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C Appendix C - Key modelled structures

C.1 Tributary, access culvert

Included in model? (state reason if not):	Yes																																												
Model label:	FUL_449, FUL_449CU, FUL_449CD																																												
Type:	Circular concrete culvert																																												
How has structure been modelled?	The structure was modelled as circular culvert unit using FLOOD MODELLER. The following modelling parameters were used: <table><tr><td></td><td>FUL_499</td><td>CULVERT</td><td>INLET</td><td>FUL_499CU</td></tr><tr><td></td><td>FUL_499CU</td><td>CONDUIT</td><td>CIRCULAR</td><td></td></tr><tr><td></td><td>FUL_499CD</td><td>CONDUIT</td><td>CIRCULAR</td><td></td></tr><tr><td></td><td>FUL_499CD</td><td>CULVERT</td><td>OUTLET</td><td>FUL_492</td></tr></table> Inlet Control Data <table><tr><td>Conduit Type Code:</td><td>K:</td><td>M:</td></tr><tr><td>TYPE A</td><td>0.0078</td><td>2</td></tr><tr><td>C:</td><td>Y:</td><td></td></tr><tr><td>0.0292</td><td>0.74</td><td></td></tr></table> Ki: 0.3 Headloss Type: STATIC Reverse Flow Mode: CALCULATED Geometry <table><tr><td>Distance to Next Conduit:</td><td>Elevation Of Invert:</td><td>Diameter:</td></tr><tr><td>7.200</td><td>155.770</td><td>1.200</td></tr></table> Friction <table><tr><td>Equation:</td><td>Value Below Axis:</td><td>Value Above Axis:</td></tr><tr><td>MANNING</td><td>0.02500</td><td>0.02500</td></tr></table> Overtopping of the structure was represented within the 2D domain due to the length of the culvert (water is not likely to spill along the culvert's centre line).		FUL_499	CULVERT	INLET	FUL_499CU		FUL_499CU	CONDUIT	CIRCULAR			FUL_499CD	CONDUIT	CIRCULAR			FUL_499CD	CULVERT	OUTLET	FUL_492	Conduit Type Code:	K:	M:	TYPE A	0.0078	2	C:	Y:		0.0292	0.74		Distance to Next Conduit:	Elevation Of Invert:	Diameter:	7.200	155.770	1.200	Equation:	Value Below Axis:	Value Above Axis:	MANNING	0.02500	0.02500
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Equation:	Value Below Axis:	Value Above Axis:																																											
MANNING	0.02500	0.02500																																											
Upstream face, looking downstream	Downstream face, looking upstream																																												
	NO PHOTO AVAILABLE																																												

C.2 Pipe crossing

Included in model? (state reason if not):	Yes																																																																
Model label:	BLI_1594, BLI_1594B, BLI_1594BD																																																																
Type:	Pipe crossing																																																																
How has structure been modelled?	The structure was modelled as circular culvert unit using FLOOD MODELLER. The following modelling parameters were used: <table border="1"> <tr> <td>BLI_1594</td> <td>JUNCTION</td> <td>OPEN</td> <td>BLI_1594B</td> <td>BLI_1594SU</td> <td></td> </tr> <tr> <td>BLI_1594B</td> <td>BRIDGE</td> <td>USBPR1978</td> <td>BLI_1594BD</td> <td>BLI_1594</td> <td>BLI_1594D</td> </tr> <tr> <td>BLI_1594SU</td> <td>SPILL</td> <td></td> <td>BLI_1594SD</td> <td></td> <td></td> </tr> <tr> <td>BLI_1594BD</td> <td>JUNCTION</td> <td>OPEN</td> <td>BLI_1594SD</td> <td>BLI_1594D</td> <td></td> </tr> </table> Dual Bridge ☐ Model as Dual Bridge Bridge Width: 0.000 Dual Distance: 0.000 Piers ☐ Specify Piers ☒ Specify Soffit Shape Soffit Shape: FLAT Calibration Coefficient: 1.000 Skew Angle: 0.000 Abutment Type: 3 Abutment Alignment: ALIGNED Channel Section: <table border="1"> <thead> <tr> <th>Cross-Chainage (m)</th> <th>Elevation (m AD)</th> <th>Mannings n</th> <th>Embankments</th> </tr> </thead> <tbody> <tr><td>29.106</td><td>156.270</td><td>0.060</td><td></td></tr> <tr><td>29.631</td><td>156.284</td><td>0.060</td><td></td></tr> <tr><td>32.737</td><td>156.344</td><td>0.060</td><td></td></tr> <tr><td>33.443</td><td>156.348</td><td>0.060</td><td></td></tr> <tr><td>33.473</td><td>156.348</td><td>0.040</td><td></td></tr> <tr><td>33.518</td><td>155.537</td><td>0.040</td><td></td></tr> <tr><td>33.545</td><td>155.055</td><td>0.040</td><td></td></tr> </tbody> </table> Openings: <table border="1"> <thead> <tr> <th>Start (m)</th> <th>Finish (m)</th> <th>Springing Level (m AD)</th> <th>Soffit Level (m AD)</th> </tr> </thead> <tbody> <tr> <td>33.443</td> <td>37.828</td> <td>156.800</td> <td>156.800</td> </tr> </tbody> </table> Overtopping of the structure was represented within the 1D domain using an in-line spill unit at level 158.41 mAO.	BLI_1594	JUNCTION	OPEN	BLI_1594B	BLI_1594SU		BLI_1594B	BRIDGE	USBPR1978	BLI_1594BD	BLI_1594	BLI_1594D	BLI_1594SU	SPILL		BLI_1594SD			BLI_1594BD	JUNCTION	OPEN	BLI_1594SD	BLI_1594D		Cross-Chainage (m)	Elevation (m AD)	Mannings n	Embankments	29.106	156.270	0.060		29.631	156.284	0.060		32.737	156.344	0.060		33.443	156.348	0.060		33.473	156.348	0.040		33.518	155.537	0.040		33.545	155.055	0.040		Start (m)	Finish (m)	Springing Level (m AD)	Soffit Level (m AD)	33.443	37.828	156.800	156.800
BLI_1594	JUNCTION	OPEN	BLI_1594B	BLI_1594SU																																																													
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Upstream face, looking downstream	Downstream face, looking upstream																																																																
	NO PHOTO AVAILABLE																																																																

C.3 Bridge crossing, Cresswell Road

Included in model? (state reason if not):	Yes																																												
Model label:	BLI_1374, BLI_1374D																																												
Type:	Arch bridge																																												
How has structure been modelled?	The structure was modelled as arch bridge unit using FLOOD MODELLER. The following modelling parameters were used: Dual Bridge ☐ Model as Dual Bridge Bridge Width: 0.000 Dual Distance: 0.000 Calibration Coefficient: 1.000 Skew Angle: 0.000 Channel Section: <table border="1"> <thead> <tr> <th>Cross-Chainage (m)</th> <th>Elevation (m AD)</th> <th>Mannings n</th> <th>Embankments</th> </tr> </thead> <tbody> <tr><td>23.312</td><td>155.837</td><td>0.045</td><td></td></tr> <tr><td>26.400</td><td>155.537</td><td>0.045</td><td></td></tr> <tr><td>27.488</td><td>155.227</td><td>0.045</td><td></td></tr> <tr><td>27.614</td><td>155.203</td><td>0.045</td><td></td></tr> <tr><td>28.243</td><td>155.086</td><td>0.045</td><td></td></tr> <tr><td>29.353</td><td>154.925</td><td>0.045</td><td></td></tr> <tr><td>30.028</td><td>154.820</td><td>0.040</td><td></td></tr> </tbody> </table> Openings: <table border="1"> <thead> <tr> <th>Start (m)</th> <th>Finish (m)</th> <th>Springing Level (m AD)</th> <th>Soffit Level (m AD)</th> </tr> </thead> <tbody> <tr> <td>28.243</td> <td>32.431</td> <td>155.720</td> <td>156.770</td> </tr> <tr> <td>33.818</td> <td>38.191</td> <td>155.720</td> <td>156.790</td> </tr> </tbody> </table> Overtopping of the structure was represented within the 2D domain due to the length of the culvert (water is not likely to spill cross the bridge along its centre line).	Cross-Chainage (m)	Elevation (m AD)	Mannings n	Embankments	23.312	155.837	0.045		26.400	155.537	0.045		27.488	155.227	0.045		27.614	155.203	0.045		28.243	155.086	0.045		29.353	154.925	0.045		30.028	154.820	0.040		Start (m)	Finish (m)	Springing Level (m AD)	Soffit Level (m AD)	28.243	32.431	155.720	156.770	33.818	38.191	155.720	156.790
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Upstream face, looking downstream	Downstream face, looking upstream																																												
																																													

C.4 Access bridge 1

Included in model? (state reason if not):	Yes																																																																
Model label:	BLI_1145, BLI_1145B, BLI_1145BD																																																																
Type:	Bridge																																																																
How has structure been modelled?	The structure was modelled as bridge unit using FLOOD MODELLER. The following modelling parameters were used: <table border="1"> <tr> <td>BLI_1145</td> <td>JUNCTION</td> <td>OPEN</td> <td>BLI_1145B</td> <td>BLI_1145SU</td> <td></td> </tr> <tr> <td>BLI_1145B</td> <td>BRIDGE</td> <td>USBPR1978</td> <td>BLI_1145BD</td> <td>BLI_1145</td> <td>BLI_1145D</td> </tr> <tr> <td>BLI_1145SU</td> <td>SPILL</td> <td></td> <td>BLI_1145SD</td> <td></td> <td></td> </tr> <tr> <td>BLI_1145BD</td> <td>JUNCTION</td> <td>OPEN</td> <td>BLI_1145SD</td> <td>BLI_1145D</td> <td></td> </tr> </table> Dual Bridge ☐ Model as Dual Bridge Bridge Width: 0.000 Dual Distance: 0.000 Piers ☐ Specify Piers ☒ Specify Soffit Shape Soffit Shape: FLAT Calibration Coefficient: 1.000 Skew Angle: 0.000 Abutment Type: 3 Abutment Alignment: ALIGNED Channel Section: <table border="1"> <thead> <tr> <th>Cross-Chainage (m)</th> <th>Elevation (m AD)</th> <th>Mannings n</th> <th>Embankments</th> </tr> </thead> <tbody> <tr><td>19.000</td><td>156.320</td><td>0.030</td><td></td></tr> <tr><td>19.836</td><td>156.328</td><td>0.030</td><td></td></tr> <tr><td>20.089</td><td>156.335</td><td>0.045</td><td></td></tr> <tr><td>20.098</td><td>156.050</td><td>0.045</td><td></td></tr> <tr><td>20.517</td><td>155.703</td><td>0.045</td><td></td></tr> <tr><td>21.419</td><td>155.077</td><td>0.045</td><td></td></tr> <tr><td>22.612</td><td>154.764</td><td>0.045</td><td></td></tr> </tbody> </table> Openings: <table border="1"> <thead> <tr> <th>Start (m)</th> <th>Finish (m)</th> <th>Springing Level (m AD)</th> <th>Soffit Level (m AD)</th> </tr> </thead> <tbody> <tr> <td>20.517</td> <td>31.091</td> <td>155.990</td> <td>155.990</td> </tr> </tbody> </table> Overtopping of the structure was represented within the 1D domain using an in-line spill unit at level 157.76 mAOD (top of stone wall).	BLI_1145	JUNCTION	OPEN	BLI_1145B	BLI_1145SU		BLI_1145B	BRIDGE	USBPR1978	BLI_1145BD	BLI_1145	BLI_1145D	BLI_1145SU	SPILL		BLI_1145SD			BLI_1145BD	JUNCTION	OPEN	BLI_1145SD	BLI_1145D		Cross-Chainage (m)	Elevation (m AD)	Mannings n	Embankments	19.000	156.320	0.030		19.836	156.328	0.030		20.089	156.335	0.045		20.098	156.050	0.045		20.517	155.703	0.045		21.419	155.077	0.045		22.612	154.764	0.045		Start (m)	Finish (m)	Springing Level (m AD)	Soffit Level (m AD)	20.517	31.091	155.990	155.990
BLI_1145	JUNCTION	OPEN	BLI_1145B	BLI_1145SU																																																													
BLI_1145B	BRIDGE	USBPR1978	BLI_1145BD	BLI_1145	BLI_1145D																																																												
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Upstream face, looking downstream	Downstream face, looking upstream																																																																
	NO PHOTO AVAILABLE																																																																

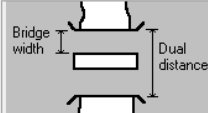
C.5 Access bridge 2

Included in model? (state reason if not):	Yes																																																																
Model label:	BLI_862, BLI_862B, BLI_862BD																																																																
Type:	Bridge																																																																
How has structure been modelled?	The structure was modelled as bridge unit using FLOOD MODELLER. The following modelling parameters were used: <table border="1"> <tr> <td>BLI_862</td> <td>JUNCTION</td> <td>OPEN</td> <td>BLI_862B</td> <td>BLI_862SU</td> <td></td> </tr> <tr> <td>BLI_862B</td> <td>BRIDGE</td> <td>USBPR1978</td> <td>BLI_862BD</td> <td>BLI_862</td> <td>BLI_862D</td> </tr> <tr> <td>BLI_862SU</td> <td>SPILL</td> <td></td> <td>BLI_862SD</td> <td></td> <td></td> </tr> <tr> <td>BLI_862BD</td> <td>JUNCTION</td> <td>OPEN</td> <td>BLI_862SD</td> <td>BLI_862D</td> <td></td> </tr> </table> Dual Bridge ☐ Model as Dual Bridge Bridge Width: 0.000 Dual Distance: 0.000 Piers ☐ Specify Piers ☒ Specify Soffit Shape Soffit Shape: FLAT Calibration Coefficient: 1.000 Skew Angle: 0.000 Abutment Type: 3 Abutment Alignment: ALIGNED Channel Section: <table border="1"> <thead> <tr> <th>Cross-Chainage (m)</th> <th>Elevation (m AD)</th> <th>Mannings n</th> <th>Embankments</th> </tr> </thead> <tbody> <tr><td>19.922</td><td>154.595</td><td>0.045</td><td></td></tr> <tr><td>20.963</td><td>154.464</td><td>0.045</td><td></td></tr> <tr><td>23.394</td><td>154.158</td><td>0.045</td><td></td></tr> <tr><td>23.575</td><td>154.138</td><td>0.045</td><td></td></tr> <tr><td>23.882</td><td>154.062</td><td>0.045</td><td></td></tr> <tr><td>23.912</td><td>154.053</td><td>0.045</td><td></td></tr> <tr><td>24.148</td><td>153.142</td><td>0.045</td><td></td></tr> </tbody> </table> Openings: <table border="1"> <thead> <tr> <th>Start (m)</th> <th>Finish (m)</th> <th>Springing Level (m AD)</th> <th>Soffit Level (m AD)</th> </tr> </thead> <tbody> <tr> <td>23.575</td> <td>30.545</td> <td>154.150</td> <td>154.150</td> </tr> </tbody> </table> Overtopping of the structure was represented within the 1D domain using an in-line spill at level 155.42 mAOD (top of stone wall).	BLI_862	JUNCTION	OPEN	BLI_862B	BLI_862SU		BLI_862B	BRIDGE	USBPR1978	BLI_862BD	BLI_862	BLI_862D	BLI_862SU	SPILL		BLI_862SD			BLI_862BD	JUNCTION	OPEN	BLI_862SD	BLI_862D		Cross-Chainage (m)	Elevation (m AD)	Mannings n	Embankments	19.922	154.595	0.045		20.963	154.464	0.045		23.394	154.158	0.045		23.575	154.138	0.045		23.882	154.062	0.045		23.912	154.053	0.045		24.148	153.142	0.045		Start (m)	Finish (m)	Springing Level (m AD)	Soffit Level (m AD)	23.575	30.545	154.150	154.150
BLI_862	JUNCTION	OPEN	BLI_862B	BLI_862SU																																																													
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Upstream face, looking downstream	Downstream face, looking upstream																																																																
	NO PHOTO AVAILABLE																																																																

C.6 Access bridge 3

Included in model? (state reason if not):	Yes																																																																
Model label:	BLI_391, BLI_391B, BLI_391BD																																																																
Type:	Brick arch within a pipe																																																																
How has structure been modelled?	The structure was modelled as a full arch conduit unit using FLOOD MODELLER. The following modelling parameters were used: <table border="1"> <tr> <td>BLI_391</td> <td>JUNCTION</td> <td>OPEN</td> <td>BLI_391B</td> <td>BLI_391SU</td> <td></td> </tr> <tr> <td>BLI_391B</td> <td>BRIDGE</td> <td>ARCH</td> <td>BLI_391BD</td> <td>BLI_391</td> <td>BLI_391D</td> </tr> <tr> <td>BLI_391SU</td> <td>SPILL</td> <td></td> <td>BLI_391SD</td> <td></td> <td></td> </tr> <tr> <td>BLI_391BD</td> <td>JUNCTION</td> <td>OPEN</td> <td>BLI_391SD</td> <td>BLI_391D</td> <td></td> </tr> </table> Dual Bridge ☐ Model as Dual Bridge Bridge Width: 0.000 Dual Distance: 0.000 Calibration Coefficient: 1.000 Skew Angle: 0.000 Channel Section: <table border="1"> <thead> <tr> <th>Cross-Chainage (m)</th> <th>Elevation (m AD)</th> <th>Mannings n</th> <th>Embankments</th> </tr> </thead> <tbody> <tr><td>6.000</td><td>153.616</td><td>0.060</td><td></td></tr> <tr><td>7.978</td><td>153.190</td><td>0.060</td><td></td></tr> <tr><td>8.233</td><td>153.169</td><td>0.060</td><td></td></tr> <tr><td>8.685</td><td>153.065</td><td>0.050</td><td></td></tr> <tr><td>9.065</td><td>151.371</td><td>0.050</td><td></td></tr> <tr><td>9.283</td><td>151.439</td><td>0.050</td><td></td></tr> <tr><td>10.222</td><td>151.224</td><td>0.060</td><td></td></tr> </tbody> </table> Openings: <table border="1"> <thead> <tr> <th>Start (m)</th> <th>Finish (m)</th> <th>Springing Level (m AD)</th> <th>Soffit Level (m AD)</th> </tr> </thead> <tbody> <tr> <td>9.283</td> <td>15.577</td> <td>151.720</td> <td>153.280</td> </tr> </tbody> </table> Overtopping of the structure was represented within the 1D domain using an in-line spill unit at level 153.84 mAO.	BLI_391	JUNCTION	OPEN	BLI_391B	BLI_391SU		BLI_391B	BRIDGE	ARCH	BLI_391BD	BLI_391	BLI_391D	BLI_391SU	SPILL		BLI_391SD			BLI_391BD	JUNCTION	OPEN	BLI_391SD	BLI_391D		Cross-Chainage (m)	Elevation (m AD)	Mannings n	Embankments	6.000	153.616	0.060		7.978	153.190	0.060		8.233	153.169	0.060		8.685	153.065	0.050		9.065	151.371	0.050		9.283	151.439	0.050		10.222	151.224	0.060		Start (m)	Finish (m)	Springing Level (m AD)	Soffit Level (m AD)	9.283	15.577	151.720	153.280
BLI_391	JUNCTION	OPEN	BLI_391B	BLI_391SU																																																													
BLI_391B	BRIDGE	ARCH	BLI_391BD	BLI_391	BLI_391D																																																												
BLI_391SU	SPILL		BLI_391SD																																																														
BLI_391BD	JUNCTION	OPEN	BLI_391SD	BLI_391D																																																													
Cross-Chainage (m)	Elevation (m AD)	Mannings n	Embankments																																																														
6.000	153.616	0.060																																																															
7.978	153.190	0.060																																																															
8.233	153.169	0.060																																																															
8.685	153.065	0.050																																																															
9.065	151.371	0.050																																																															
9.283	151.439	0.050																																																															
10.222	151.224	0.060																																																															
Start (m)	Finish (m)	Springing Level (m AD)	Soffit Level (m AD)																																																														
9.283	15.577	151.720	153.280																																																														
Upstream face, looking downstream	Downstream face, looking upstream																																																																
	NO PHOTO AVAILABLE																																																																

C.7 Access bridge 4

Included in model? (state reason if not):	Yes																																								
Model label:	BLI_0, BLI_OD																																								
Type:	Bridge																																								
How has structure been modelled?	The structure was modelled as bridge unit using FLOOD MODELLER. The following modelling parameters were used: Dual Bridge ☐ Model as Dual Bridge Bridge Width: 0.000 Dual Distance: 0.000   Calibration Coefficient: 1.000 Skew Angle: 0.000 Channel Section: <table border="1"> <thead> <tr> <th>Cross-Chainage (m)</th><th>Elevation (m AD)</th><th>Mannings n</th><th>Embankments</th></tr> </thead> <tbody> <tr><td>5.976</td><td>151.853</td><td>0.050</td><td></td></tr> <tr><td>6.107</td><td>151.062</td><td>0.050</td><td></td></tr> <tr><td>7.302</td><td>150.716</td><td>0.050</td><td></td></tr> <tr><td>9.532</td><td>149.889</td><td>0.050</td><td></td></tr> <tr><td>10.081</td><td>149.638</td><td>0.050</td><td></td></tr> <tr><td>10.548</td><td>149.620</td><td>0.040</td><td></td></tr> <tr><td>10.751</td><td>149.602</td><td>0.040</td><td></td></tr> </tbody> </table> Openings: <table border="1"> <thead> <tr> <th>Start (m)</th><th>Finish (m)</th><th>Springing Level (m AD)</th><th>Soffit Level (m AD)</th></tr> </thead> <tbody> <tr> <td>10.081</td><td>16.48</td><td>151.210</td><td>151.210</td></tr> </tbody> </table> Overtopping of the structure was represented within the 2D domain due to the length of the culvert (water is not likely to spill cross the bridge along its centre line).	Cross-Chainage (m)	Elevation (m AD)	Mannings n	Embankments	5.976	151.853	0.050		6.107	151.062	0.050		7.302	150.716	0.050		9.532	149.889	0.050		10.081	149.638	0.050		10.548	149.620	0.040		10.751	149.602	0.040		Start (m)	Finish (m)	Springing Level (m AD)	Soffit Level (m AD)	10.081	16.48	151.210	151.210
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D Appendix D - Model Sensitivity Analysis

The hydraulic model was tested for sensitivity to key model parameters which might impact flood risk at the proposed development site. This included the following scenarios:

- Increasing the Manning's 'n' values by +20%. This was done both in the Flood modeller 1D channel and in the 2D TUFLOW domain
- Increasing flows by 20%
- Increasing the downstream boundary by 250mm in the 1D domain.

The following sections discuss the impacts of this sensitivity scenarios.

D.1 Sensitivity to flow

Figure 4-1 shows the changes in peak water level compared to the baseline 100-year event when an increase of 20% is applied to all inflows. There is a maximum increase in peak water level of 0.26m at FUL_499CU. The average increase in peak water level throughout the model is 0.12m. The model is most sensitive to an increase in peak flow at the upstream end of the Fulford tributary and between cross section BLI_1445 to BLI_1663.