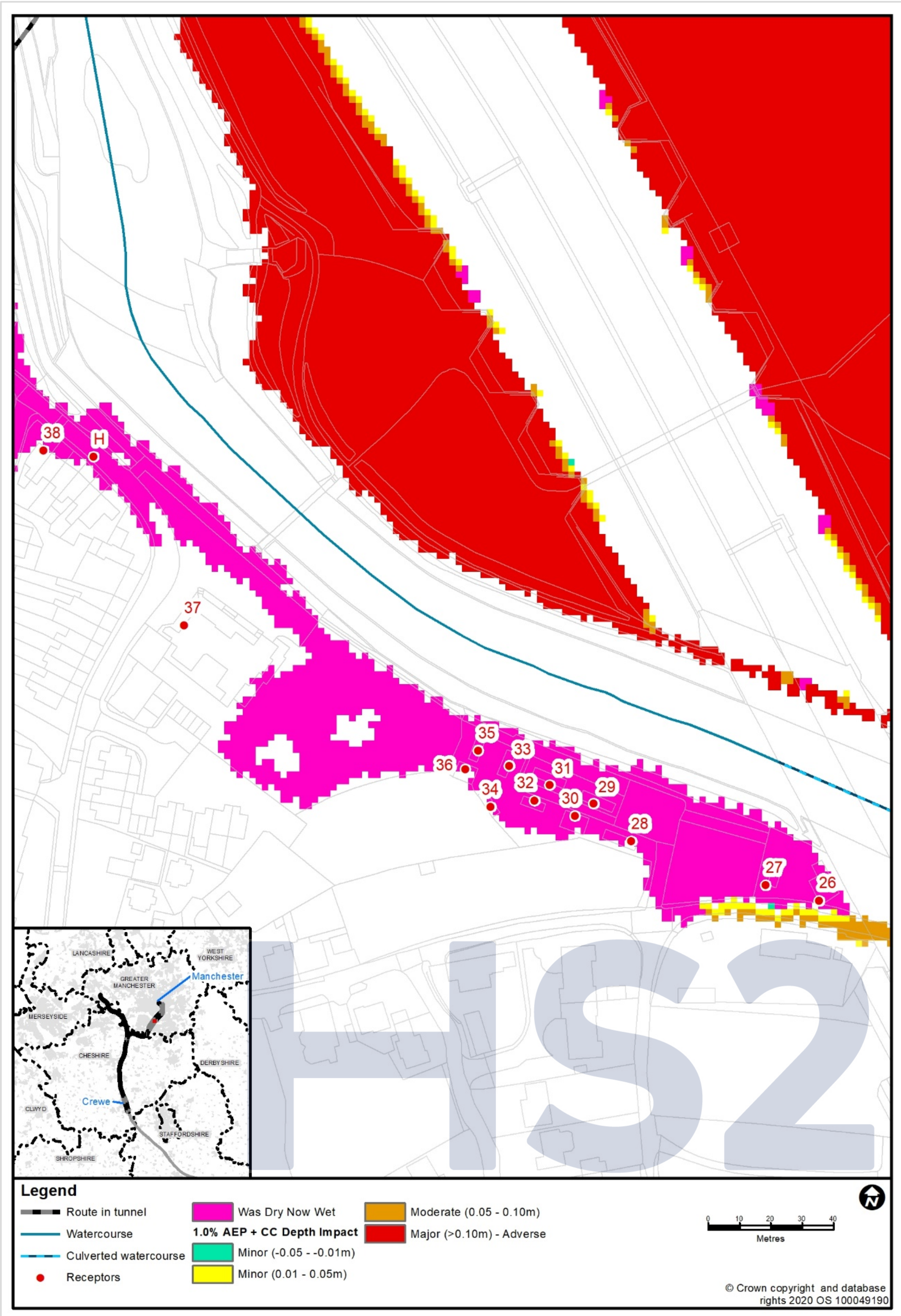


Figure 25: Baseline peak flood depth in Northenden (Ford Lane)

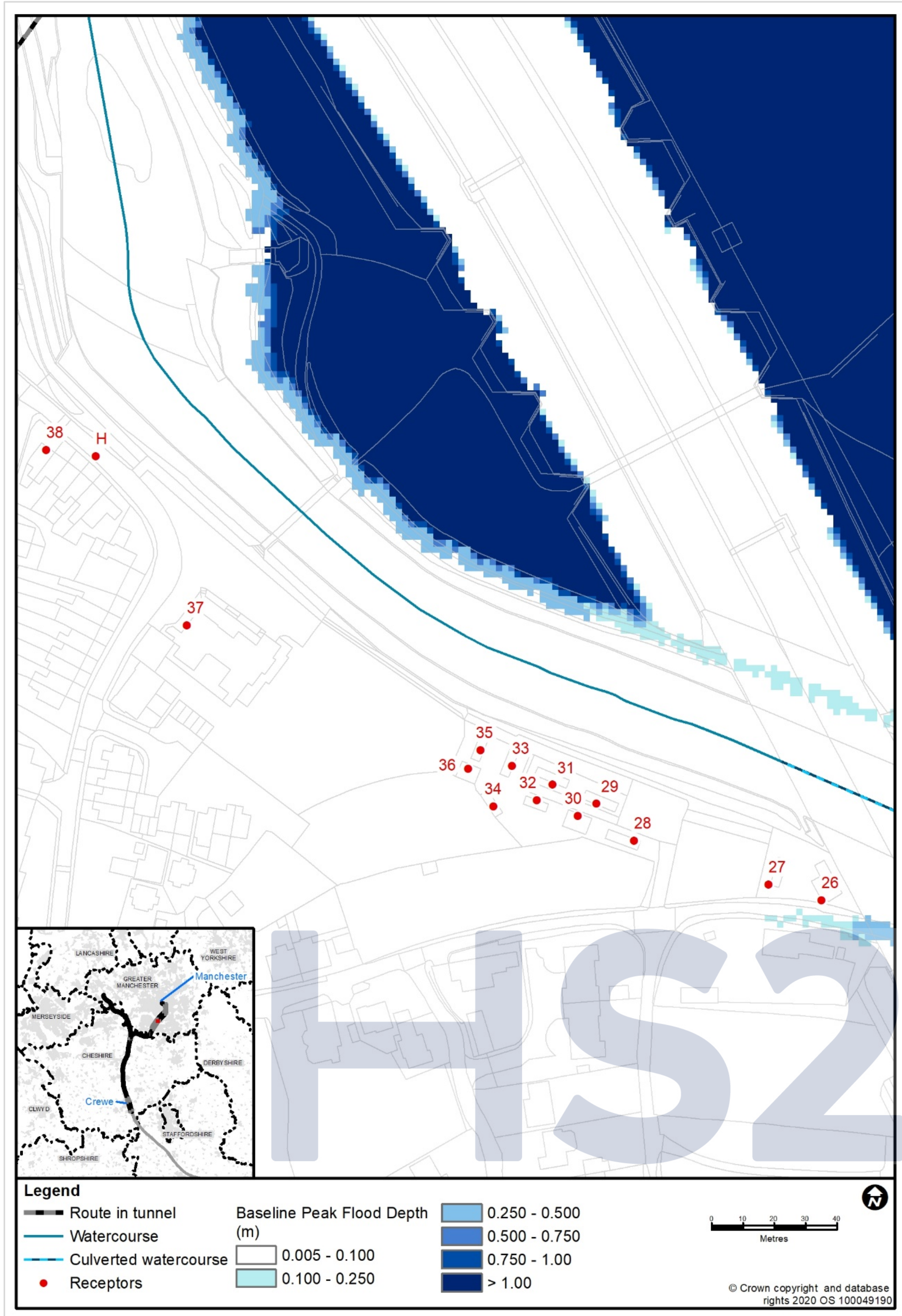


Table 6: Change in peak flood level in Northenden (Ford Lane) (see Figure 24)

Receptor details				Peak flood levels mAOD (depth above ground level (m))		Peak water level
ID	Receptor type	Ground level (mAOD)	Assumed threshold level (mAOD)	Baseline water level	Proposed Scheme (including compensation storage) scenario	Difference (m)
22	Residential	29.354	29.654	30.389 (1.035)	30.485 (1.131)	0.096
23	Residential	29.378	29.678	30.388 (1.010)	30.485 (1.107)	0.097
24	Residential	29.313	29.613	30.387 (1.074)	30.484 (1.171)	0.097
25	Residential	29.566	29.866	30.386 (0.820)	30.483 (0.917)	0.097
26	Residential	29.287	29.587	Dry	29.821 (0.534)	0.534
27	Residential	29.037	29.337	Dry	29.634 (0.597)	0.597
28	Residential	29.222	29.522	Dry	29.634 (0.412)	0.412
29	Residential	28.959	29.259	Dry	29.634 (0.675)	0.675
30	Residential	29.153	29.453	Dry	29.634 (0.481)	0.481
31	Residential	29.041	29.341	Dry	29.634 (0.593)	0.593
32	Residential	29.209	29.509	Dry	29.634 (0.425)	0.425
33	Residential	29.117	29.417	Dry	29.634 (0.517)	0.517
34	Residential	29.341	29.641	Dry	Dry	N/A
35	Residential	28.990	29.290	Dry	29.633 (0.643)	0.643
36	Residential	29.178	29.478	Dry	Dry	N/A
37	Commercial	30.793	31.093	Dry	Dry	N/A
38	Residential	29.416	29.716	Dry	Dry	N/A

Figure 26: Change in peak flood level in Northenden (Mill Lane)

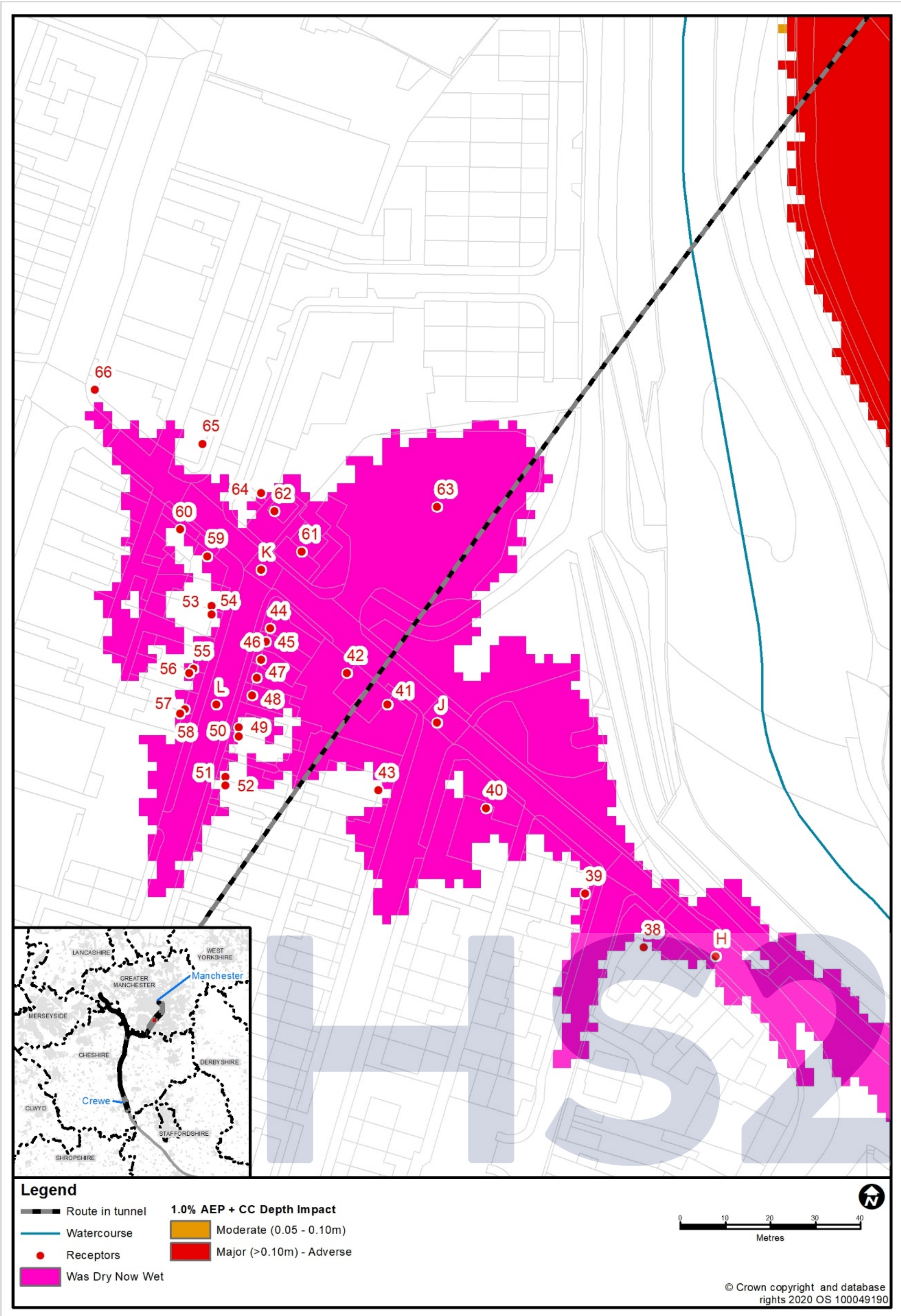


Figure 27: Baseline peak flood depth in Northenden (Mill Lane)

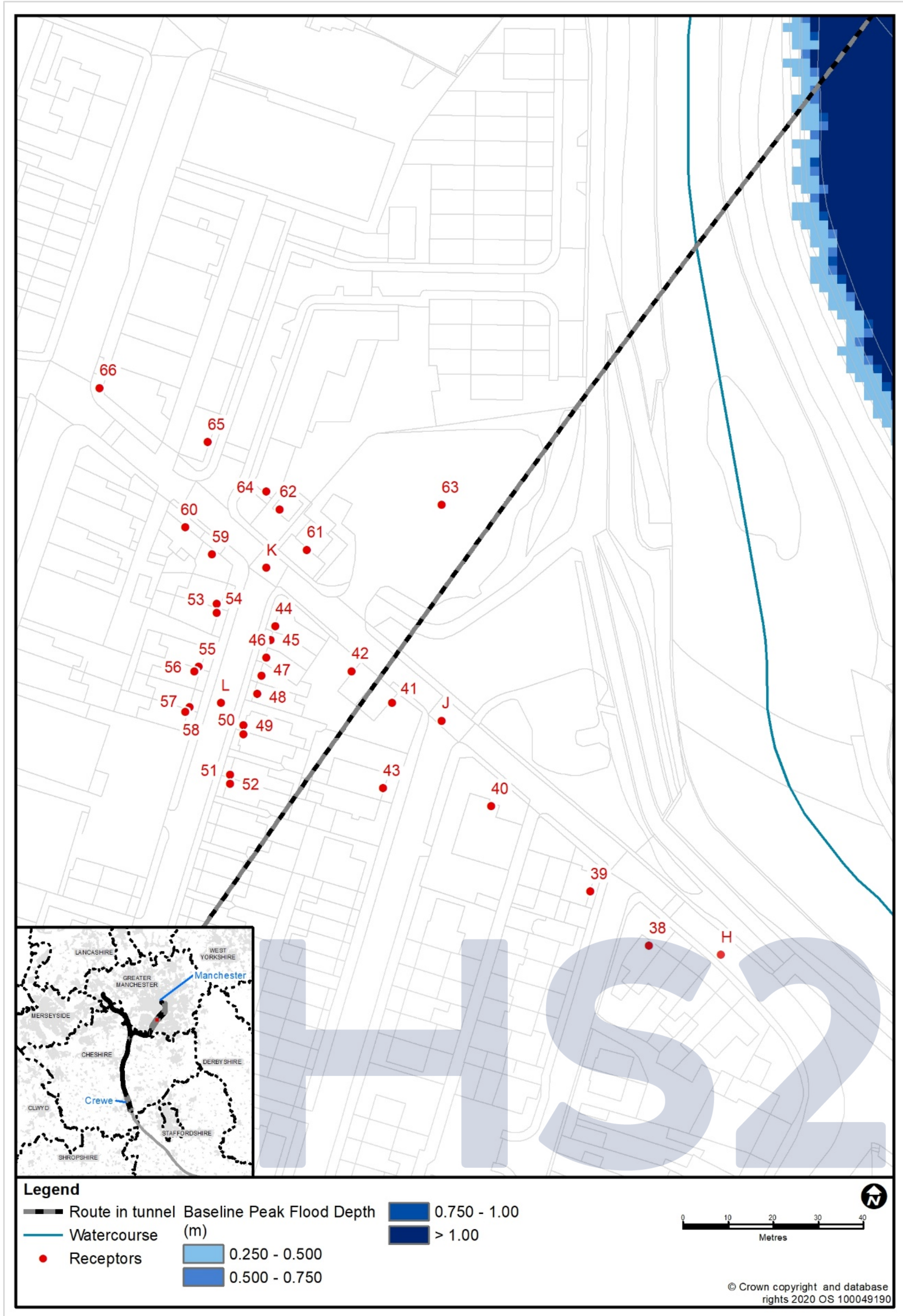


Table 7: Change in peak flood level in Northenden (Mill Lane) (see Figure 26)

Receptor details				Peak flood levels mAOD (depth above ground level (m))		Peak water level
ID	Receptor type	Ground level (mAOD)	Assumed threshold level (mAOD)	Baseline water level	Proposed Scheme (including compensation storage) scenario	Difference (m)
39	Residential	29.358	29.658	Dry	Dry	N/A
40	Residential	28.879	29.179	Dry	29.357 (0.478)	0.478
41	Residential	28.725	29.025	Dry	29.357 (0.632)	0.632
42	Residential	28.729	29.029	Dry	29.357 (0.628)	0.628
43	Residential	29.207	29.507	Dry	Dry	N/A
44	Residential	29.039	29.339	Dry	29.357 (0.318)	0.318
45	Residential	29.119	29.419	Dry	29.357 (0.238)	0.238
46	Residential	29.065	29.365	Dry	29.357 (0.292)	0.292
47	Residential	29.007	29.307	Dry	29.357 (0.350)	0.350
48	Residential	28.946	29.246	Dry	29.357 (0.411)	0.411
49	Residential	29.291	29.591	Dry	Dry	N/A
50	Residential	29.291	29.591	Dry	Dry	N/A
51	Residential	29.264	29.564	Dry	Dry	N/A
52	Residential	29.309	29.609	Dry	Dry	N/A
53	Residential	29.051	29.351	Dry	Dry	N/A
54	Residential	29.052	29.352	Dry	29.357 (0.305)	0.305
55	Residential	29.221	29.521	Dry	29.357 (0.136)	0.136
56	Residential	29.232	29.532	Dry	29.357 (0.125)	0.125
57	Residential	29.230	29.530	Dry	29.357 (0.127)	0.127
58	Residential	29.215	29.515	Dry	Dry	N/A
59	Residential	29.127	29.427	Dry	29.357 (0.230)	0.230
60	Residential	29.058	29.358	Dry	Dry	N/A
61	Commercial	29.102	29.402	Dry	29.357 (0.255)	0.255
62	Secondary electrical substation	28.891	29.191	Dry	29.357 (0.466)	0.466
63	Car park	29.198	29.198	Dry	29.357 (0.159)	0.159
64	Residential	29.427	29.727	Dry	Dry	N/A
65	Residential	29.985	30.285	Dry	Dry	N/A
66	Residential	29.724	30.024	Dry	Dry	N/A
H	Road	29.121	29.121	Dry	29.357 (0.236)	0.236
J	Road	28.801	28.801	Dry	29.357 (0.556)	0.556
K	Road	28.815	28.815	Dry	29.357 (0.541)	0.541
L	Road	29.075	29.075	Dry	29.357 (0.282)	0.282

Figure 28: Change in peak flood level east of Didsbury flood storage basin (Stenner Lane)

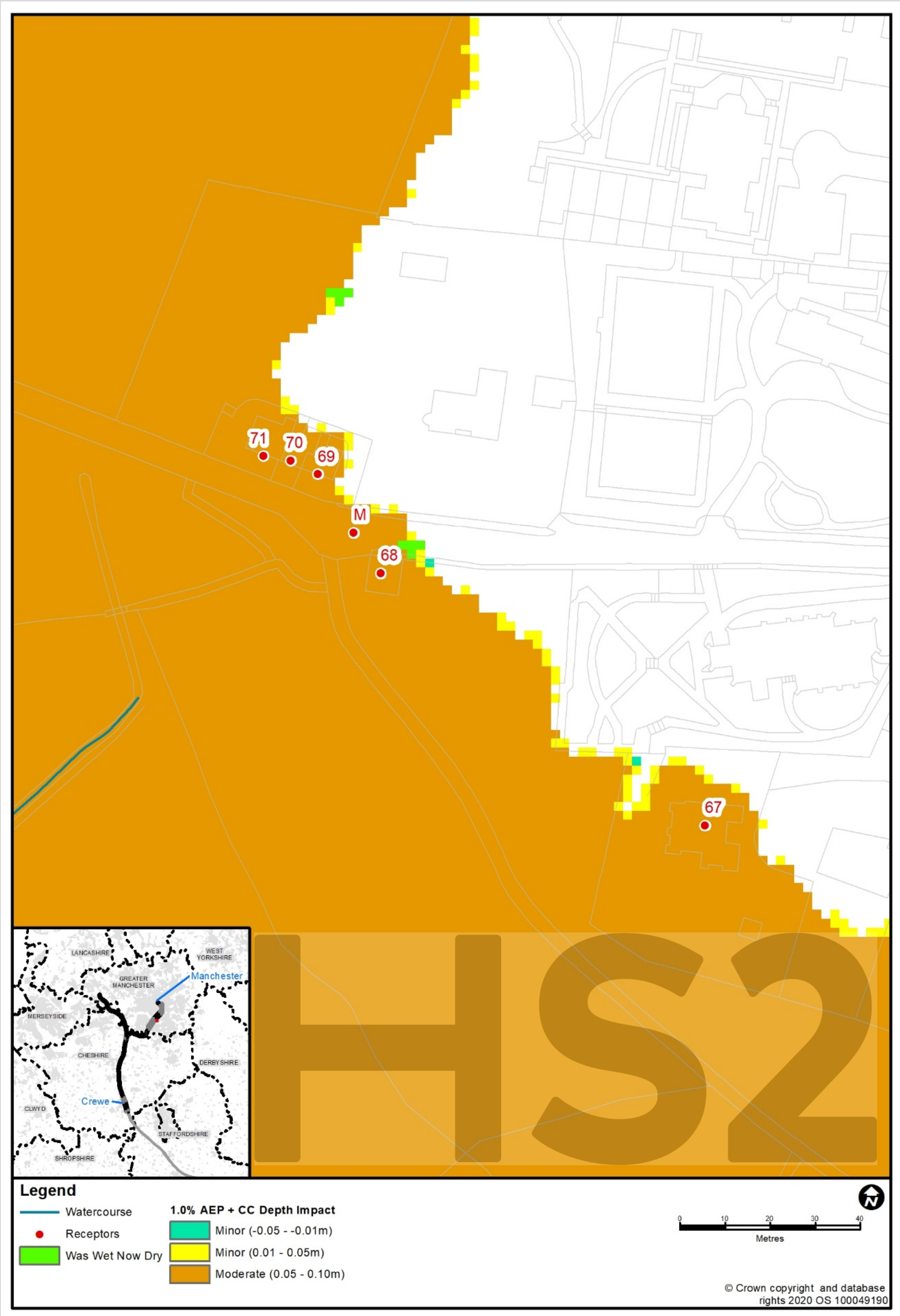


Figure 29: Baseline peak flood depth east of Didsbury flood storage basin (Stenner Lane)

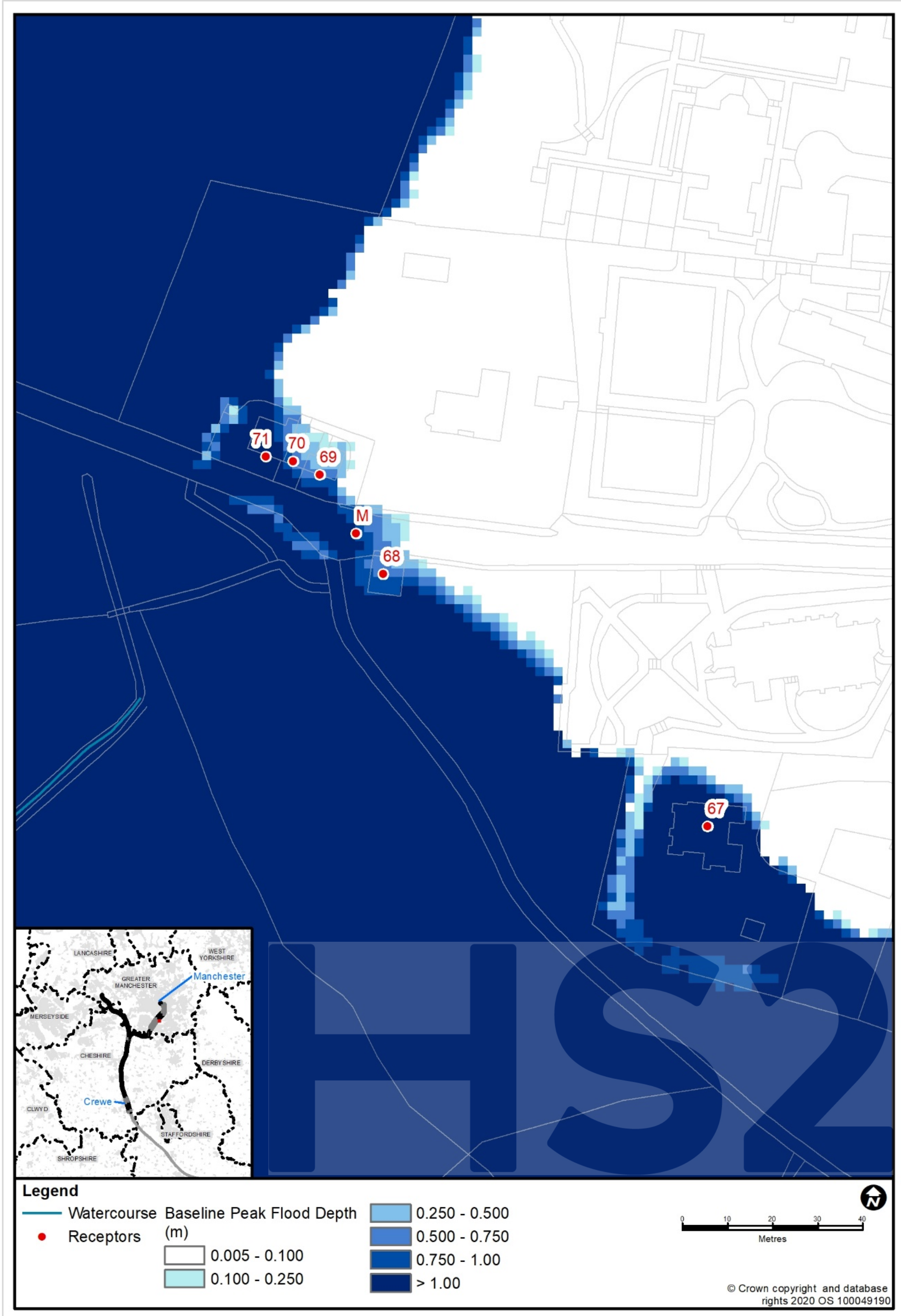


Table 8: Change in peak flood level east of Didsbury flood storage basin (Stenner Lane) (see Figure 28)

Receptor details				Peak flood levels mAOD (depth above ground level (m))		Peak water level
ID	Receptor type	Ground level (mAOD)	Assumed threshold level (mAOD)	Baseline water level	Shaft and compensation storage scenario	Difference (m)
67	Residential	29.329	29.629	30.724 (1.395)	30.803 (1.474)	0.079
68	Commercial	29.920	30.220	30.706 (0.786)	30.785 (0.865)	0.079
69	Residential	29.825	30.125	30.704 (0.879)	30.785 (0.960)	0.081
70	Residential	29.560	29.860	30.704 (1.144)	30.784 (1.224)	0.080
71	Residential	28.929	29.229	30.704 (1.775)	30.784 (1.855)	0.080
M	Road	29.595	29.595	30.705 (1.110)	30.784 (1.189)	0.079

6.2.5 The maps indicate the areas where increased flood risk impacts are likely to occur for the 1.0% AEP + CC AEP event. These are as follows:

- Palatine Road: receptors are affected by an increase in modelled peak flood level of up to 182mm, (see Figure 20 and Figure 21);
- Northenden, south of Junction 5 of the M60 motorway (Princess Parkway Interchange): receptors are affected in the area located to the south of the M60 Junction 5 at Northenden by an increase in modelled peak flood level of 45mm (see Figure 22 and Figure 23);
- western side of River Mersey in Northenden: the area in Northenden from Ford Lane to Mill Lane which remains dry in the baseline scenario would become flooded to a maximum depth of 675mm with the Proposed Scheme in place (see Figure 24 to Figure 27); and
- Stenner Lane area: receptors are affected by an increase in modelled peak flood levels of up to 81mm in the eastern part of the Didsbury flood storage basin (see Figure 28 and Figure 29).

6.2.6 During extreme flood events Palatine Road acts as a spillway from the Didsbury flood storage basin, discharging excess water from the basin back towards the River Mersey. The Proposed Scheme vent shaft and its associated raised compound create a barrier along part of this spillway and, therefore, have a widespread impact on flood flow conveyance in the area. This results in an increase in peak flood levels in the Didsbury flood storage basin of up to 0.136m. This increased water level in the basin in turn increases peak water levels in the River Mersey, resulting in increases in peak water levels in the surrounding floodplain area.

6.2.7 The proposed vent shaft and its associated raised compound also have a localised effect on flow conveyance, flow routes around the shaft and the mechanism of flooding in the Palatine Road area, between the Didsbury flood storage basin and the River Mersey.

6.2.8 For the 5% event, minor localised impacts are observed at three properties along Palatine Road and two properties on Stenner Lane.

7 Limitations

7.1.1 New topographic surveys were not undertaken and the Proposed Scheme model was built using available information supplied in the 2012[4] and 2018[5] Environment Agency models.

7.1.2 One event, Storm Christoph, has been utilised in the calibration of this Proposed Scheme model. However, further calibration and verification events will be undertaken as part of design development.

8 Conclusions and recommendations

8.1.1 A 1D-2D Proposed Scheme modelling approach has been selected to allow for effective modelling of the complex flood mechanisms in the Didsbury area.

8.1.2 The 2D Proposed Scheme model domain comprises the Didsbury flood storage basin and a sufficiently large area upstream and downstream of the flood storage basin, to ensure that the impact of the vent shaft and the potential effectiveness of mitigation measures can be assessed.

8.1.3 The Proposed Scheme model has been reviewed externally by a third party. Following the updates to the Proposed Scheme model as a result of this review, the Proposed Scheme model has been calibrated against the Storm Christoph event of January 2021. The calibration points used were the water level gauges at Northenden Weir, Stenner Lane and Withington Golf Course.

8.1.4 The Proposed Scheme model results indicate that the Proposed Scheme will have a minor impact on three properties in Palatine Road and two properties at Stenner Lane for the 5% AEP event. For the 1% AEP + CC event impacts are modelled at 63 receptors, with increases in peak water level of up to 0.675m.

8.1.5 The Proposed Scheme model results indicate that the current proposed design achieves the freeboard requirements for the shaft.

Annex A: Flood level impact maps

The water level difference has been mapped for the 5.0% AEP and 1.0% AEP + CC events as described in Section 0, see Figure A 1 and Figure A 2.

Figure A 1: River Mersey impact map for 5.0% AEP (1 in 20 year)

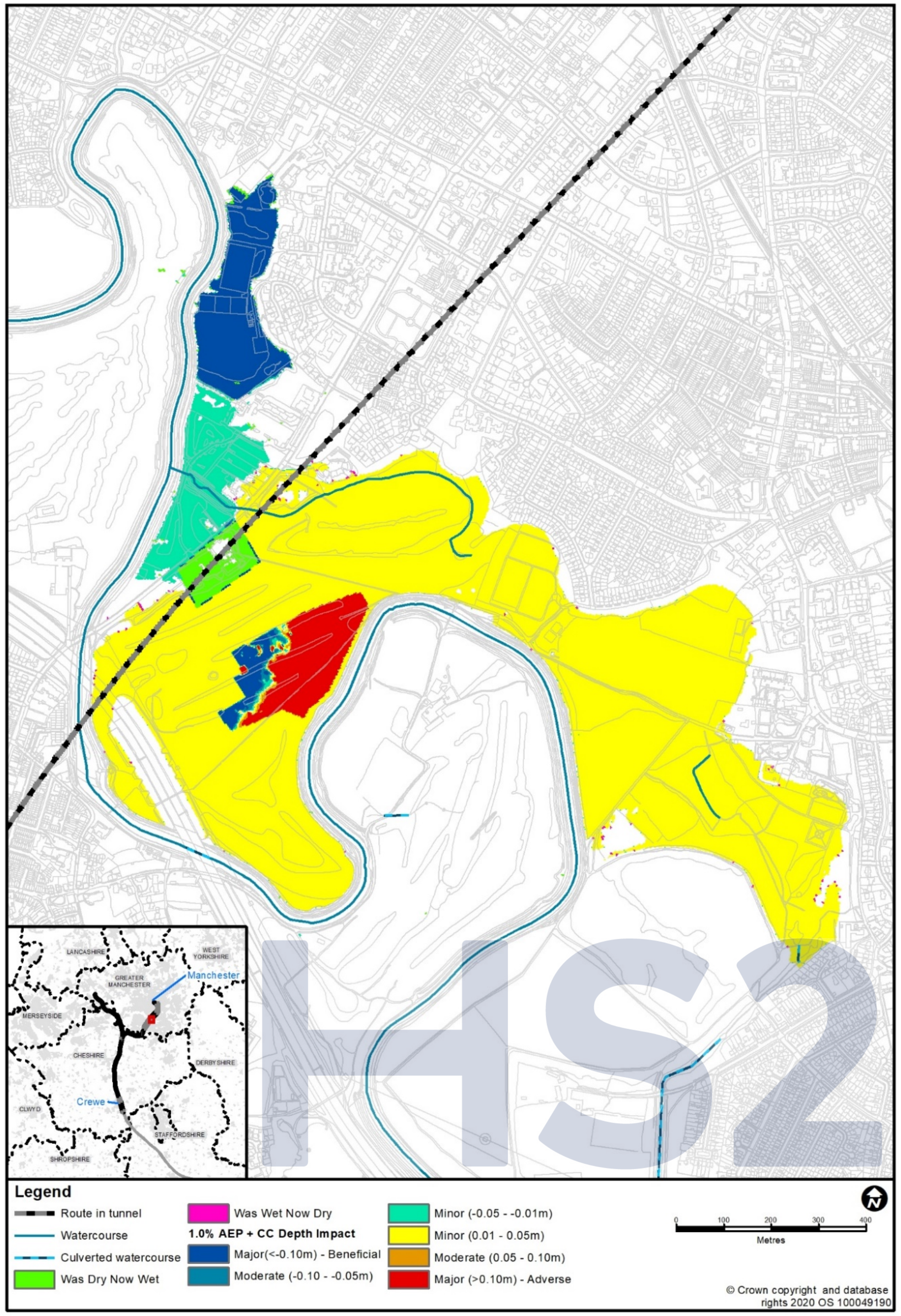


Figure A 2: River Mersey impact map for 1.0% AEP (1 in 100 year plus climate change)