Appendix C - JFlow Broadscale Modelling Reports

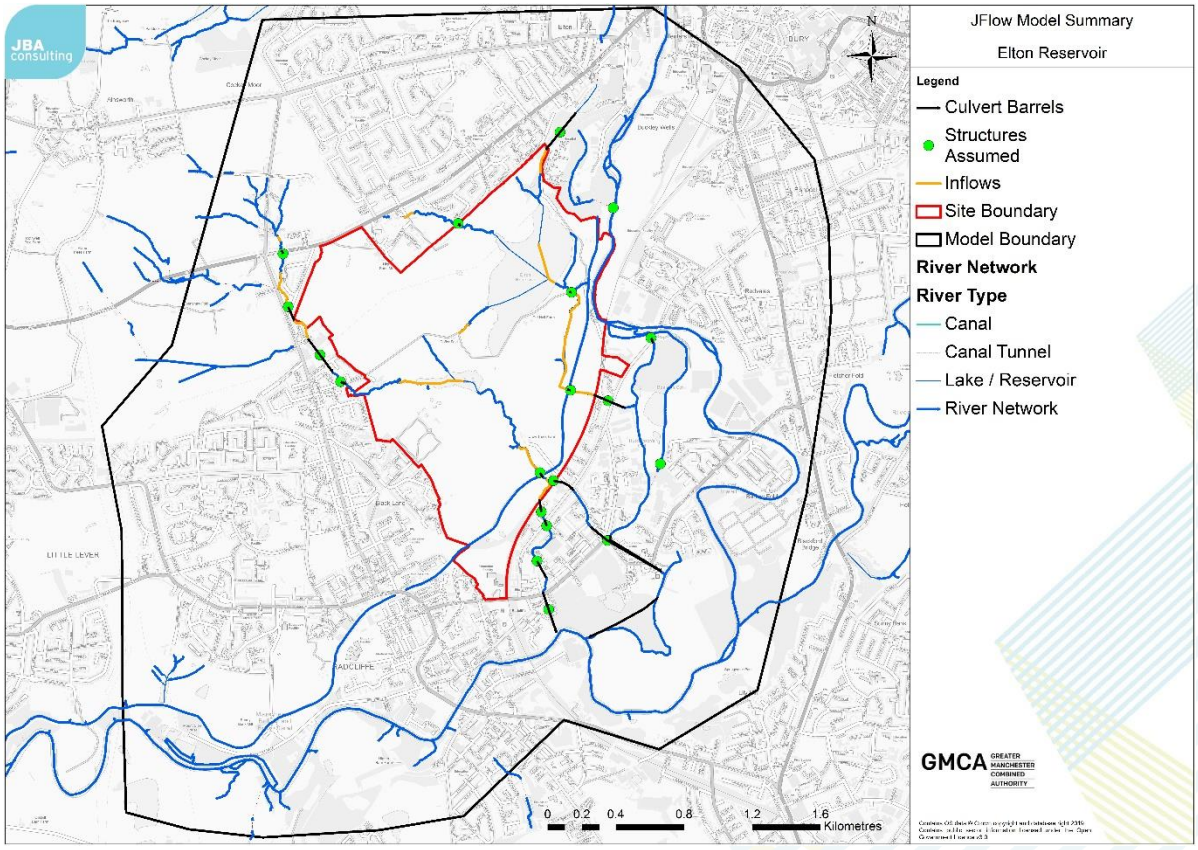
TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA SFRA L2
Client	GMCA
Day, Date and Time	20 January 2020
Author	Elba Boavida
Reviewer / Sign-off	Andrew Fielding
Subject	JFlow Elton Reservoir Summary Report

1 Model Name: Elton Reservoir

The development site is located within the Greater Manchester area, in the vicinity of Elton Reservoir (379052, 409328), limited to the north by Bury and Bolton Road (A58) and east and south by a railway embankment from Bury to Radcliffe. There are two main watercourses running through the modelled area:

- Crows Tree Brook - located on the western side of the site boundary;
- Elton Watercourse - the watercourse to the east which discharges from Elton Reservoir. This includes two additional unnamed tributaries that enter the reservoir.



Culverts have been represented throughout the model, where the LIDAR-based DTM showed blockage of the river channel allowing water to be conveyed downstream, preserving flows in channel.

1.1 Modelled Structures

The following table contains details of all modelled structures:

ID	X Y Coordinates	Dimensions (shape, width, height, manning's n)	Comments
Crows Tree Brook			
107	377493, 409484	*Shape: *Rectangular *Width: 2 *Height: 1 *Manning's n: 0.012	Culvert added to pass flows through Bury and Bolton Road (A58).
108	377542, 409128	*Shape: *Rectangular *Width: 1.5 *Height: 1.5 *Manning's n: 0.012	Culvert added to pass flows through Grindsbrook Road.
109	377693, 408905	*Shape: *Rectangular *Width: 2 *Height: 1 *Manning's n: 0.012	Culvert added beneath Miller and Hardman Streets.
110	377850, 408714	*Shape: *Rectangular *Width: 1.5 *Height: 1 *Manning's n: 0.012	St Andrew's Road crossing the channel.
111	379013, 408175	*Shape: *Rectangular *Width: 2 *Height: 1 *Manning's n: 0.012	Culvert added beneath a canal near Withins Avenue.
112	379118, 408135	*Shape: *Rectangular *Width: 2	Culvert added through a transport embankments

		*Height: 1 *Manning's n: 0.012	and Cocklestorm Fencing building.
113	379418, 407778	*Shape: *Rectangular *Width: 1 *Height: 1 *Manning's n: 0.012	Culvert added through buildings and embankments (including Bury Street).
114	379006, 407996	*Shape: *Rectangular *Width: 1 *Height: 1 *Manning's n: 0.012	Culvert added beneath Olsberg Close.
115	379035, 407901	*Shape: *Rectangular *Width: 1.5 *Height: 1.5 *Manning's n: 0.012	Culvert added beneath Bury Road.
116	379012, 407625	*Shape: *Rectangular *Width: 1 *Height: 1 *Manning's n: 0.012	Culvert added beneath a field near Park Street.
117	379059, 407373	*Shape: *Rectangular *Width: 1 *Height: 1 *Manning's n: 0.012	Culvert added beneath a sequence of roads to convey flows into Irwell River
118	379570, 407318	*Shape: *Rectangular *Width: 2 *Height: 1 *Manning's n: 0.012	Culvert added to allow water back into river Irwell (from Bealey's Goit)
Elton Watercourse			

100	379148, 410218	Note: Not in use. Culvert from the canal feeder into the reservoir. Maximum capacity of 0.75m³/s provided by The Canal and River Trust in an email dated 04/11/2019. The culvert has not been modelled, and it is assumed that the culvert is running at full capacity during high flow events (as it is likely to receive a lot of water from the Irwell and other tributaries discharging into it).	
102	379503, 407741	*Shape: *Rectangular *Width: 1 *Height: 1 *Manning's n: 0.012	Culvert added to allow flows back into channel.
103	379183, 409247	*Shape: *Rectangular *Width: 1 *Height: 1 *Manning's n: 0.012	Culvert added through unnamed road downstream from the reservoir dam.
105	379173, 408674	Shape: Circular (but assumed rectangular) Width: 1.6 Height: 1.6 Length: 22.1 *Manning's n: 0.012	Culvert added to represent the syphon beneath the canal. Dimensions provided by The Canal and River Trust.
106	379401, 408606	*Shape: *Rectangular *Width: 1.5 *Height: 1.5 *Manning's n: 0.012	Culvert added beneath a railway/Farcroft Avenue and a sequence of roads.
119	379662, 408964	*Shape: *Rectangular *Width: 1 *Height: 1	Note: Not in use. Culvert added through Bury Road (near Radcliffe Road).

		*Manning's n: 0.012	
120	378531409641	*Shape: *Rectangular *Width: 1 *Height: 1 *Manning's n: 0.012	Culvert added beneath a bridge crossing the channel.

*Data assumed due to lack of survey information.

1.2 Other Comments/Assumptions/Uncertainty/Sensitivity Testing

- Due to lack of survey data culvert dimensions were assumed based on the LIDAR DTM and aerial imagery whenever possible, unless specified otherwise.
- Culvert monitoring points have been assigned to all culverts to obtain discharge capacity data at the inlet and outlet boundaries.
- Assuming that culvert barrels were considered to be constructed of concrete, manning's n values of 0.012 have been assigned based on Chow, 1959.
- Elton Reservoir is fed by a canal feeder (379148, 410218) upstream of the Elton Watercourse. This feeder runs from an offtake on the Irwell approximately 4km upstream of the reservoir and is also fed by two large watercourses upstream of Elton Reservoir (Elton Brook and Warshaw Brook). However, flows into Elton Reservoir are restricted by a low capacity culvert, which allows only a maximum carrying volume of 0.75m³/s[1]. The structure is not included within the model, as it is upstream of the site boundary. However, a constant flow is being applied downstream from it, based on the maximum culvert capacity.
- The Canal and Rivers Trust (email dated 04/11/2019) stated that there is (under normal operating conditions) a constant base outflow from the reservoir controlled by a 229mm diameter pipe. Hence, by using culvert capacity equations, assuming a gradient of 0.12 based on LIDAR, it was possible to calculate that the base outflow from the reservoir is ~0.18m³/s.
- Therefore, subtracting the constant base outflow from the fixed inflow from the canal feeder results in a constant inflow of 0.57m³/s, which is applied during the modelled flood events, into Elton Reservoir.
- Elton Reservoir levels have been stamped at the top water level (87.7 mAOD), as requested by the Environment Agency (in an email dated 21/11/2019). The reservoir dam has a DTM fill where there are gaps in the LiDAR; otherwise no further modifications have been implemented. This results in the total outflow from the reservoir modelled to flow down the spillway (which is set at the elevation of

1 Provided by the Canal and River Trust in an email dated 04/11/2019, referencing HR Wallingford.

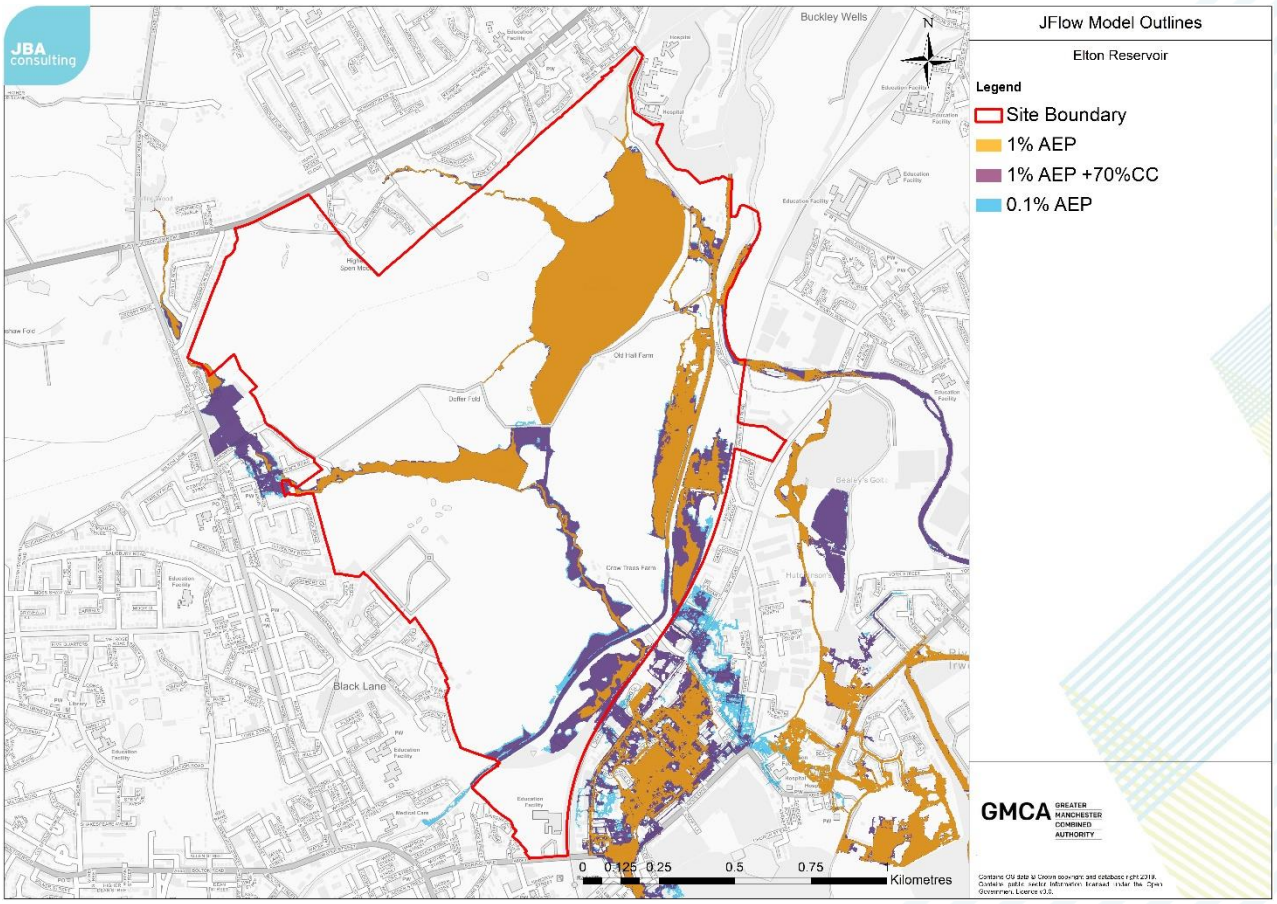
the top water level within the LIDAR data), which represents what would happen in reality.

- A flow splitter near the downstream of Elton Reservoir spillway directs the majority of the water into the canal and the remaining into Elton Watercourse to the south. This has been defined from LIDAR and the model appears to represent what would likely happen in reality.
- An overflow weir into the River Irwell (opposite where the flows enter the canal) is active in most of the modelled events, except in the 10% AEP. This is modelled based on the LIDAR DTM (as there was no additional information provided), although this results in a reasonable representation of what would be expected in reality.
- A syphon under the canal is represented with given dimensions as follows:
  - Shape - Circular (rectangular used instead, with equivalent barrel area and centroid)
  - Length - 22.1m
  - Diameter - 1.6m.
  - This is information was provided by the Canal and Rivers Trust (email dated 04/11/2019).
- DEM modifications were applied to enforce the channel into the LIDAR where there are visible blockages. This was to allow flows through in a more realistic manner. Dimensions of the cuts were based on LIDAR only as no survey data or aerial imagery was available to provide further information.
- Flow Estimation Points representing upstream inflows to the model have been applied as line inflows on the upstream face of the modelled watercourse. Lateral inflows were distributed as lines (split over culverts) representing flows entering the watercourse following the DRN and the DTM as closely as possible. CROT represents flows into Crows Tree Brook, and ELTN represents flows into Elton Watercourse. Further details on how the inflows were derived can be found in the Elton Hydrological Assessment.

Inflows Name	Percentage split
CROT_01 (Top Inflow)	100%
CROT_02 (Lateral Inflow)	
• CROT_02_1	60%
• CROT_02_2	40%
CROT_03 (Lateral Inflow)	100%
CROT_04 (Lateral Inflow)	
• CROT_04_1	60%
• CROT_04_2	40%
TRIB01_US (Top Inflow)	100%

TRIB02_US (Top Inflow)	100%
ELTN_01 (Top Inflow)	100%
ELTN_02 (Lateral Inflow)	100%
ELTN_03 (Lateral Inflow)	
• ELTN_03_1	80%
• ELTN_03_2	20%

- Simulation start/end times were defined to start/end when the first/last flows are released in each modelled simulation, to ensure it provides greater computational efficiency.
- Flows reach the transmissive model boundary further downstream in some modelled events. However no further impacts are expected to occur as it happens far from the site area and the boundary type allows water to leave the model domain in a realistic manner.
- It should be made clear that the reservoir breach and the site risk categories will need to be reviewed by an All Panel Reservoir Engineer before using the outcomes of this work to take anything forward within this site allocation. This assessment has not looked at flood risk from any sources other than fluvial; in the case of Elton Reservoir, risk and consequence of a reservoir breach should also be assessed before progressing with this site.
- Detailed sensitivity checks were beyond the scope of this work however the following have been tested:
  - 0.1% AEP sensitivity test was modelled and run to give an idea on flows routing and extents, using final hydrographs. Results show flood water not reaching a culvert immediately downstream from the dam (ID 103) which would not be realistic.
- DEM modification lines were applied in channel, where the DTM shows the channel to be blocked. These were carried out at a minimum width of 2m, however 1m/1.5m tests were ran; proving these to be more effective as they still convey water through with the final outputs looking more sensible.
- The JFlow model assumes a channel capacity of QMED (Q2), which is a general assumption when using JFlow as the channel depth is not accurately represented in the DTM.
- Additional DEM modifications have been added immediately downstream from the reservoir where the channel is blocked in the DTM due to vegetation coverage. This causes a total diversion of flows ensuring water flows in channel in a more realistic manner.
- Some culverts (IDs 100 and 119) were not within the flood reach and were therefore deleted from the model.


JBA consulting
Buckley Wells
N
JFlow Model Outlines
Elton Reservoir
Legend
Site Boundary
1% AEP
1% AEP +70%CC
0.1% AEP
Black Lane
0 0.125 0.25 0.5 0.75
Kilometres
GMCA
GREATER MANCHESTER COMBINED AUTHORITY

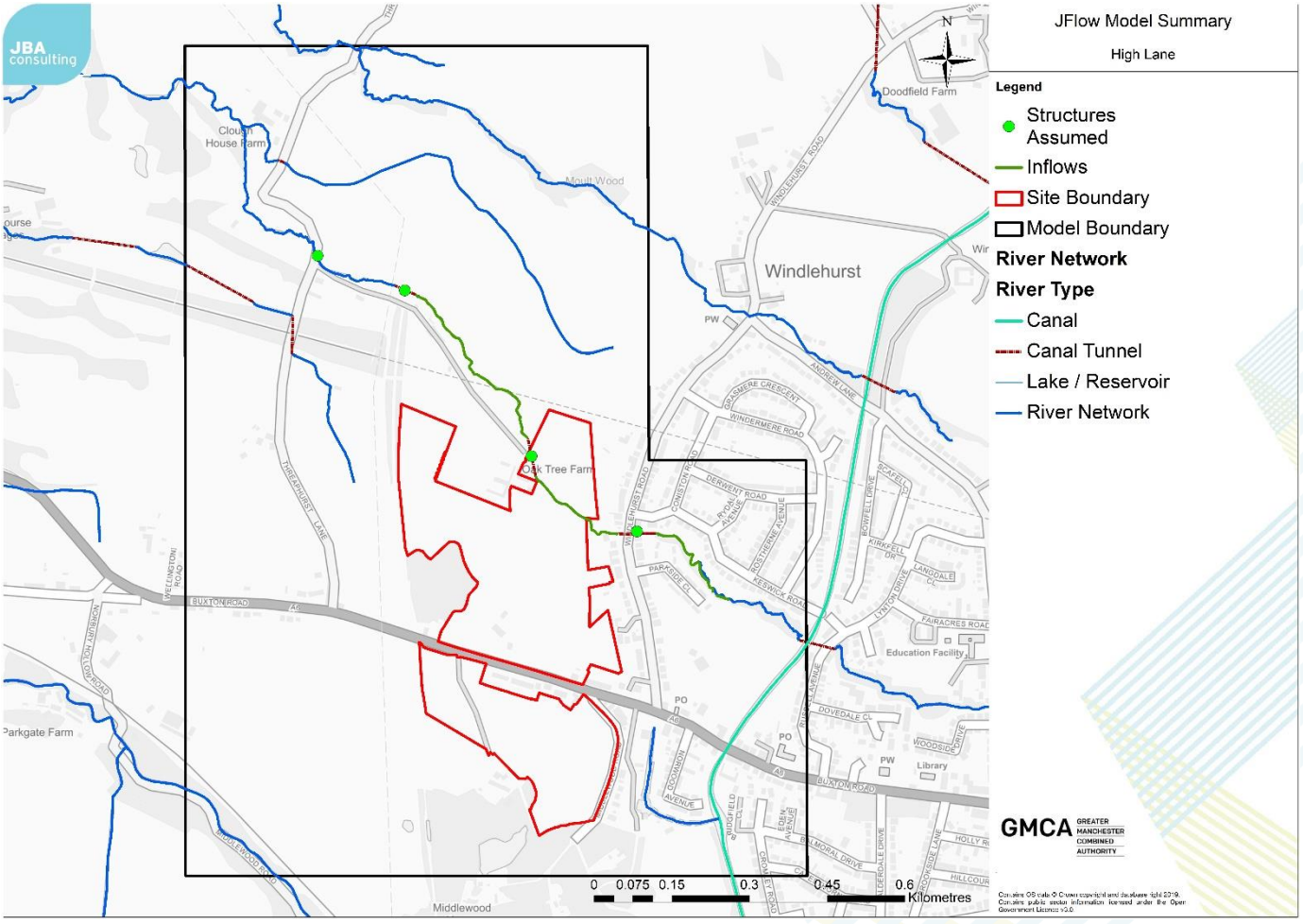
TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA SFRA L2
Client	GMCA
Day, Date and Time	20 January 2020
Author	Elba Boavida
Reviewer / Sign-off	Andrew Fielding
Subject	JFlow High Lane Summary Report

1 Model Name: High Lane

The High Lane development site is located within Greater Manchester area, south east of Stockport (394715, 385766), bounded to the east by Windlehurst Road and extending to the south of Buxton Road (A6). A watercourse referenced 'HISH' (hereafter referred to as so) runs through the northernmost section of the site, flowing from southeast to northwest up to the confluence with a tributary, where it becomes a single watercourse referenced 'HAZE'.

Culverts have been applied along HISH, where the DTM showed blockage of the river channel allowing water to be conveyed downstream, preserving flows in channel.



1.1 Modelled Structures

The following table contains details of all modelled structures:

X Y Coordinates	Dimensions (width, height, manning's n, length, shape)	Comments
394879, 385760	*2, 1, 0.03, 73.56, Rectangular	Culvert added to allow water through Windlehurst Road
394675, 385908	*0.75, 0.75, 0.012, 75.21, Rectangular	Culvert added to allow water through structure in a field at oak tree farm
394432, 386230	*2, 1, 0.03, 15.21, Rectangular	Culvert added to allow water through Middlewood Way
394261, 386294	*1, 1, 0.012, 42.31, Rectangular	Culvert added to allow water through Threaphurst Lane

*Data assumed due to lack of survey information; all assumed culverts are concrete rectangular.

The second culvert listed above was surveyed as a concrete circular structure running 5m in length (as shown below), which then changes to a rectangular culvert. Given its total length (~75m), a rectangular structure was assumed to be more representative for the whole structure.

1.2 Other Comments/Assumptions/Uncertainty/Sensitivity Testing

- The DTM is 1m resolution LiDAR based and was used to define the length of culvert barrels.
- The DRN shows that HISH watercourse flows are divided between an open channel and culverted sections from upstream of the Windlehurst Road and Middlewood Way.
- Further downstream where Threaphurst Lane intersects the watercourse, another culvert was added as the DTM shows a blocked channel, roughly 1m high.
- Culvert monitoring points have been assigned to all culverts to obtain discharge capacity data at the inlet and outlet boundaries.
- Circular culverts have not yet been implemented in this version of JFlow, therefore these structures have been converted into rectangular structures with an equivalent barrel area and centroid.
- Assuming that culvert barrels were considered to be constructed of concrete, manning's n values of 0.012 have been assigned based on Chow, 1959[1].
- DEM modifications were applied to enforce the channel into the LiDAR at 394133,386380 and 394126,386415. This was to allow water flow through in a more realistic manner. Dimensions of the cuts were based on LiDAR only as no survey data or aerial imagery was available to provide further information.
- All negative flows calculated as part of the flow estimation points (FEP) have been set to zero given that JFlow does not recognise negative values.
- FEP representing upstream inflows to the model have been applied as line inflows on the upstream face of the modelled watercourse. Lateral flows however, were

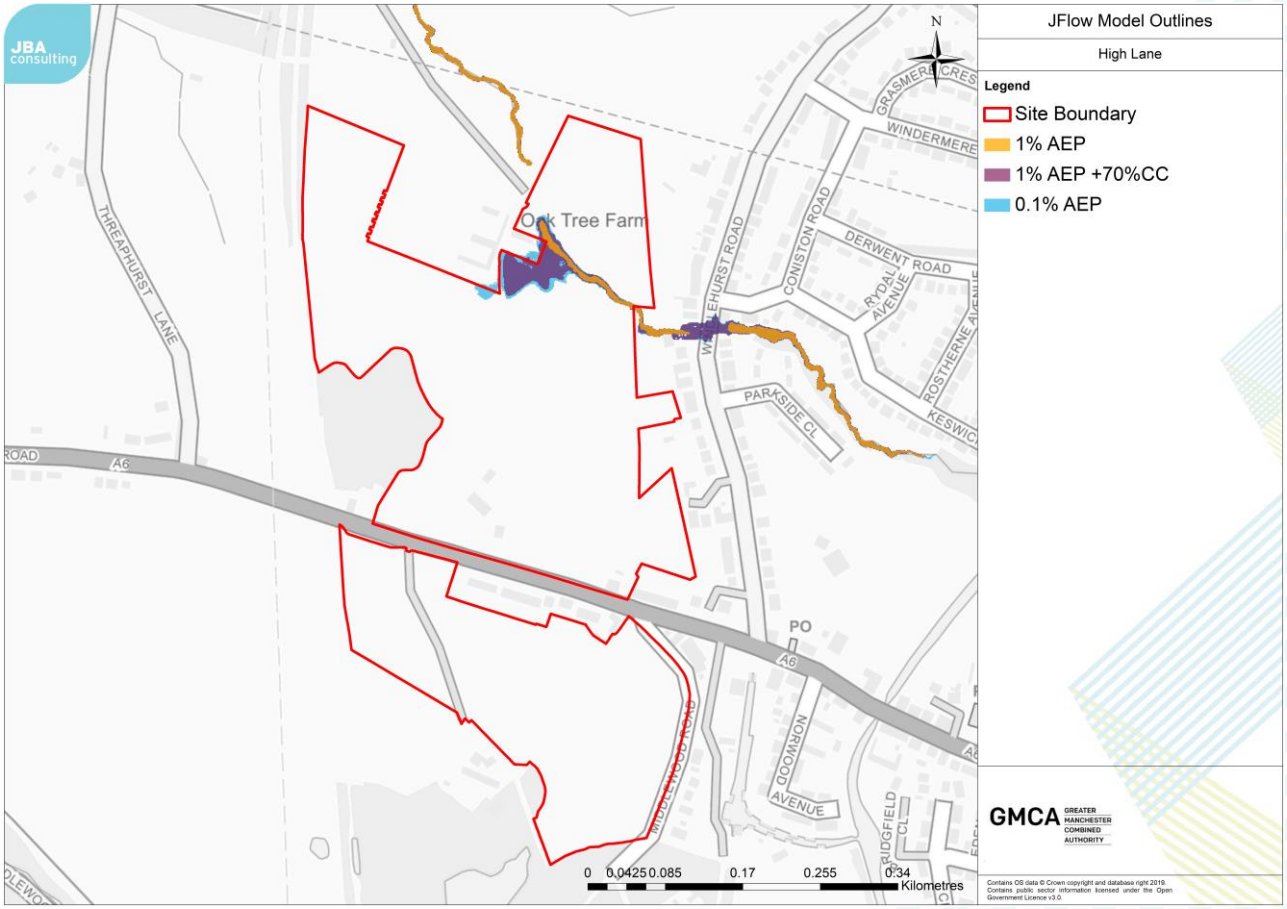
1 http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

distributed as lines (split over culverts) representing flows entering the watercourse following the DRN and DTM as closely as possible.

- 'HISH_DS' inflow hydrograph was split into three, where culvert structures are being used to represent blockages within the flowpath as follows:
  - HISH_DS1 corresponding to 24%
  - HISH_DS2 corresponding to 27%
  - HISH_DS3 corresponding to 49% of HISH_DS respectively
  - Each percentage has been derived from the cumulative lines' length.
- Simulation end time was defined by multiplying the latest time point from the selected hydrographs by three to ensure that all flooding is outputted without the need to determine individual end times for each simulation.
- Flows reach the transmissive model boundary further downstream, however no further impacts are expected to occur as it happens far from the site area and the boundary type allows water to leave the model domain in a realistic manner. Therefore, it was deemed not necessary to increase the bounding box.
- The JFlow model assumes a channel capacity of QMED (Q2), which is a general assumption when using JFlow as the channel depth is not accurately represented in the DTM.
- Detailed sensitivity checks were beyond the scope of this work however the following have been tested:
  - Q2 was modelled to give an idea on the flow routing using draft hydrology. Results show flood waters out of channel and overtopping Threaphurst Lane hence, a culvert was added at that location
  - DEM modifications have been added to all modelled return periods where the DTM shows the channel blocked
  - The first and third structures listed in the table above, applied through Windlehurst Road and Middlewood Way respectively, were modelled with a manning's n of 0.03 which results in a decreased flow rate through the barrels. Manning's n 0.012 was defined as the most sensible value in this case.

TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA SFRA L2
Client	GMCA
Day, Date and Time	20 January 2020
Author	Elba Boavida
Reviewer / Sign-off	Andrew Fielding
Subject	JFlow High Lane Summary Report



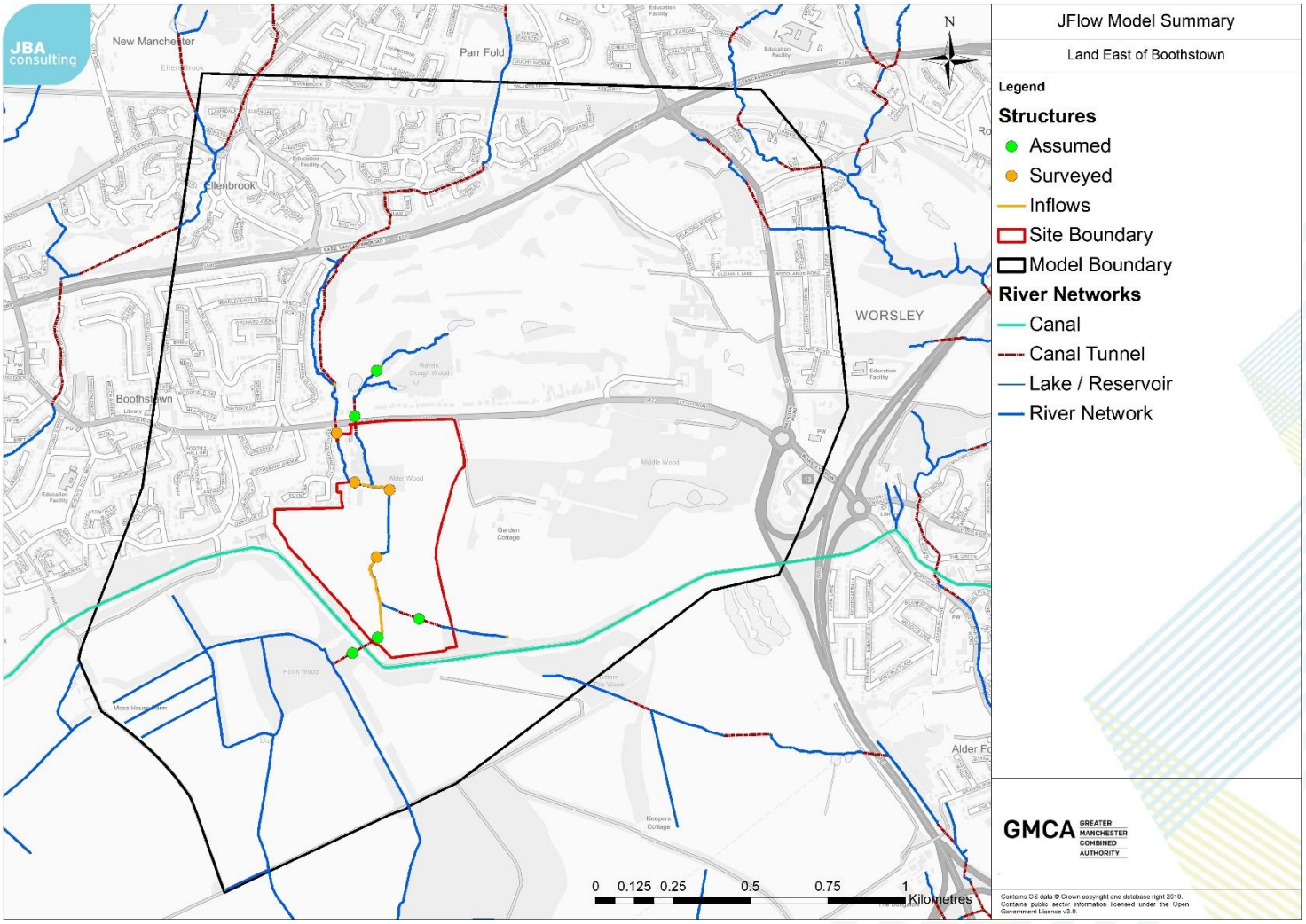
TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA L2 SFRA
Client	GMCA
Day, Date and Time	30 January 2020
Author	Joseph Landells-Molloy
Reviewer / Sign-off	Mike Williamson
Subject	Land East of Boothstown

1 Model Name: Land East Boothstown

Land East Boothstown is located off Leigh Road (A572), Worsley, Manchester M28 1LF.

Shaw Brook and its tributary flow southward in parallel beneath Leigh Road and converge within the north western area of the site. Shaw Brook continues to flow southward through the centre of the site and converges with a second tributary from the south east. Shaw Brook is culverted beneath the Bridgewater Canal which forms the south and southwestern bounds of the site.



1.1 Modelled Structures

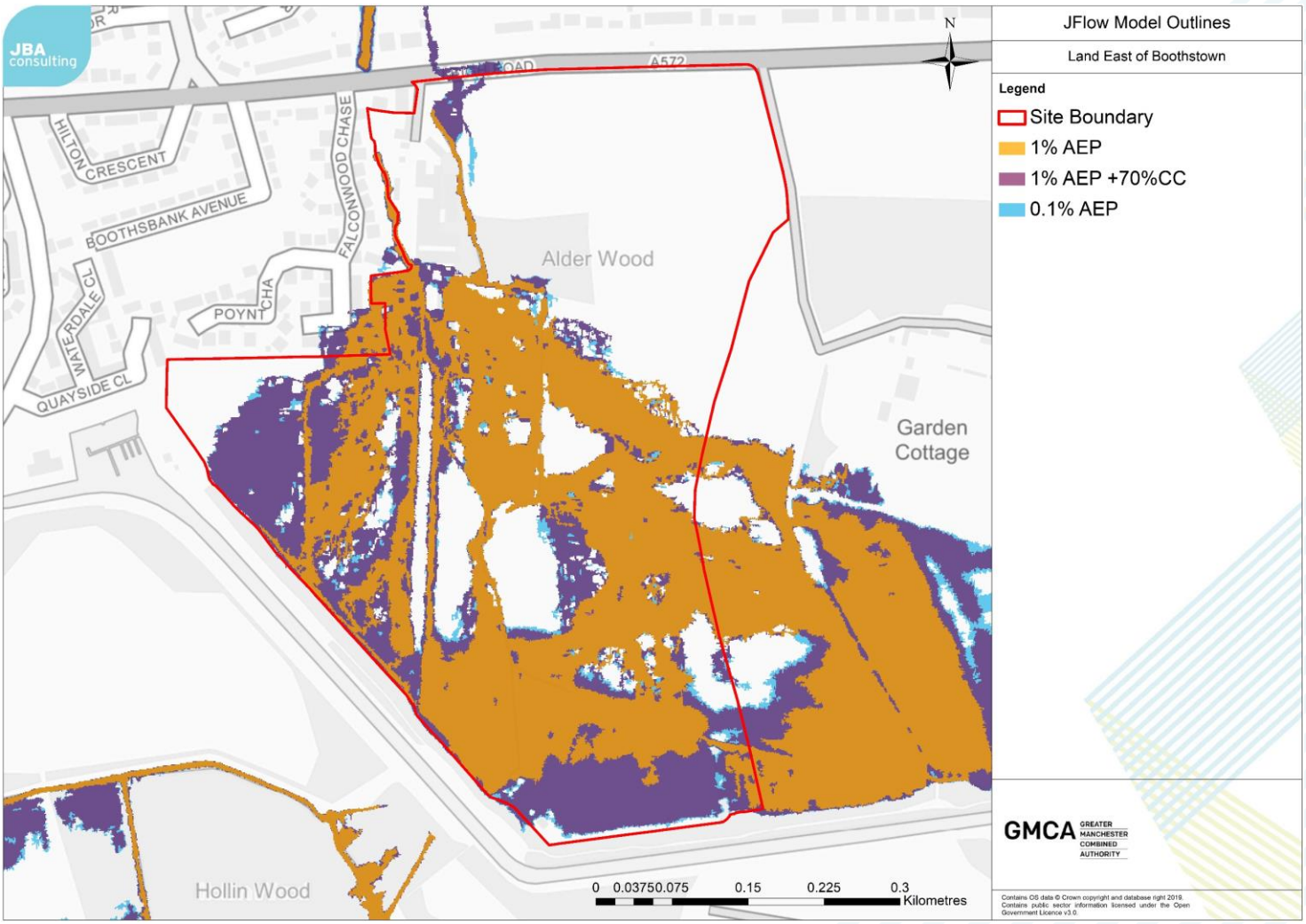
The following table contains details of all modelled structures:

X Y Coordinates	Dimensions (width, height, shape)	Comments
373024 400711	1.23, Circular	Shaw Brook culvert beneath A572
373082 400552	1.1, Circular	Shaw Brook culvert east of Falconwood Chase
373152 400912	*1.5, 1.0, Rectangular	Shaw Brook Trib01 access track
373082 400766	*2.0, 0.5, Rectangular	Shaw Brook Trib01 culvert beneath A572
373195 400528	1.2, Circular	Shaw Brook access track at Alder Wood
373153 400310	1.2, Circular	Shaw Brook field access
373290 400111	*0.6, Circular	Shaw Brook Trib02 east to west culvert
373156 400050	*1.5, 0.5, Rectangular	Shaw Brook culvert upstream of canal
373075 400001	*1.2, Circular	Shaw Brook culvert beneath canal

*Data assumed due to lack of survey information; all assumed culverts are concrete and assigned a Manning's n of 0.012 derived from Chow (1959).

1.2 Other Comments/Assumptions/Uncertainty/Sensitivity Testing

- DRN indicates that Shaw Brook flows are divided between an open channel and culverted section downstream of East Lancashire Road (A580). Inflow SHAW_01 has been applied downstream of the confluence (downstream of the catchment boundary).
- JFlow model outputs should tie into existing Flood Zone 2/3 outlines. However, JFlow modelling does not indicate significant flood risk associated with Shaw Brook culvert east of Falconwood Chase. It is noted that this culvert is not included in the DRN, therefore, a 0.1% AEP event sensitivity scenario has been tested excluding this culvert (equivalent to 100% blocked) resulting in increased flood risk that is more aligned with the FZ2 extent. Further, catchments downstream of the canal have not been included for, therefore, flood extents are reduced compared to the published Flood Zone 2/3 outlines.
- LiDAR has been used to define culvert barrel lengths.
- Circular culverts have not yet been implemented in this version of JFlow, therefore, have been converted into square culverts with an equivalent barrel area and centroid location.
- The JFlow model assumes a channel capacity of QMED (Q2), which is a general assumption when using JFlow as the channel depth is not accurately represented in the DTM.
- 4 of the structures had already been surveyed and represented in the Shaw Brook 2009 model. Dimensions were taken from that study and used for these structures in this study. The summary map highlights these structures.
- Simulation end time defined by multiplying the latest time point from the selected hydrographs by three to ensure that all flooding is outputted without the need to determine individual end times for each simulation.


JFlow Model Outlines
Land East of Boothstown
Legend
Site Boundary
1% AEP
1% AEP +70%CC
0.1% AEP
A572
HILTON CRESCENT
BOOTHSBANK AVENUE
FALCONWOOD CHASE
WATERDALE CL
QUAYSIDE CL
Alder Wood
Garden Cottage
Hollin Wood
N
0 0.0375 0.075 0.15 0.225 0.3
Kilometres
GMCA GREATER MANCHESTER COMBINED AUTHORITY

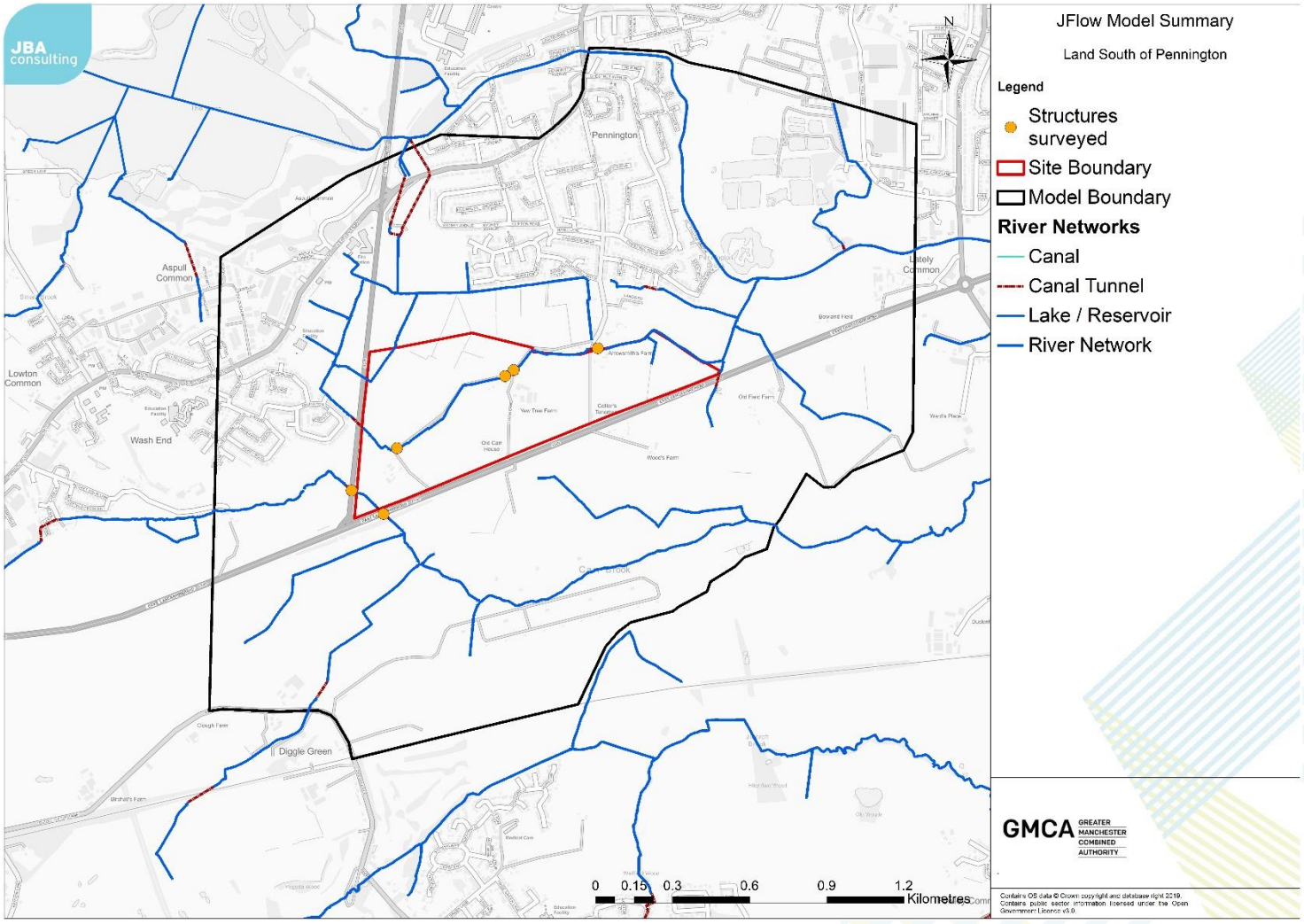
TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA L2 SFRA
Client	GMCA
Day, Date and Time	20 January 2020
Author	Joseph Landells-Molloy
Reviewer / Sign-off	Andrew Fielding
Subject	Land South Pennington

1 Model Name: Land South Pennington

Land South Pennington is located off Carr Lane, Leigh, Warrington WM7 3RY. It Is bounded to the west by the A579 and to the south by the A580.

Carr Brook flows through the south western extent of the site in a southerly direction. WHEG and its tributaries flow southward into the site via a culvert beneath the A579 before flowing eastward and outfalling into Pennington Brook approximately 1.5 kilometres to the east.



1.1 Modelled Structures

The following table contains details of all modelled structures:

X Y Coordinates	Dimensions (width, height, shape)	Comments
364504 397501	1.75, 0.9, Rectangular	Carr Brook culvert beneath A579
364625 397409	1.75, 3.0, Rectangular	Carr Brook culvert beneath A580
365460 398047	0.9, Circular	WHEG culvert beneath Carr Lane
364681 397660	0.3, 0.15, Rectangular	Culvert downstream of WHEG_01
365101 397941	0.5, Circular	Culvert upstream of Carr Lane
365135 397964	0.5, Circular	Culvert beneath Carr Lane

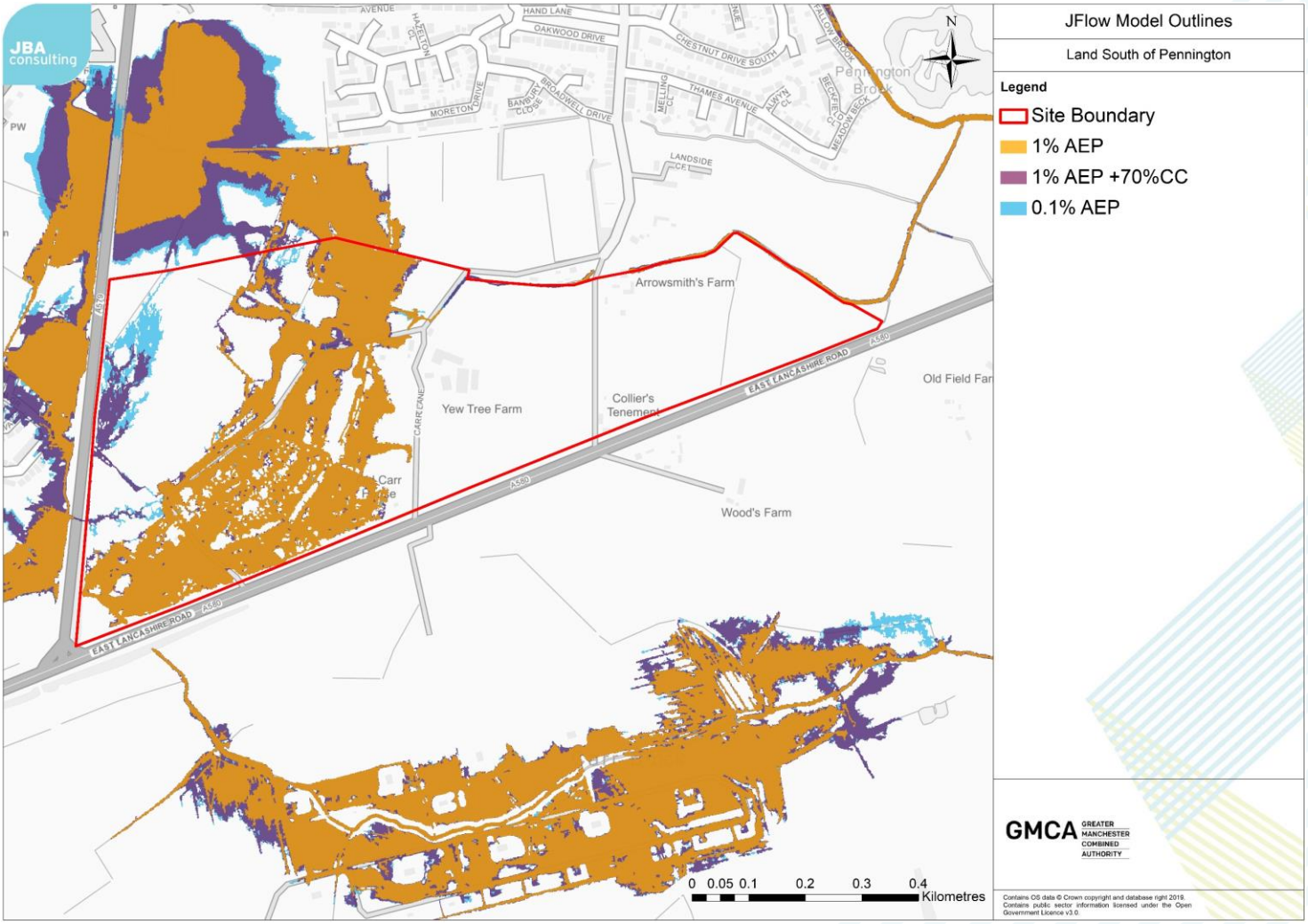
*Data assumed due to lack of survey information; all assumed culverts are concrete and assigned a Manning's n of 0.012 derived from Chow (1959).

1.2 Other Comments/Assumptions/Uncertainty/Sensitivity Testing

- It is noted that there is an existing pumping station to the north of the site that has not been modelled (undefended scenario in accordance with Environment Agency defined Flood Zones), therefore, LiDAR directs flows from catchments TRIB01_US and TRIB02_US northward where it ponds, however, does not impact flood risk at the proposed development site. Also, LiDAR directs flows from WHEG_03 towards Land South Pennington.
- LiDAR has been used to define culvert barrel lengths.
- Circular culverts have not yet been implemented in this version of JFlow, therefore, have been converted into square culverts with an equivalent barrel area and centroid location.
- The JFlow model assumes a channel capacity of QMED (Q2), which is a general assumption when using JFlow as the channel depth is not accurately represented in the DTM.
- Simulation end time defined by multiplying the latest time point from the selected hydrographs by three to ensure that all flooding is outputted without the need to determine individual end times for each simulation.

TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA L2 SFRA
Client	GMCA
Day, Date and Time	20 January 2020
Author	Joseph Landells-Molloy
Reviewer / Sign-off	Andrew Fielding
Subject	Land South Pennington



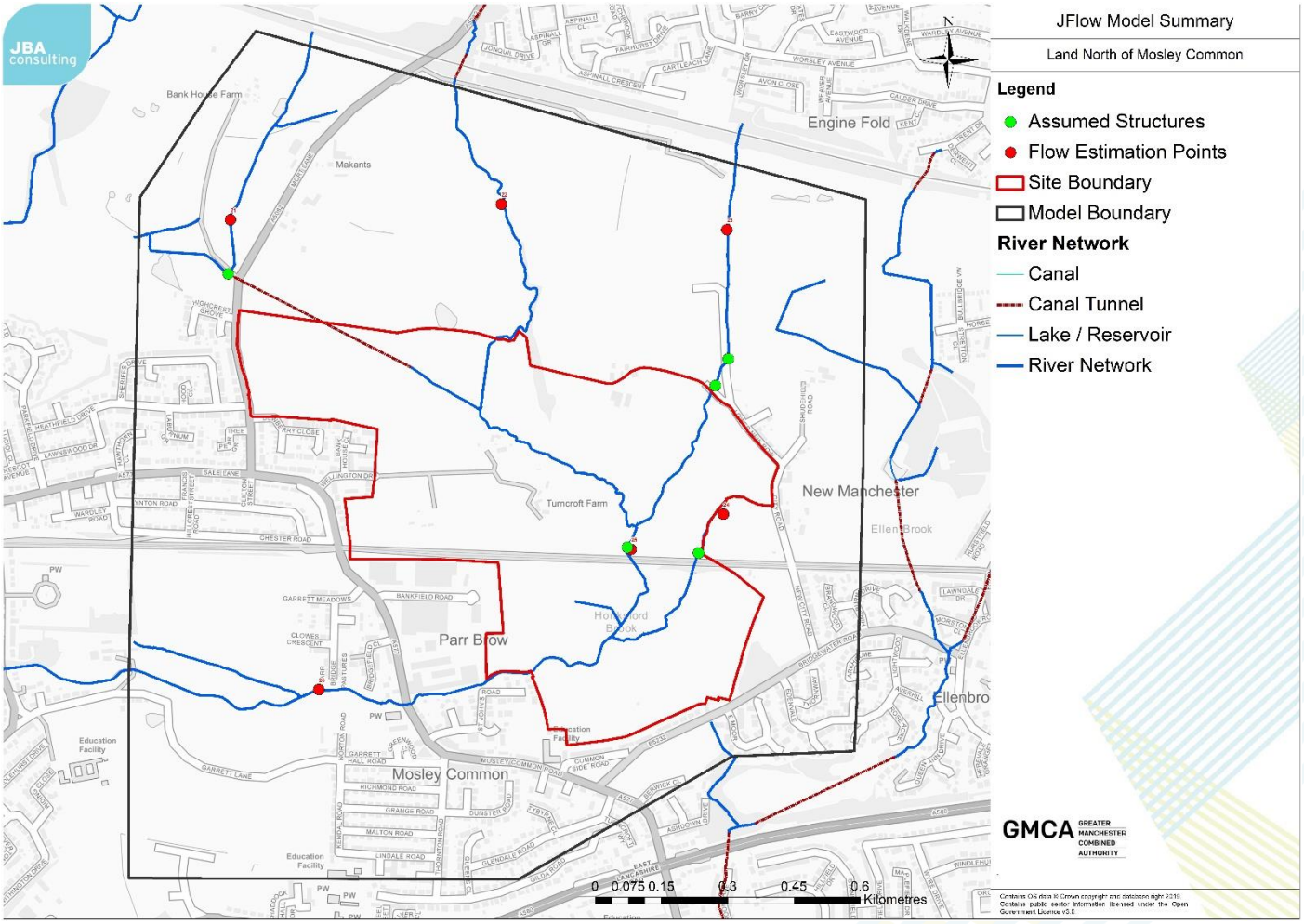
TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA Level 2 Hybrid SFRA
Client	Greater Manchester Combined Authority
Day, Date and Time	30th January 2020
Author	Chris Knight
Reviewer / Sign-off	Andrew Fielding
Subject	JFlow Summary Report Land North of Mosley Common

1 Model Name: Land North of Mosley Common

Allocation site (371757, 401950) is located north of Mosley Common Road (A577) and east of Mort Lane (A5082) in Tyldesley, Greater Manchester.

Honksford Brook, a designated main river, flows to the south and west through the site and is fed by three small tributaries. Honksford Brook converges with two of the tributaries upstream of a guided bus route that runs from Leigh to the west to Ellenbrook in the east and is culverted beneath it. The third tributary watercourse is also culverted beneath the bus route before converging with Honksford Brook.



1.1 Modelled Structures

The following table contains details of all modelled structures:

X Y Coordinates	Dimensions (width, height, shape)	Comments
371014 4402485	*0.6, Circular	Culvert under A5082 Mort Lane
372133 402272	*1, Circular	Culvert 1 under Lower New Row
372097 402212	*1, Circular	Culvert 2 under Lower New Row
371917 401836	*2, Circular	Culvert 1 under Guided Bus Route
372067 401837	*1.5, Circular	Culvert 2 under Guided Bus Route

*Data assumed due to lack of survey information; all assumed culverts are concrete. Where channel width information is available, culvert diameter assumed to be 0.5m less than surveyed channel width.

1.2 Other Comments/Assumptions/Uncertainty/Sensitivity Testing

- None of the structures within this study area have been surveyed, dimensions have been taken from LiDAR.
- Circular culverts have not yet been implemented in this version of JFlow, so have therefore been converted into square culverts with an equivalent barrel area and centroid location.
- Assuming that structures are constructed on concrete a Manning's n of 0.012 has been applied, derived from Chow (1959).
- The DTM is 1m resolution LiDAR. This was used in combination with DRN to define the length of culvert barrels.
- Simulation end time has been defined by multiplying the latest time point from the selected hydrographs by 3 to ensure that all flooding is outputted without the need to determine individual end times for each simulation.
- The following annual exceedance probability (AEP) events were modelled: 10% (1 in 10), 5% (1 in 20), 4% (1 in 25), 2% (1 in 50), 1% (1 in 100) and 0.1% (1 in 1000). Allowances for climate change were also modelled, with runs completed for 1 in 100 events plus 30%, 35% and 70% increases in flows respectively.
- Flow estimation points at the upstream model extents were applied as point inflows at the upstream boundaries. Intermediate calculated flows were distributed as a line between flow estimation points, following the DRN and DTM as closely as possible.

- DEM modification lines inserted at five locations to allow more realistic passage of flow. Channel widths estimated from LiDAR.
- The JFlow model assumes a channel capacity of QMED (Q2), which is a general assumption when using JFlow as the channel depth is not accurately represented in the DTM.
- Inflow hydrographs calculated with reference 'HONKM_02' at the river confluence upstream of the guided bus route were split equally between Honksford Brook and its tributary, with the tributary flows split further where culvert structures are represented in the flow path. The percentage split of HONKM_02 inflow hydrographs are as follows:

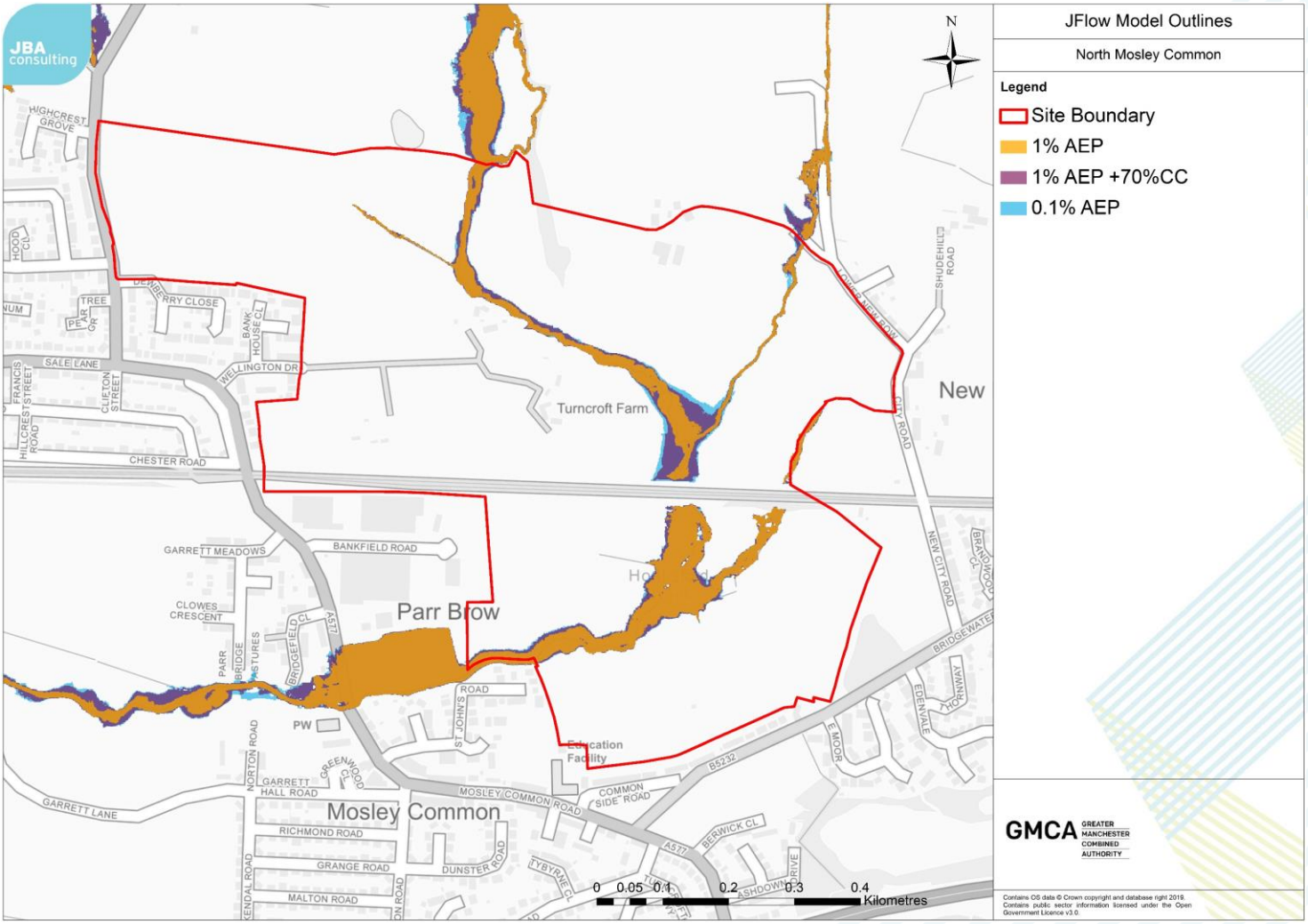
  HONKM_02_1 = 50%

  HONKM_02_2 = 25%

  HONKM_02_3 = 25%

TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA Level 2 Hybrid SFRA
Client	Greater Manchester Combined Authority
Day, Date and Time	30th January 2020
Author	Chris Knight
Reviewer / Sign-off	Andrew Fielding
Subject	JFlow Summary Report Land North of Mosley Common



TECHNICAL NOTE

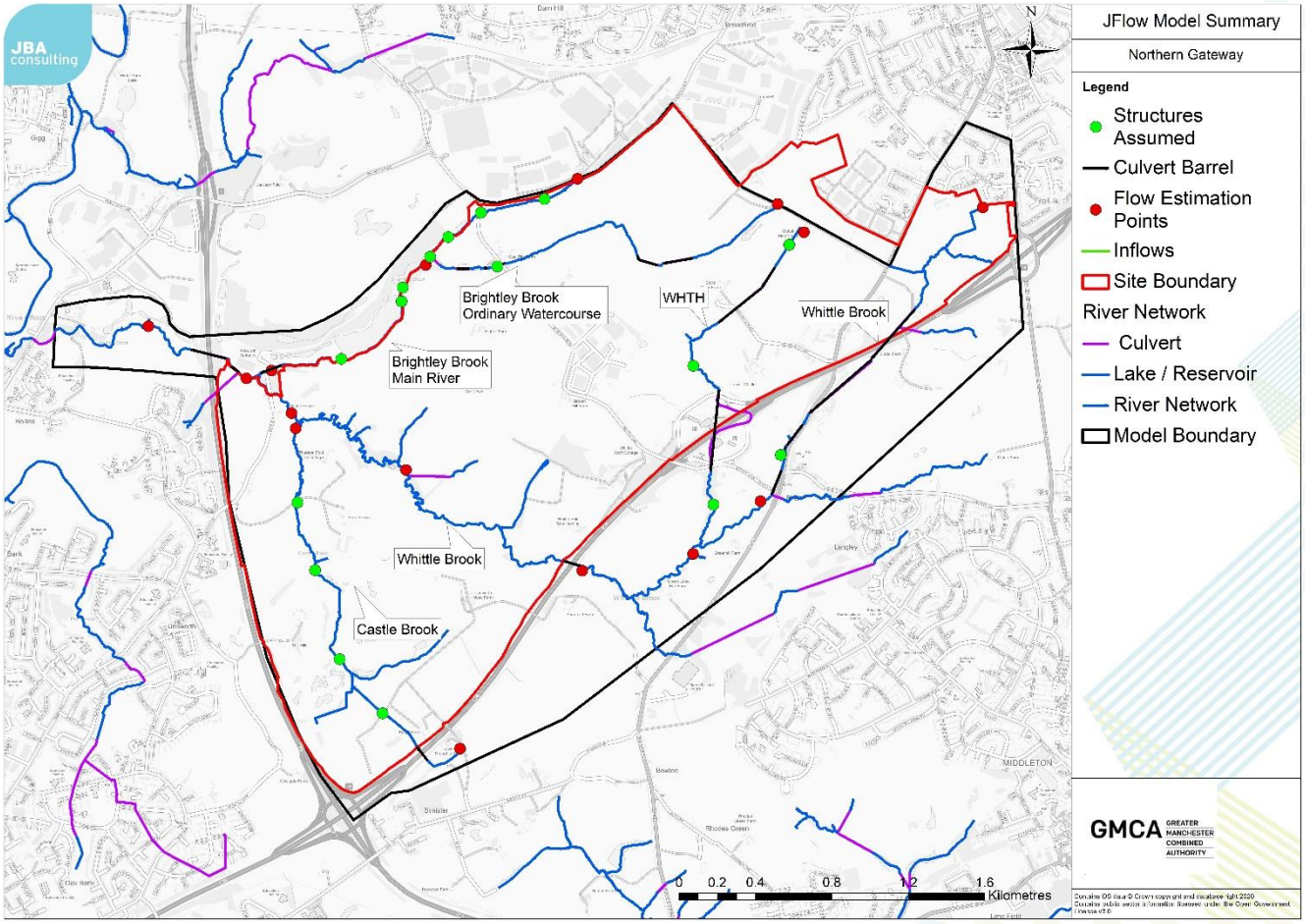
JBA Project Code	2019s0820
Contract	GMCA L2 SFRA
Client	GMCA
Day, Date and Time	20 January 2020
Author	Freyja Scarborough
Reviewer / Sign-off	Katherine Dixon
Subject	Northern Gateway JFlow

1 Model Name:

The Northern Gateway allocation is located immediately north of the M62 near Heywood, to the north of Manchester (383901, 408166). The site is bound by the M62 to the south, the M66 to the West, the Brightely Brook and to the North, Hareshill Road. There are five watercourses which impact this site:

- Whittle Brook
- Brightley Brook Main River
- Brightley Brook Ordinary Watercourse (named BRIGO for this study)
- Castle Brook
- Unnamed watercourse named WHTH for this study

Whittle Brook which cuts through the flows into the River Roch ~1.5km downstream (to the north west) of the site allocation. There is a reservoir on Brightley Brook which may impact flood risk in this area, although the reservoir itself is outside of the site allocation.



1.1 Modelled Structures

The following table contains details of all modelled structures:

X Y Coordinates	Dimensions	Comments
Whittle Brook		
385672, 408409	*Shape: Rectangular Length: 343.6 Width: 13 Height: 5 Manning's: 0.012	Whittle Brook Culvert under M62 at Siddal Farm
385524, 408249	*Shape: Rectangular Length: 425.8 Width: 0.8 Height: 0.8 Manning's: 0.012	Whittle Brook Field culvert SW of Siddal Farm
385212, 407942	*Shape: Circular Length: 127.4 Width: 0.6 Manning's: 0.012	Whittle Brook field Culvert parallel to A6045
385149, 407863	*Shape: Circular Length: 14.1 Width: 0.6 Manning's: 0.012	Whittle Brook field Culvert under carpark *(Not within the DRN)*
385088, 407637	*Shape: Rectangular Length: 140.3 Width: 0.8 Height: 0.8 Manning's: 0.012	Whittle Brook Culvert under Whittle Lane
384037, 407253	*Shape: Rectangular Length: 88.9 Width: 13 Height: 5 Manning's: 0.012	Whittle Brook Culvert under M62 at Sandfield Farm
382135, 408350	*Shape: Rectangular Length: 191.6 Width: 13 Height: 5 Manning's: 0.012	Hollins Brook Culvert under M62
382288, 408256	*Shape: Rectangular Length: 55.51 Width: 0.8 Height: 0.8	Hollins Brook Culvert under field access to Garic

	Manning's: 0.012	
Whittle Drain		
385169, 408920	*Shape: Circular Length: 9.3 Width: 0.6 Manning's: 0.012	Whittle Drain field culvert South of Hareshill Road *(Not within the DRN)*
385067, 408763	*Shape: Circular Length: 138.7 Width: 0.6 Manning's: 0.012	Whittle Drain field culvert north of Doctor Fold Lane
384893, 408590	*Shape: Circular Length: 292.3 Width: 0.6 Manning's: 0.012	Whittle Drain Field culvert under Doctor Fold Lane
384674, 408284	*Shape: Rectangular Length: 14.8 Width: 0.8 Height: 0.8 Manning's: 0.012	Whittle Drain Culvert under farm track, North of the M62 *(Not within the DRN)*
384793, 407944	*Shape: Rectangular Length: 450.8 Width: 13 Height: 5 Manning's: 0.012	Whittle Drain Culvert under M62 Services
384769, 407569	*Shape: Circular Length: 8.9 Width: 0.6 Manning's: 0.012	Whittle Drain Field culvert South of Whittle Lane *(Not within the DRN)*
Brightly Drain		
384590, 408841	*Shape: Circular Length: 156.2 Width: 0.6 Manning's: 0.012	Brightley Drain field Culvert NW from Stock Nook Farm
384412, 408838	*Shape: Circular Length: 106.9 Width: 0.6 Manning's: 0.012	Brightley Drain field Culvert N of Broom Hill Farm
383667, 408820	*Shape: Rectangular Length: 41.7 Width: 0.8 Height: 0.8 Manning's: 0.012	Brightley Drain Culvert under Moss Hall Road *(Not within the DRN)*

383578, 408803	*Shape: Rectangular Length: 17.3 Width: 0.8 Height: 0.8 Manning's: 0.012	Brightley Drain Culvert West of Moss Hall Road under farm track *(Not within the DRN)*
383465, 408798	*Shape: Circular Length: 74.3 Width: 0.6 Manning's: 0.012	Brightley Drain Field culvert West of Moss Hall Road parallel to pond
Brightley Drain		
384590, 408841	*Shape: Circular Length: 5.7 Width: 0.6 Manning's: 0.012	Brightley Brook Field culvert 340m West of Moss Hall Road *(Not within the DRN)*
383546, 409087	*Shape: Rectangular Length: 23.6 Width: 0.8 Height: 0.8 Manning's: 0.012	Brightley Brook Culvert under Moss Hall Road *(Not within the DRN)*
383388, 408964	*Shape: Circular Length: 5.5 Width: 0.6 Manning's: 0.012	Brightley Brook Field culvert under farm track *(Not within the DRN)*
383291, 408858	*Shape: Circular Length: 6.4 Width: 0.6 Manning's: 0.012	Brightley Brook Field culvert Upstream of confluence with Brightley Drain *(Not within the DRN)*
383153, 408707	*Shape: Circular Length: 16.5 Width: 0.6 Manning's: 0.012	Brightley Brook Field culvert downstream of small reservoir *(Not within the DRN)*
383139, 408631	*Shape: Circular Length: 8.8 Width: 0.6 Manning's: 0.012	Brightley Brook field Culvert under access track upstream reservoir *(Not within the DRN)*
382843, 408325	*Shape: Rectangular Length: 27 Width: 0.8 Height: 0.8 Manning's: 0.012	Brightley Brook Culvert connecting Brook to Reservoir outlet *(Not within the DRN)*
382459, 408274	*Shape: Rectangular Length: 117.01	Brightley Brook Culvert under Pilsworth Cottages

	Width: 13 Height: 5 Manning's: 0.012	
Caste Brook		
383246, 406263	*Shape: Rectangular Length: 86.2 Width: 13 Height: 5 Manning's: 0.012	Castle Brook Culvert under M62
382814, 406756	*Shape: Rectangular Length: 6.3 Width: 0.8 Height: 0.8 Manning's: 0.012	Caste Brook Culvert 1 crossing the golf course *(Not within the DRN)*
382770, 406804	*Shape: Rectangular Length: 3.5 Width: 0.8 Height: 0.8 Manning's: 0.012	Caste Brook Culvert 2 crossing the golf course *(Not within the DRN)*
382687, 407223	*Shape: Rectangular Length: 6.9 Width: 0.8 Height: 0.8 Manning's: 0.012	Caste Brook Culvert 3 crossing the golf course *(Not within the DRN)*
383045, 406469	*Shape: Rectangular Length: 10.1 Width: 0.8 Height: 0.8 Manning's: 0.012	Caste Brook Culvert under Egypt Lane *(Not within the DRN)*

*Data assumed due to lack of survey information

1.2 Other Comments/Assumptions/Uncertainty/Sensitivity Testing

- The following events were ran: 10%, 5%, 3.3%, 2%, 1%, 0.1% AEPs. Allowances for climate change were also modelled, with runs completed for 1% AEP events plus 30%, 35% and 70% increases in peak flows.
- The DTM is 1m resolution LiDAR.
- Structures were unable to be surveyed due to no access to the asset or it being unable to be found. As such all structures were modelled using assumed dimensions taken from LIDAR and aerial imagery. LiDAR has been used to define culvert barrel lengths.
- Circular culverts have not yet been implemented in this version of JFlow, therefore, have been converted into square culverts with an equivalent barrel area and centroid location.

- Manning's n values have been derived using Chow 1959. Structures assumed to be constructed of concrete and were assigned values of 0.012 for rectangular culverts and 0.01 for circular.
- The JFlow model assumes a channel capacity of QMED (Q2), which is a general assumption when using JFlow as the channel depth is not accurately represented in the DTM.
- Flow estimation points at the upstream model extents were applied as point inflows at the upstream boundaries.

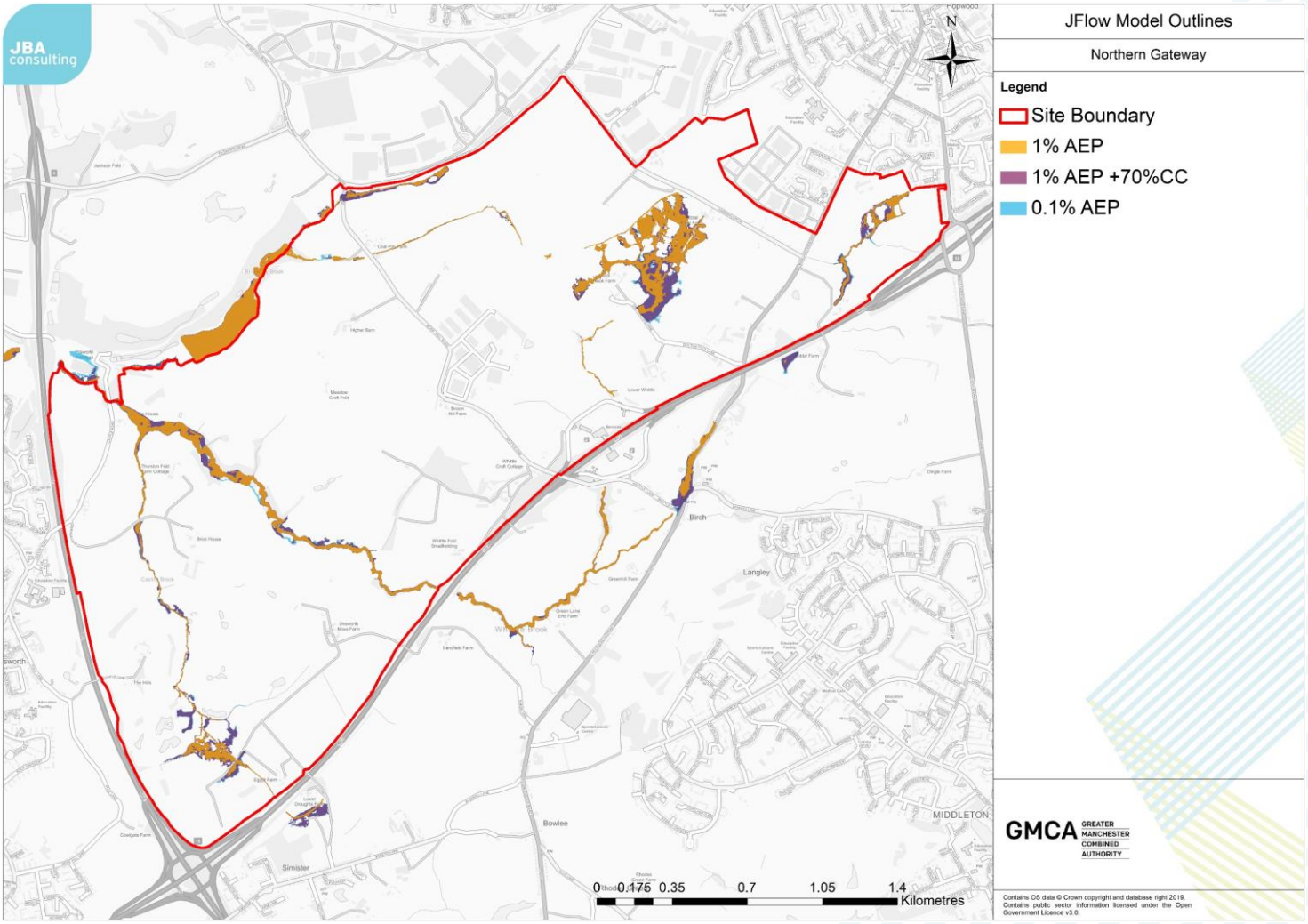
Top Inflow Name
WHIT_01
WHTH_01
CAST_01
BRIGM_01
BRIGO_01

- Intermediate calculated flows were distributed as a line between flow estimation points, following the DRN and DTM as closely as possible. Where structures interrupt intermediate flows these lines where split further. The table below outlines the percentage splits for each intermediate flow. The naming convention for these splits starts as _01 at the northern most split and increases sequentially (e.g. _02, _03 …).

Name	Percentage Spilt
WHIT_02	
WHIT_02_01	50%
WHIT_02_02	50%
WHIT_03	
WHIT_03_01	25%
WHIT_03_02	25%
WHIT_03_03	25%
WHIT_03_04	25%
WHIT_04	100%
WHIT_05	100%
WHIT_06	100%
WHIT_08	
WHIT_08_01	20%
WHIT_08_02	80%

Name	Percentage Spilt
CAST_02	
CAST_02_01	20%
CAST_02_02	20%
CAST_02_03	20%
CAST_02_04	20%
CAST_02_05	20%
BRIGM_02	
BRIGM_02_01	25%
BRIGM_02_02	25%
BRIGM_02_03	10%
BRIGM_02_04	30%
BRIGM_02_05	10%
BRIGM_02	
BRIGM_03_01	33.3%
BRIGM_03_02	33.3%
BRIGM_03_03	33.3%

- Simulation end time defined by multiplying the latest time point from the selected hydrographs by three to ensure that all flooding is outputted without the need to determine individual end times for each simulation.


JFlow Model Outlines
Northern Gateway
Legend
Site Boundary
1% AEP
1% AEP +70%CC
0.1% AEP
N
0 0.175 0.35 0.7 1.05 1.4
Kilometres
GMCA GREATER MANCHESTER COMBINED AUTHORITY
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TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA L2 SFRA
Client	GMCA
Day, Date and Time	20 January 2020
Author	Hannah Bishop
Reviewer / Sign-off	Andrew Fielding
Subject	South of Hyde

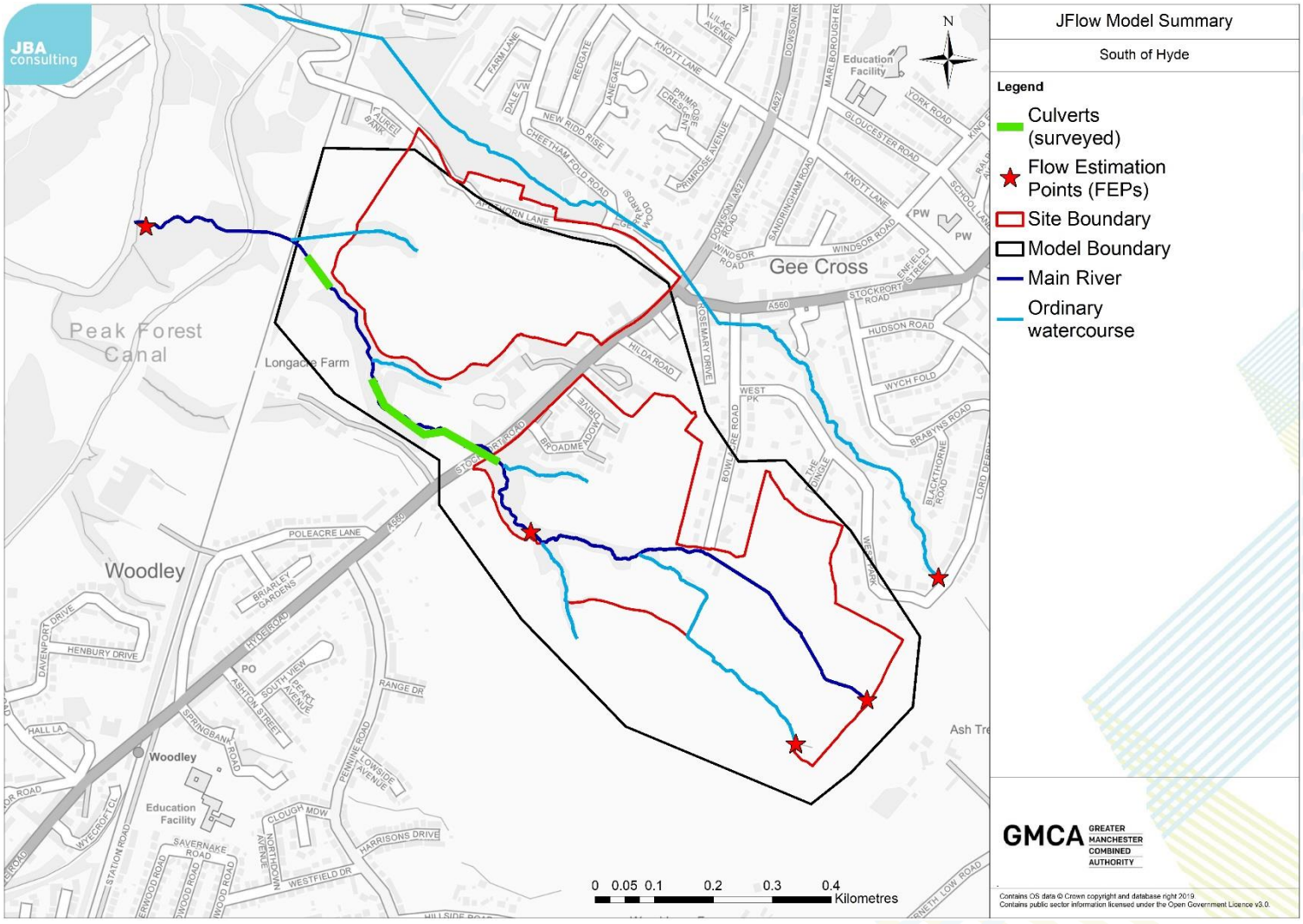
1 Model Name: South of Hyde

The South of Hyde allocation is located across Stockport Road in Gee Cross, to the south-east of Manchester. The BOWL watercourse and unnamed tributary both flow into the River Tame just 350m downstream of the site allocation.

Some of the catchments are very small (<0.5km^2) but the overall BOWL watercourse catchment was large enough to have a catchment on the FEH Web Service (0.82km^2).

The catchments draining into the unnamed tributary are urban, whilst the catchments draining to the BOWL watercourse are rural.

There is an ordinary watercourse that runs along the western boundary of the South of Hyde allocation.



1.1 Modelled Structures

The following table contains details of all modelled structures, both were surveyed:

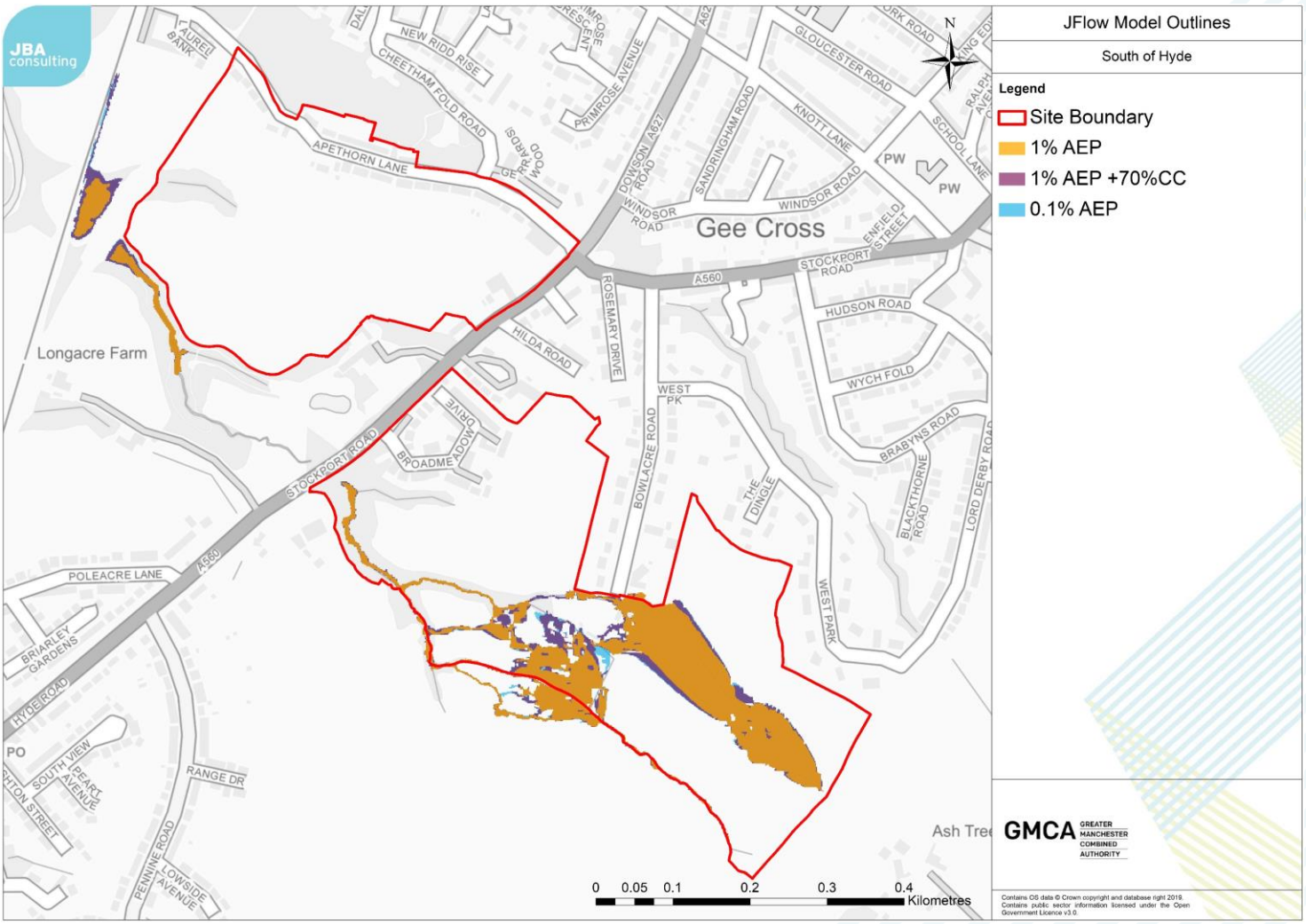
X Y Coordinates	Dimensions (width, height, shape)	Comments
394545 393016	0.8, 0.65, Rectangular	Culvert under Stockport Road A560
394239 393340	1.0, 1.3, Rectangular	Culvert under railway lines

The culverts are concrete and assigned a Manning's n of 0.012 derived from Chow (1959).

1.2 Other Comments/Assumptions/Uncertainty/Sensitivity Testing

- The inflows TRIB01_US and TRIB01_DS relate to inflows located on the ordinary watercourse that runs to the west of the site allocation; this watercourse was chosen not to be modelled and rather to focus on the BOWL watercourse that runs through the centre of the site and thus the two inflows were disregarded.
- Negative flows were calculated as part of the hydrographs for the flow estimation points (FEPs), as JFlow cannot input negative values, these were changed to 0.
- Inflow BOWL_03 was required to be split due to there being a structure located between the confluence of BOWL watercourse and tributary and the downstream. Due to JFlow being limited in being able to support multi-line polygons, the inflow was split applying 30% to the watercourse above the structure (BOWL_03_US) and the remaining 70% downstream (BOWL_03_DS).
- There is a gap in the LiDAR coverage (394440, 393056) from the drone survey; a culvert runs into this section. Therefore, the culvert outlet has been placed where the LiDAR coverage begins again.
- The culvert that passes under Stockport Road A560 was surveyed as a block arch culvert (width 0.9m and height 0.65m). It has been modelled as a rectangular culvert with reduced width of 0.8m to accommodate for the change in shape; height was kept the same.
- The JFlow model assumes a channel capacity of QMED (Q2), which is a general assumption when using JFlow as the channel depth is not accurately represented in the DTM.
- Simulation end time defined by multiplying the latest time point from the selected hydrographs by three to ensure that all flooding is outputted without the need to determine individual end times for each simulation.

JBA Project Code	2019s0820
Contract	GMCA L2 SFRA
Client	GMCA
Day, Date and Time	20 January 2020
Author	Hannah Bishop
Reviewer / Sign-off	Andrew Fielding
Subject	South of Hyde

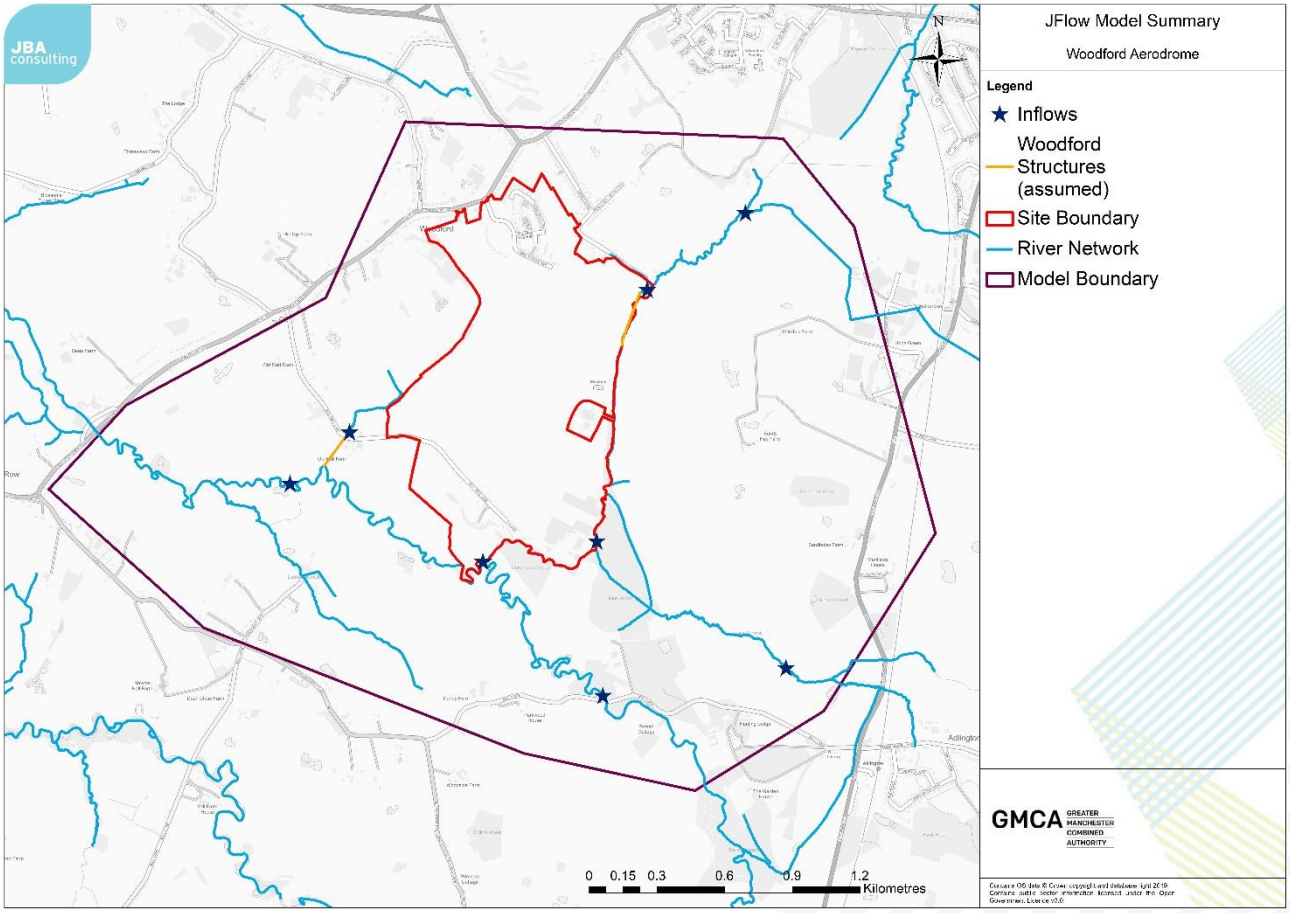


TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA SFRA L2
Client	GMCA
Day, Date and Time	30 January 2020
Author	Jack Pordham
Reviewer / Sign-off	Katherine Dixon
Subject	Woodford Aerodrome JFlow Report Summary

1 Model Name: Woodford Aerodrome

- The allocation site lies south of the village of Woodford in Stockport, Manchester (389630, 382060). An unnamed watercourse flows down the eastern boundary of the site before its confluence with the larger Red Brook at the site's south-eastern corner. The brook continues before reaching its own confluence with the River Dean flowing to the West.
- The site has an area of approximately 120ha with a proposed residential land use.



1.1 Modelled Structures

The following table contains details of all modelled structures:

X Y Coordinates	Dimensions (width, height, shape)	Comments
390138,382438	*Circular conduit type, length- 244.62m, barrel width- 0.6m, manning's n- 0.012	Culvert near Bridle Road. No survey data available, all dimensions assumed
388834,381800	*Circular conduit type, length-161.05m, barrel width- 0.6m, manning's n- 0.012	Culvert under Old Hall Lane. No survey data available, all dimensions assumed

*Data assumed due to lack of survey information; all assumed culverts are concrete circular.

Culvert under Old Hall Lane:

Outfall

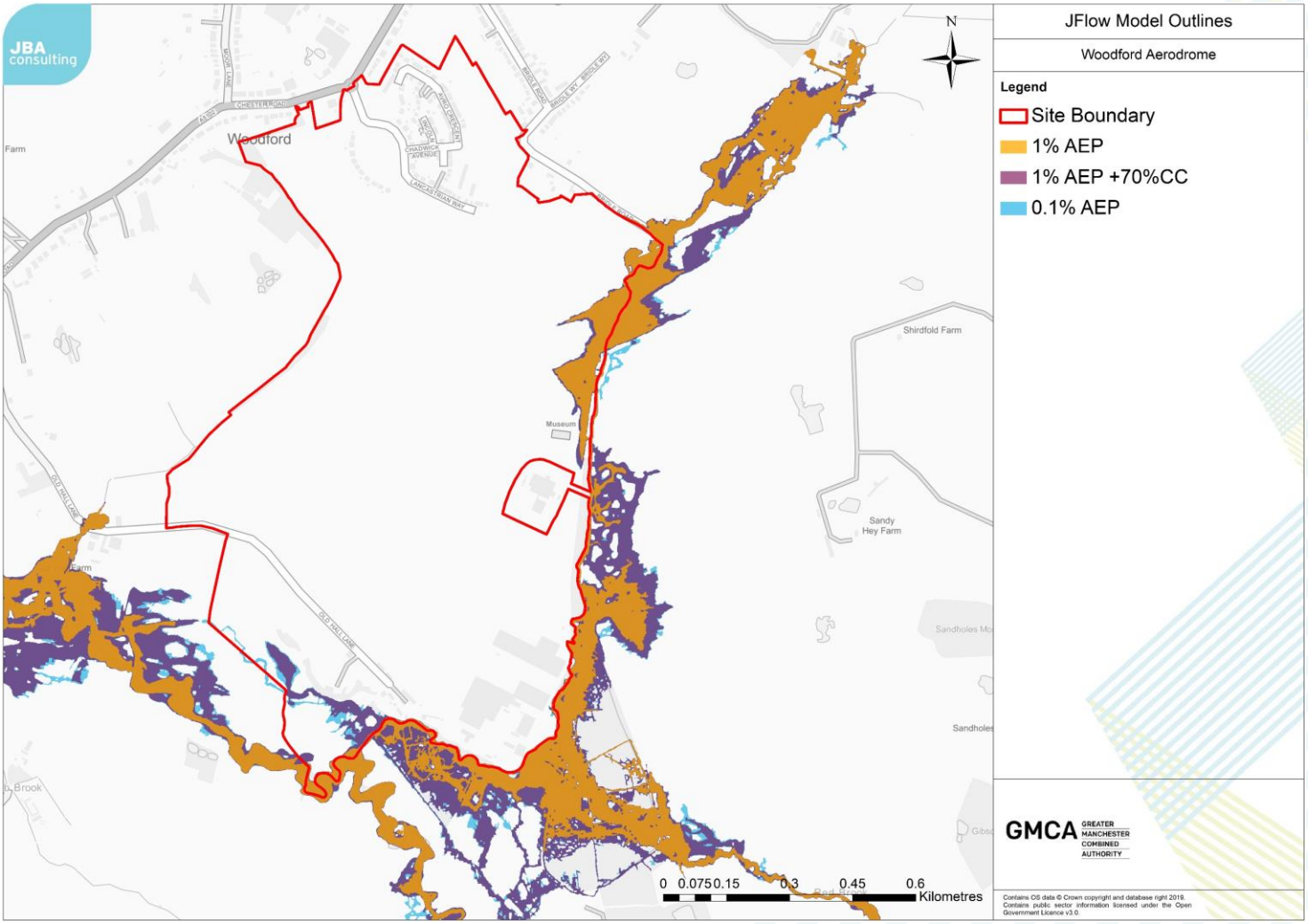
1.2 Other Comments/Assumptions/Uncertainty/Sensitivity Testing

- As of December 2019, residential development is ongoing at the site. As no site plans are available to be provided, the model has assumed the area as greenfield.
- Both structures were unable to be surveyed due to no access to the asset or it being unable to be found. As such all structures were modelled using assumed dimensions taken from LIDAR and aerial imagery. DRN was used to define barrel length.
- Circular culverts have not yet been implemented in this version of JFlow, therefore, have been converted into square culverts with an equivalent barrel area and centroid location.
- Manning's n values have been derived using Chow 1959[1]. Structures assumed to be constructed of concrete and were assigned values of 0.012.
- Negative flows were calculated as part of the hydrographs for the flow estimation points (FEPs), as JFlow cannot input negative values, these were changed to 0.
- FEPs representing upstream inflows to the model were applied as polygons. Lateral inflows or points representing the distance between two areas i.e. confluences were drawn into the model as lines following the LIDAR and DRN as closely as possible.
- Inflow 'RETI_DS', representing the water entering the catchment between the upstream and a confluence, was required to be split due to there being a structure (culvert near Bridle road) located between these points. Due to the limitations of JFlow being unable to support multi-line polygons, the inflow was split applying 25% to the watercourse above the structure (RETI_DS1) and the remaining 75% downstream (RETI_DS2).
- A DEM modification was applied to enforce the channel into the LIDAR at 389976, 381478. This was to allow water to flow in a more realistic manner through this area. Dimensions of the cut were based on LIDAR as no survey data or aerial imagery was available to provide further information.
- Sense checks of comparing the modelled 1% AEP and 0.1% AEP to existing Flood Map for Planning for zones 2 and 3 were performed. There were some similarities in the flood extents at the downstream of the model though modelled outlines generally proved different to published mapping. All outlines increase in size and see greater depths with higher events as would be expected.
- 2 sensitivity tests were ran using the 1% AEP and 0.1% AEP events. The culvert near Bridle Road was removed from the model run to investigate effects in this area. Currently, there is flood water sheeting overland into the north-east corner of the development site. Testing was to ascertain if this was caused by culvert capacity. The 1% AEP event showed there to be slight increases in maximum flood extents in this area though the pattern and extent remained broadly similar meaning flooding here is a product of both the flood event, channel geometry and

1 http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

the profile of the land. The latter seeing a downwards gradient on land to the east of the site towards the development area. Depths increased here by ~0.2m. Elsewhere in the study area, the culvert removal had no discernible negative impacts upon the development site. This pattern is repeated in the 0.1% AEP event.

- The JFlow model assumes a channel capacity of QMED (Q2), which is a general assumption when using JFlow as the channel depth is not accurately represented in the DTM.
- Simulation end time defined by multiplying the latest time point from the selected hydrographs by three to ensure that all flooding is outputted without the need to determine individual end times for each simulation.


JFlow Model Outlines
Woodford Aerodrome
Legend
Site Boundary
1% AEP
1% AEP +70%CC
0.1% AEP
N
Woodford
Shirdfold Farm
Sandy Hey Farm
Museum
0 0.075 0.15 0.3 0.45 0.6
Kilometres
GMCA GREATER MANCHESTER COMBINED AUTHORITY

TECHNICAL NOTE

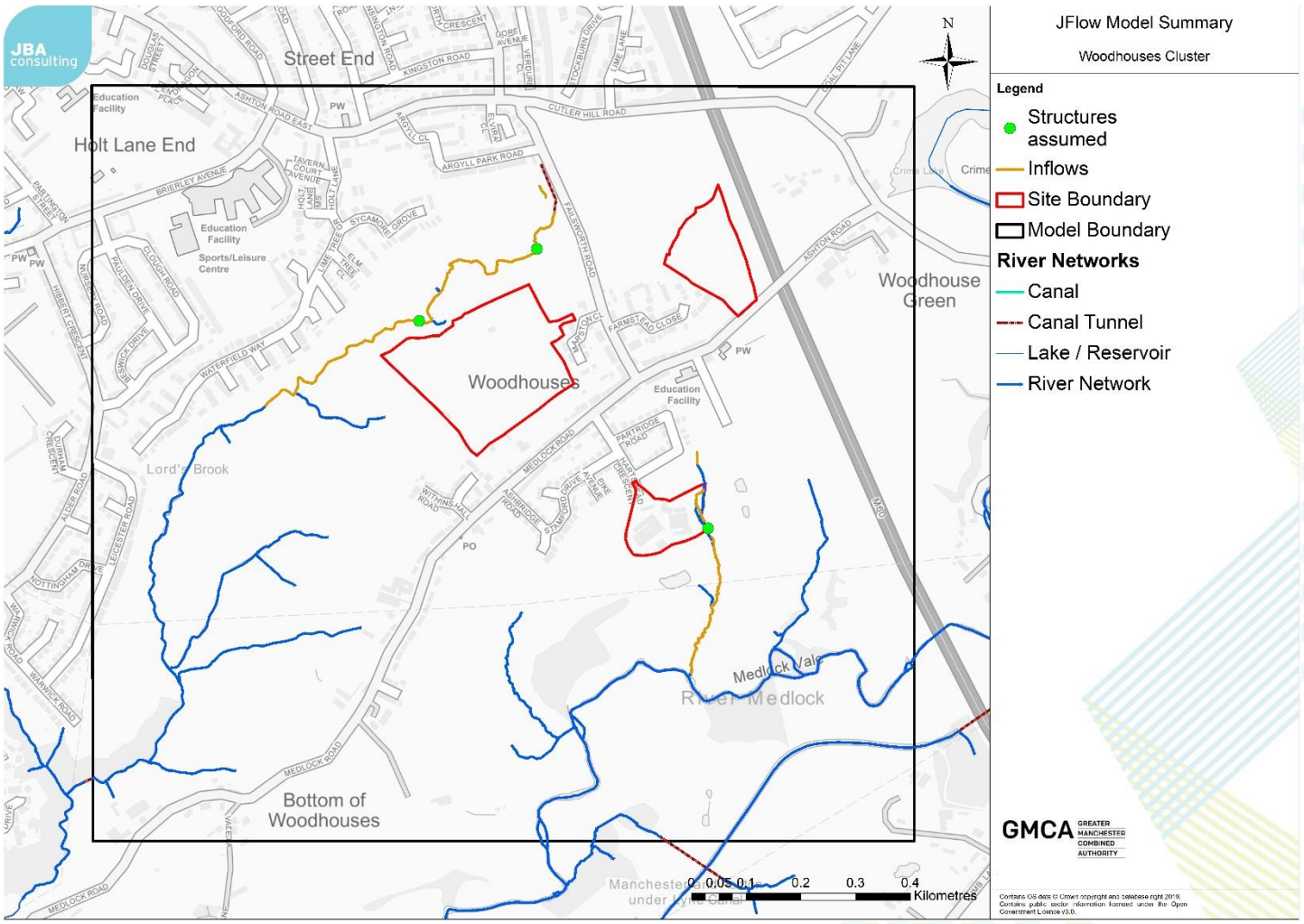
JBA Project Code	2019s0820
Contract	GMCA SFRA L2
Client	GMCA
Day, Date and Time	30 January 2020
Author	Elba Boavida
Reviewer / Sign-off	Andrew Fielding
Subject	JFlow Woodhouses Cluster Summary Report

1 Model Name: Woodhouses Cluster

Woodhouses Cluster site is located within greater Manchester area, north of Fairfield (390922, 400929), limited to the east by Manchester Outer Ring Road (M60).

Lord's Brook and an unnamed tributary 'LORD' and 'TRIB01' respectively (hereafter referred to as so) run to the north site and through the southmost section of the site, in general flowing from north to south up to the confluence with river Medlock.

Culverts have been applied along LORD and TRIB01, where the DTM showed blockage of the river channel allowing water to be conveyed downstream, preserving flows in channel.



1.1 Modelled Structures

The following table contains details of all modelled structures:

X Y Coordinates	Dimensions (width, height, manning's n, length, shape)	Comments
391244, 400593	*0.75, 0.75, 0.012, 26.14, Rectangular	Culvert added beneath a path to allow water through
390932, 401105	*0.75, 0.75, 0.012, 6.38, Rectangular	Culvert added beneath Lords Brook walking path

*Data assumed due to lack of survey information; all assumed culverts are concrete rectangular.

1.2 Other Comments/Assumptions/Uncertainty/Sensitivity Testing

- The DTM is 1m resolution, LiDAR based and was used to define the length of culvert barrels.
- The DTM shows that the main flowpath is blocked within LORD and TRIB01 which justifies the culverts being applied at those locations to convey water through and prevent flood under or overestimation.
- Culvert monitoring points have been assigned to all culverts to obtain discharge capacity data at the inlet and outlet boundaries.
- Assuming that culvert barrels were constructed of concrete, manning's n values of 0.012 have been assigned based on Chow, 1959[1].
- DEM modifications were applied to enforce the channel into the LiDAR at locations where the channel is poorly defined. This was to allow flows through in a more realistic manner. Dimensions of the cuts were based solely on LiDAR as no survey data or aerial imagery was available to provide further information.
- All negative flows calculated as part of the flow estimation points (FEP) have been set to zero given that JFlow doesn't recognise negative values.
- FEP representing upstream inflows to the model have been applied as line inflows on the upstream face of the modelled watercourse. Lateral flows however, were distributed as lines (split over culverts) representing flows entering the watercourse following the DRN and DTM as closely as possible.
- 'LORD_02' inflow hydrograph was split into two, where culvert structures are being used to represent blockages within the flowpath as follows: LORD02_1 corresponding to 10% and LORD02_2 corresponding to 90% of LORD_02 respectively.

1 http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

- Similarly, 'TRIB01_DS' inflow hydrograph was split into two, where culvert structures are being used to represent blockages within the flowpath as follows: TRIB01DS_1 corresponding to 19% and TRIB01DS_2 corresponding to 81% of the flows.
- Each inflow line percentage has been derived from the cumulative lines' length.
- Vertical inflow rates are all smaller than 1m/s therefore, inflow line lengths does not appear to have any significant implication on modelling outputs.
- The JFlow model assumes a channel capacity of QMED (Q2), which is a general assumption when using JFlow as the channel depth is not accurately represented in the DTM.
- Simulation end time was defined by multiplying the latest time point from the selected hydrographs by three to ensure that all flooding is outputted without the need to determine individual end times for each simulation.
- Detailed sensitivity checks were beyond the scope of this work however the following has been tested:
    - DEM modifications have been added to all modelled returning periods where the DTM shows the channel blocked

TECHNICAL NOTE

JBA Project Code	2019s0820
Contract	GMCA SFRA L2
Client	GMCA
Day, Date and Time	30 January 2020
Author	Elba Boavida
Reviewer / Sign-off	Andrew Fielding
Subject	JFlow Woodhouses Cluster Summary Report