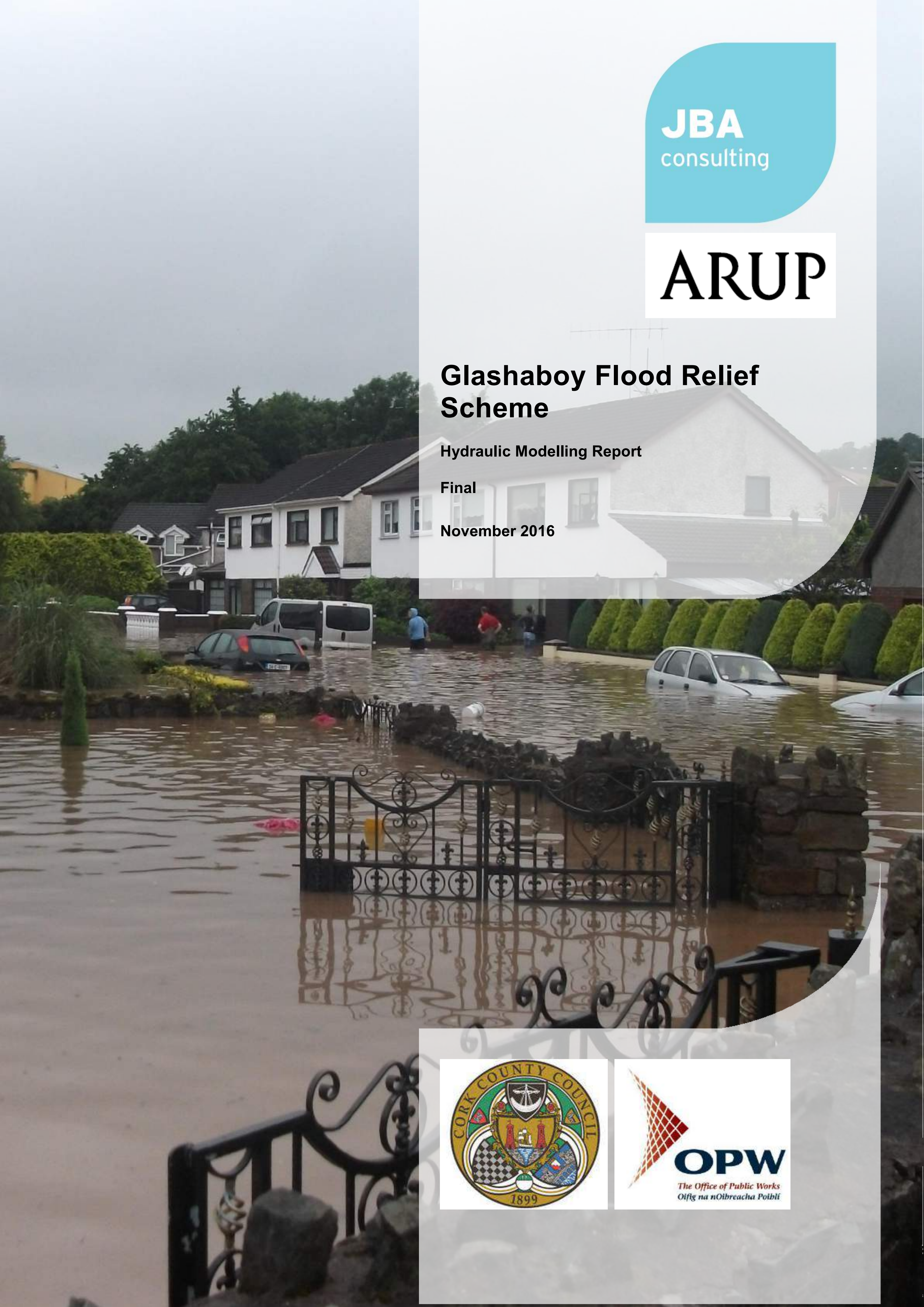

Glashaboy Flood Relief Scheme

Hydraulic Modelling Report

Final

November 2016

JBA Project Manager

Elizabeth Russell
24 Grove Island
Corbally
Limerick
Ireland

Revision History

Revision Ref / Date Issued	Amendments	Issued to
Version 1	Initial issue	Steering Group
Version 2	Various updates following SG review	Steering Group
Version 3	Updates following 2015/2016 calibration	Steering Group
Version 4	Final updates	Steering Group

Contract

This report describes work commissioned by the Cork County Council, under the Glashaboy FRS. CCC's representative for the contact was Colm Brennan. David Moran of JBA Consulting carried out this work.

Prepared by .... David Moran BEng MEng MIEI

Engineer

Reviewed by .... Elizabeth Russell BSc MSc CEnv MCIWEM C.WEM

Project Manager

Reviewed by .... Jonathan Cooper BEng MSc DipCD CEng MICE MCIWEM C.WEM MloD MIEI

Managing Director

Purpose

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Acknowledgements

The residents of the greater Glanmire area and the OPW who provided information on recent and historical flooding.

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Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
AEP	Annual Exceedance Probability
CFRAM	Catchment Flood Risk Assessment and Management
CFRAMS	Catchment-Based Flood Risk Assessment and Management Study
DS	Downstream
DTM	Digital Terrain Model
ISIS	Hydrology and hydraulic modelling software
LiDAR	Light Detection And Ranging
OPW	Office of Public Works
Q100	Flow at the 100-year return period
TUFLOW	Two-dimensional Unsteady FLOW (a hydraulic model)

1 Introduction

1.1 Context of the study

The Greater Glanmire area, County Cork has a long history of serious flooding, primarily due to high flows in the River Glashaboy exceeding channel and structure capacity. The fluvial flood risk is primarily in the Riverstown and Sallybrook areas, while Glanmire Village is more susceptible to tidal flood risk. Tidal flooding results from tides and storm surges from Cork Harbour propagating up the Glashaboy River estuary. Surface water flooding associated with heavy rainfall and exceedance of the drainage system is also a problem. The highest recorded flooding occurred in June 2012. Flooding has also occurred in the town in November 2009, October 2004 and November 2000 and most recently in December 2015.

Arup and JBA Consulting were commissioned by Cork County Council (CCoC) to assess the flood risk within the Glanmire Area and develop a flood relief scheme and other measures to manage this risk. This commission was following on from recommendations contained within the Lee Catchment and Flood Risk Management Study (CFRAMS), in particular the Flood Risk Management Plan (FRMP), and the extreme flooding experience during the 2012 flood event,

The whole project will comprise five stages:

- Stage I - Feasibility study and preparation of a flood risk management plan
- Stage II - Public exhibition
- Stage III - Detailed design, confirmation and tender
- Stage IV - Construction
- Stage V - Handover of works

This hydraulic report is one of a series being produced under Stage I of the project.

1.2 Project Brief

The key task identified in the project brief for the hydraulic analysis and modelling are to:

- Use the ISIS 1D hydraulic model developed from Lee CFRAMS.
- Update the hydraulic model to ensure it is suitable for the study.
- Assess the hydraulic model outputs to identify potential flood-prone properties within the study area, over a range different fluvial flows and tidal levels.
- Undertake model runs to assess and develop Scheme options and the preferred Scheme.

1.3 Scope of this report

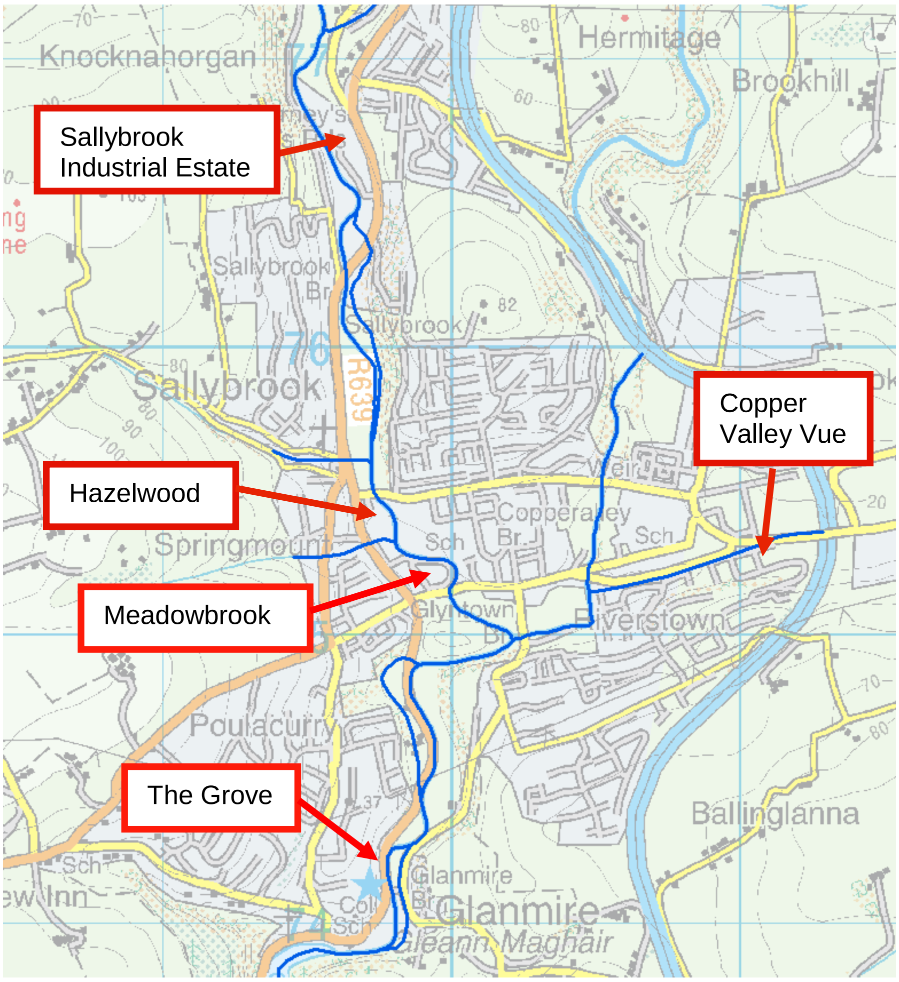
This report provides an assessment of the flood risk in the Greater Glanmire Study area from the Glashaboy. The different sections of the report detail the review and update of the Lee CFRAMS hydraulic model, the model calibration to the 2012 event, analysis of model results and development of flood alleviation options.

2 Hydraulic Modelling

2.1 Glashaboy study area

This section summarises the hydraulic modelling that has been carried out to develop a suitable baseline model for the design and testing of a flood relief scheme for the greater Glanmire urban area. The area covered by the Glashaboy Flood Relief Scheme (FRS) study is shown in Figure 2-1. The key flood risk locations are the Meadowbrook housing estate, Hazelwood shopping centre and Sallybrook Industrial Estate.

Figure 2-1 Glashaboy Study Area



2.2 Catchment description

The Glashaboy FRS study area's main watercourse is the Glashaboy, which rises in the Nagle Mountains and flow into Lee at Dunkettle. The river flows in a general north to south direction to its confluence with the Lee which is under the tidal effects of Cork Harbour.

The most significant tributary is the Butlerstown River, which drains the east of the catchment and joins the Glashaboy at John O'Callaghan Park. At the confluence, the catchment area of the two rivers is roughly the same at~75km^2 (See Figure 2-2. Within the study area the Glashaboy has three other minor tributaries: Bleach Hill, Cois na Gleann and Springmount. These have contributory catchment area of 3.5km^2, 2.1km^2 and 1.1km^2 respectively. The Glashaboy also has three mill races that loop in and out of the main watercourse. These mill races range from ~0.4km to ~0.8km in length. The Butlerstown has one tributary in the study area, the Glenmore. It has a contributory catchment area of 20 km^2. See Figure 2-3 for a schematic of the different watercourses in the study area.

Figure 2-2 Butlerstown and Glashaboy Catchments

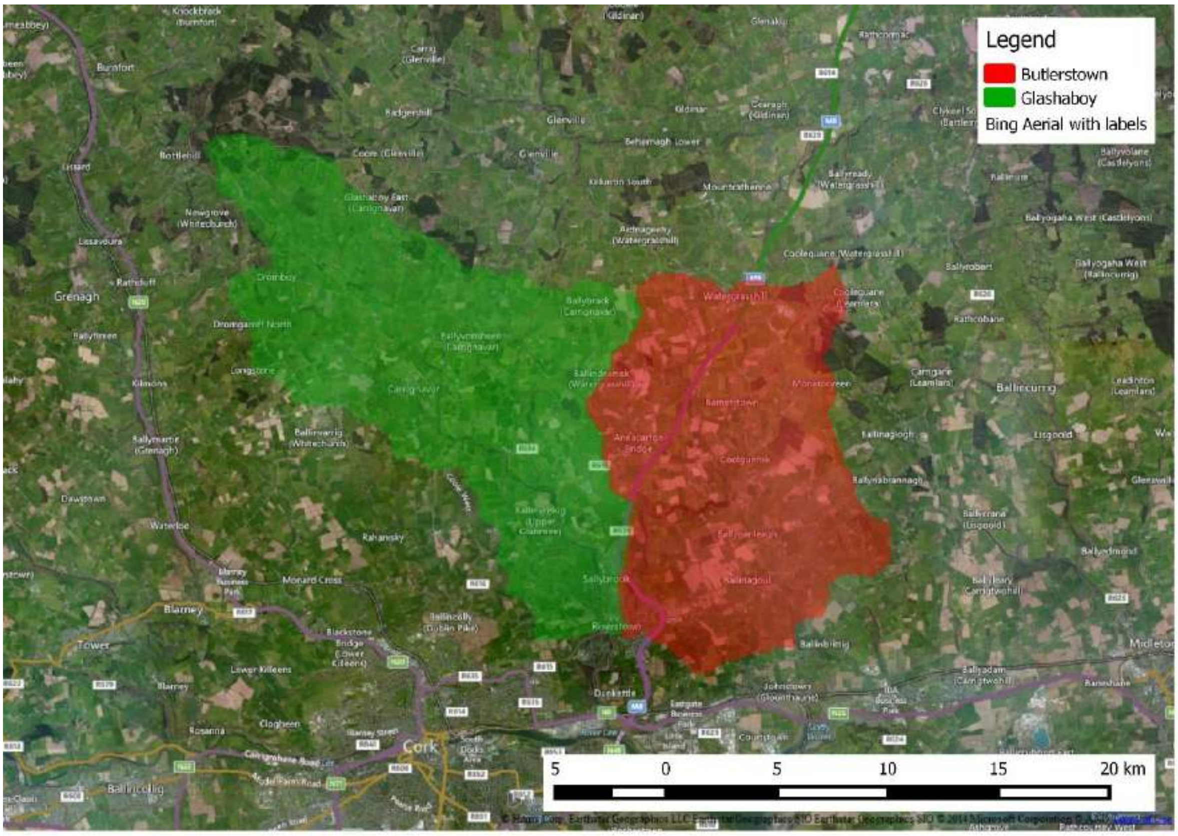


Figure 2-3 Watercourses in the Glashaboy study area

2.3 Flood History

An overview of the Glanmire flood is detailed in Table 2-1 below. The most extreme flood event occurred in 2012 with significant damages occurring. A complete review and analysis of historical flooding can be found in the accompanying Hydrology Report and is analysed hydraulically in more detail in Section 3.

Table 2-1 - Historical Flood Chronology

Date of Flood	Comment
1968/1969 (date is uncertain in the flood reports)	Report of property flooding along the R369 in Riverstown
November 2000	N8 south of Watergrasshill and Annacartin Bridge closed along with flooding of Meadowbrook Estate
October 2004	House flooding occurred near Kearney's Cross Roads. Bridge capacity issues at Riverstown caused road flooding and flooding at Riverstown Park and Hotel
19 November 2009	Large Flows in the Glashaboy River caused by heavy rainfall resulted in overflows onto the adjoining R369 between Glanmire Bridge and Riverstown Cross. 300m of the R369 were flooded
28 June 2012	Significant flooding occurred. Flood waters flowed through Sallybrook, Hazelwood Cross, Hazelwood Shopping Centre, Meadowbrook Estate, Riverstown Park and Riverstown Cross to Glanmire Bridge road.
December 2015/ January 2016	Flooding in Copper Valley Vue with other out of bank flow recorded in Hazelwood, The Grove and R369.

Source**: www.floodmaps.ie**

2.4 Available data

2.4.1 Survey data

Cross-sectional survey was collected May 2007 by Maltby Land Surveys Ltd. as part of the Lee CFRAMS. Additional infill survey data was supplied by Murphy Surveys and delivered in April 2014. The following issues were drivers for the infill survey:

- The original model did not have a number of tributaries and mill races in the urban area making it an oversimplified representation of the study area.
- The Riverstown Bridge has an additional skewed pier for a footbridge on its upstream face which was not represented.
- Changes to channel sections had occurred at the GAA pitches and SuperValu.
- A lack of detail in flood defence levels for the key receptors areas.

The additional survey provided data for the previously unsurveyed watercourses which included the Glenmore, Springmount, Cois na Gleann, Bleach Hill and the Mill Races. Additionally, cross-sections of the Glashaboy were surveyed where the section was deemed to have changed since the Lee CFRAMS survey or that more detail was required.

Table 2-2 Watercourse references in hydraulic model

Reference	Description
4GLA	Glashaboy (Lee CFRAMS)
4BUT	Butlerstown
19GLAS	Glashaboy (Infill Survey)
19BLCH	Bleach Hill Stream
19MLR3	Mill Race 3
19MLR2	Mill Race 2
19MLR1	Mill Race 1
19COIS	Cois na Gleann Stream
19 SPRG	Springmount Stream

19GLEN	Glenmore

The Lee CFRAMS LiDAR data had incomplete coverage of the study area. To provide a full coverage of the study area a 1m dataset from Furgo flown in 2007 was resampled to a 2m grid and merged with the Lee CFRAMS 2m DTM.

2.5 Hydraulic modelling overview

The hydraulic model produced by Halcrow for the Lee CFRAMS was inherited for this study. The model was updated with the additional survey data as discussed in section 2.4. The model was also upgraded to an ISIS-TUFLOW 1D-2D model from the original ISIS 1D only model. In the Lee CFRAMS model, flood extents were derived by projecting a maximum water level across a DTM, rather than by using a 2D modelling software package for out of bank flow. Using the new data, the model was developed in the following stages:

- The upper part of this model was outside the study area and the model was trimmed to Templeusque, ~0.8km upstream of where the R616 crosses the river.
- The model was reviewed for any misrepresentation of structure or river sections and amendments where made where deemed appropriate. This review was based on the cross-section survey data, photographs and site visits.
- The infill survey sections were added to the 1D model including the previously unsurveyed tributaries and mill races.
- Adjustments were made to the 1D model to address issues found in the review.
- A 2D (TUFLOW) model of river floodplain was created and linked to the 1D component of the model. This was done incrementally for each water course in the study area. The 2D domain was set from the upstream of the Sallybrook Industrial Estate to the Glashaboy Estuary.

Figure 2-4 Hydraulic model schematic

2.6 Review of CFRAMS 1D model

A formal review of the Lee CFRAMS model was conducted to check the appropriateness of the modelling approach and means to improve model stability. Through the advancement of the model into 1D-2D additional improvements and amendments were also carried out.

As part of the review of the hydraulic model, all structures and cross sections were checked to see if they were an accurate representation. This entailed examining the geometry relative to the supplied survey and also checking the parameters used for roughness and inlet losses.

Some issues encountered in the review were:

- There were a large number of interpolate cross sections that did not appear to contribute significantly to the accuracy or stability of the model results.
- Orifice flow had not been enabled for surcharging bridges.
- The weir coefficients for in-line weirs were generally consistent at the default value of 1.7, however in some locations, a more conservative value should have been considered. Similarly, for some overtopping spills for structures had misrepresentative weir coefficients.
- Roughness values applied to some river reaches were not in-keeping with reality.
- The supplied 1D (ISIS) model was tested with the supplied Lee CFRAMS 1% AEP fluvial flow and 20% AEP tidal boundary design flows for stability and performance issues with the following outcome:
    - Several ISIS advanced parameters had been changed to run the supplied model (dflood = 100, psdeep = 3m). It is advisable where possible to avoid changing the default parameters since they have the potential to impact on the model results.
    - Automated Preismann Slots were activated for the model's river sections, allowing it to run at low flows.
    - The model was being run with a lower timestep (1s) than the minimum specified for the adaptive unsteady run (3s). This was because the model was very unstable at the beginning of the run, indicating a possible problem with the initial conditions.

2.7 Updating the 1D model

Following the 1D model review and prior to calibration, the supplied Lee CFRAMS model was updated in a variety ways which have been summarised in the sections below.

2.7.1 Riverstown Bridge

The Riverstown Bridge is located where the L3010 road cross the Glashaboy, just south of Meadowbrook (See Figure 2-5). As it is located adjacent to the major flood risk receptor it is deemed a key structure. The road bridge is a masonry arch bridge, with a concrete flat deck pedestrian bridge attached to its upstream face (See Figure 2-6). The pedestrian bridge was included in the updated model, as it was previously omitted. The piers of the pedestrian bridge extenuate the skew of the bridge and are critical in determining the bridge's effect on water level in Meadowbrook.

Figure 2-5 Location of Riverstown Bridge

Figure 2-6 Upstream and downstream faces of Riverstown Bridge

Downstream face of masonry arch bridge	Upstream face showing the pedestrian bridge and piers

2.7.2 Model roughness

Roughness was applied to the 1D model by using Manning's *n* values for the different reach of the watercourses. To accurately represent the in bank river section three different panels were applied: left bank, bed and right bank. These values were attributed by visual inspection, with bed values calibrated using check gauging data where available (see Hydrology Report for more details of model calibration).

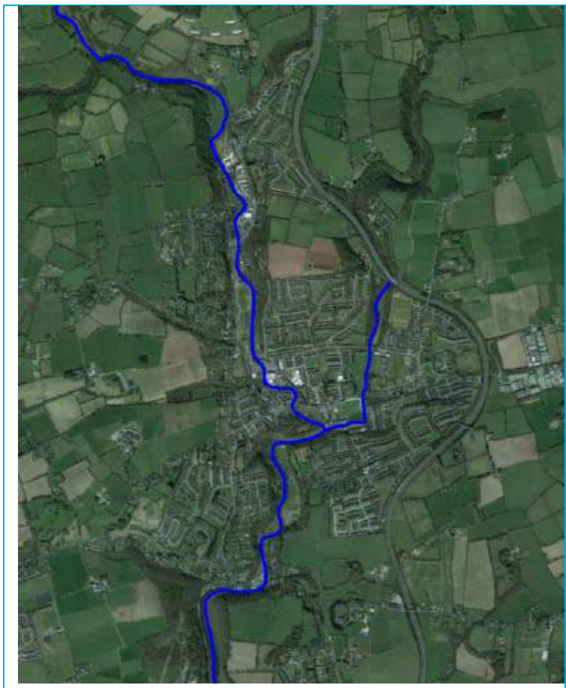
The riparian strips on the Glashaboy are a distinct feature of the watercourse. These banks have heavy vegetation, bushes and trees as seen in Figure 2-4. The riparian strip roughness was represented by the left bank and right bank panels. The roughness in these panels varies between seasons due to the deciduous nature of the vegetation. To account for the seasonality of the roughness a winter (*n*=0.05) a summer roughness (*n*=0.07) value was applied.

Figure 2-7 4GLA_04471_DS showing the vegetated state of the Glashaboy banks

2.7.3 Additional surveyed Watercourses

As part of the infill survey additional watercourse within the study area were survey. These included the Bleach Hill Stream, Mill Race 3, Cois na Gleann, Springmount Stream, Glenmore, Mill Race 2 and Mill Race 1. Additional cross-sections of the Glashaboy River were also included, for example at the GAA pitches were section changes had occurred since the original survey was commissioned.

Figure 2-8 Schematic comparing Lee CFRAMS and updated models

	
Lee CFRAMS model included just the Butlerstown and Glashaboy rivers	Updated model including the additional watercourses

2.7.4 Cois na Gleann Stream modelling

The Cois na Gleann Stream was modelled separately to the main river due to the hydraulic complexity at the confluence of it and the Glashaboy. This was due to the final 110m of the river being in the Glashaboy floodplain, immediately south of the GAA pitches.

Figure 2-9 Location of 2D spills on the Cois na Gleann Stream

The out of bank flow in the study area from the Cois na Gleann comes from the entrance to the culvert system and a well opening, located at the middle of the culvert. Out of bank flow is also noted upstream of the culvert entrance. The outflow hydrographs for these two location were applied as external source flow-time (QT) boundaries in the 1D-2D model. The flow passing through the culvert system was applied upstream of the junction with the Glashaboy by an ISIS QT boundary.

2.7.5 Downstream boundary

The downstream boundary of the model is located at Dunkettle, where the Glashaboy meets the Lee. A tidal (HT) boundary is used to simulate the different tidal scenarios required for this study. The extreme tidal events calculated as part of the Lee CFRAMS were used for this study (Table 2-3). These calculated tidal curves were deemed acceptable after a tidal boundary assessment was conducted by JBA as part of the Lower Lee Scheme.

Table 2-3: Extreme water levels used as downstream boundary

Annual exceedence probability	Water level (mOD)
50%	2.43
20%	2.54
10%	2.61
5%	2.67
2%	2.7
1%	2.77
0.5%	2.85
0.1%	2.93

2.7.6 Removal of interpolate cross-sections

In the original model, interpolates were added to most reaches in the study, but having reviewed the model they did not add to the stability or accuracy of the model. Therefore, in the revised model, any unnecessary interpolates were removed. Interpolates were only retained if they markedly contributed to model stability or accuracy of the results. Over 500 interpolates were removed.

2.8 Comparison of Lee CFRAMS and revised 1D models

Table 2-4 compares and summarises the differences in the 1D node counts between the Lee CFRAMS and revised models.

Table 2-4 Comparison of Lee CFRAMS and revised ISIS models

Lee CFRAMS model			Glashaboy FRS Revised Model		
Unit	**Sub-Unit**	**Count**	**Unit**	**Sub-Unit**	**Count**
BRIDGE	ARCH	6	BRIDGE	ARCH	12
BRIDGE	USBPR1978	11	BRIDGE	USBPR1978	14
CONDUIT	CIRCULAR	0	CONDUIT	CIRCULAR	8
CONDUIT	RECTANUGLAR	0	CONDUIT	RECTANGULAR	12
CULVERT	INLET	0	CULVERT	INLET	10
CULVERT	OUTLET	0	CULVERT	OUTLET	10
INTERPOLATE	n/a	545	INTERPOLATE	n/a	41
JUNCTION	OPEN	43	JUNCTION	OPEN	85
LATERAL	n/a	2	LATERAL	n/a	0
REPLICATE	n/a	0	REPLICATE	n/a	1
RIVER	SECTION	138	RIVER	SECTION	247
SLUICE	VERTICAL	0	SLUICE	VERTICAL	2
SPILL	n/a	31	SPILL	n/a	51
TOTAL NODES		**583**	**TOTAL NODES**		**465**

Following these changes a more accurate, and more up to date, model of the study area was achieved.

2.9 Floodplain modelling - 2D model

In the Lee CFRAMS model, the floodplains were represented within the ISIS domain. Water levels calculated in the 1D model were projected across a digital terrain model (DTM) until it reached high ground. This is not an ideal set-up as 1D-solvers are better suited to modelling flows through defined cross-sections such as river channels and structure openings. Flow across a floodplain is much more accurately derived using a 2D modelling package which can represent flow routes and floodplain attributes. The TUFLOW grid in the active 2D domain through Hazelwood and Meadowbrook is shown in Figure 2-10.

Figure 2-10 2D domain and grid through Hazelwood and Meadowbrook

2.9.1 Key features of the 2D model

2.9.1.1 Sallybrook

Key levels of the flood defences at Grandon Car Sales, constructed post the 2012 event, were recorded as part of the infill survey (Figure 2-11). These were applied to the 2D domain using TUFLOW Zpts and Zlines features to create a higher definition of the bank crest.

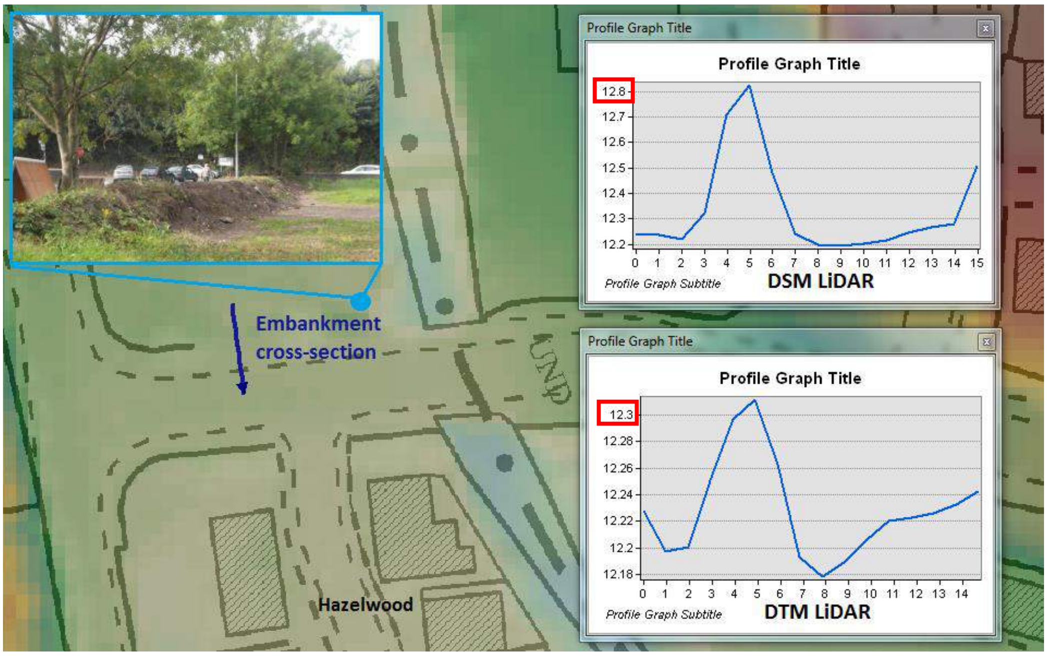
Figure 2-11 Defences constructed at Grandon Car Sales prior to the 2012 event

2.9.1.2 Hazelwood and Meadowbrook

From the topography infill survey key level of defences walls in Meadowbrook and Hazelwood were added to the model. These were applied to the 2D domain using TUFLOW Zpts and Zlines features to create a higher definition of the bank crest

A primary feature of the 2012 extreme flood event was flow through the GAA pitches into Hazelwood shopping centre. To accurately represent this flow route and mechanisms some walls and embankment, not represented in the DTM LiDAR, were added. Their respective heights were calculated using the unfiltered Digital Surface Model (DSM) data and visual inspection. Figure 2-12 illustrated the difference in level of the embankment in the two LiDAR sets.

Figure 2-12 Embankment level from DTM versus DSM



The GAA pitch is a significant floodplain in the study area. To accurately represent this, the Cois na Gleann banks top points were applied using Zpts and Zline with a Non-Coniferous Woodland roughness applied to them to represent the trees not included in the OSI NTF land use polygons data. The fence separating the two GAA pitches was also modelled in the calibration event to determine its effect on attenuation across the pitches, particularly as there is evidence to show the fence operated like a solid wall as it was blocked with vegetation.

2.9.1.3 Glanmire

The R369 road forms the right bank of the Glashaboy as it approaches Glanmire Village. An embankment and/or wall provides protection for the road along this reach of the river. However localised low points and gaps (Figure 2-13) occur which are not represented in the surveyed cross-sections. The defence is rendered ineffective in these locations and the bank level has been reduced to the level of the adjacent footpath along the section of wall.

Figure 2-13 Gap in wall between the Glashaboy right bank and the R639

2.9.1.4 Roughness

Within the 2D domain a roughness template is applied to represent the different surfaces. The 2D roughness template is based on OSI NTF land use polygons. This provides a high definition dataset within urban areas due to the prevalence of roads and buildings in the NTF data.

The 2D Manning's *n* roughnesses allocated to the land use categories were as follows:

- General Natural Surfaces - 0.050
- Buildings - 1.0
- Roads, Tracks and Paths - 0.025
- Non-Coniferous Woodland - 0.070
- Coniferous Trees - 0.100
- Rock - 0.050
- Mixed Vegetation - 0.080

3 Model calibration

3.1 Calibration Data

As detailed in Section 2.3 there have been several flood events which the hydraulic model performance could theoretically be calibrated against. However, the quantity, and quality, of data available for each event decreases with the length of time since it occurred. The only event with sufficient information available to allow model calibration to be undertaken was the 2012 flood. The process of calibrating the model is described in the following sections.

3.2 Calibration against 28th June 2012 event

The 28th June 2012 event has been chosen to be the primary means by which the hydraulic model is calibrated due to the following:

- The event is the largest recorded flood to have occurred in recent memory.
- There is a considerable wealth of information available to inform the calibration process.
- It caused a significant amount of damage to the study area
- Insufficient data is available to calibrate any other event.

The details of the 28th June 2012 flood event can be found in the accompanying Hydrology Report

3.2.1 Calibration assumptions and inputs

In order to calibrate the model to the conditions recorded in the Glashaboy catchment certain assumptions were made. These were based on recorded data, visual records and witness testimony:

- Roughness values for the channel bed were set to the calibrated values as detailed in the hydraulic check file (Appendix A). The side bank panels, representing the riparian strips of the channel, were set to the summer value (n=0.07) as the event occurred in June. This higher roughness is caused by the trees' and bushes' denser foliage in the summer months.
- The calibration was run assuming no blockage of any structure. Given the heavy wooded nature of the catchment and anecdotal evidence[1] partial blockage of certain bridges is suspected. A sensitivity test was conducted on key structures to determine the effect a partial blockage of 30% would have.
- The shape of the hydrograph recorded at Meadowbrook during the event was used as the input hydrograph at the upstream boundary of the model. The hydrograph was scaled to match the peak flow recorded at Meadowbrook gauge cross-section. This ensured the significant floodplain flow and attenuation that occurs between the upstream boundary of the model and the gauge was accounted for.
- Since the event in 2012, informal defences have been constructed by local residents and business. These were recorded in the additional survey conducted in 2014. For the calibration run, the defences at Grandon Car Sales were omitted and cross-section survey from 2007 was used. The defences at Meadowbrook were included as they were deemed to have been unchanged.
- The inflow for the Glashaboy tributaries of Bleach Hill, Springmount, Cois na Gleann were set to the Q100 flow. This is in agreement with the estimated return period of the event.
- The inflow for the Butlerstown was set to a Q25 flow, which was calibrated using the recorded wrack marks along that reach and the photos of the flooding extent. The Glenmore inflow was set to a Q2 flow as it was reported to have had a minimal flow during the event[2].
- Downstream boundary was set as a steady low level for model stability. No significant tidal cycle occurred during the fluvial event, with the low tide coinciding with the peak of

[1] Testified by Martin Grandon, Grandon Car Sales and Glanmire Area Engineer

[2] Testified by resident at Brooklodge Grove road bridge, an area which would normally be considered the major flood risk area of the Glenmore River

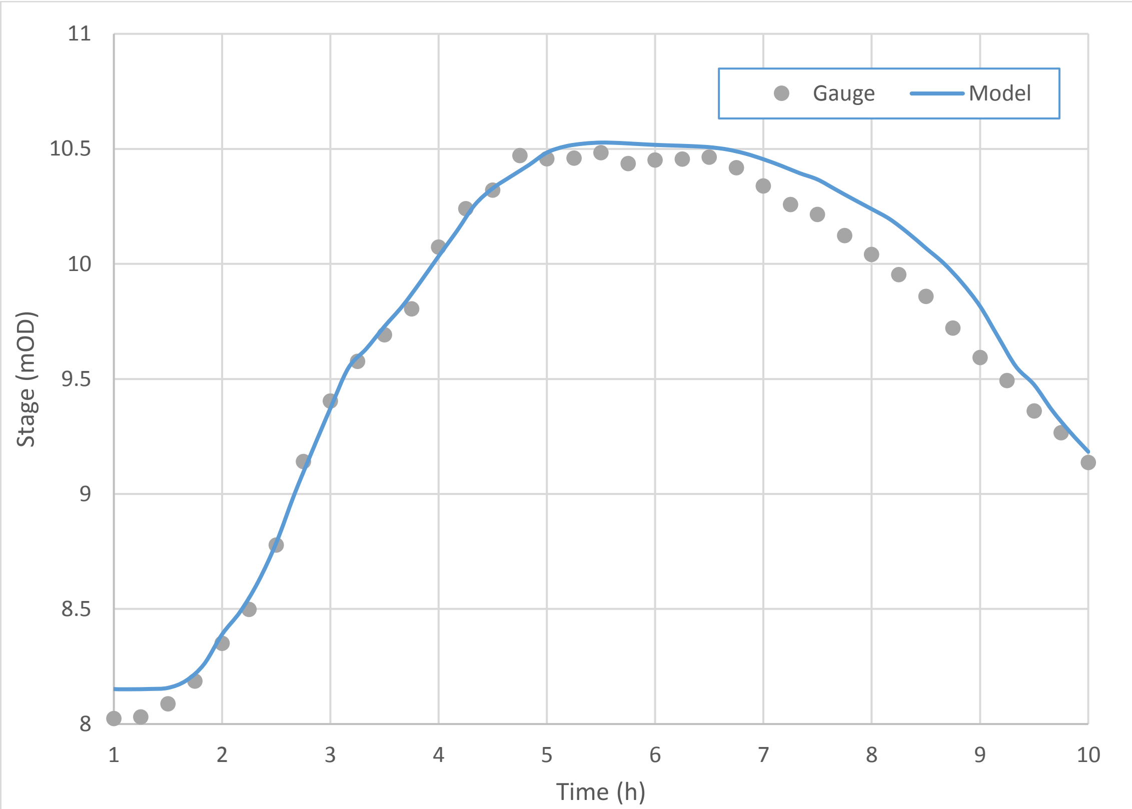
the event. There was deemed to be no tidal influence during the calibration event and the approach was deemed appropriate.

- In accordance with the revised rating at Meadowbrook, the model was run to calibrate to a hydrograph peak of 81m^3/s at Meadowbrook gauge. See Appendix B of Final Hydrology Report for further details

3.2.2 Calibration to gauges

The gauge at Meadowbrook was the only operating gauge during the 2012 event, and was used as the primary source of calibration. The recorded hydrograph shape was used as the input hydrograph of the event. Figure 3-1 compares the hydrograph recorded at the gauge with that of the model at the corresponding cross-section. The rising limb and the peak shows a very strong fit, with the falling limb slightly overestimating the stage. The overestimation on the falling limb is attributed to the model not fully capturing the retention time related to attenuation in the catchment.

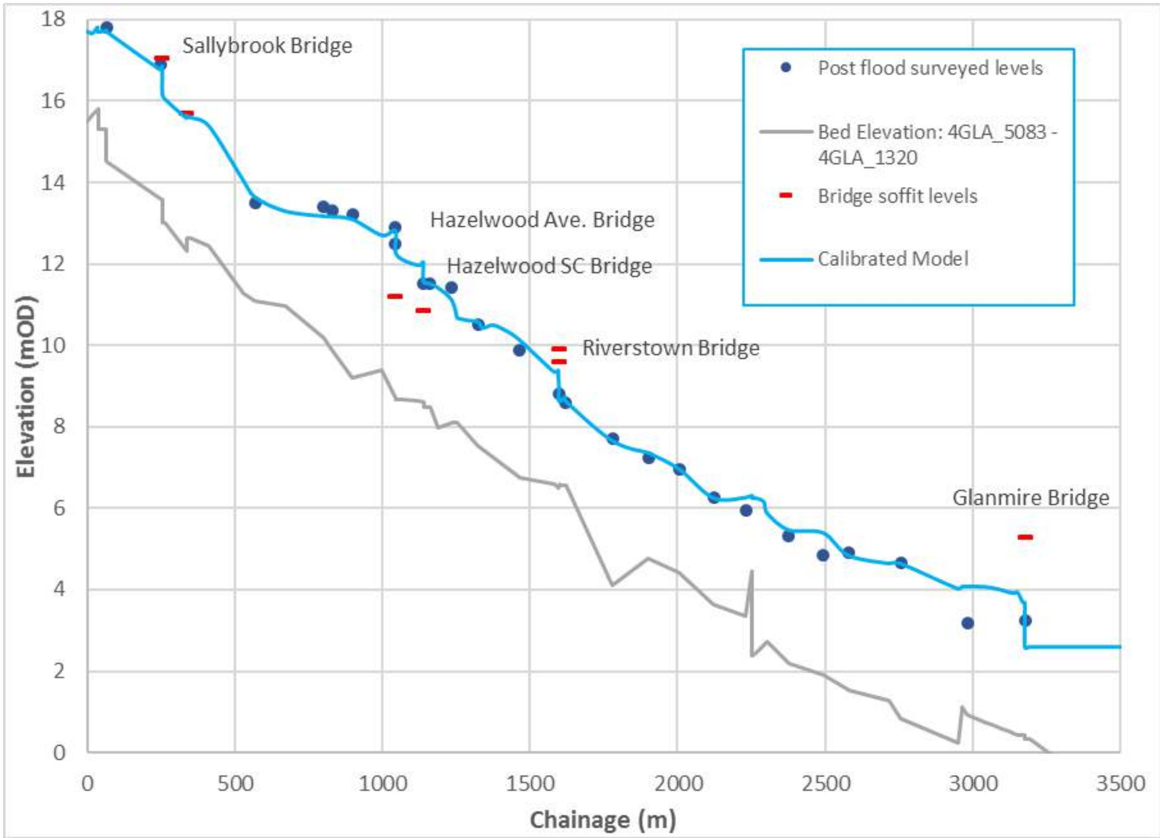
Figure 3-1 Calibration of model to the Meadowbrook Gage (19032)



3.2.3 Long section calibration

The hydraulic model of the 2012 event was calibrated by comparing the modelled long section maximum levels to recorded wrack marks. This data was recorded in the days following the 2012 event in a post event survey conducted by the OPW. The survey estimated maximum stage levels in the Glashaboy and the Butlerstown rivers at locations corresponding to the model nodes. The survey provided an excellent source of data to ensure the hydraulic profile of the model was consistent with that experienced during the 2012 event. It also provided a means of calculating the flow in the Butlerstown River, where no flow data was recorded. In total 35 data points were collected extending from the Sallybrook Industrial Estate to the Glanmire Bridge on the Glashaboy, and the final 1km of the Butlerstown before the confluence with the Glashaboy.

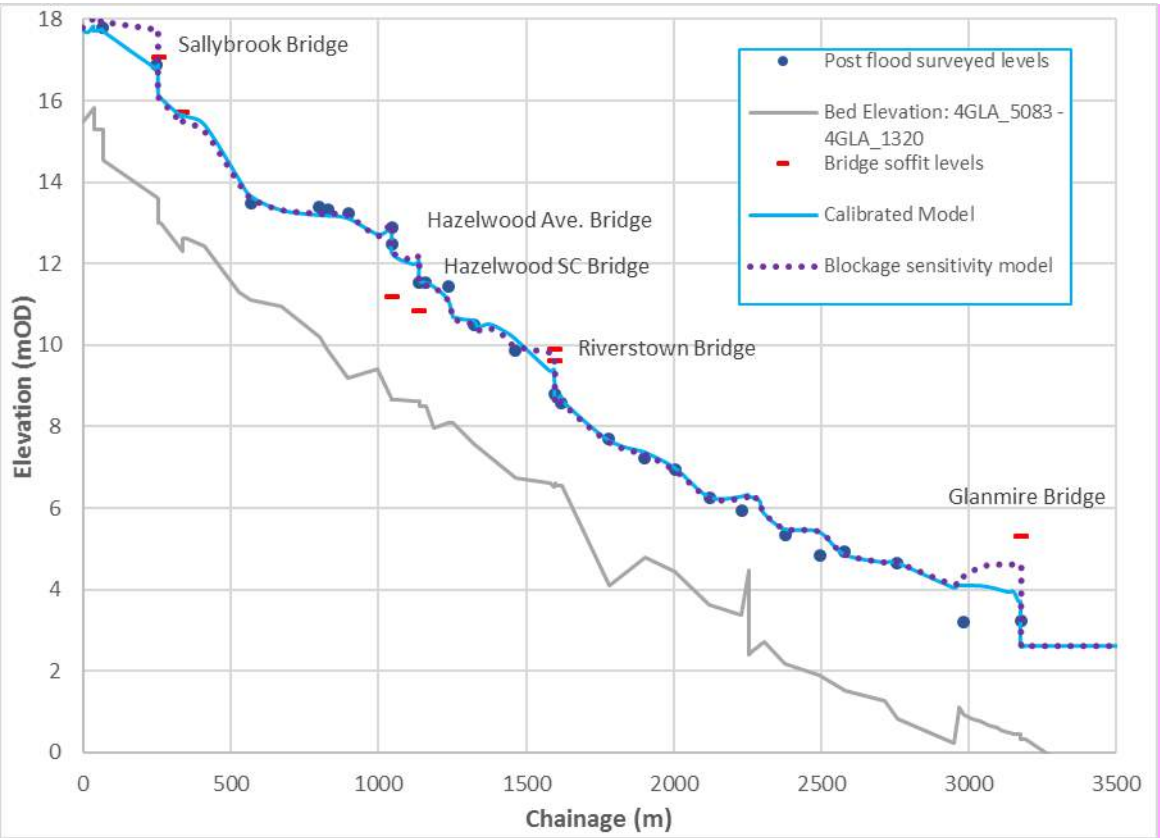
Figure 3-2 Calibration of 2012 event



The long section in Figure 3-2 demonstrates the goodness of fit with the recorded data, within the limitations of the data. Given the nature of using wrack marks to estimate levels, and the assumptions detailed above, a certain level of dissimilarity between the two data sets is expected.

A sensitively test on key structures was conducted to investigate the potential effect of blockage on the model calibration. The model was originally run with no blockage, however during the actual event some partial blockage was reported, as detailed above. To investigate the potential effect that a partial blockage of structure would cause, a blockage of 30% was added to the Sallybrook, Hazelwood Avenue, Riverstown and Glanmire bridges. The results are compared to the post flood survey and the run with no blockage in Figure 3-3.

Figure 3-3 Blockage sensitivity of 2012 Calibration

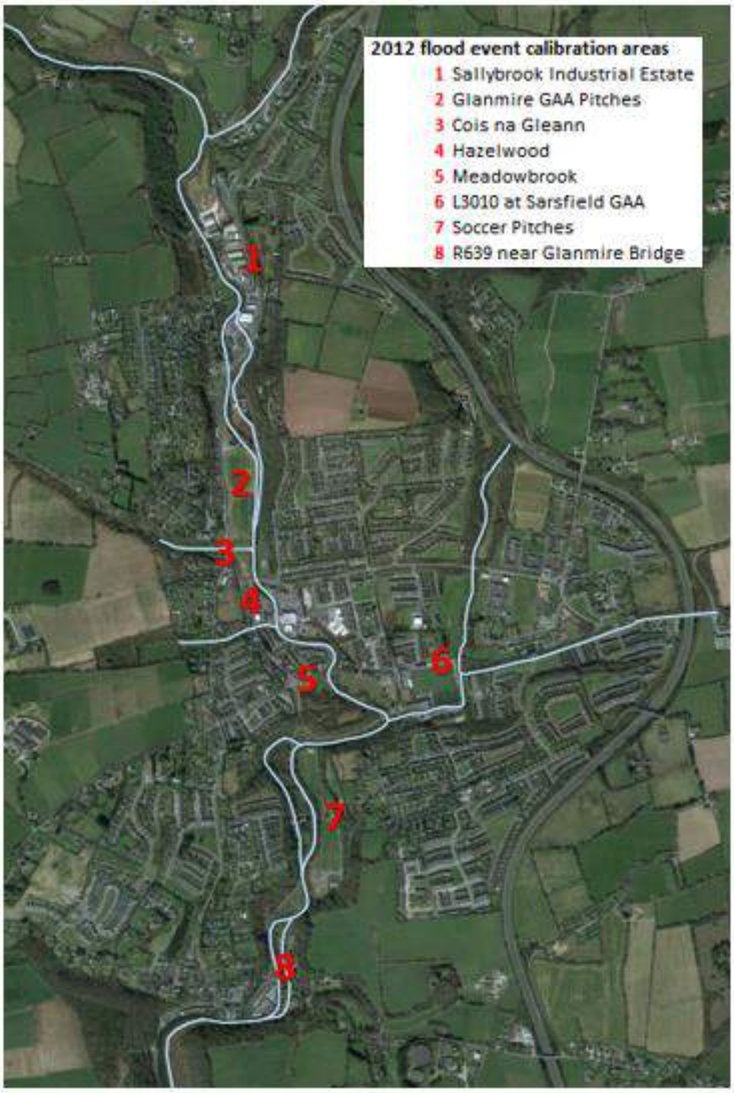


The results demonstrate blockage causes a significant back-up of water levels at Sallybrook Bridge and Glanmire Bridge, which improves the calibration to the post flood surveyed levels at these locations. The Hazelwood Avenue Bridge is seen to not be sensitive to blockage with only a marginal increase in levels. Riverstown Bridge shows an increase in upstream water level, however the original run with no blockage has a much better fit to the post flood surveyed levels. This would indicate that no major blockage occurred at this bridge during the event.

3.2.4 Extent calibration

The model extent produced from the long section calibration was also verified against flood extents and depth recorded data. From photos taken during the event and in the post event survey, along with information provided at the PCD, eight key area were identified. These areas are displayed in Figure 3-4 and were used for the extent calibration.

Figure 3-4 2012 extent calibration areas map



3.2.4.1 Sallybrook Industrial Estate

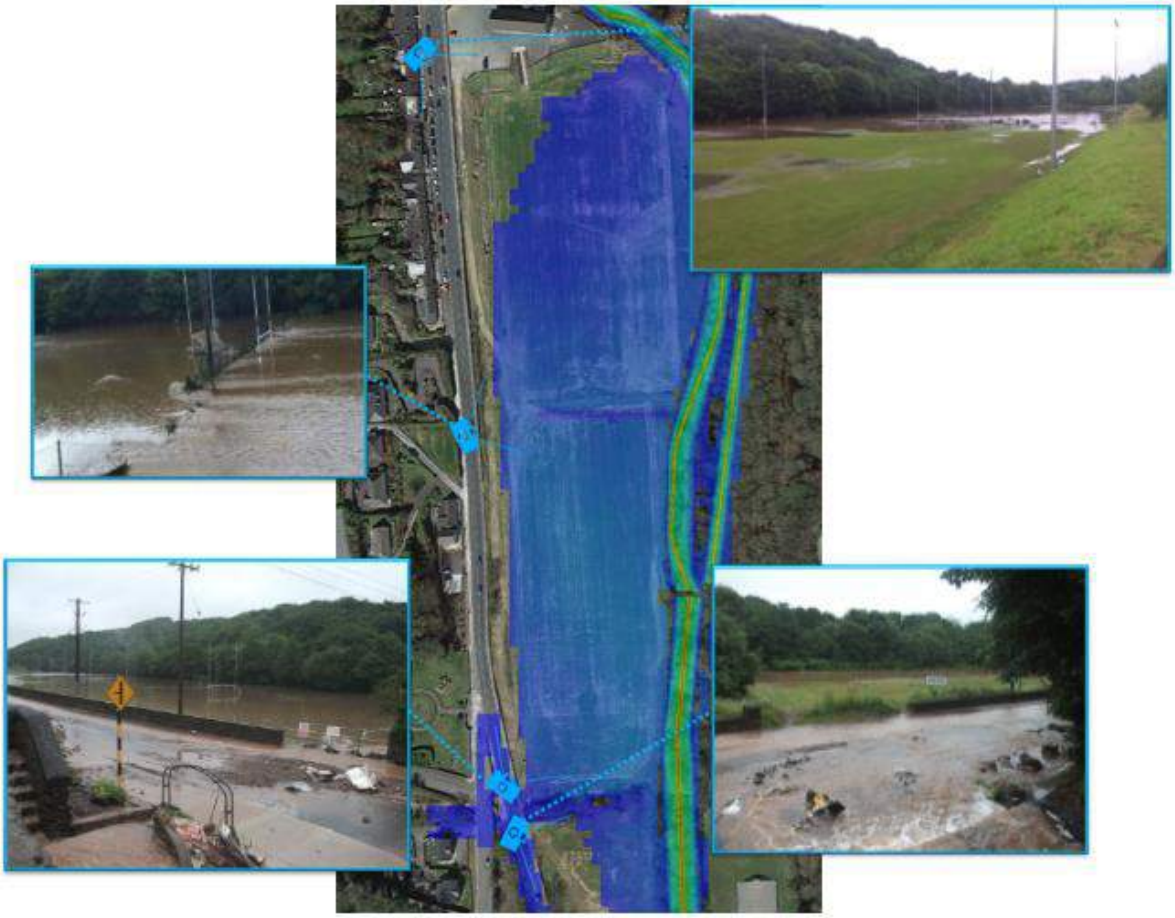
Significant flooding of Sallybrook occurred during the extreme event in 2012. Figure 3-5 shows the modelled extent of this flooding, with inserted photos of wrack marks taken after the event. The flood extent is consistent with report of the Sallybrook Industrial Estate. Exact calibration of flood depths at Grandons proves difficult to attain due to the uncertainty in bank levels during the event. Reports from the proprietor, Mr. Grandon, state that part of the bank was eroded and that several trees reduced capacity in the channel. The wrack marks indicate water levels of 0.6m at the garage which were not achieved in the model outputs (0.2m). However, the model showed these flood depths in the car lot immediately south of the garage and immediately north in the industrial estate. The waters extended over the R639 as confirmed with Mr. Grandon.

Figure 3-5 Grandon Car Sales extent calibration

3.2.4.2 Glanmire GAA Pitches

The Glanmire GAA pitches are a significant floodplain in the urban area of Glanmire. They provide a large amount of attenuation due to the raised level of the R639 road, to the immediate west (see Figure 3-6). The extent produced by the model was consistent with that experienced during the 2012 flood event with the entirety of the pitches being inundated. Flood depths were slightly underestimated by approximately 0.2m, based on estimations from photos and wrack marks.

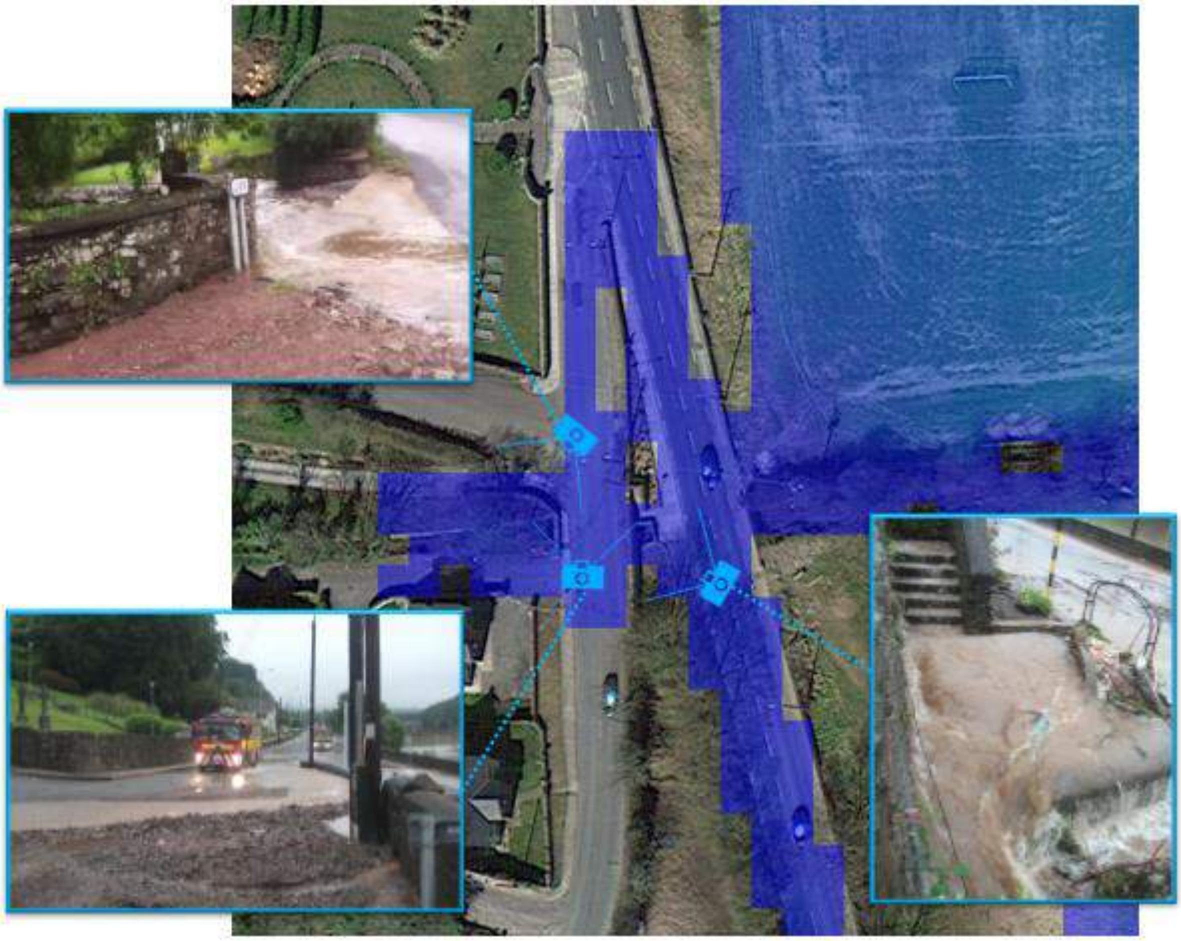
Figure 3-6 Glanmire GAA pitches extent calibration



3.2.4.3 Cois na Gleann

The flood extent from the Cois na Gleann stream is shown in Figure 3-7. The flood mechanisms in this location are the culvert entrance causing flow down the driveway of the accompanying property and the well located in the middle of the culvert system. These features have been represented in the model using external source spills into the 2D domain, as detailed in section 2.7.4. The model outputs compare favourably with that seen in the inserted photos in Figure 3-7. Flow routes from this location are south down the R639 road towards Hazelwood and east into the GAA pitches via a gate (see bottom left photo in Figure 3-6). It is noted that the channel is currently poorly maintained which increases the likelihood of out of bank flow upstream in this location.

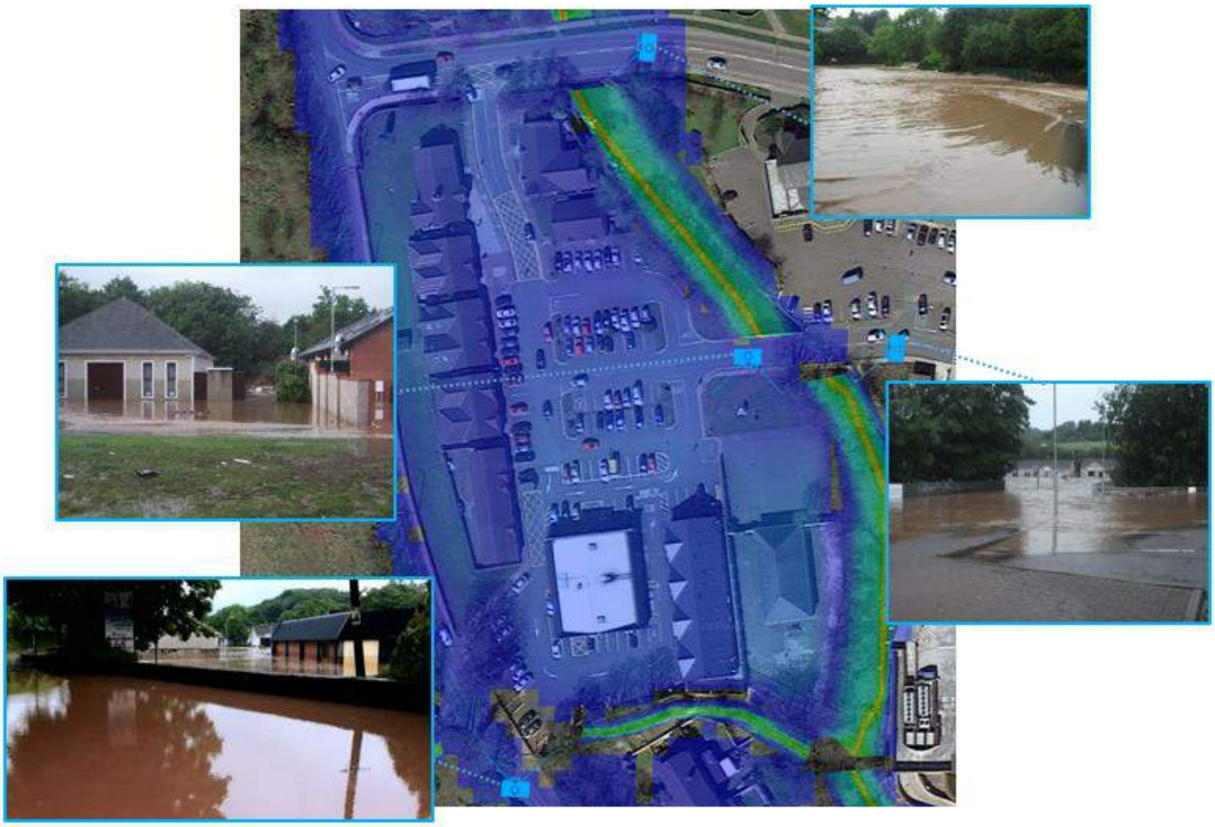
Figure 3-7 Cois na Gleann extent calibration



3.2.4.4 Hazelwood

The Hazelwood shopping centre flood extent is displayed below in Figure 3-8. The model extent is consistent with that shown in the inserted photos. The dominant flood mechanism is the overtopping of Hazelwood Avenue Bridge when its capacity is exceeded. The flooding of the R369 in this location is also contributed to by overflow from the Cois na Gleann stream flowing south and overflow from the Springmount stream heading north. Flood depths at the front of the funeral home (top left photo in Figure 3-8) are approximately one metre which is consistent with wrack marks on photo. Similarly, the flood depth of 0.3m at the northern part of the shopping centre, as reported in the PCD, is consistent with the model.

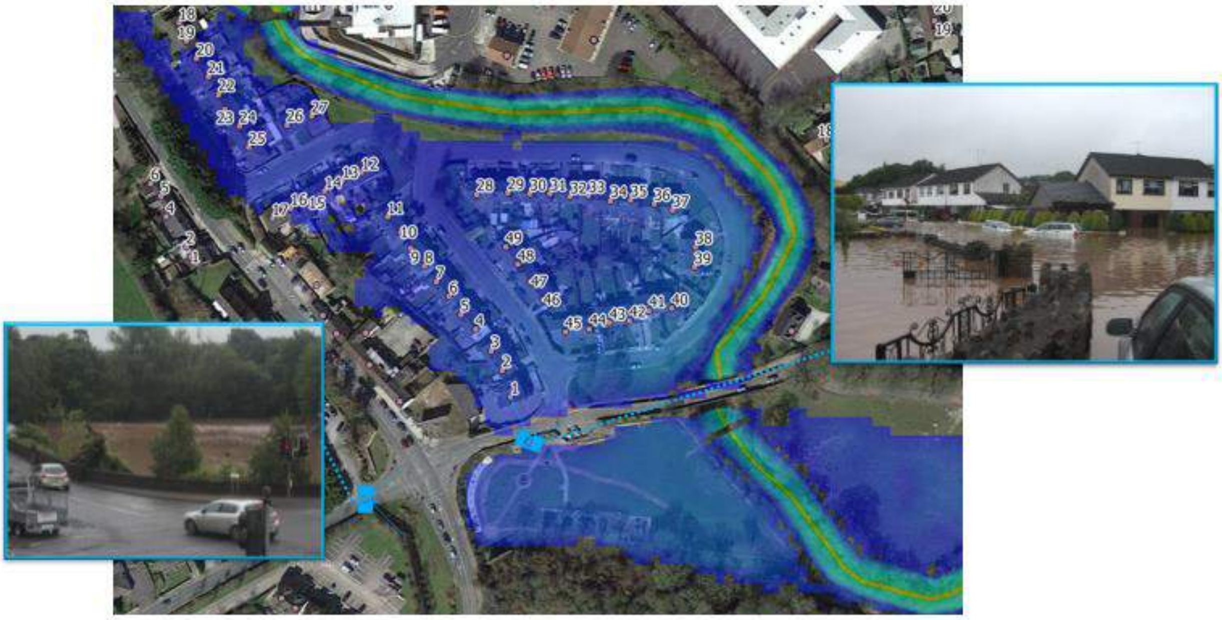
Figure 3-8 Hazelwood Shopping Centre extent calibration



3.2.4.5 Meadowbrook

The modelled flood extent for the Meadowbrook area is shown in Figure 3-9, along with inserted photos used in the calibration. This figure demonstrates the magnitude of the flooding in the Meadowbrook housing estate and John O'Callaghan Park. The model extents in these locations are consistent with the photos and information received from local residents at the Public Consultation Day (PCD). Estimations of flood depth at several the houses were recorded at the PCD and used in the calibration. The model showed good calibration at the south of the estate matching a maximum flood depth of 1.2m, as recorded at house No. 44. The depths at the north of the estate were underestimated in the model outputs. This is due to the model not being able to represent the exact flow paths, and water retention, caused by garden walls and houses. Additionally, there is some uncertainty over the wall level on the Springmount stream at the time of the flood. This is due to the construction and reconstruction of wall post the 2012 event. The PCD data showed flood depth of 0.6m and 0.5m (houses No. 17 and 19), while the model had a depth of 0.3m. Conversely PCD data for house No. 24 showed a flood depth of 0.1m, while the model had a depth of 0.2m.

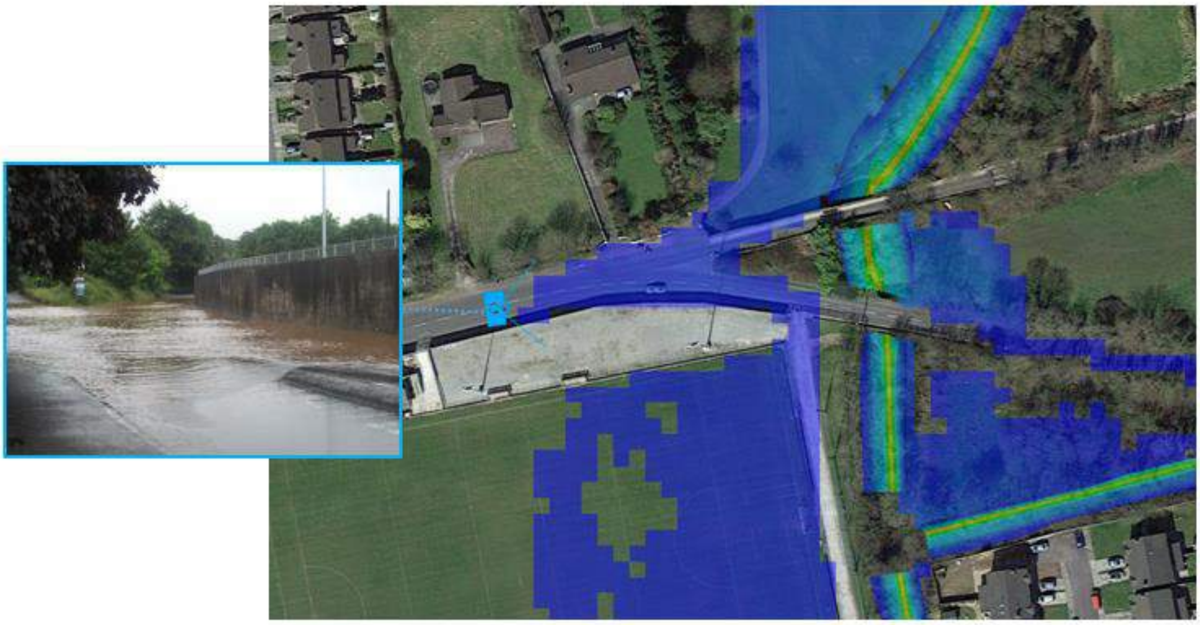
Figure 3-9 Meadowbrook extent calibration



3.2.4.6 L3010 at Sarsfield GAA

The modelled flood extent for Sarsfield GAA area of Glanmire is shown in Figure 3-10. Limited information is available for this area, however the inserted photo of the L3010 road shows a good fit with the model extent.

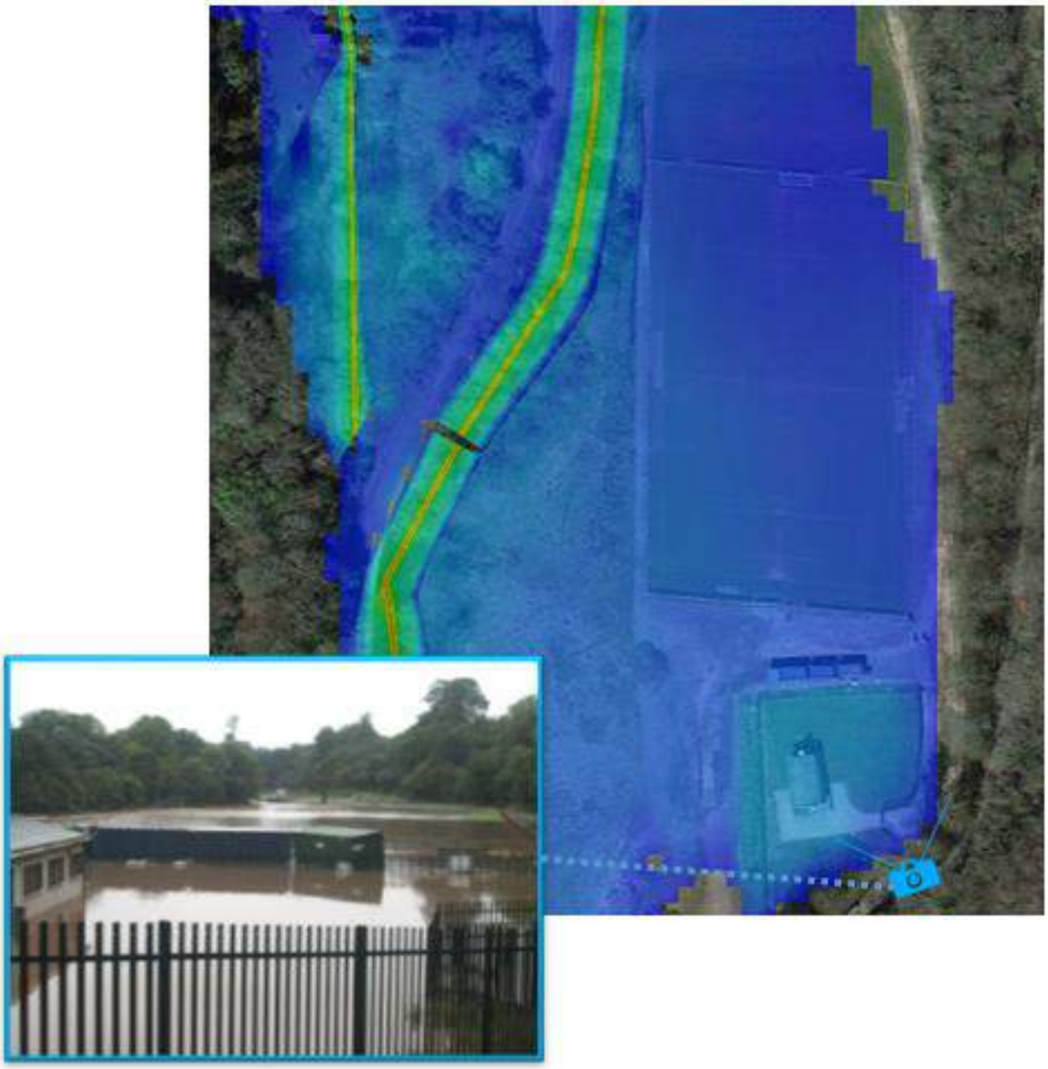
Figure 3-10 Sarsfield GAA extent calibration



3.2.4.7 Soccer Pitches

The 2012 calibration flood extent at the Soccer Pitches location is displayed in Figure 3-11. The pitches are located north of Glanmire village and downstream of the Butlerstown and Glashaboy confluence. The modelled flood extent is consistent with photos of the location and data received from Mr. Gibson Bowles, the resident of the Saint Patrick Mills which are located to the west of the pitches. The reported water depth in the mill property is consistent with the model[3]. The main reported flood source for the mill property is overtopping of the left bank of the Glashaboy, which is confirmed by the model. The calibrated depths in the soccer pitches are ~0.2m below recorded wrack levels. This is deemed within the limitations of the accuracy of the data.

Figure 3-11 Soccer Pitches extent calibration

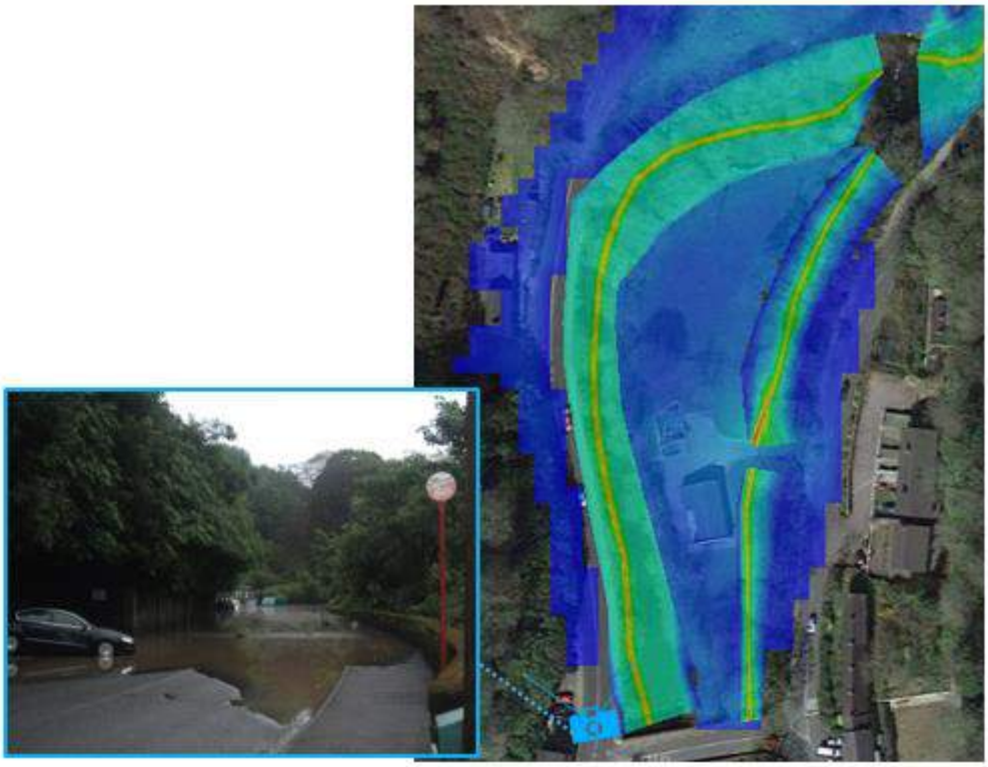


3.2.4.8 R639 near Glanmire Bridge

The flood extent upstream of Glanmire Bridge is shown in Figure 3-12. The inserted photo of the L639 road shows water flooding across the road which is replicated by the modelled flood extent. Residents in The Grove experienced flooding in their property in this location during the event. The mechanism for flooding here is backwatering from Glanmire Bridge causing flow onto the road 150m upstream of the bridge. This is due to gaps in the wall rendering it ineffective as a flood defence (Figure 2-13).

[3] Depth reported to be at "chest height at the bridge" located to the south of the mill building by resident G. Bowles. The model has a depth of 1.2m which is deemed consistent.

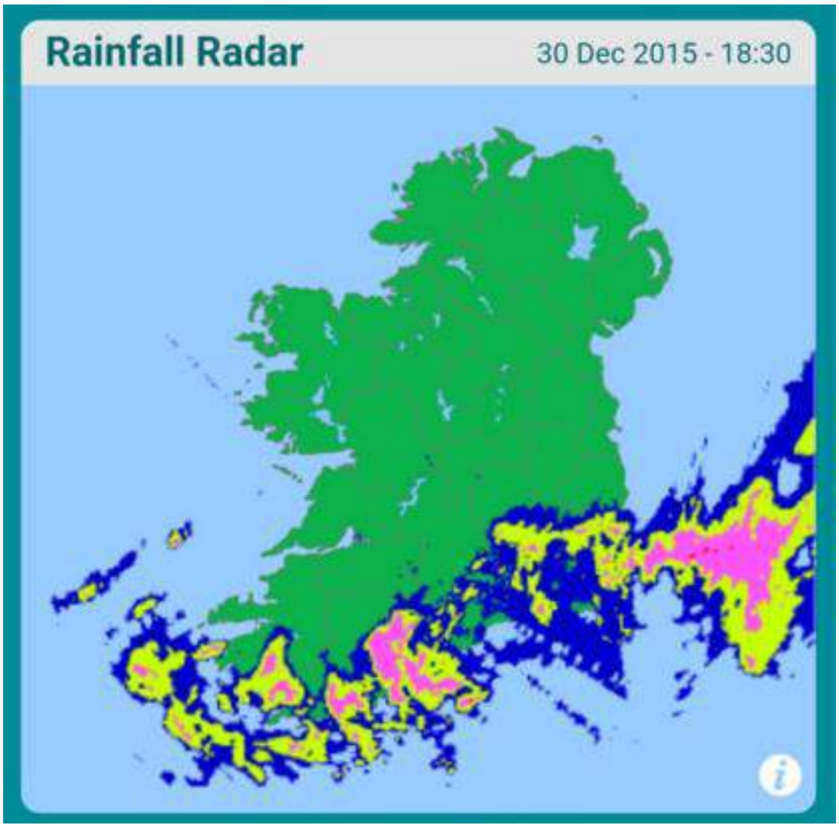
Figure 3-12 L639 at Glanmire calibration



3.3 Calibration of December 2015 and January 2016

During the end of December 2015 and the start of January 2016 several flood events occurred in the Glashaboy Catchment. A historically wet December produced a high saturation of the Glashaboy Catchment. The event is attributed to the cluster of extreme fluvial flows occurring between December 29th and January 1st.

Figure 3-13: Rainfall Radar showing extreme rainfall over Cork



Source: ww.met.ie

A post-flood report was completed on the areas effected with the Glashaboy catchment (see Hydrology Report Appendix D). The findings of this report concluded the sources of flooding was fluvial and pluvial. The flood risk areas reported on will be the focus of this calibration and they are:

- Hazelwood
- Meadowbrook
- Copper Valley Vue
- The Grove

Using surveyed wrack mark, reports from residents and photographs, a calibration to the events has been completed to validate the representation of the hydraulic model. No gauge data was available for these events as the only active gauging station at Meadowbrook had been suspended during the time of the event.

3.3.1 Calibration assumptions and inputs

In order to calibrate the model to the conditions recorded in the Glashaboy catchment certain assumptions were made. These were based on recorded data, visual records and witness testimony:

- Bed roughness values for the channel bed were set to the calibrated values as detailed in the hydraulic check file (Appendix A). The side bank panels, representing the riparian strips of the channel, were set to the winter value (n=0.05) as the events occurred in

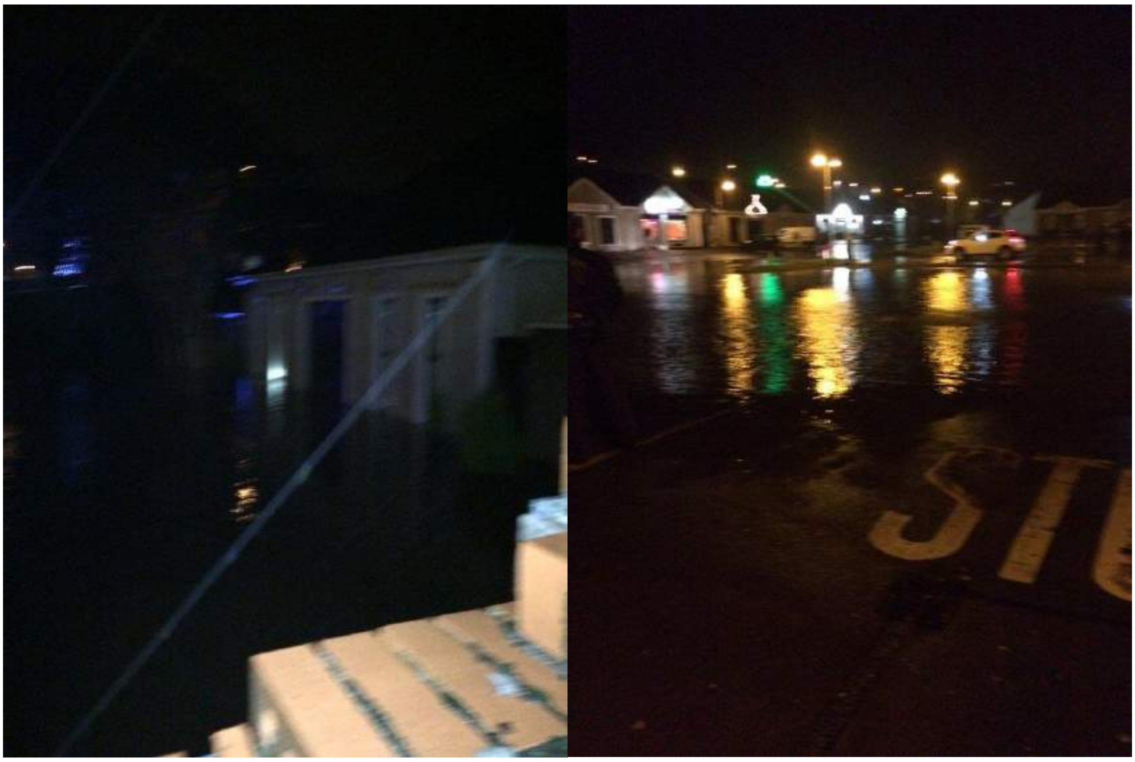
December and January. This lower roughness is caused by the trees and bushes have no foliage in the winter months.

- Design hydrograph shapes were used as no gauged hydrograph was available
- Informal defences were put in place in Copper Valley Vue by residents to manage overland flow paths into the housing estate. A small wall has been added to the model to represent sandbags used, and a wall is removed on the downstream face of the entrance bridge to replicate what occurred
- Downstream boundary was set as a steady low level for model stability. No significant tidal cycle occurred during the fluvial event, with the low tide coinciding with the peak of the event. There was deemed to be no tidal influence during the calibration event and the approach was deemed appropriate.
- A range of design flows were run through the hydraulic model to estimate the return period of the event.

3.3.2 Hazelwood

Hazelwood Shopping Centre experienced flooding during the 2015/2016 flood events. Small flood depths were accumulated on the Hazelwood Ave and R639 roads in the Hazelwood area. Similarly, small flood depths were reported in the car park of the shopping centre, with the largest depth occurring in the Funeral Home. This is the natural low point of the area which had estimated flood depth of 0.3m.

Figure 3-14: Photos of Funeral Home and Carpark in Hazelwood Shopping Centre on 29/12/2015

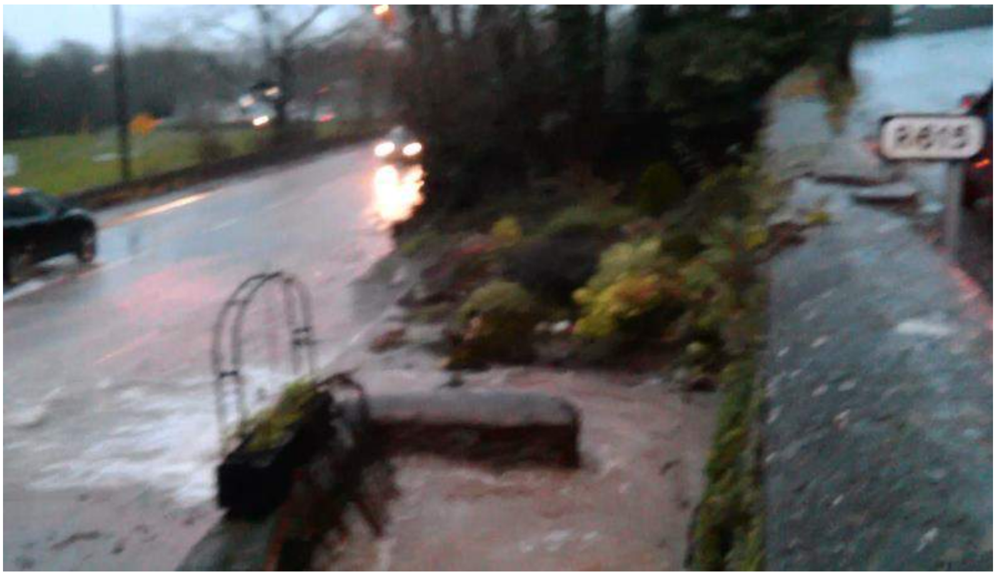


Source: https://twitter.com/bryanofficial

3.3.2.1 Flood source

The fluvial flooding source comes from the small Glashaboy tributaries of Springmount and Cois na Gleann. The streams surcharged and flowed onto the R639 where flow then entered the Hazelwood SC from the Hazelwood Avenue entrance to the north and the pedestrian entrance to the south west. Figure 3-15 shows the Cois na Gleann stream surcharging onto the R639 road during the 2016 flood event.

Figure 3-15: Surcharging well on Cois na Gleann Stream 01/01/2016



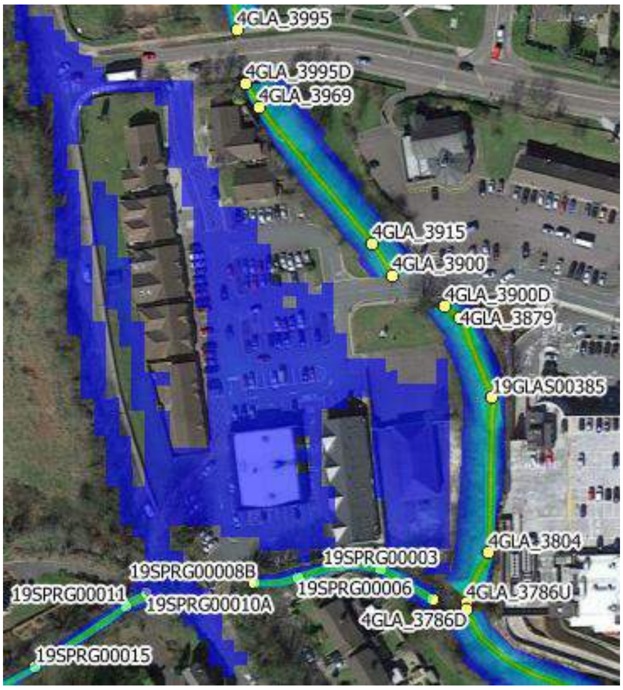
Water levels in the main Glashaboy River through Hazelwood are understood to have remained in bank during the event. Water level were high and at the peak could have reached soffit level of the two Hazelwood bridges. Figure 3-16 shows the high-water level through Hazelwood before the peak of the 2016 event.

Figure 3-16: Glashaboy downstream of Hazelwood Avenue Bridge 01/01/2016

3.3.2.2 Model calibration

Figure 3-17 shows the modelled flood extent in Hazelwood. The extent shows a good representation to the reported event. A modelled water depth at the funeral home of 0.25m shows good calibration to estimated depths. The modelled flow is the 20% AEP flow, and the event is concluded to be in this order.

Figure 3-17: 2015/2016 extent calibration



3.3.3 Meadowbrook

The flooding in Meadowbrook Estate during the 2015/2016 events has been determined to be from a pluvial source (see post flood report in hydrology report). The Meadowbrook gauge was not recording during the event which limits the calibration. However, a post-flood wrack mark has been recorded and is compared to the 20% AEP event, as modelled through Hazelwood. Table 3-1 compares the wrack mark to the modelled level. The results show a marginal over prediction of 0.1m. This is deemed appropriate and confirms the 20% AEP calibration upstream at Hazelwood

Table 3-1: Calibration to Meadowbrook wrack mark

Location	Wrack mark level	Modelled level	Difference
Meadowbrook gauge	9.58mOD	9.65mOD	+0.1m

3.3.4 Copper Valley Vue

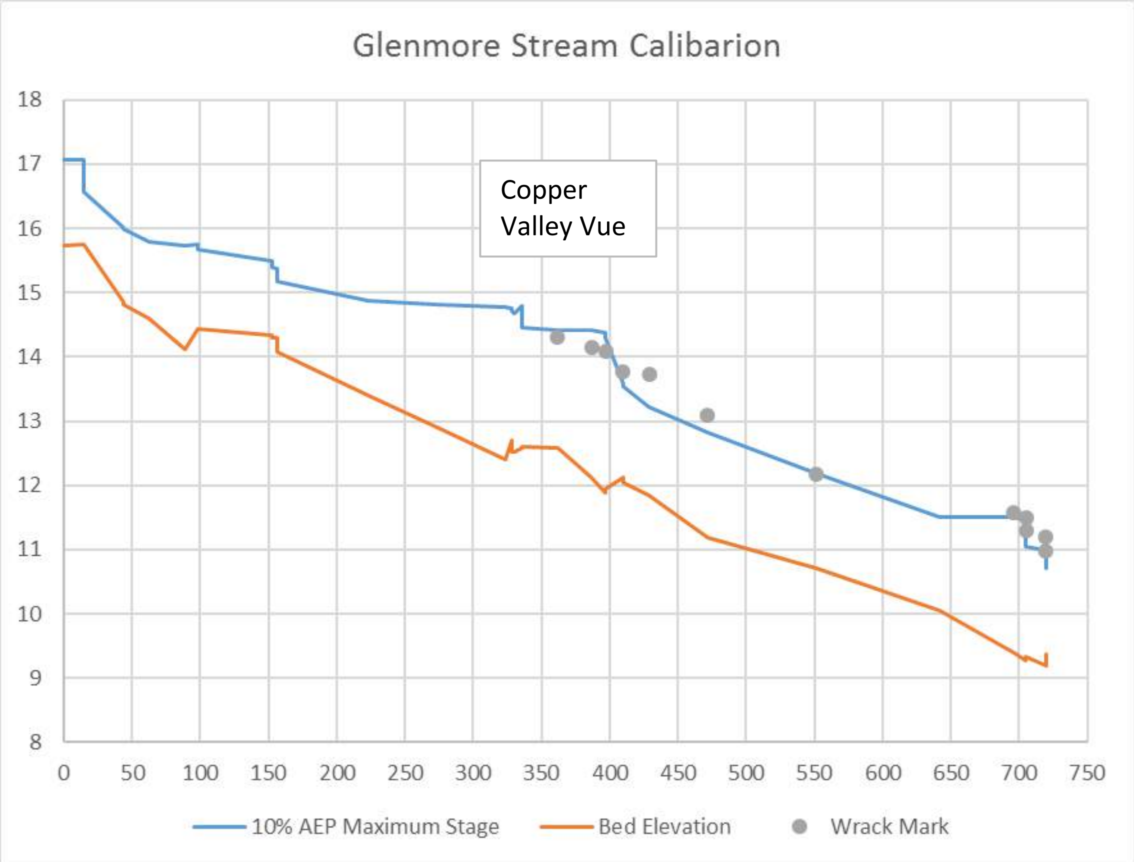
Flooding occurred in the Copper Valley Vue estate during the December 2015 events. It is reported the source was from the Glenmore at Brooklodge Grove Rd Bridge, which brought flow onto the road and through the entrance of the estate. As an emergency response to this flow path a temporary wall was constructed out of sandbags and a wall removed to guide flow back into the river. Figure 3-18 shows this emergency measure.

Figure 3-18: Emergency surface flow management measures at the entrance to Copper Valley Vue

3.3.4.1 Model calibration

In the post event survey several wrack marks were collected along the Glenmore stream. To calibrate to these marks, the 10% AEP flow was applied to the model, along with the emergency measure which were put in place by the residents. To provide a better calibration to the river reach downstream the roughness panel has been adjusted to better represent the vegetation within the channel. The manning's values have remained the same. Figure 3-19 shows the long section along the modelled Glenmore Stream. The maximum stage shows a general good fit with the surveyed wrack marks.

Figure 3-19: Glenmore long section calibration to surveyed wrack mark



3.3.5 The Grove

During the 2015 event the occupant of No.1 The Grove experienced flooding. It is reported that flood depths of 0.15m were reached inside the property and approximately 0.8m on the road in front of his house. Figure 3-20 shows the location of the house upstream of the Glanmire Bridge.

Figure 3-20: Location of No.1 The Grove

3.3.5.1 Flood source

The source of flooding is determined to be a combination of pluvial and fluvial sources. The property is located at a low point on R639 and rainwater will natural gather in this location if not effectively drained to the river. The fluvial source is understood to stem from wall gaps upstream on the right bank of the Glashaboy (see Figure 2-13). Figure 3-21 shows flood waters during the event on the road in front of the property and in the soccer pitch located on the left flood plain of the Glashaboy further upstream

Figure 3-21: Flooding at in front of The Grove (right) and on the soccer pitches upstream of The Grove(left) 30/12/2016

Source https://twitter.com/corks96fm/status/682166775409147904

3.3.5.2 Calibration

Using an initial modelled flow equivalent to the 20%AEP, it was found that the flood extent was under predicted compared with the data collected in the area. To calibrate the model using the established flow in the Glashaboy river upstream some adjustments would have been made to the head losses at Glanmire bridge and the previous CFRAM model representation of the upstream weir. A review of the ISIS bridge unit performance, led to the bridge transitional zone being lowered to the springing level on the main arch. These adjustment increases the head losses at the bridge and hence replicates the flood extent reported during the event. A headloss across the bridge of 1m is predicted by the revised model, similar to the anecdotal report from the December 2015 event. The modelled flood extent is shown in Figure 3-22. Maximum modelled flood depth in front of the property are 0.7mOD, comparable to the anecdotal evidence.

Figure 3-22: Modelled flood extent at The Grove

3.3.6 Conclusions

The calibration to the 2015/2016 flooding events have validated some of the previous assumptions made in the hydraulic model. An adjustment has been made to the transitional zone at Glanmire Bridge, and the roughness panels on the Glenmore Stream. The design hydraulic model is updated accordingly. The estimated return period of the 2015 event is approximately 20% AEP on the main Glashaboy River and 10% AEP on the Glenmore and Butlerstown as confirmed by the model calibration runs.

4 Model Results

4.1 Flood risk mapping

The suite of flood risk maps is provided in the Figures Section at the end of this report. The figures give flood extents for the 2, 5, 10, 20, 50, 100, 200 and 1000-year flood events for both fluvial and tidal events. These are displayed in conjunction with the long section profiles extracted from the hydraulic model.

4.2 Key flood risk mechanisms

Further to the information presented in the flood risk maps, a brief description of the key flood risk sites and flooding mechanisms is provided below.

4.2.1 Flooding at Hazelwood

The main source of flooding at Hazelwood is from the Hazelwood Avenue Bridge. The bridge has a calculated capacity of $52m^3/s$ which provides a Standard of Protection (SOP) of 1 in 20 years. When the SOP is exceeded flow over tops the bridge directly through its railing. Flow also overtops the embankment on the right flood plain which attenuates the flood volume in the upstream GAA pitches (See Figure 4-1 of 2012 event).

Downstream of the Hazelwood Avenue Bridge is the Hazelwood Shopping Centre Bridge. The close proximately of the two bridges (70m) means that the downstream bridge has a backwatering effect of the upstream Hazelwood Avenue Bridge. This reduces the hydraulic performance of the bridge.

Figure 4-1 Flooding source of Hazelwood from the L2966 Road Bridge

4.2.2 Flooding at Meadowbrook

The Meadowbrook housing estate is the major risk receptor in the Glanmire study area. Since its construction in the 1970's, a number of flood defences have been installed. Upon construction of the housing estate a large earth embankment, on the right bank of the Glashaboy, was built. In the 1980s the defence was upgraded with the construction of a flood wall on top of embankment.

However, this does not cover the entire bank with low points located by the Riverstown Bridge and at the junction with the Springmount Stream that borders the north of Meadowbrook (See Figure 4-2).

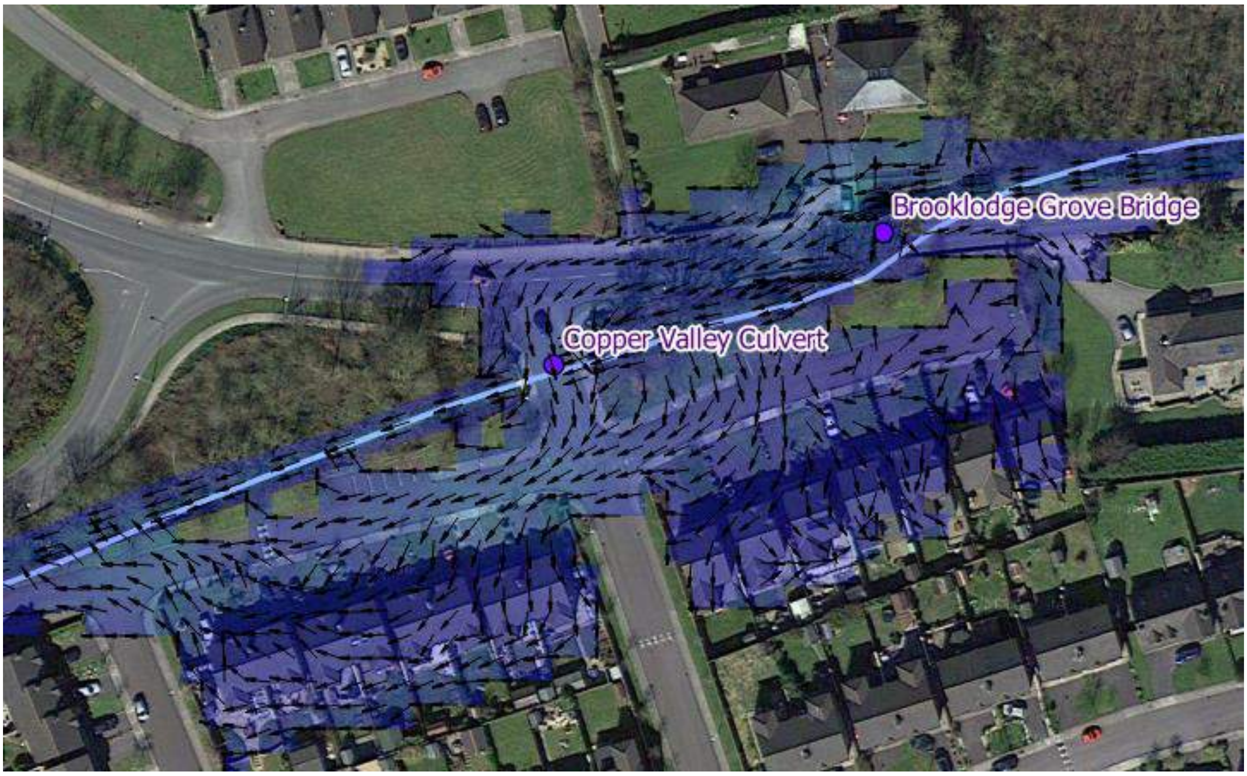
Figure 4-2 Defence wall and bank heights at Meadowbrook

This discontinuity of the defence is what facilitated water entering the Meadowbrook housing estate. Water first enters at the upstream low point, before the flood defence wall, where the bank height drops to 0.5m below the wall. Overtopping occurs slightly later in the flood event at the downstream low point where the defence wall is discontinued. These low points in the flood defence equate to a SOP of 1 in 50 years. In the model the capacity of the Riverstown Bridge is not shown to influence flooding of Meadowbrook and the bridge has a calculated capacity more than the Q100 flow.

4.2.3 Flooding on Glenmore

The main flood risk receptors on the Glenmore River are located in the Copper Valley housing estate. There are two road bridges in this location that overtop and cause out-of-bank flow. Figure 4-3 shows the flow paths, with the excess flow from the Brooklodge Grove Bridge following the road west and into the Copper Valley Estate. The Brooklodge Grove Bridge has a SOP of 1 in 2 years, while the Copper Valley Culvert has an SOP of 1 in 20 years.

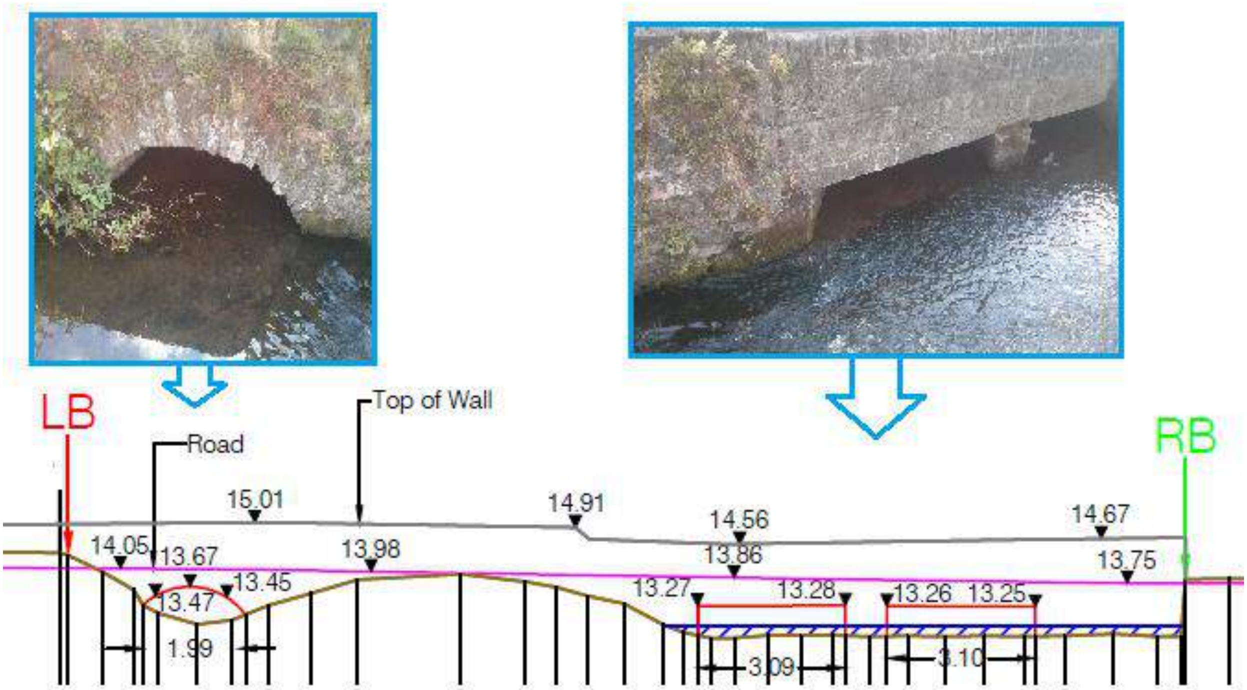
Figure 4-3 Flooding flow paths for Copper Valley on the Glenmore River



***extent is during the Q100 event but not at the peak**

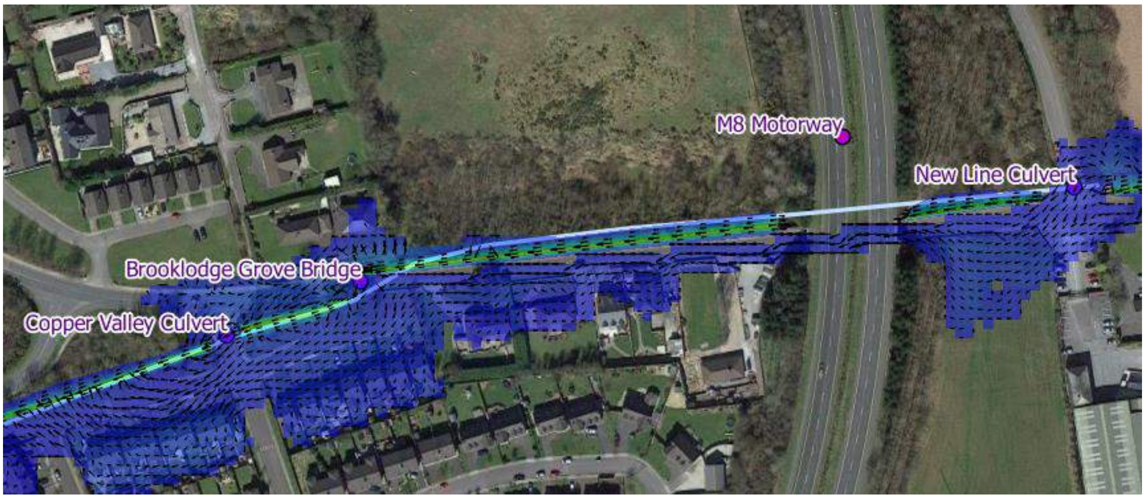
The Brooklodge Grove Bridge has a reduced capacity due to an eye being blocked. The masonry arch eye seen in Figure 4-4 is blocked on the downstream side, which reduces the capacity of the structure. There is also a 90-degree bend in the channel immediately upstream of the bridge which causes headloss and a further decrease in conveyance capacity.

Figure 4-4 Bridge opening on the Brooklodge Grove Bridge



An additional flood risk source to Copper Valley Vue has been identified as the New Line culvert located east of the M8 motorway. This is a tapered culvert under downstream control that can surcharge causing out-of-bank flow on the road on the right back. The road slopes from east to west which facilitates flow to travel westly, under the M8 flyover, and down the road to Copper Valley Vue (Figure 4-5).

Figure 4-5: Flooding flow paths for Copper Valley from New Line Culvert



4.3 Tidal

The downstream section of the Glashaboy is under the tidal influence of Cork Harbour. Ordinary tides propagate upstream as far the Glanmire Bridge in Glanmire Village. An HT boundary is used to model the range of tidal event as discussed in Section 2.7.5.

The different fluvial model runs have been modelled with a two year downstream tidal boundary. Similarly, the tidal model runs have a two-year fluvial inflow. The following sub-sections demonstrate the different consideration made in the tidal modelling approach.

4.3.1 Timing of fluvial and tidal peaks

For the design model runs, the fluvial peak has been timed to coincide with the tidal peak, to give a conservative (worst case) result. No further sensitivity testing has been undertaken in relation to timing of fluvial and tidal peaks.

4.3.2 Joint probability events

To determine the extent to which a joint probability event will result in additional flood risk a combined flood event has been modelled. A conservative approach has been adopted and the 50-year fluvial event has been combined with the 50-year tidal event. The results from this event are used to highlights the sensitivity of the river to a combined event.

The joint probability event extent is compared to that of the 100-year fluvial event and the 200-year tidal event. A marginal increase in extent (one TUFLOW cell, 4m) is evident in the area upstream of the Glanmire Bridge. This does not encroach on any additional properties, and it is deemed that the effects of joint probability are not an issue. As no additional properties are shown to be at risk in the joint probability run, no further testing of joint probability is considered necessary.

5 Flood alleviation measures

This section details the different flood alleviation measures that will be used to develop the options for the flood risk locations in the greater Glanmire study area.

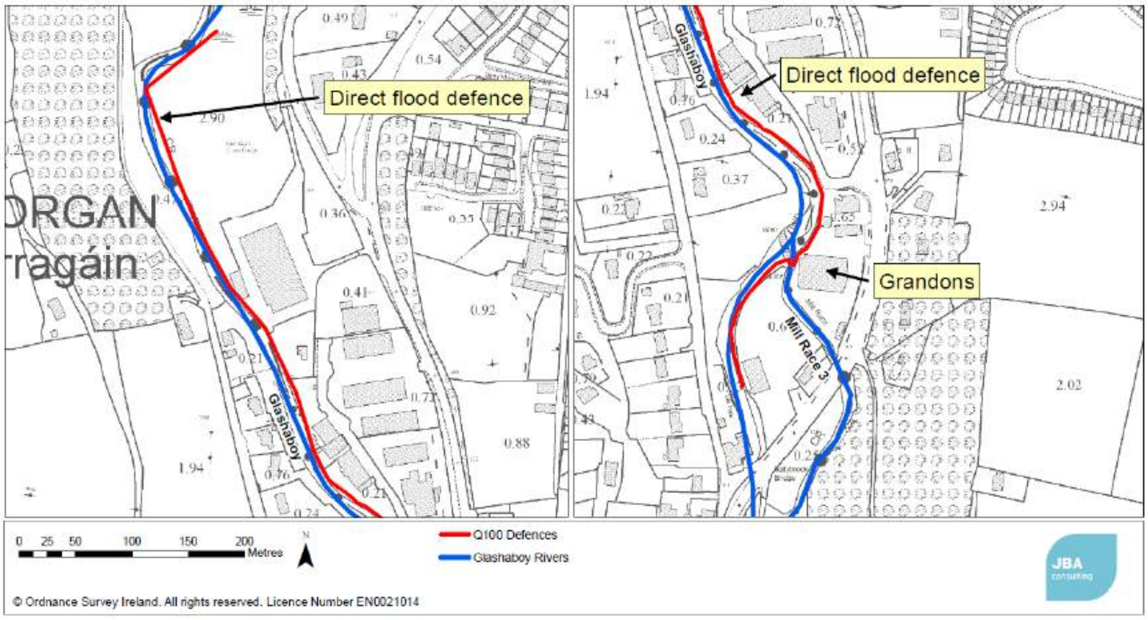
5.1 Major risk receptors

The major risk receptors have been identified from the model results discussed in Section 4. To mitigate this flood risk a number of options have been analysed. The water and defence levels discussed all relate to the 100-year fluvial event, with a 2-year tide at the downstream end, or a 200-year tide with a 2-year fluvial inflow. It should also be noted that the water depths quoted below are relative to the ground behind the modelled defence wall / embankment, and does not include freeboard which also needs to be accounted for.

5.1.1 Sallybrook

The Sallybrook area, which includes the Industrial Estate and Grandon Car Sales, is at flood risk due to water levels in the Glashaboy exceeding its left bank height. This out-of-bank flow occurs in numerous locations from the north of the Industrial Estate to 500m downstream of Grandons. To mitigate the flood risk in this area a direct flood defence is modelled. At Grandon Car Sales, the informally built defences are at a sufficient level due to the reconstruction, and raising, of the embankment subsequent to the extreme event in June 2012 (See section 2.9.1.). The structure of the bank must be checked to ensure it is stable before being formalised into an acceptable flood defence. It may be that the embankment needs to be reconstructed to the same level, but using formalised techniques. Design water levels are 0.1-0.4 above existing ground levels in this area.

Figure 5-1 Direct defences for Sallybrook Industrial Estate/Grandon Car Sales



5.1.2 Hazelwood

Flood risk at the Hazelwood Shopping Centre arises from the two bridges in this location, predominately the Hazelwood Avenue Bridge. To mitigate the flood risk a combination of conveyance improvements and direct flood defence were considered.

5.1.2.1 Hazelwood conveyance improvements

To improve the conveyance through this reach a number of difference measures were considered. They predominantly focused on upgrades to the two bridges in the reach. These included raising the soffit of the bridges, removal of the Hazelwood SC Bridge and the inclusion of a flood relief culvert to the left bank of the Hazelwood Ave Bridge. Different combinations of these options were modelled to determine the optimal solution. Additionally, a dredge measure was also modelled.

The different measures for improving conveyance in the Hazelwood reach are described in Table 5-1. The increase in soffit is based on the maximum feasible increase to facilitate road ramps to the car. Similarly, the increase in width is based on the available space on the left bank of the Hazelwood Avenue Bridge, along with downstream reach, and the right bank of the Hazelwood SC Bridge.

Table 5-1 Defence options for the Hazelwood Bridges

Option	Hazelwood Avenue Bridge	Hazelwood SC Bridge	Channel Dredge
H1	-	-	1.2m
H2	width +3m, soffit +0.8m	-	-
H3	width +3.0m	-	-
H4	width +3m	Removed	-
H5	3.5m second arch added	soffit + 1.85m	-
H6	5.5m second arch added	Removed	-

The different bridge options all include a requirement for direct flood defence. The defence options described in Table 5-1 have a varying effect on the required direct defence levels. Figure 5-2 shows the hydraulic profile of the maximum water levels for the different bridge options. The varying effect on direct design is tabulated in Table 5-2 showing the maximum water level at the upstream face of both bridges.

Figure 5-2 Defence options for Hazelwood

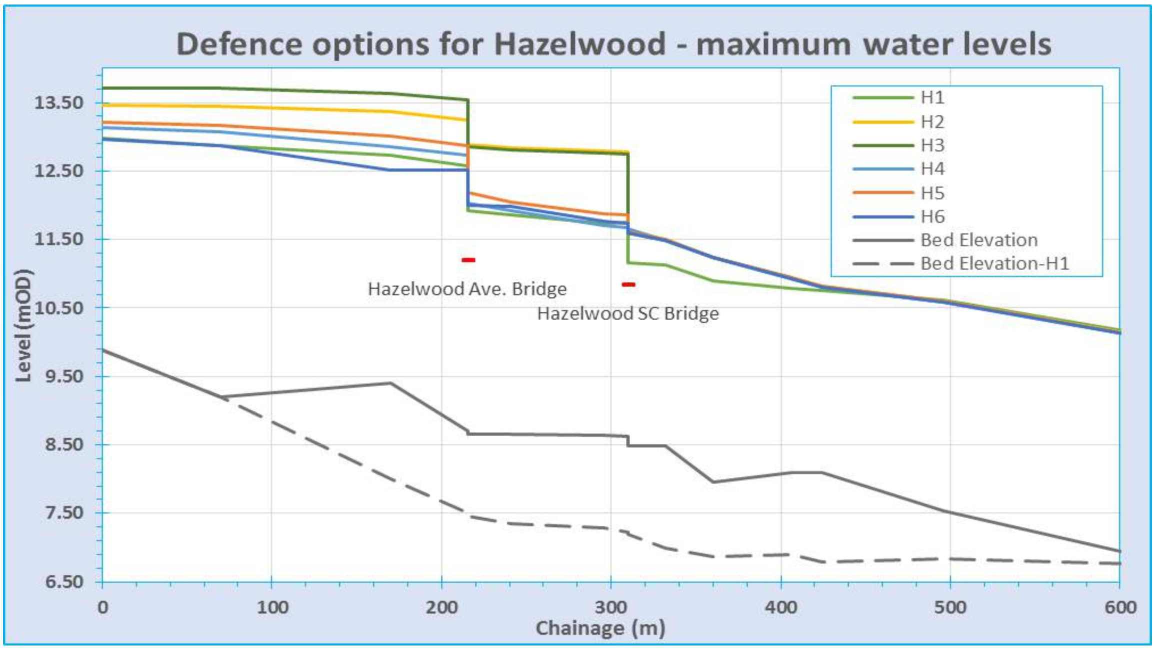


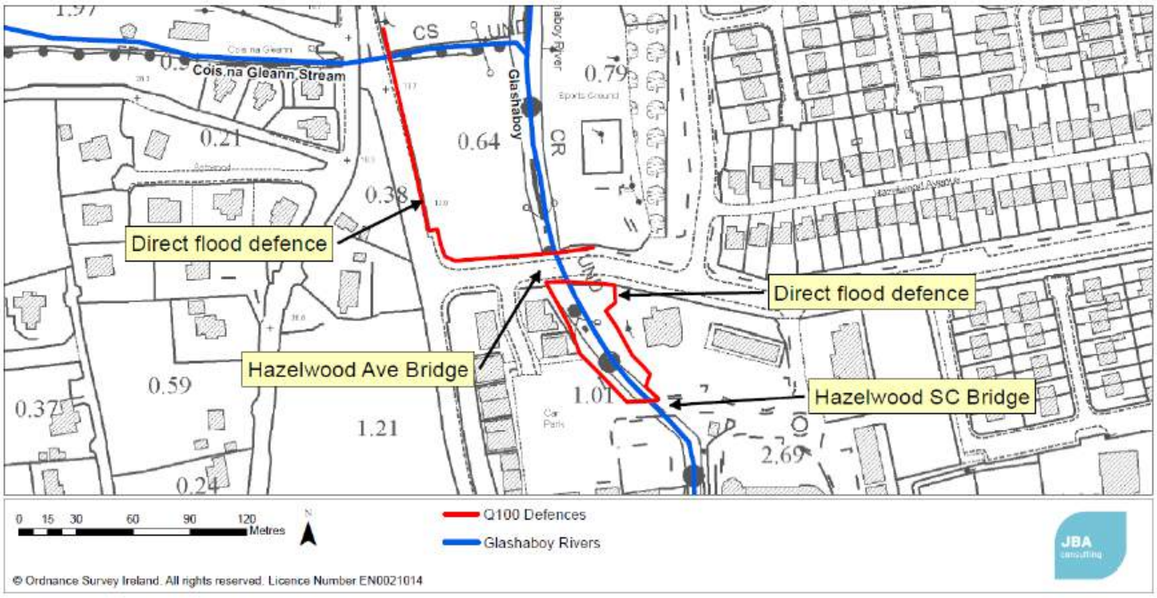
Table 5-2: Max water level for conveyance measures at Hazelwood bridges

Location	Max water level (m) H1	H2	H3	H4	H5	H6
Hazelwood Ave	12.58	13.24	13.55	12.73	12.87	12.52
Hazelwood SC Bridge	11.76	12.78	12.75	11.68	11.85	11.74

5.1.2.2 Hazelwood direct defences

As discussed in the previous section, direct defences are required to be coupled with any conveyance improvement measures. In plan view the direct defences are displayed in Figure 5-3 with a wall at the u/s face of the Hazelwood Avenue. Bridge and its left flood plain. Additional direct defences were modelled along the reach between the two bridges to contain the increased water levels resulting from the pressure head caused by the wall at the upstream of the Hazelwood Avenue Bridge.

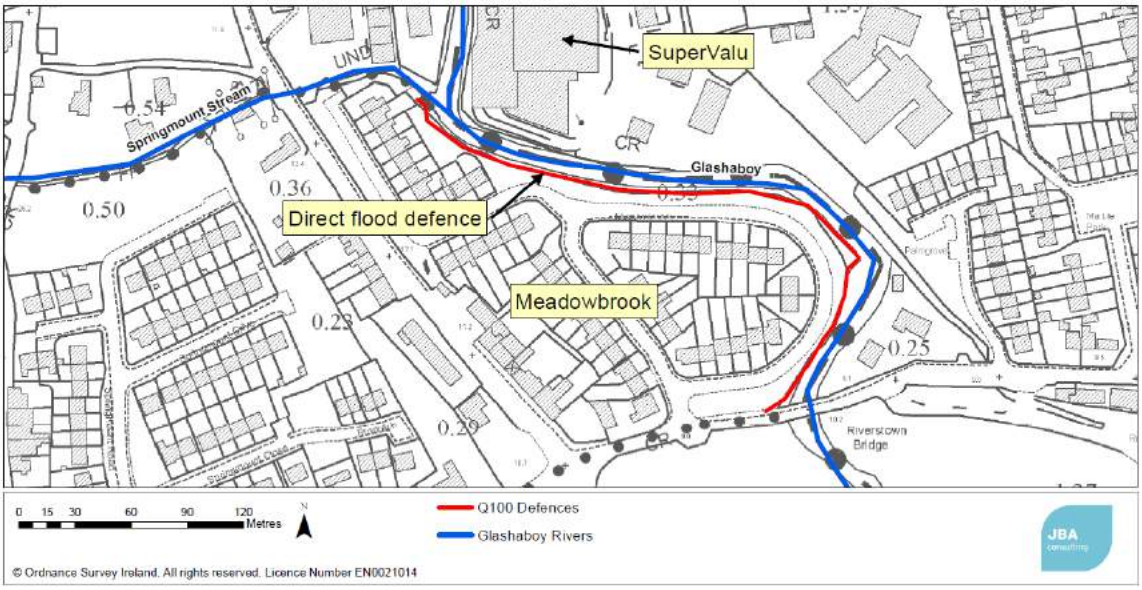
Figure 5-3 Flood Defence walls schematic at Hazelwood



5.1.3 Meadowbrook

The Meadowbrook housing estate has an existing direct defence consisting of a flood wall on top of an embankment. The defence wall has two low sections at the upstream and downstream limits of the wall that compromise the continuity of the existing defence (Figure 4-2). From a condition survey conducted the existing defence wall has been deemed to be in a structurally poor condition. A direct defence is proposed for the reach, to address the two low points and replace the existing not-fit-for-purpose defence wall. The proposed measure is a direct defence on the right bank of the river as identified in Figure 5-4. Design water levels are 0.3-0.5m below the top of the existing defence wall in this location.

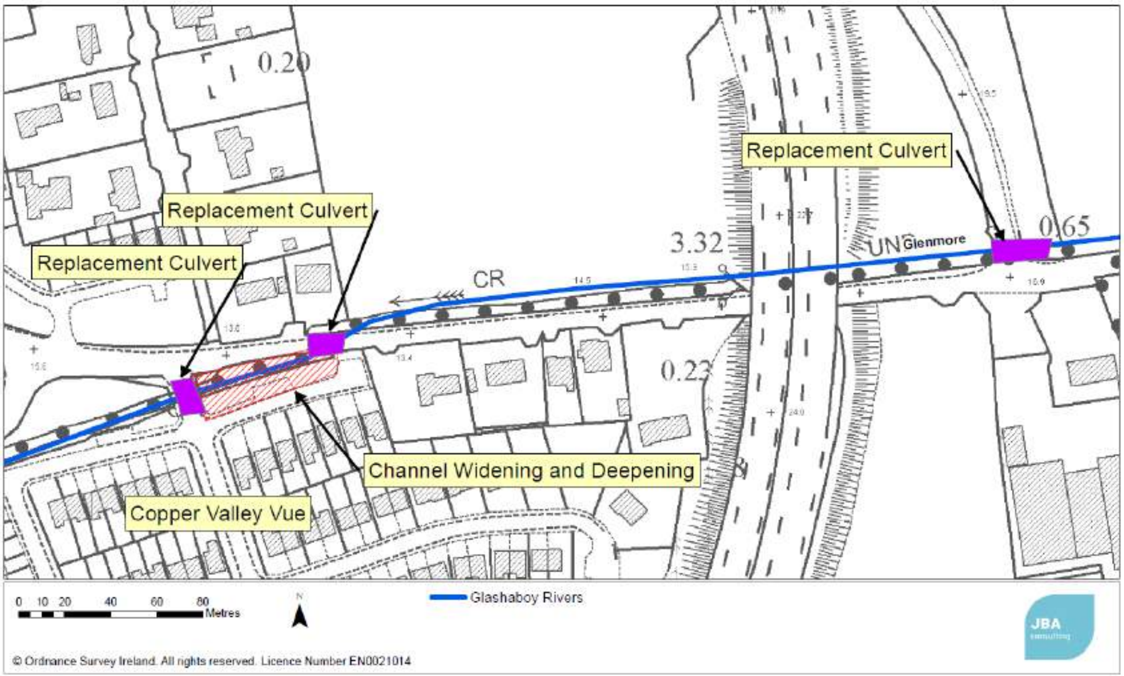
Figure 5-4 Defences for Meadowbrook



5.1.4 Copper Valley Vue

Flood risk at Copper Valley arises from the three bridges in this location. To mitigate the flood risk a combination of conveyance improvements and direct flood defence were considered. To avoid the necessity for an overland flow route a culvert replacement was deemed the most suitable option to progress. The upstream Brooklodge Grove Bridge has a twin 3.2m by 0.7m opening and will be replaced with a 10m by 1.9m box culvert. The Copper Valley entrance road bridge with a current 3.7m by 1.5m opening is to be replaced with a 10m by 1.95m box culvert. To accommodate the new culverts some channel widening and deepening is required. This will require approximately 7m of the left bank for the reach between the bridges. The third replacement is upstream on the New Line culvert, east of the M8 motorway. It has an opening of 4.9m by 2.2m tapering to a 3.1m by 1.6m outlet and will be replaced by an 8.25m by 2.58m box culvert. Localised bed regarding will be required to facilitate the new culvert.

Figure 5-5: Defences at Copper Valley

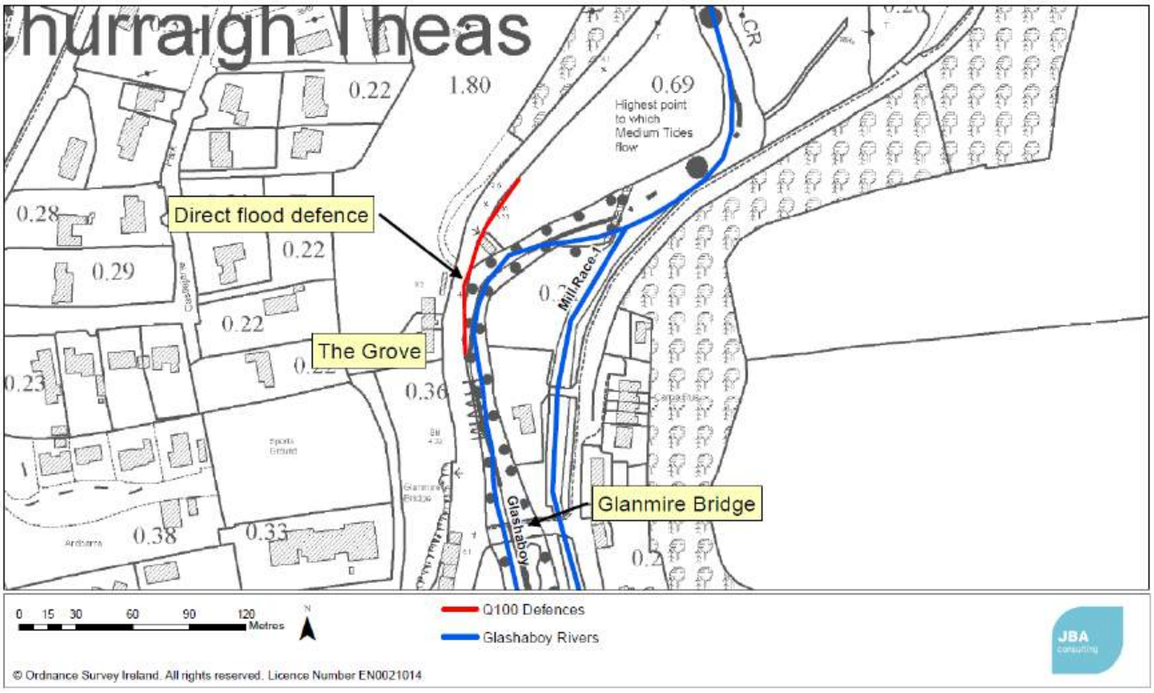


An additional culvert replacement is required upstream at the culvert immediately east of the M8.

5.1.5 The Grove

As identified in the calibration of the 2015/2016 flood events, the source of flooding at The Grove is from wall gaps in the existing defence wall on right bank of the Glashaboy. The 1 in 100-year design event was used to determine the suitable height of the wall for the existing defence. The results show that the maximum water levels to be 0.4-1.2 below the existing wall height. The proposed solution is to replacement a section of the wall to act as a direct defence wall. Figure 5-6 show the extent of replacement wall that will act as a suitable defence.

Figure 5-6: Defences for the Grove



5.2 Note on upstream storage

An alternative option to direct defences in the urban area of Glanmire is to construct an upstream storage area, which would be used to curtail extreme flows. To achieve this a suitable location must be selected to contain the required volume of water. The upper catchment of the Glashaboy was investigated to assess the viability of using upstream storage as a flood defence. The results of this investigation showed that the Glashaboy was unsuitable for such a defence measure. The steep nature of the catchment means that the ground rises steeply outside the floodplain (slope of 1:1 to 1:2). The storage area would have to contain the required volume to reduce flood risk in the study area, in addition to the volume normally stored in the floodplain for an extreme event. This would require the construction of large embankments and/or a dam. Such a defence would not be feasible due to the high cost of construction and health and safety implications should the defence fail.

5.3 Individual risk receptors

A number of individual risk receptors were identified as part of the hydraulic modelling. Measures for these options have been included in the Options Report. These receptors include Mill buildings on Mill Race 1 and Mill Race 2; Irish water assets including water intake, pump house, wastewater treatment; and minor works on upgrading undersized culverts on small tributaries

5.4 Freeboard

Freeboard is a factor of safety usually expressed in height above a flood level for purposes of flood risk management. Freeboard is typically applied to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood, such as uncertainty of the effect of bridges, hydrological uncertainty, uncertainty in model roughness etc. The OPW traditionally applied a freeboard of 0.3m for hard defences and 0.5m for soft defences, and whilst this is appropriate in many situations, there are instances where a higher freeboard should be allowed. A specific freeboard allowance has been calculated for this scheme as follows:

$$F_B = \sqrt{\sum A_1^2 + A_2^2 + A_3^2 + \ldots A_n^2}$$

Where:

F_B is the Freeboard Allowance in meters;

A_1 to A_n are the uncertainty in water level estimates for each input type. It was decided to take the average difference through the given reach and apply the one standard deviation value to the average. This way the value chosen will consider a range of values concentrated around the average and excludes any outliers that may be unduly influencing the freeboard.

Table 5-3 presents the input parameters tested with a brief description. Please refer to Appendix D for further details on the sensitivity testing that was used to derive the appropriate uncertainty levels, and therefore freeboard.

Table 5-3: Freeboard hydrologic/hydraulic parameter tested

Parameter	Type	Description
A1	Peak Flow	The uncertainty in the derived peak flow was developed and this allows an assessment of sensitivity flow on the water levels. A 23.5% increase in flow accounts for the uncertainty the calculation of Qmed, the Growth Curve and the Q100 Rating.
A2	Roughness	The models manning's n value indicating general roughness was increased to cover the uncertainty of the initial estimation. Roughness values are increased to the upper bounds limit of their classification
A3	Afflux at Bridges	The coefficients of velocity of bridges where defences are proposed have been reduced from 1.0 to 0.7 to assess their sensitivity.

The sea level element of the freeboard is dictated by the uncertainty in deriving the peak sea level for the design tidal event. This was assessed during the Lee CFRAM and based on the uncertainty analysis of the downstream boundary a figure of 0.3m was calculated.

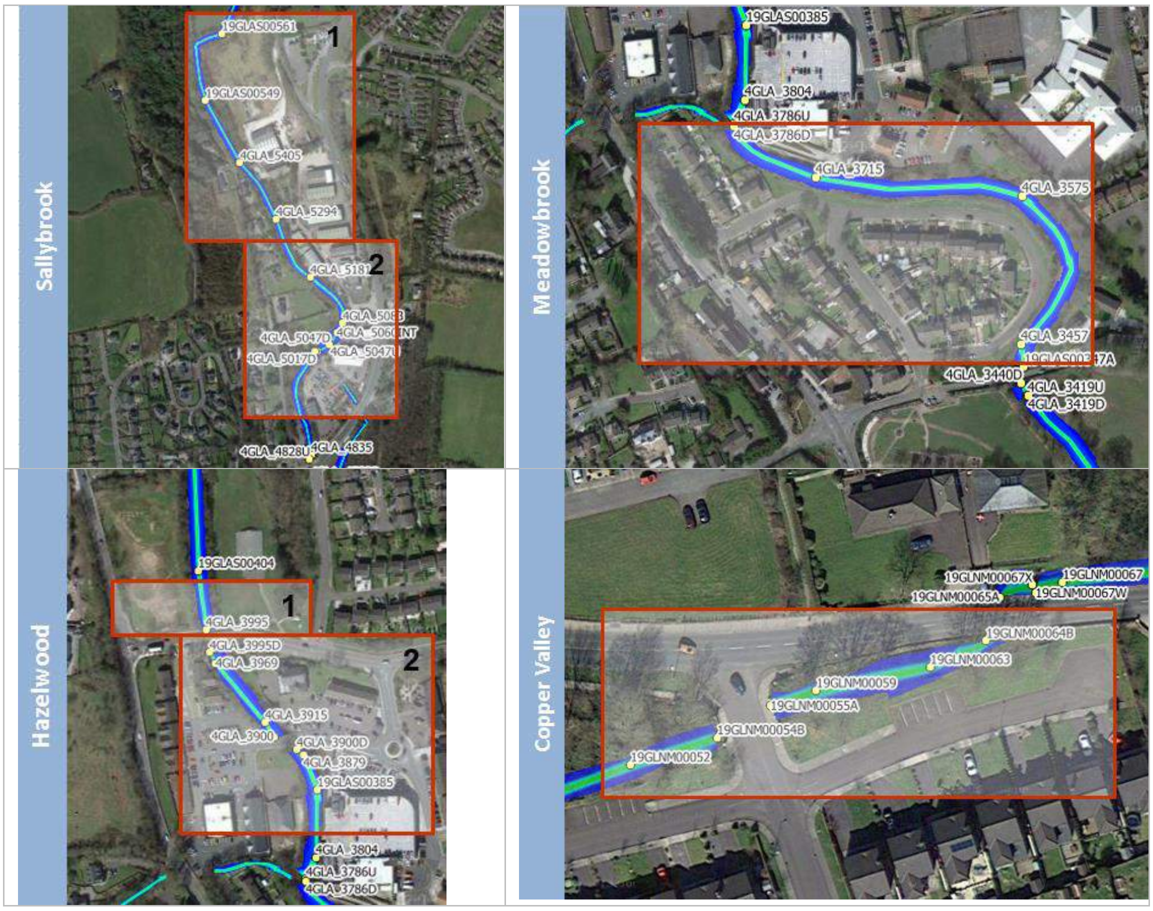
The emerging flood relief option in Section 5.4 was analysed in the following sections in terms of uncertainty and resulting freeboard allowance. Table 5-4 and Figure 5-31 shows the breakdown of the reaches in terms of sections and the locations throughout the Glashaboy catchment.

Table 5-4: Reaches selected for freeboard analysis

Reach	Description	US Node	DS Node
1	Sallybrook Industrial estate	19GLAS00561	4GLA_5017D
2	Hazelwood	19GLA_3995	4GLA_3804
3	Meadowbrook	4GLA_3786D	19GLAS00347A
4	The Grove	4GLA_2057	4GLA_1862
5	Copper Valley	19GLNM0064B	19GLNM00052
6	Butlerstown	4BUT_571	4BUT_468

Figure 5-7: Overview of freeboard reach locations

Figure 5-8: Breakdown of freeboard reaches



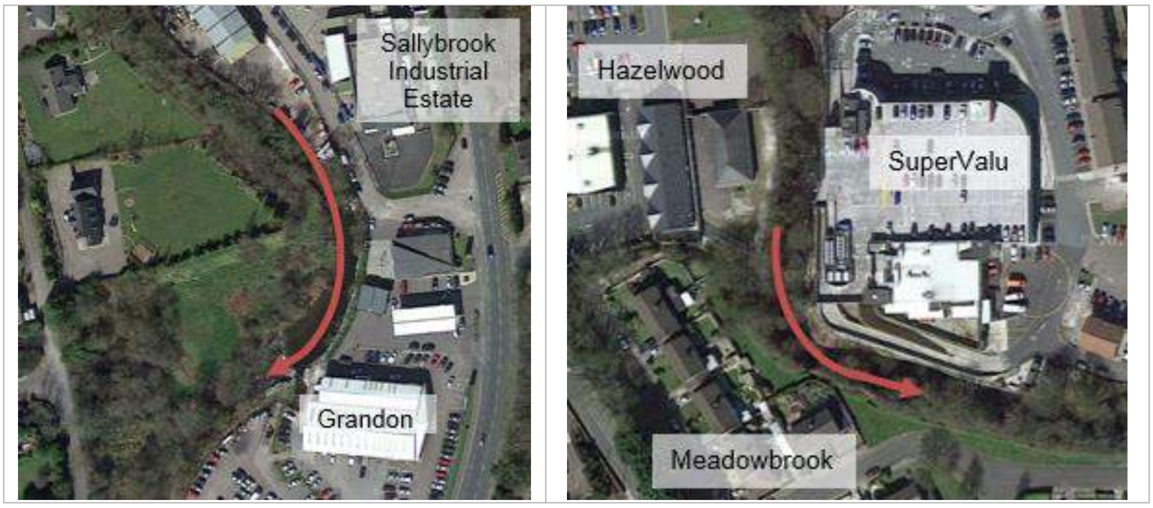
5.4.1 Superelevation

Superelevation is the effective increase in water levels as the river flows around a bend. There is an increase in the water level at the outer bank and a decrease water level on the inner bank because of the centrifugal force that is been exerted on the river body. Observations in the physical model testing of the Lower Lee FRS showed superelevation may be critical in confined, high velocity reaches. Through analysis of flood data from the 2012 this was identified as a cause of increased water levels at Meadowbrook. Accordingly, to account for the effect two bends have been identified for analysis, and the findings feed into the recommended freeboard allowances for the direct defences. These bends are at Grandon Car Sales in Sallybrook and at North of the Meadowbrook estate by SuperValu.

The superelevation has been calculated using the free vortex method[4] using the channel conditions in the defenced scenario. Figure 5-9 depicts the two bends considered in the superelevation calculations.

[4].Free vortex method based on V.T. Chow (1973), pp.444-448, Equation (16-11).

Figure 5-9: Bends at Grandons and Meadowbrook where superelevation is calculated



5.4.2 Summary results

The summary of the freeboard results can be seen in Table 5-5. The majority are higher than the 0.3m typically applied by the OPW. This is because of the complex nature of the Glashaboy system. The freeboard calculated ranges from 0.26m to 0.78m. These values do not account for construction allowances but super-elevation has been included as discussed in section 5.4.1.

Table 5-5: Summery results of freeboard analysis

Reach	Description	Hydraulic freeboard (m)	Superelevation (m)	Sea level uncertainty freeboard (m)	Total (m)
1	Sallybrook 1	0.26	-	-	0.26
1	Sallybrook 2	0.40	0.26	-	0.66
2	Hazelwood 1	0.74	-	-	0.74
2	Hazelwood 2	0.52	-	-	0.52
3	Meadowbrook	0.45	0.33	-	0.78
4	The Grove 1	0.33	-	-	0.33
4	The Grove 2	0.46	-	-	0.46
5	Copper Valley	0.35	-	-	0.35

6 Climate change adaption

6.1 Approaches to managing climate change

The OPW have defined a number of approaches to managing climate change risks, which are discussed further in the following sections. Of the four approaches, the sensitivity based approach has not been explicitly discussed; rather a sensitivity based approach is used to inform which of the other approaches would be appropriate for the design and implementation of measures. It has also extended to consideration of factors such as freeboard. The decision as to which approach is most applicable to a situation is driven by a number of factors, and primarily the benefit-cost ratio of a given situation. This is largely driven by the increase in flood risk which will be experienced overtime, but would also consider the practicalities associated with taking a course of action now, or delaying it until the future.

6.1.1 Assumptive approach

This approach assumes that a certain degree of impacts arising from climate change will occur. This means the scheme would be designed and built now to the levels estimated for the future. Although providing a degree of certainty in protection, the levels are reliant on today's estimates of climate change impacts (i.e. the anticipated increases in river flows) being correct. If the estimates are too high, the scheme would be built to a greater than necessary level, which could be visually intrusive and incur a high level of additional expenditure. Consequently, this has a negative impact on the cost benefit analysis for the scheme (higher costs and reduced visual and environmental benefits) making the scheme less likely to be beneficial. Alternatively, the estimates of climate change impacts may be too low, and river flows increase to a higher than anticipated level over a shorter than planned timeframe. This means the scheme would still not be sufficient to defend against the climate change levels and would still need to be reviewed in the future.

6.1.2 Adaptive approach

The adaptive approach provides a greater level of flexibility into the future, allowing the scheme to be built up as estimates improve, or increased evidence of climate change emerges.

Planning to increase defences in the future would require additional investment in the foundations of the scheme, but would allow easier 'up-build' in the future. The works to build the new, or in-fill, walls and embankments highlighted above would still be required in the future, but more certainty on the location and heights of these assets would develop over time. However, the scheme now would need to be designed to allow future construction to tie in to the current scheme.

In advance of undertaking adaptive works, the design of the scheme would allow some take up of the water level increases through the freeboard allowances. The freeboard is based on uncertainties derived from the modelling, and it is possible that as a better understanding of the hydrological record develops (i.e. as the record gets longer and more flood events are experienced) the modelling uncertainty will reduce, thereby warranting a reduced freeboard. The reduction in required freeboard could balance the increase in water levels due to climate change. The full freeboard allowance would contain the MRFS event at most, but not all, cross sections. There is a significant level of overtopping associated with nearly all sections under the HEFS. However, it should be stressed that the freeboard is an important element of the design, and is derived from factors other than just model uncertainty so it would be considered inappropriate to rely fully on freeboard as the adaptation measure. In addition, this assessment of freeboard has assumed the river banks on both sides of the river have a freeboard allowance, when in some cases the scheme is relying on existing structures which are unlikely to have an inbuilt freeboard, or the natural ground levels, which have no freeboard at all.

6.1.3 No physical provision

The final approach is to design and build the scheme with no adaptability for the future. This would see the walls, embankments and dredging implemented as designed. Whilst this avoids the initial increased costs in foundations, there is no scope for adaptability over time.

Appendices

A Hydraulic model results

A.1 1D model flows

Table A-1: 1D model peak current flows (fluvially dominant)

Cross Section	Peak Flow in Model (m3/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4GLA_8994D	20	31	38	46	54	61	68	86
4GLA_7993	20	31	38	46	54	61	68	86
4GLA_7983	20	31	38	46	54	61	68	86
4GLA_7983D	20	31	38	46	54	61	68	86
4GLA_7962	20	31	38	46	54	61	68	86
4GLA_7940	20	31	38	46	54	61	68	86
4GLA_7909U	20	31	38	46	54	61	68	86
4GLA_7909D	20	31	38	46	54	61	68	86
19GLAS00746	20	31	38	46	54	61	68	86
4GLA_7163	20	31	38	46	54	61	69	86
4GLA_6882U	20	31	38	46	54	61	68	86
4GLA_6882D	21	32	40	47	56	64	71	89
19GLAS00652	21	33	41	48	57	65	73	91
4GLA_6310	22	34	42	50	60	67	76	95
4GLA_5867	23	35	41	45	47	50	51	57
GLAS00570U	23	35	41	45	48	51	52	57
GLAS00570D	24	38	44	49	53	56	58	64
19GLAS00561	24	29	30	30	30	31	33	41
19GLAS00549	24	38	47	55	65	71	76	85
4GLA_5405	24	38	47	55	65	72	78	89
4GLA_5294	24	38	47	55	61	65	68	75
4GLA_5181	24	38	47	55	62	64	65	70
4GLA_5083	24	38	47	55	66	73	78	87
4GLA_5047U	24	38	47	55	64	69	74	85
4GLA_5047D	23	35	44	52	61	66	71	82
4GLA_5017U	23	35	42	46	49	52	55	59
4GLA_5017D	23	35	42	46	49	52	55	59
4GLA_4835	23	35	44	52	62	68	73	75
4GLA_4828U	23	35	44	52	62	68	73	75
4GLA_4792D	23	35	44	52	62	68	73	75
4GLA_4785	23	35	44	52	62	68	73	76
4GLA_4703U	23	36	44	52	62	69	74	87
4GLA_4703D	23	36	44	52	62	69	74	87
4GLA_4689	23	36	44	52	62	69	74	85
4GLA_4627	23	36	44	52	62	69	74	84
19GLAS00451	23	36	44	52	62	69	74	84
19GLAS00446	23	36	44	52	62	69	74	84
19GLAS00430	23	35	41	45	49	52	54	57
19GLAS00424	23	35	37	38	38	38	39	40
19GLAS00421U	23	35	37	37	38	38	38	38
19GLAS00421D	25	39	40	40	40	40	45	60
19GLAS00414	25	39	42	44	48	52	56	67
19GLAS00404	25	39	47	55	63	72	83	110
4GLA_3995	25	39	47	48	48	48	48	48
4GLA_3995D	25	39	47	48	48	48	48	48
4GLA_3969	25	39	47	51	57	61	65	71
4GLA_3915	25	39	47	51	54	57	64	78
4GLA_3900	25	39	47	50	51	51	51	51
4GLA_3900D	25	39	47	50	51	51	51	51
4GLA_3879	25	39	47	50	51	51	51	51
19GLAS00385	25	39	47	50	51	51	51	51
4GLA_3804	25	39	47	50	57	61	66	80
4GLA_3786U	25	39	49	57	67	73	81	99

Cross Section	Peak Flow in Model (m3/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4GLA_3786D	26	40	49	57	68	74	82	100
4GLA_3715	26	40	49	57	68	74	81	94
GLAS02	26	40	49	57	68	74	81	94
GLAS01	26	40	49	57	68	74	81	94
4GLA_3575	26	40	49	57	68	74	81	94
4GLA_3457	26	40	49	57	68	74	80	82
19GLAS00347A	26	40	49	57	68	76	85	90
19GLAS00347B	26	40	49	57	68	76	85	90
4GLA_3440	26	40	49	57	68	76	85	90
4GLA_3440D	26	40	49	57	68	76	85	90
4GLA_3419U	26	40	47	50	56	62	67	73
4GLA_3419D	26	40	47	50	56	62	67	73
4GLA_3259	26	40	49	57	63	65	68	69
4GLA_3138U	26	38	43	43	47	51	55	61
4GLA_3138D	44	63	76	76	101	111	120	143
4GLA_3034	44	64	78	78	108	117	127	153
4GLA_2917	44	65	80	80	115	129	143	179
4GLA_2809U	44	65	80	80	115	130	143	180
4GLA_2809D	42	62	75	75	103	116	128	165
4GLA_2786	42	62	75	75	102	114	125	143
4GLA_2786D	42	62	75	75	102	114	125	143
4GLA_2734	42	62	74	73	86	90	95	101
4GLA_2662	42	62	74	73	86	89	92	93
4GLA_2545	42	57	60	60	68	73	78	89
4GLA_2460	42	62	74	74	98	104	110	120
4GLA_2323U	42	59	66	66	79	83	88	98
4GLA_2323D	44	62	72	72	86	88	93	103
4GLA_2282	44	60	67	67	77	78	82	92
4GLA_2090	44	65	80	80	117	130	131	139
4GLA_2079	44	65	80	80	118	133	135	141
4GLA_2074	38	52	55	55	55	56	56	82
4GLA_2057	38	52	54	54	54	55	55	92
4GLA_1886	39	56	67	67	68	68	76	149
4GLA_1862	39	56	67	67	80	92	107	152
4GLA_1862D	39	56	67	67	80	92	107	152
4GLA_1846	39	56	67	67	79	92	107	153
4GLA_1702	39	57	68	68	98	112	125	168
4GLA_1628U	40	57	68	68	98	112	125	167
4GLA_1628D	45	66	80	80	115	129	142	183
4GLA_1626	45	66	80	80	115	129	142	183
4GLA_1418	46	67	81	81	116	130	142	187
4GLA_1320	47	67	82	82	116	130	143	188
4GLA_1146	49	69	84	84	118	132	145	198
4GLA_1012	51	71	86	85	120	134	146	193
4GLA_867	53	73	88	87	122	136	148	196
4GLA_750	54	75	89	89	123	137	149	193
4GLA_612	56	76	91	90	124	139	151	196
4GLA_493	58	78	92	92	126	140	153	196
4GLA_338	60	81	95	95	129	143	155	200
4GLA188	63	83	97	97	131	145	157	198
4GLA_0	66	87	101	101	134	149	161	210
4BUT_1284	14	21	26	31	37	42	47	59
4BUT_1212	14	21	26	31	37	42	47	59
4BUT_1098	14	21	26	31	37	42	47	59
4BUT_1072U	14	21	26	31	37	42	47	59
4BUT_1072D	14	21	26	31	37	42	47	59
4BUT_1007	14	21	26	31	37	42	47	59
4BUT_915	14	21	26	31	37	42	47	58

Cross Section	Peak Flow in Model (m3/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4BUT_806	14	21	26	31	37	42	47	58
4BUT_795	14	21	26	31	37	42	47	58
4BUT_795D	14	21	26	31	37	42	47	58
4BUT_759	14	21	26	31	37	42	47	58
4BUT_677	14	21	25	27	28	28	30	37
4BUT_571	14	20	22	24	25	27	29	34
4BUT_488	14	18	21	25	28	30	32	39
4BUT_468	14	21	26	30	34	36	39	45
4BUT_468D	14	21	26	30	34	36	39	45
4BUT_452	14	20	25	29	37	43	50	63
4BUT_442U	14	21	26	30	32	32	33	34
4BUT_442D	14	21	26	30	32	32	33	34
4BUT_416U	14	21	26	29	32	33	35	38
4BUT_416D	19	32	40	47	53	58	64	76
4BUT_349	19	32	40	47	53	58	64	76
4BUT_262	19	32	40	47	53	58	64	75
4BUT_152	19	32	40	47	53	58	64	76
4BUT_42	19	32	40	47	56	63	71	85
4BUT_25U	19	32	40	47	56	63	71	88
4BUT_25D	19	32	40	47	56	63	71	88
4BUT_0U	19	32	41	51	62	70	79	99
19GLNM00101	7.1	11	14	16	19	22	24	31
19GLNM00100A	7.1	11	14	16	19	18	19	20
19GLNM00096B	7.1	11	14	16	20	18	19	20
19GLNM00095	7.1	11	14	16	18	18	19	20
19GLMN00086	7.1	11	14	17	18	19	19	20
19GLNM00085A	7.1	11	14	15	18	18	18	20
19GLNM00084B	7.1	11	14	17	18	20	20	20
19GLNM00084W	7.1	11	14	15	21	16	17	20
19GLNM00083	7.1	11	14	15	21	16	17	20
19GLNM00067	7.1	11	14	16	16	19	20	22
19GLNM00067W	7.1	11	14	20	15	21	21	20
19GLNM00067X	7.1	11	14	20	15	21	21	20
19GLNM00066X	7.1	12	14	16	17	16	16	21
19GLNM00065A	7.1	8.8	9.2	9.4	10.5	9.6	9.6	10.1
19GLNM00064B	7.1	8.8	9.2	9.4	11	10	10	10
19GLNM00063	7	8.2	9.5	11.2	10	12	12	12
19GLNM00059	7.1	8.5	9.8	10	12	14	17	22
19GLNM00055A	7.1	9.8	10	11	11	11	11	11
19GLNM00054B	7.1	9.8	10	11	11	11	11	11
19GLNM00052	7.1	10	11	13	14	16	19	22
19GLNM00051	7.1	10.1	12	14	17	19	21	27
19GLNM00043	7.1	11	14	17	19	20	21	25
19GLNM00035	7.1	11	14	16	19	22	25	30
19GLNM00029	7.1	11	13	16	19	22	24	30
19GLNM00028A	7.1	11	12	12	12	12	12	12
19GLNM00028B	7.1	11	12	12	12	12	12	12
19GLNM00027A	7.1	11	12	13	14	15	15	15
19GLNM00027B	7.1	11	12	13	14	15	15	15
19GLNM00026	7.1	11	12	13	15	16	17	20
19GLNM00022	7.1	11	12	13	15	16	17	21
19GLNM00014	7.1	11	12	14	16	17	20	21
19GLNM00007	7.1	11	13	15	18	20	22	25
19GLNM00000	7.1	11	14	17	21	25	29	38
19BLCH00078	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.3
19BLCH00064	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.3
19BLCH00050	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.3
19BLCH00039	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.3

Cross Section	Peak Flow in Model (m3/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
19BLCH00031	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.3
19BLCH00022	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.2
19BLCH00015	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.1
19BLCH00014A	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.1
19BLCH00013B	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.1
19BLCH00012	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.1
19BLCH00007	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.1
19BLCH00006A	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.1
19BLCH00006B	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.1
19BLCH00003W	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.1
19BLCH00003X	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.1
19BLCH00002	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.1
19BLCH00001	1.7	2.6	3.2	3.9	4.6	5.2	5.8	7.2
19MLR300084	1.5	2.3	2.8	3.3	3.7	3.7	3.7	3.7
19MLR300083A	1.5	2.3	2.8	3.3	3.7	3.7	3.7	3.7
19MLR300079B	1.5	2.3	2.8	3.3	3.7	3.7	3.7	3.7
19MLR300077	1.5	2.3	2.8	3.3	3.7	4.8	6.9	7.8
19MLR300074A	1.5	2.3	2.8	3.3	3.7	5	5.6	5.6
19MLR300071B	1.5	2.3	2.8	3.3	3.7	5	5.6	5.6
19MLR300070	1.5	2.3	2.8	3.3	3.7	5	5.6	5.6
19MLR300065	1.5	2.3	2.8	3.3	3.7	5.3	11.6	25.5
19MLR300059	1.5	2.3	2.8	3.3	3.7	5.3	11	25.6
19MLR300053	1.5	2.1	2.5	2.9	3.3	4.5	8	12.1
19MLR300052A	1.5	2.1	2.5	2.9	3.3	4.5	8.3	10.8
19MLR300051B	1.5	2.1	2.5	2.9	3.3	4.5	8.3	10.8
19MLR300047	1.5	2.1	2.5	2.9	3.3	4.5	8.5	14.7
19MLR300039	1.5	2.2	2.5	2.9	3.3	4.5	8.5	19.2
19MLR300028	1.5	2.1	2.5	2.9	3.3	4.5	8.5	19
19MLR300014	1.5	2.1	2.5	2.9	3.2	4.4	8.3	19.8
19MLR300004	1.5	2.3	2.5	2.9	3.3	4.5	8.6	20.5
19MLR200002	2.5	3.3	6.8	10	13	15	17	17
19MLR200003A	2.5	3.3	6.8	10	13	15	17	17
19MLR200003B	2.5	3.3	6.8	10	13	15	17	17
19MLR200006	2.5	3.3	6.8	10	13	15	17	17
19MLR200012	2.5	3.3	6.8	10	13	15	16	16
19MLR200022	2.5	3.3	6.8	10	13	15	16	16
19MLR200028	2.5	3.3	6.8	10	13	15	16	16
19MLR200038	2.5	3.3	6.5	9	11	13	13	23
19MLR200042A	2.5	2.9	3.1	3.2	3.3	3.3	3.4	3.4
19MLR200042B	2.5	2.9	3.1	3.2	3.3	3.3	3.4	3.4
19MLR200047B	2.5	2.9	3.2	3.4	3.8	4	4.6	9.2
19MLR200046	2.5	3.3	4.5	5.5	6	5.8	6.3	8.7
19MLR200055	2.6	4	6.9	8.3	8.4	8.3	8.4	8.3
19MLR200058A	2.6	4	6.9	8.3	8.4	8.3	8.4	8.4
19MLR100001	7.3	16	50	49	170	173	173	173
19MLR100008	6.1	9.6	24	23	137	144	144	145
19MLR100009A	6.1	9.6	18	18	52	54	54	54
19MLR100009B	6.1	9.6	18	18	52	54	54	54
19MLR100011	6.1	9.6	18	18	62	65	65	65
19MLR100015	6.1	9.6	16	16	44	42	43	42
19MLR100016A	6.1	9.6	16	16	44	43	43	42
19MLR100016B	6.1	9.6	16	16	44	43	43	42
19MLR100019	6.1	9.6	16	16	44	42	43	42
19MLR100023	6.1	9.3	13	13	21	20	20	20
19MLR100024A	6.1	9.3	13	13	18	19	19	19
19MLR100025B	6.1	9.3	13	13	18	19	19	19
19MLR100027	6.1	9.3	13	13	20	18	19	19
19MLR100028A	6.2	9.3	13	13	16	16	16	16

Cross Section	Peak Flow in Model (m3/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
19MLR100028B	6.2	9.3	13	13	16	16	16	16
19MLR100029	6.2	9.3	13	13	19	18	18	18
19MLR100030A	6.2	9.3	13	13	18	18	18	18
19MLR100031	6.2	9.3	13	13	18	18	18	18
19MLR100033B	6.2	9.3	13	13	18	18	18	18
19MLR100034	6.2	9.3	13	13	18	18	18	18
19MLR100034A	6.2	9.3	13	13	18	18	18	18
19MLR100034B	6.2	9.3	13	13	18	18	18	18
19MLR100036	6.2	9.3	13	13	18	18	18	18
19MLR100039	6.2	9.4	13	13	18	18	18	19
19SPRG00027	0.6	0.9	1.1	1.3	1.6	1.8	2.0	2.5
19SPRG00026A	0.6	0.9	1.1	1.3	1.6	1.8	2.0	2.5
19SPRG00026B	0.6	0.9	1.1	1.3	1.6	1.8	2.0	2.5
19SPRG00025	0.6	0.9	1.1	1.3	1.6	1.8	2.0	2.5
19SPRG00019	0.6	0.9	1.1	1.3	1.6	1.8	2.0	2.5
19SPRG00015	0.6	0.9	1.1	1.3	1.6	1.8	2.0	2.5
19SPRG00011	0.6	0.9	1.1	1.3	1.6	1.8	2.0	2.5
19SPRG00010A	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
19SPRG00008B	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
19SPRG00006	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7
19SPRG00003	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7
19SPRG00001	0.5	0.6	0.5	0.5	0.7	1.0	1.2	1.9

Table A-2: 1D model peak current flows (tidally dominant)

Cross Section	Peak Flow in Model (m3/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4GLA_8994D	20	20	20	20	20	20	20	20
4GLA_7993	20	20	20	20	20	20	20	20
4GLA_7983	20	20	20	20	20	20	20	20
4GLA_7983D	20	20	20	20	20	20	20	20
4GLA_7962	20	20	20	20	20	20	20	20
4GLA_7940	20	20	20	20	20	20	20	20
4GLA_7909U	20	20	20	20	20	20	20	20
4GLA_7909D	20	20	20	20	20	20	20	20
19GLAS00746	20	20	20	20	20	20	20	20
4GLA_7163	20	20	20	20	20	20	20	20
4GLA_6882U	20	20	20	20	20	20	20	20
4GLA_6882D	21	21	21	21	21	21	21	21
19GLAS00652	21	21	21	21	21	21	21	21
4GLA_6310	22	22	22	22	22	22	22	22
4GLA_5867	23	23	23	23	23	23	23	23
GLAS00570U	23	23	23	23	23	23	23	23
GLAS00570D	24	24	24	24	24	24	24	24
19GLAS00561	24	24	24	24	24	24	24	24
19GLAS00549	24	24	24	24	24	24	24	24
4GLA_5405	24	24	24	24	24	24	24	24
4GLA_5294	24	24	24	24	24	24	24	24
4GLA_5181	24	24	24	24	24	24	24	24
4GLA_5083	24	24	24	24	24	24	24	24
4GLA_5047U	24	24	24	24	24	24	24	24
4GLA_5047D	23	23	23	23	23	23	23	23
4GLA_5017U	23	23	23	23	23	23	23	23
4GLA_5017D	23	23	23	23	23	23	23	23
4GLA_4835	23	23	23	23	23	23	23	23
4GLA_4828U	23	23	23	23	23	23	23	23
4GLA_4792D	23	23	23	23	23	23	23	23
4GLA_4785	23	23	23	23	23	23	23	23

Cross Section	Peak Flow in Model (m3/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4GLA_4703U	23	23	23	23	23	23	23	23
4GLA_4703D	23	23	23	23	23	23	23	23
4GLA_4689	23	23	23	23	23	23	23	23
4GLA_4627	23	23	23	23	23	23	23	23
19GLAS00451	23	23	23	23	23	23	23	23
19GLAS00446	23	23	23	23	23	23	23	23
19GLAS00430	23	23	23	23	23	23	23	23
19GLAS00424	23	23	23	23	23	23	23	23
19GLAS00421U	23	23	23	23	23	23	23	23
19GLAS00421D	25	25	25	25	25	25	25	25
19GLAS00414	25	25	25	25	25	25	25	25
19GLAS00404	25	25	25	25	25	25	25	25
4GLA_3995	25	25	25	25	25	25	25	25
4GLA_3995D	25	25	25	25	25	25	25	25
4GLA_3969	25	25	25	25	25	25	25	25
4GLA_3915	25	25	25	25	25	25	25	25
4GLA_3900	25	25	25	25	25	25	25	25
4GLA_3900D	25	25	25	25	25	25	25	25
4GLA_3879	25	25	25	25	25	25	25	25
19GLAS00385	25	25	25	25	25	25	25	25
4GLA_3804	25	25	25	25	25	25	25	25
4GLA_3786U	25	25	25	25	25	25	25	25
4GLA_3786D	26	26	26	26	26	26	26	26
4GLA_3715	26	26	26	26	26	26	26	26
GLAS02	26	26	26	26	26	26	26	26
GLAS01	26	26	26	26	26	26	26	26
4GLA_3575	26	26	26	26	26	26	26	26
4GLA_3457	26	26	26	26	26	26	26	26
19GLAS00347A	26	26	26	26	26	26	26	26
19GLAS00347B	26	26	26	26	26	26	26	26
4GLA_3440	26	26	26	26	26	26	26	26
4GLA_3440D	26	26	26	26	26	26	26	26
4GLA_3419U	26	26	26	26	26	26	26	26
4GLA_3419D	26	26	26	26	26	26	26	26
4GLA_3259	26	26	26	26	26	26	26	26
4GLA_3138U	26	26	26	26	26	26	26	26
4GLA_3138D	44	44	44	44	44	44	44	44
4GLA_3034	44	44	44	44	44	44	44	44
4GLA_2917	44	44	44	44	44	44	44	44
4GLA_2809U	44	44	44	44	44	44	44	44
4GLA_2809D	41	41	41	41	41	41	41	41
4GLA_2786	41	41	41	41	41	41	41	41
4GLA_2786D	41	41	41	41	41	41	41	41
4GLA_2734	41	41	41	41	41	41	41	41
4GLA_2662	41	41	41	41	41	41	41	41
4GLA_2545	41	41	41	41	41	41	41	41
4GLA_2460	41	41	41	41	41	41	41	41
4GLA_2323U	41	41	41	41	41	41	42	42
4GLA_2323D	44	44	44	44	44	44	44	44
4GLA_2282	44	44	44	44	44	44	43	43
4GLA_2090	44	44	44	44	44	44	44	44
4GLA_2079	44	44	44	44	44	44	44	44
4GLA_2074	38	38	38	38	37	37	37	36
4GLA_2057	38	38	38	38	37	37	37	36
4GLA_1886	39	39	39	39	39	38	38	38
4GLA_1862	39	39	39	39	39	39	38	38
4GLA_1862D	39	39	39	39	39	39	38	38
4GLA_1846	39	39	39	39	39	39	38	38

Cross Section	Peak Flow in Model (m3/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4GLA_1702	39	40	39	39	39	39	39	40
4GLA_1628U	39	40	40	40	39	39	39	40
4GLA_1628D	45	46	46	46	46	46	46	46
4GLA_1626	45	46	46	46	46	46	46	46
4GLA_1418	46	47	47	47	47	47	47	48
4GLA_1320	47	48	48	48	48	48	48	48
4GLA_1146	49	50	50	50	51	51	51	51
4GLA_1012	51	53	53	53	53	53	53	53
4GLA_867	53	55	55	55	56	56	55	55
4GLA_750	54	57	57	57	57	57	57	57
4GLA_612	56	59	59	59	59	59	59	59
4GLA_493	58	61	61	61	62	62	62	62
4GLA_338	60	64	65	64	65	65	65	65
4GLA188	63	67	68	68	68	68	68	69
4GLA_0	66	72	72	72	73	73	73	74
4BUT_1284	14	14	14	14	14	14	14	14
4BUT_1212	14	14	14	14	14	14	14	14
4BUT_1098	14	14	14	14	14	14	14	14
4BUT_1072U	14	14	14	14	14	14	14	14
4BUT_1072D	14	14	14	14	14	14	14	14
4BUT_1007	14	14	14	14	14	14	14	14
4BUT_915	14	14	14	14	14	14	14	14
4BUT_806	14	14	14	14	14	14	14	14
4BUT_795	14	14	14	14	14	14	14	14
4BUT_795D	14	14	14	14	14	14	14	14
4BUT_759	14	14	14	14	14	14	14	14
4BUT_677	14	14	14	14	14	14	14	14
4BUT_571	14	14	14	14	14	14	14	14
4BUT_488	14	14	14	14	14	14	14	14
4BUT_468	14	14	14	14	14	14	14	14
4BUT_468D	14	14	14	14	14	14	14	14
4BUT_452	14	14	14	14	14	14	14	14
4BUT_442U	14	14	14	14	14	14	14	14
4BUT_442D	14	14	14	14	14	14	14	14
4BUT_416U	14	14	14	14	14	14	14	14
4BUT_416D	19	19	19	19	19	19	19	19
4BUT_349	19	19	19	19	19	19	19	19
4BUT_262	19	19	19	19	19	19	19	19
4BUT_152	19	19	19	19	19	19	19	19
4BUT_42	19	19	19	19	19	19	19	19
4BUT_25U	19	19	19	19	19	19	19	19
4BUT_25D	19	19	19	19	19	19	19	19
4BUT_0U	19	19	19	19	19	19	19	19
19GLNM00101	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00100A	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00096B	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00095	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLMN00086	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00085A	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00084B	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00084W	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00083	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00067	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00067W	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00067X	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00066X	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00065A	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00064B	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1

Cross Section	Peak Flow in Model (m3/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
19GLNM00063	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
19GLNM00059	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00055A	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00054B	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00052	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00051	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00043	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00035	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00029	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00028A	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00028B	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00027A	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00027B	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00026	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00022	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00014	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00007	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19GLNM00000	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
19BLCH00078	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00064	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00050	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00039	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00031	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00022	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00015	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00014A	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00013B	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00012	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00007	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00006A	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00006B	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00003W	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00003X	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00002	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19BLCH00001	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
19MLR300084	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300083A	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300079B	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300077	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300074A	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300071B	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300070	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300065	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300059	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300053	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300052A	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300051B	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300047	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300039	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300028	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300014	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR300004	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
19MLR200002	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200003A	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200003B	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200006	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200012	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200022	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Cross Section	Peak Flow in Model (m3/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
19MLR200028	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200038	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200042A	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200042B	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200047B	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200046	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
19MLR200055	2.6	2.6	2.6	2.7	2.8	2.7	2.6	2.7
19MLR200058A	2.6	2.7	2.7	2.7	2.9	2.8	2.7	2.8
19MLR100001	7.3	8.4	9.0	9.8	11.3	12.8	14.6	31.5
19MLR100008	6.1	6.4	6.6	6.9	7.5	8.0	8.4	14.9
19MLR100009A	6.1	6.4	6.6	6.9	7.5	8.0	8.4	13.1
19MLR100009B	6.1	6.4	6.6	6.9	7.5	8.0	8.4	13.1
19MLR100011	6.1	6.4	6.6	6.9	7.5	8.1	8.4	13.2
19MLR100015	6.1	6.4	6.6	6.9	7.5	8.1	8.4	12.6
19MLR100016A	6.1	6.4	6.6	6.9	7.5	8.1	8.4	12.6
19MLR100016B	6.1	6.4	6.6	6.9	7.5	8.1	8.4	12.6
19MLR100019	6.1	6.4	6.6	6.9	7.5	8.1	8.4	12.7
19MLR100023	6.1	6.5	6.6	6.7	6.8	6.9	6.9	6.9
19MLR100024A	6.1	6.5	6.6	6.7	6.8	6.9	6.9	6.9
19MLR100025B	6.1	6.5	6.6	6.7	6.8	6.9	6.9	6.9
19MLR100027	6.1	6.5	6.6	6.7	6.8	6.9	6.9	6.9
19MLR100028A	6.2	6.5	6.6	6.7	6.8	6.9	6.9	7.0
19MLR100028B	6.2	6.5	6.6	6.7	6.8	6.9	6.9	7.0
19MLR100029	6.2	6.5	6.6	6.7	6.9	6.9	6.9	7.0
19MLR100030A	6.2	6.5	6.6	6.7	6.9	6.9	6.9	7.0
19MLR100031	6.2	6.5	6.6	6.7	6.9	6.9	6.9	7.0
19MLR100033B	6.2	6.5	6.6	6.7	6.9	6.9	7.0	7.0
19MLR100034	6.2	6.5	6.7	6.7	6.9	6.9	7.0	7.0
19MLR100034A	6.2	6.5	6.7	6.7	6.9	6.9	7.0	7.0
19MLR100034B	6.2	6.5	6.7	6.7	6.9	6.9	7.0	7.0
19MLR100036	6.2	6.5	6.7	6.8	6.9	6.9	7.0	7.0
19MLR100039	6.2	6.6	6.7	6.8	6.9	7.0	7.0	7.1
19SPRG00027	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
19SPRG00026A	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
19SPRG00026B	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
19SPRG00025	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
19SPRG00019	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
19SPRG00015	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
19SPRG00011	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
19SPRG00010A	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
19SPRG00008B	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
19SPRG00006	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
19SPRG00003	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
19SPRG00001	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54

A.2 1D model water levels

Table A-3: 1D model peak current water levels (fluvially dominant)

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4GLA_8994D	38.3	38.6	38.8	38.9	39.0	39.2	39.3	39.5
4GLA_7993	32.2	32.5	32.7	32.8	33.0	33.2	33.4	33.8
4GLA_7983	32.2	32.5	32.7	32.9	33.1	33.3	33.5	33.9
4GLA_7983D	31.9	32.2	32.4	32.6	32.8	32.9	33.1	33.4
4GLA_7962	31.7	32.1	32.3	32.5	32.7	32.8	33.0	33.3
4GLA_7940	31.6	31.9	32.1	32.3	32.5	32.7	32.8	33.1

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4GLA_7909U	31.4	31.7	31.9	32.1	32.7	32.9	33.1	33.4
4GLA_7909D	31.4	31.7	31.9	32.1	32.3	32.5	32.6	32.9
19GLAS00746	28.9	29.1	29.3	29.4	29.6	29.7	29.9	30.1
4GLA_7163	27.3	27.6	27.7	27.7	27.8	27.9	28.0	28.1
4GLA_6882U	25.9	26.1	26.2	26.3	26.4	26.4	26.5	26.6
4GLA_6882D	25.9	26.1	26.2	26.3	26.4	26.4	26.5	26.6
19GLAS00652	23.9	24.2	24.4	24.6	24.8	25.0	25.2	25.5
4GLA_6310	22.8	23.3	23.5	23.7	24.0	24.2	24.3	24.7
4GLA_5867	20.7	21.0	21.1	21.2	21.3	21.4	21.5	21.7
GLAS00570U	20.6	20.7	20.8	20.9	21.1	21.2	21.3	21.5
GLAS00570D	20.6	20.7	20.8	20.9	21.1	21.2	21.3	21.5
19GLAS00561	19.6	20.0	20.3	20.5	20.7	20.9	21.0	21.2
19GLAS00549	19.1	19.6	19.9	20.2	20.4	20.6	20.7	20.9
4GLA_5405	18.6	19.1	19.4	19.6	19.8	19.9	19.9	20.1
4GLA_5294	18.0	18.5	18.8	19.1	19.3	19.4	19.5	19.7
4GLA_5181	17.6	18.0	18.2	18.4	18.6	18.9	19.0	19.3
4GLA_5083	16.8	17.0	17.2	17.3	17.5	17.7	17.8	18.0
4GLA_5047U	16.7	17.0	17.2	17.3	17.5	17.7	17.9	18.1
4GLA_5047D	16.4	16.7	17.0	17.2	17.4	17.6	17.8	18.0
4GLA_5017U	16.4	16.7	16.9	17.2	17.4	17.6	17.8	18.0
4GLA_5017D	16.3	16.7	16.9	17.1	17.4	17.6	17.8	18.0
4GLA_4835	14.8	15.3	15.7	16.0	16.3	16.6	17.1	17.5
4GLA_4828U	15.0	15.5	15.8	16.1	16.4	16.7	17.2	17.5
4GLA_4792D	14.7	15.2	15.5	15.7	16.0	16.1	16.5	16.9
4GLA_4785	14.6	15.0	15.3	15.5	15.8	15.9	16.4	16.8
4GLA_4703U	14.2	14.6	14.8	15.0	15.3	15.5	16.1	16.4
4GLA_4703D	14.2	14.6	14.9	15.1	15.4	15.5	15.7	15.8
4GLA_4689	14.2	14.6	14.8	15.1	15.3	15.5	15.6	15.8
4GLA_4627	13.9	14.3	14.6	14.8	15.1	15.3	15.4	15.6
19GLAS00451	13.1	13.5	13.7	13.8	13.9	14.0	14.1	14.2
19GLAS00446	12.9	13.3	13.5	13.6	13.6	13.6	13.6	13.7
19GLAS00430	12.4	12.8	12.9	13.0	13.2	13.2	13.3	13.6
19GLAS00424	11.4	12.2	12.7	12.9	13.0	13.1	13.2	13.5
19GLAS00421U	11.4	12.1	12.6	12.9	13.0	13.1	13.2	13.5
19GLAS00421D	11.4	12.1	12.6	12.9	13.0	13.1	13.2	13.5
19GLAS00414	11.2	12.1	12.6	12.8	12.9	13.0	13.1	13.5
19GLAS00404	10.8	11.9	12.4	12.6	12.7	12.7	12.7	12.7
4GLA_3995	10.7	11.8	12.3	12.5	12.7	12.8	12.9	13.0
4GLA_3995D	10.7	11.4	11.8	12.0	12.2	12.3	12.4	12.6
4GLA_3969	10.6	11.3	11.7	11.9	12.0	12.1	12.2	12.3
4GLA_3915	10.3	11.1	11.5	11.7	11.9	12.0	12.0	12.1
4GLA_3900	10.3	11.1	11.5	11.7	12.0	12.1	12.2	12.3
4GLA_3900D	10.2	10.7	11.0	11.2	11.4	11.5	11.7	12.0
4GLA_3879	10.2	10.6	10.9	11.1	11.3	11.5	11.6	12.0
19GLAS00385	10.0	10.4	10.7	10.9	11.2	11.4	11.6	11.9
4GLA_3804	9.64	10.1	10.4	10.7	11.0	11.1	11.2	11.5
4GLA_3786U	9.42	9.88	10.2	10.4	10.6	10.7	10.8	10.9
4GLA_3786D	9.42	9.88	10.2	10.4	10.6	10.7	10.8	10.9
4GLA_3715	9.13	9.62	9.91	10.1	10.3	10.4	10.6	10.7
GLAS02	9.09	9.56	9.82	10.0	10.2	10.3	10.4	10.5
GLAS01	9.01	9.51	9.81	10.0	10.2	10.4	10.5	10.6
4GLA_3575	8.66	9.14	9.42	9.64	9.88	10.0	10.1	10.1
4GLA_3457	8.19	8.58	8.81	8.99	9.18	9.29	9.46	9.88
19GLAS00347A	8.16	8.59	8.83	9.01	9.22	9.34	9.48	9.75
19GLAS00347B	8.06	8.47	8.70	8.89	9.08	9.20	9.35	9.46
4GLA_3440	7.99	8.35	8.56	8.73	8.87	8.96	9.05	9.15
4GLA_3440D	7.87	8.20	8.38	8.51	8.59	8.62	8.64	8.70
4GLA_3419U	7.74	8.03	8.29	8.50	8.62	8.68	8.73	8.80

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4GLA_3419D	7.53	7.84	8.17	8.41	8.53	8.57	8.62	8.67
4GLA_3259	6.61	6.99	7.25	7.47	7.60	7.70	7.82	8.09
4GLA_3138U	6.40	6.84	7.06	7.23	7.40	7.52	7.65	7.94
4GLA_3138D	6.40	6.73	6.96	6.96	7.34	7.45	7.56	7.85
4GLA_3034	5.94	6.28	6.53	6.53	6.97	7.14	7.29	7.62
4GLA_2917	5.65	5.83	6.00	5.99	6.26	6.32	6.42	6.64
4GLA_2809U	5.59	5.75	5.94	5.94	6.26	6.35	6.41	6.43
4GLA_2809D	5.59	5.75	5.94	5.94	6.26	6.35	6.41	6.43
4GLA_2786	5.60	5.77	5.97	5.97	6.31	6.40	6.48	6.57
4GLA_2786D	5.02	5.63	5.91	5.90	6.25	6.34	6.41	6.48
4GLA_2734	4.74	5.27	5.51	5.51	5.87	5.96	6.01	6.18
4GLA_2662	4.47	4.90	5.06	5.06	5.46	5.61	5.71	6.05
4GLA_2545	4.12	4.64	4.91	4.91	5.40	5.53	5.64	5.89
4GLA_2460	3.97	4.41	4.55	4.55	4.78	4.91	4.99	5.29
4GLA_2323U	3.47	3.82	4.02	4.02	4.47	4.68	4.77	5.15
4GLA_2323D	3.47	3.82	4.02	4.02	4.47	4.68	4.77	5.15
4GLA_2282	3.27	3.63	3.87	3.87	4.43	4.65	4.74	5.15
4GLA_2090	2.84	3.07	3.23	3.23	3.45	3.75	4.09	4.81
4GLA_2079	2.84	3.07	3.24	3.24	3.50	3.80	4.14	4.84
4GLA_2074	2.80	3.04	3.23	3.22	3.52	3.81	4.14	4.81
4GLA_2057	2.79	3.02	3.22	3.22	3.53	3.82	4.14	4.78
4GLA_1886	2.70	2.86	2.99	2.99	3.52	3.75	3.96	4.67
4GLA_1862	2.68	2.84	2.97	2.97	3.28	3.47	3.73	4.49
4GLA_1862D	2.47	2.50	2.53	2.53	2.72	2.78	2.85	3.20
4GLA_1846	2.46	2.49	2.53	2.53	2.71	2.77	2.83	3.19
4GLA_1702	2.43	2.43	2.44	2.44	2.44	2.44	2.44	2.43
4GLA_1628U	2.44	2.45	2.46	2.46	2.48	2.50	2.51	2.57
4GLA_1628D	2.44	2.45	2.46	2.46	2.48	2.50	2.51	2.57
4GLA_1626	2.44	2.44	2.45	2.45	2.47	2.48	2.49	2.53
4GLA_1418	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43
4GLA_1320	2.44	2.44	2.45	2.45	2.46	2.47	2.47	2.50
4GLA_1146	2.44	2.44	2.44	2.44	2.46	2.46	2.47	2.50
4GLA_1012	2.43	2.44	2.44	2.44	2.46	2.46	2.47	2.49
4GLA_867	2.43	2.44	2.44	2.44	2.45	2.45	2.46	2.48
4GLA_750	2.43	2.43	2.44	2.44	2.44	2.44	2.45	2.46
4GLA_612	2.43	2.43	2.43	2.43	2.43	2.44	2.44	2.45
4GLA_493	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.44
4GLA_338	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43
4GLA188	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42
4GLA_0	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42
4BUT_1284	14.1	14.4	14.5	14.6	14.8	14.9	14.9	15.1
4BUT_1212	13.5	13.8	13.9	14.0	14.1	14.1	14.2	14.3
4BUT_1098	13.0	13.3	13.4	13.5	13.6	13.6	13.7	13.9
4BUT_1072U	12.9	13.2	13.3	13.4	13.5	13.6	13.6	13.9
4BUT_1072D	12.8	12.9	13.0	13.1	13.2	13.2	13.3	13.6
4BUT_1007	12.1	12.3	12.4	12.5	12.6	12.7	12.9	13.5
4BUT_915	11.2	11.6	11.8	12.0	12.2	12.5	12.8	13.5
4BUT_806	10.9	11.4	11.7	11.9	12.2	12.5	12.8	13.5
4BUT_795	10.9	11.4	11.7	11.9	12.2	12.5	12.8	13.5
4BUT_795D	10.5	10.7	10.9	11.0	11.1	11.2	11.3	11.5
4BUT_759	10.2	10.5	10.6	10.6	10.7	10.7	10.7	10.9
4BUT_677	9.69	10.0	10.1	10.2	10.4	10.5	10.6	10.8
4BUT_571	9.14	9.64	9.82	10.0	10.3	10.4	10.5	10.7
4BUT_488	8.93	9.62	9.81	10.0	10.2	10.4	10.5	10.7
4BUT_468	8.88	9.59	9.76	10.0	10.2	10.3	10.4	10.6
4BUT_468D	8.84	9.50	9.63	9.77	10.0	10.1	10.1	10.3
4BUT_452	8.83	9.50	9.63	9.77	9.94	10.0	10.1	10.2
4BUT_442U	8.82	9.49	9.62	9.76	10.0	10.1	10.2	10.3

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4BUT_442D	8.47	8.88	9.08	9.25	9.42	9.56	9.72	10.1
4BUT_416U	8.28	8.72	8.93	9.12	9.27	9.38	9.51	9.87
4BUT_416D	8.28	8.72	8.93	9.12	9.27	9.38	9.51	9.87
4BUT_349	8.12	8.59	8.81	9.00	9.16	9.28	9.41	9.86
4BUT_262	7.76	8.26	8.47	8.66	8.84	8.97	9.12	9.67
4BUT_152	7.06	7.40	7.60	7.79	7.98	8.11	8.26	9.34
4BUT_42	6.41	6.85	7.10	7.31	7.53	7.69	7.88	9.23
4BUT_25U	6.44	6.89	7.14	7.35	7.57	7.73	7.92	9.23
4BUT_25D	6.39	6.80	7.03	7.21	7.38	7.49	7.62	7.92
4BUT_0U	6.41	6.85	7.08	7.26	7.43	7.55	7.68	7.99
19GLNM00101	16.8	17.1	17.3	17.5	17.6	17.6	17.6	17.6
19GLNM00100A	16.7	17.1	17.3	17.5	17.6	17.7	17.8	18.0
19GLNM00096B	15.7	16.0	16.2	16.3	16.4	16.5	16.5	16.5
19GLNM00095	15.5	15.8	16.0	16.2	16.3	16.3	16.3	16.3
19GLMN00086	15.4	15.7	15.9	16.1	16.2	16.2	16.3	16.4
19GLNM00085A	15.4	15.8	15.9	16.2	16.3	16.4	16.4	16.3
19GLNM00084B	15.1	15.4	15.6	15.6	15.9	15.8	15.8	16.0
19GLNM00084W	15.1	15.4	15.5	15.9	15.7	16.0	16.0	16.0
19GLNM00083	14.9	15.1	15.4	15.7	15.5	15.9	15.9	15.9
19GLNM00067	14.2	14.8	14.9	14.9	15.3	15.0	15.0	15.3
19GLNM00067W	14.2	14.7	14.8	15.0	15.1	15.0	15.0	15.2
19GLNM00067X	14.2	14.7	14.8	14.9	15.1	14.9	14.9	15.1
19GLNM00066X	14.2	14.7	14.7	14.8	14.9	14.8	14.8	15.0
19GLNM00065A	14.2	14.8	14.9	14.9	15.2	15.0	15.0	15.2
19GLNM00064B	14.0	14.4	14.5	14.5	14.6	14.6	14.6	14.7
19GLNM00063	13.9	14.3	14.4	14.5	14.5	14.6	14.6	14.7
19GLNM00059	13.9	14.3	14.4	14.5	14.5	14.6	14.6	14.6
19GLNM00055A	13.9	14.3	14.4	14.4	14.6	14.6	14.6	14.7
19GLNM00054B	12.9	13.1	13.2	13.4	13.6	13.8	14.0	14.3
19GLNM00052	12.6	12.8	13.0	13.1	13.2	13.4	13.4	13.7
19GLNM00051	12.2	12.5	12.7	12.8	12.9	12.9	12.9	13.0
19GLNM00043	11.6	11.8	11.9	12.1	12.2	12.3	12.5	12.7
19GLNM00035	10.7	11.1	11.2	11.4	11.5	11.6	11.6	11.8
19GLNM00029	10.3	11.1	11.2	11.4	11.4	11.5	11.5	11.5
19GLNM00028A	10.2	11.0	11.3	11.5	11.6	11.7	11.8	12.0
19GLNM00028B	10.2	10.6	10.8	10.9	11.1	11.3	11.4	11.5
19GLNM00027A	10.3	10.7	10.8	10.9	11.1	11.2	11.3	11.5
19GLNM00027B	10.2	10.4	10.5	10.5	10.6	10.7	10.8	11.1
19GLNM00026	10.0	10.2	10.2	10.3	10.3	10.4	10.5	10.7
19GLNM00022	9.81	10.0	10.1	10.2	10.3	10.3	10.5	10.6
19GLNM00014	9.09	9.28	9.39	9.53	9.67	9.79	9.92	10.4
19GLNM00007	8.60	8.88	9.07	9.25	9.44	9.59	9.77	10.3
19GLNM00000	8.28	8.72	8.93	9.12	9.27	9.38	9.51	9.87
19BLCH00078	43.4	43.5	43.6	43.6	43.7	43.7	43.7	43.8
19BLCH00064	39.3	39.4	39.5	39.6	39.7	39.7	39.7	39.8
19BLCH00050	34.7	34.8	34.9	34.9	35.0	35.0	35.1	35.2
19BLCH00039	30.9	31.0	31.1	31.1	31.3	31.3	31.4	31.4
19BLCH00031	29.0	29.1	29.2	29.2	29.2	29.2	29.3	29.5
19BLCH00022	26.0	26.0	26.1	26.1	26.3	26.6	27.2	28.6
19BLCH00015	24.9	25.0	25.2	25.6	26.1	26.6	27.2	28.6
19BLCH00014A	24.7	25.0	25.2	25.6	26.1	26.6	27.2	28.6
19BLCH00013B	24.3	24.4	24.5	24.6	24.6	24.7	24.7	24.8
19BLCH00012	24.0	24.1	24.2	24.2	24.3	24.3	24.3	24.4
19BLCH00007	22.4	22.5	22.5	22.6	22.7	22.7	22.8	22.9
19BLCH00006A	22.3	22.4	22.4	22.5	22.6	22.6	22.7	22.8
19BLCH00006B	22.3	22.4	22.4	22.5	22.5	22.6	22.6	22.7
19BLCH00003W	22.2	22.4	22.4	22.5	22.5	22.6	22.6	22.7
19BLCH00003X	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.7

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
19BLCH00002	20.6	20.8	20.9	20.9	21.0	21.1	21.2	21.4
19BLCH00001	20.6	20.7	20.8	20.9	21.1	21.2	21.3	21.5
19MLR300084	16.7	17.0	17.2	17.3	17.5	17.7	17.9	18.1
19MLR300083A	16.7	17.0	17.1	17.3	17.5	17.7	17.9	18.1
19MLR300079B	16.1	16.3	16.4	16.4	16.6	17.0	17.5	18.3
19MLR300077	16.1	16.3	16.4	16.5	16.6	17.0	17.4	17.9
19MLR300074A	16.1	16.3	16.4	16.5	16.6	17.0	17.5	17.8
19MLR300071B	16.1	16.2	16.2	16.3	16.3	16.5	16.9	17.4
19MLR300070	16.0	16.1	16.2	16.3	16.3	16.4	16.9	17.4
19MLR300065	16.0	16.1	16.2	16.2	16.3	16.4	16.8	17.0
19MLR300059	16.0	16.1	16.2	16.2	16.3	16.4	16.8	17.0
19MLR300053	15.9	16.0	16.0	16.1	16.1	16.3	16.6	16.9
19MLR300052A	15.8	15.9	16.0	16.0	16.1	16.2	16.5	16.8
19MLR300051B	12.4	12.6	12.8	13.0	13.1	13.2	13.5	14.3
19MLR300047	12.2	12.4	12.7	12.9	13.1	13.2	13.4	14.0
19MLR300039	11.9	12.2	12.7	12.9	13.0	13.1	13.3	13.7
19MLR300028	11.6	12.2	12.7	12.9	13.0	13.1	13.2	13.6
19MLR300014	11.4	12.1	12.6	12.9	13.0	13.1	13.2	13.5
19MLR300004	11.4	12.1	12.6	12.9	13.0	13.1	13.2	13.5
19MLR200002	5.59	5.82	6.03	6.18	6.32	6.39	6.45	6.45
19MLR200003A	5.59	5.82	6.03	6.18	6.32	6.39	6.45	6.45
19MLR200003B	5.59	5.81	6.01	6.14	6.24	6.30	6.34	6.34
19MLR200006	5.58	5.81	5.99	6.10	6.20	6.25	6.29	6.31
19MLR200012	5.57	5.80	5.97	6.07	6.17	6.21	6.25	6.31
19MLR200022	5.55	5.78	5.94	6.01	6.07	6.10	6.12	6.23
19MLR200028	5.54	5.78	5.92	5.97	6.01	6.02	6.03	6.22
19MLR200038	5.54	5.77	5.91	5.96	6.00	6.02	6.03	6.04
19MLR200042A	5.51	5.75	5.90	5.96	6.02	6.04	6.06	6.20
19MLR200042B	3.51	4.00	4.25	4.50	4.74	4.87	4.99	5.38
19MLR200047B	3.49	3.98	4.24	4.48	4.73	4.86	5.00	5.20
19MLR200046	3.49	3.99	4.24	4.48	4.73	4.86	5.02	5.19
19MLR200055	3.49	3.98	4.23	4.47	4.72	4.85	4.99	5.37
19MLR200058A	3.49	3.98	4.23	4.47	4.72	4.85	5.00	5.36
19MLR100001	2.84	3.07	3.24	3.24	3.50	3.80	4.14	4.84
19MLR100008	2.80	3.10	3.71	3.70	4.15	4.16	4.15	4.82
19MLR100009A	2.78	3.04	3.32	3.31	4.65	4.74	4.74	4.95
19MLR100009B	2.78	3.04	3.32	3.31	4.65	4.74	4.74	4.95
19MLR100011	2.76	3.03	3.34	3.34	4.22	4.32	4.32	4.78
19MLR100015	2.72	2.96	3.23	3.22	4.51	4.67	4.67	4.88
19MLR100016A	2.71	2.93	3.17	3.16	4.49	4.67	4.67	4.90
19MLR100016B	2.70	2.92	3.09	3.09	3.32	3.31	3.35	3.34
19MLR100019	2.70	2.93	3.13	3.13	3.16	3.17	3.16	3.16
19MLR100023	2.55	2.70	2.94	2.93	3.81	3.79	3.86	3.79
19MLR100024A	2.59	2.76	3.03	3.02	3.98	3.88	3.91	3.88
19MLR100025B	2.56	2.69	2.86	2.85	3.42	3.37	3.35	3.38
19MLR100027	2.54	2.65	2.81	2.80	3.30	3.39	3.35	3.41
19MLR100028A	2.50	2.57	2.67	2.66	3.31	3.38	3.31	3.38
19MLR100028B	2.50	2.56	2.62	2.62	3.14	3.15	3.11	3.15
19MLR100029	2.51	2.60	2.69	2.69	3.14	3.11	3.10	3.10
19MLR100030A	2.49	2.55	2.61	2.60	3.00	2.93	2.97	2.95
19MLR100031	2.45	2.48	2.50	2.49	2.59	2.59	2.60	2.67
19MLR100033B	2.45	2.47	2.48	2.48	2.55	2.56	2.57	2.63
19MLR100034	2.45	2.46	2.48	2.47	2.53	2.54	2.55	2.61
19MLR100034A	2.45	2.46	2.48	2.48	2.53	2.54	2.55	2.62
19MLR100034B	2.45	2.46	2.48	2.48	2.53	2.54	2.55	2.62
19MLR100036	2.45	2.46	2.48	2.48	2.53	2.54	2.55	2.62
19MLR100039	2.45	2.47	2.48	2.48	2.55	2.56	2.57	2.62
19SPRG00027	23.1	23.2	23.2	23.2	23.2	23.2	23.3	23.3

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
19SPRG00026A	21.5	21.6	21.6	21.7	21.7	21.8	21.8	21.9
19SPRG00026B	21.5	21.6	21.6	21.7	21.7	21.8	21.8	21.9
19SPRG00025	19.1	19.2	19.2	19.2	19.2	19.3	19.3	19.3
19SPRG00019	16.6	16.7	16.7	16.7	16.7	16.8	16.8	16.8
19SPRG00015	14.5	14.5	14.6	14.6	14.6	14.7	14.7	14.7
19SPRG00011	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.3
19SPRG00010A	13.2	13.2	13.2	13.2	13.3	13.3	13.3	13.3
19SPRG00008B	10.3	10.3	10.3	10.4	10.6	10.7	10.8	10.9
19SPRG00006	10.2	10.2	10.2	10.4	10.6	10.7	10.8	10.9
19SPRG00003	9.69	9.88	10.2	10.4	10.6	10.7	10.8	10.9
19SPRG00001	9.42	9.88	10.2	10.4	10.6	10.7	10.8	10.9

Table A-4: 1D model peak current water levels (tidally dominant)

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4GLA_8994D	38.3	38.3	38.3	38.3	38.3	38.3	38.3	38.3
4GLA_7993	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2
4GLA_7983	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2
4GLA_7983D	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9
4GLA_7962	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7
4GLA_7940	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6
4GLA_7909U	31.4	31.4	31.4	31.4	31.4	31.4	31.4	31.4
4GLA_7909D	31.4	31.4	31.4	31.4	31.4	31.4	31.4	31.4
19GLAS00746	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9
4GLA_7163	27.3	27.3	27.3	27.3	27.3	27.3	27.3	27.3
4GLA_6882U	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9
4GLA_6882D	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9
19GLAS00652	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9
4GLA_6310	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8
4GLA_5867	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7
GLAS00570U	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6
GLAS00570D	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6
19GLAS00561	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
19GLAS00549	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
4GLA_5405	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
4GLA_5294	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
4GLA_5181	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
4GLA_5083	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8
4GLA_5047U	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7
4GLA_5047D	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4
4GLA_5017U	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4
4GLA_5017D	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3
4GLA_4835	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8
4GLA_4828U	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
4GLA_4792D	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
4GLA_4785	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
4GLA_4703U	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
4GLA_4703D	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
4GLA_4689	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
4GLA_4627	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
19GLAS00451	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1
19GLAS00446	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
19GLAS00430	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
19GLAS00424	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4
19GLAS00421U	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4
19GLAS00421D	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4
19GLAS00414	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
19GLAS00404	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8
4GLA_3995	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
4GLA_3995D	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
4GLA_3969	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
4GLA_3915	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
4GLA_3900	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
4GLA_3900D	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
4GLA_3879	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
19GLAS00385	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
4GLA_3804	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64
4GLA_3786U	9.42	9.42	9.42	9.42	9.42	9.42	9.42	9.42
4GLA_3786D	9.42	9.42	9.42	9.42	9.42	9.42	9.42	9.42
4GLA_3715	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13
GLAS02	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09
GLAS01	9.01	9.01	9.01	9.01	9.01	9.01	9.01	9.01
4GLA_3575	8.66	8.66	8.66	8.66	8.66	8.66	8.66	8.66
4GLA_3457	8.19	8.19	8.19	8.19	8.19	8.19	8.19	8.19
19GLAS00347A	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16
19GLAS00347B	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06
4GLA_3440	7.99	7.99	7.99	7.99	7.99	7.99	7.99	7.99
4GLA_3440D	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87
4GLA_3419U	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74
4GLA_3419D	7.53	7.53	7.53	7.53	7.53	7.53	7.53	7.53
4GLA_3259	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61
4GLA_3138U	6.40	6.40	6.40	6.40	6.40	6.40	6.40	6.40
4GLA_3138D	6.40	6.40	6.40	6.40	6.40	6.40	6.40	6.40
4GLA_3034	5.94	5.94	5.94	5.94	5.94	5.94	5.94	5.94
4GLA_2917	5.65	5.65	5.65	5.65	5.65	5.65	5.65	5.65
4GLA_2809U	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59
4GLA_2809D	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59
4GLA_2786	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
4GLA_2786D	5.02	5.03	5.03	5.03	5.03	5.03	5.03	5.03
4GLA_2734	4.74	4.74	4.74	4.74	4.75	4.75	4.75	4.75
4GLA_2662	4.47	4.47	4.47	4.48	4.48	4.48	4.48	4.49
4GLA_2545	4.12	4.12	4.12	4.13	4.13	4.13	4.14	4.15
4GLA_2460	3.97	3.98	3.98	3.98	3.99	3.99	4.00	4.02
4GLA_2323U	3.47	3.49	3.50	3.51	3.53	3.55	3.57	3.62
4GLA_2323D	3.47	3.49	3.50	3.51	3.53	3.55	3.57	3.62
4GLA_2282	3.27	3.30	3.32	3.34	3.38	3.41	3.44	3.51
4GLA_2090	2.84	2.90	2.95	2.98	3.05	3.10	3.16	3.28
4GLA_2079	2.84	2.90	2.95	2.99	3.05	3.10	3.17	3.29
4GLA_2074	2.80	2.88	2.92	2.96	3.03	3.09	3.15	3.29
4GLA_2057	2.79	2.86	2.91	2.95	3.02	3.08	3.15	3.28
4GLA_1886	2.70	2.78	2.83	2.88	2.96	3.02	3.09	3.26
4GLA_1862	2.68	2.77	2.82	2.87	2.95	3.01	3.08	3.26
4GLA_1862D	2.47	2.57	2.64	2.70	2.80	2.89	3.01	3.26
4GLA_1846	2.46	2.57	2.64	2.70	2.80	2.89	3.01	3.26
4GLA_1702	2.43	2.55	2.62	2.68	2.78	2.89	2.99	3.24
4GLA_1628U	2.44	2.55	2.62	2.68	2.78	2.88	2.98	3.23
4GLA_1628D	2.44	2.55	2.62	2.68	2.78	2.88	2.98	3.23
4GLA_1626	2.44	2.55	2.62	2.68	2.78	2.88	2.98	3.22
4GLA_1418	2.43	2.55	2.62	2.67	2.77	2.85	2.93	3.16
4GLA_1320	2.44	2.55	2.62	2.68	2.78	2.86	2.94	3.13
4GLA_1146	2.44	2.55	2.62	2.68	2.78	2.86	2.93	3.11
4GLA_1012	2.43	2.55	2.62	2.68	2.78	2.85	2.93	3.11
4GLA_867	2.43	2.54	2.61	2.67	2.77	2.85	2.93	3.11
4GLA_750	2.43	2.54	2.61	2.67	2.77	2.85	2.93	3.11
4GLA_612	2.43	2.54	2.61	2.67	2.77	2.85	2.93	3.11

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
4GLA_493	2.43	2.54	2.61	2.67	2.77	2.85	2.93	3.11
4GLA_338	2.43	2.54	2.61	2.67	2.77	2.84	2.92	3.11
4GLA188	2.42	2.54	2.60	2.66	2.76	2.84	2.92	3.10
4GLA_0	2.42	2.53	2.60	2.66	2.76	2.84	2.92	3.10
4BUT_1284	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1
4BUT_1212	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
4BUT_1098	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
4BUT_1072U	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
4BUT_1072D	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
4BUT_1007	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
4BUT_915	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
4BUT_806	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
4BUT_795	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
4BUT_795D	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
4BUT_759	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
4BUT_677	9.69	9.69	9.69	9.69	9.69	9.69	9.69	9.69
4BUT_571	9.14	9.14	9.14	9.14	9.14	9.14	9.14	9.14
4BUT_488	8.93	8.93	8.93	8.93	8.93	8.93	8.93	8.93
4BUT_468	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88
4BUT_468D	8.84	8.84	8.84	8.84	8.84	8.84	8.84	8.84
4BUT_452	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83
4BUT_442U	8.82	8.82	8.82	8.82	8.82	8.82	8.82	8.82
4BUT_442D	8.47	8.47	8.47	8.47	8.47	8.47	8.47	8.47
4BUT_416U	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28
4BUT_416D	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28
4BUT_349	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12
4BUT_262	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76
4BUT_152	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06
4BUT_42	6.41	6.41	6.41	6.41	6.41	6.41	6.41	6.41
4BUT_25U	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44
4BUT_25D	6.39	6.39	6.39	6.39	6.39	6.39	6.39	6.39
4BUT_0U	6.41	6.41	6.41	6.41	6.41	6.41	6.41	6.41
19GLNM00101	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8
19GLNM00100A	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7
19GLNM00096B	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7
19GLNM00095	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
19GLMN00086	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4
19GLNM00085A	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4
19GLNM00084B	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
19GLNM00084W	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
19GLNM00083	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9
19GLNM00067	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
19GLNM00067W	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
19GLNM00067X	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
19GLNM00066X	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
19GLNM00065A	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
19GLNM00064B	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
19GLNM00063	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
19GLNM00059	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
19GLNM00055A	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
19GLNM00054B	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
19GLNM00052	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
19GLNM00051	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
19GLNM00043	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
19GLNM00035	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
19GLNM00029	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
19GLNM00028A	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
19GLNM00028B	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
19GLNM00027A	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
19GLNM00027B	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
19GLNM00026	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
19GLNM00022	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
19GLNM00014	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
19GLNM00007	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6
19GLNM00000	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
19BLCH00078	43.4	43.4	43.4	43.4	43.4	43.4	43.4	43.4
19BLCH00064	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3
19BLCH00050	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7
19BLCH00039	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9
19BLCH00031	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0
19BLCH00022	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
19BLCH00015	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9
19BLCH00014A	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7
19BLCH00013B	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3
19BLCH00012	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
19BLCH00007	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4
19BLCH00006A	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3
19BLCH00006B	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3
19BLCH00003W	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
19BLCH00003X	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9
19BLCH00002	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6
19BLCH00001	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6
19MLR300084	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7
19MLR300083A	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7
19MLR300079B	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
19MLR300077	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
19MLR300074A	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
19MLR300071B	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
19MLR300070	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
19MLR300065	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
19MLR300059	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
19MLR300053	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
19MLR300052A	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8
19MLR300051B	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
19MLR300047	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
19MLR300039	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
19MLR300028	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
19MLR300014	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4
19MLR300004	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4
19MLR200002	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59
19MLR200003A	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59
19MLR200003B	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59
19MLR200006	5.58	5.58	5.58	5.58	5.58	5.58	5.58	5.58
19MLR200012	5.57	5.57	5.57	5.57	5.57	5.57	5.57	5.57
19MLR200022	5.55	5.55	5.55	5.55	5.55	5.55	5.55	5.55
19MLR200028	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54
19MLR200038	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54
19MLR200042A	5.51	5.51	5.51	5.51	5.51	5.51	5.51	5.51
19MLR200042B	3.51	3.53	3.54	3.55	3.57	3.59	3.61	3.66
19MLR200047B	3.49	3.51	3.52	3.53	3.55	3.57	3.60	3.64
19MLR200046	3.49	3.51	3.52	3.54	3.56	3.58	3.60	3.65
19MLR200055	3.49	3.51	3.52	3.54	3.56	3.58	3.60	3.65
19MLR200058A	3.49	3.51	3.52	3.54	3.56	3.58	3.60	3.65
19MLR100001	2.84	2.90	2.95	2.99	3.05	3.10	3.17	3.29
19MLR100008	2.80	2.88	2.94	2.98	3.06	3.12	3.20	3.52
19MLR100009A	2.78	2.86	2.91	2.96	3.02	3.09	3.17	3.46

Cross Section	Peak Stage in Model (mOD)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
19MLR100009B	2.78	2.86	2.91	2.96	3.02	3.07	3.10	3.26
19MLR100011	2.76	2.84	2.90	2.95	3.02	3.06	3.10	3.26
19MLR100015	2.72	2.81	2.86	2.91	2.97	3.02	3.05	3.26
19MLR100016A	2.71	2.79	2.85	2.90	2.96	3.00	3.04	3.26
19MLR100016B	2.70	2.79	2.84	2.89	2.95	2.99	3.03	3.25
19MLR100019	2.70	2.79	2.85	2.90	2.96	3.00	3.04	3.25
19MLR100023	2.55	2.66	2.74	2.80	2.89	2.96	3.03	3.26
19MLR100024A	2.59	2.70	2.76	2.82	2.91	2.98	3.04	3.26
19MLR100025B	2.56	2.66	2.73	2.78	2.87	2.94	3.01	3.25
19MLR100027	2.54	2.64	2.71	2.77	2.86	2.93	3.01	3.25
19MLR100028A	2.50	2.61	2.68	2.74	2.84	2.91	3.01	3.25
19MLR100028B	2.50	2.60	2.67	2.73	2.82	2.89	3.00	3.25
19MLR100029	2.51	2.62	2.68	2.74	2.83	2.90	3.00	3.25
19MLR100030A	2.49	2.60	2.67	2.72	2.82	2.89	3.00	3.25
19MLR100031	2.45	2.56	2.63	2.69	2.79	2.89	3.00	3.25
19MLR100033B	2.45	2.56	2.63	2.69	2.79	2.89	3.00	3.24
19MLR100034	2.45	2.56	2.63	2.69	2.78	2.89	2.99	3.24
19MLR100034A	2.45	2.56	2.63	2.69	2.79	2.89	2.99	3.24
19MLR100034B	2.45	2.56	2.63	2.69	2.79	2.89	2.99	3.24
19MLR100036	2.45	2.56	2.63	2.69	2.79	2.89	2.99	3.23
19MLR100039	2.45	2.56	2.63	2.69	2.79	2.88	2.98	3.23
19SPRG00027	23.1	23.1	23.1	23.1	23.1	23.1	23.1	23.1
19SPRG00026A	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5
19SPRG00026B	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5
19SPRG00025	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
19SPRG00019	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
19SPRG00015	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
19SPRG00011	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
19SPRG00010A	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
19SPRG00008B	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
19SPRG00006	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
19SPRG00003	9.69	9.69	9.69	9.69	9.69	9.69	9.69	9.69
19SPRG00001	9.42	9.42	9.42	9.42	9.42	9.42	9.42	9.42

B Hydraulic roughness

Reaches of similar hydraulic roughness have been identified from survey photos and drawings. Manning's n values for both the river bed and banks to bank top within each of these reaches are summarised.

Upstream and Downstream Cross Section	Roughness Values (Manning's n) and materials	Photograph
4GLA_8994- 4GLA_7909	Bed - 0.035 for Coarse Gravel Bank - 0.07 for Trees with flood levels not reaching branches	 4GLA_07940_DS
4GLA_7909- 4GLA_5405	Bed - 0.03 for Gravel (2-64mm) Bank Mainly - 0.050 for light brush and occasional trees Some Bank - 0.07 for Trees with flood levels not reaching branches	 4GLA_07163_DS  4GLA_06882_LB

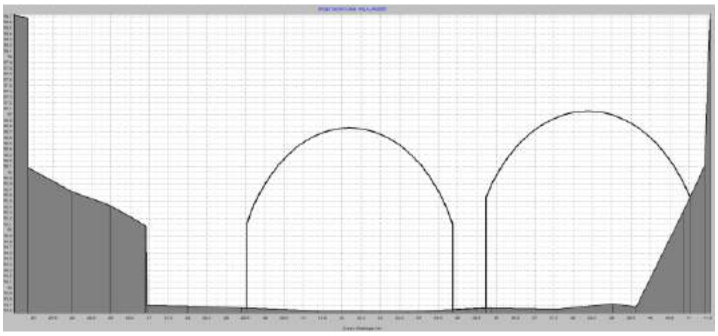
4GLA_5405- 4GLA_2079	Bed – 0.032 form calibration to Meadowbrook Rating curve Bank Mainly - 0.050 for light brush and occasional trees Some Bank - 0.07 for Trees with flood levels not reaching branches	 4GLA_04688_US
4GLA_2079- 4GLA_1628U	Bed - 0.03 for Gravel (2-64mm) Bank Mainly - 0.050 for light brush and occasional trees Some Bank - 0.07 for Trees	 4GLA_02090_US
4GLA_1628D- 4GLA_0000	Bed - 0.025 for silt tidal bed Bank Mainly - 0.050 for light brush and occasional trees Some Bank - 0.07 for Trees	 4GLA_00612_LB
MillRace3	Bed - 0.03 for Gravel (2-64mm) Bank - 0.040 for grassy banks.	 19MLR30052I_UP

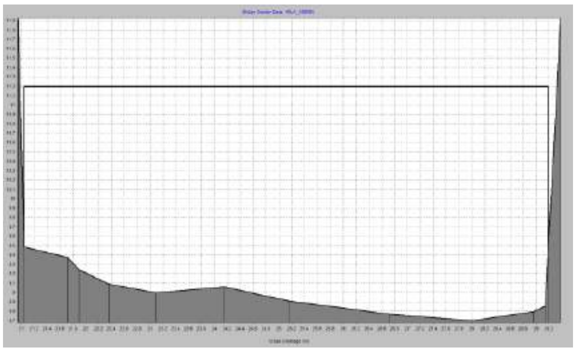
MillRace2	Bed - 0.030 for mud material. Bank - 0.050 for light brush and occasional trees	 19MLR200028_UP
MillRace1	Bed - 0.030 for mud material. Bank - 0.050 for light brush and occasional trees	 19MLR100011_UP
Spring	Bed - 0.035 for Coarse Gravel Bed – 0.04 in upper reach for stability Bank - 0.050 for light brush and occasional trees	 19SPRR00026E_DN
Glenmore	Bed - 0.030 for mud material. Bank - 0.050 for light brush and occasional trees Some Bank - 0.07 for dense vegetation and trees	 19GLNM101_UP

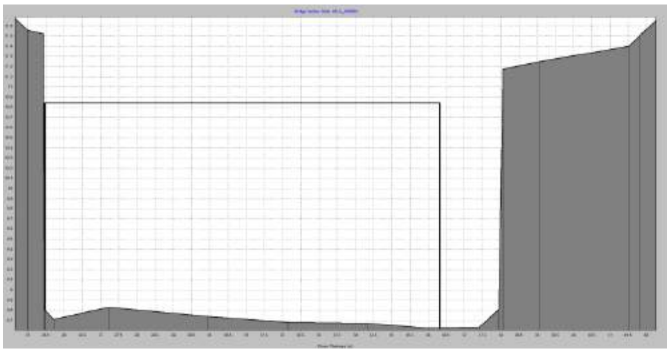
Bleach Hill	Bed - 0.035 for silt stone material. Bank - 0.050 for light brush and occasional trees.	 19BLCH00006D_UP
Butlerstown	Bed - 0.035 for Coarse Gravel Bank Mainly - 0.050 for light brush and occasional trees Some Bank - 0.07 for Trees	 8BUT_0488_DS

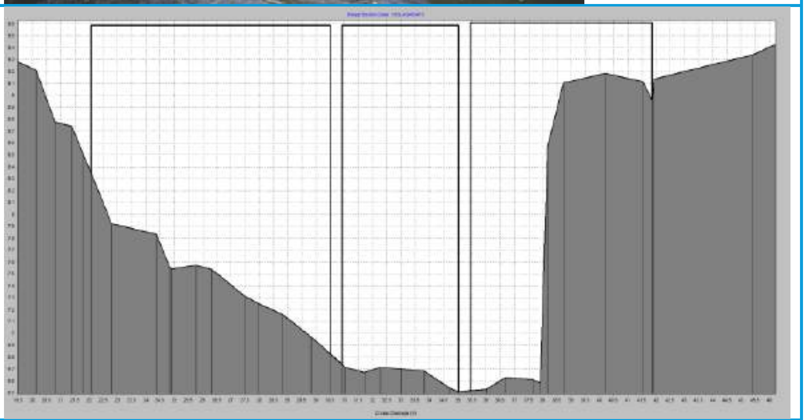
C Key Hydraulic Structures

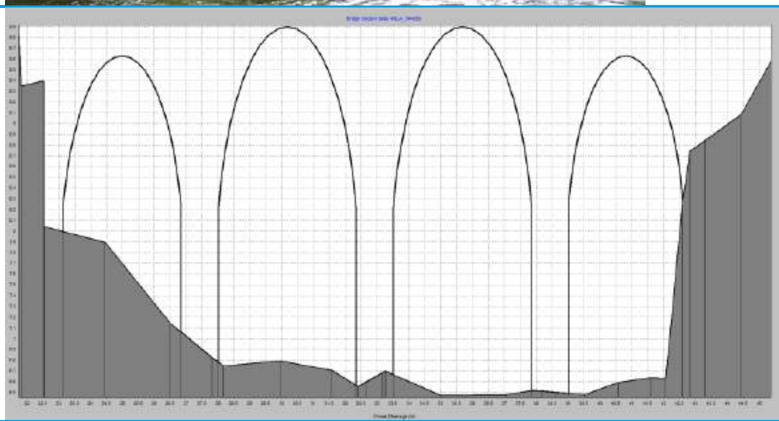
C.1 Bridges

Name/ Model node label	Sallybrook Bridge ---4GLA_4828	
Type of structure	Arch bridge	
Description	Multi arch (2) stone road bridge.	
Irish Grid reference(s)		
Included in Model	Yes	
Photograph		
Model section		
Dimensions and levels	Invert Level	13.589 mOD
	Soffit Level	17.060 mOD
Manning's n	0.032	
How modelled	ARCH Bridge	
Model assumptions and limitations	1D Spill deactivated for spill into 2D Domain, however flood levels are unlikely to reach this level. Bridge changes to a flat soffit bridge for d/s face. Arch bridge is used as it is a more conservative, and critical XS.	

Name/ Model node label	4GLA_3995	
Type of structure	Road bridge	
Description	Single flat soffit precast road bridge	
Survey reference	4GLA_3995	
Irish Grid reference(s)		
Included in Model	Yes	
Photograph		
Model cross-section		
Dimensions and levels		
	Soffit Level	11.2 mOD
Manning's n	0.032	
How modelled	USBPR 1978 unit with FLAT soffit	
Model assumptions and limitations	1D spill deactivated and over flow modelled in 2D domain. Large flow on flood plain on right bank.	

Name/ Model node label	4GLA_3900BU	
Type of structure	Road bridge	
Description	Single flat soffit precast road bridge	
Survey reference	4GLA_3900BU	
Irish Grid reference(s)		
Included in Model	Yes	
Photograph		
Model cross-section		
Dimensions and levels	Invert Level	8.621 mOD
	Springing Level	
	Soffit Level	10.84 mOD
Manning's n	0.032	
How modelled	USBPR 1978 unit with FLAT soffit	
Model assumptions and limitations	1D spill deactivated and over flow modelled in 2D domain. Office flow deactivated for calibration event. Cross section skewed to 8˚ in bridge unit	

Name/ Model node label	Riverstown Bridge Footbridge – 19GLAS0347	
Type of structure	Footbridge	
Description	3 span flat soffit concrete footbridge	
Survey reference		
Irish Grid reference(s)		
Included in Model	Yes	
Photograph		
Model cross-section		
Dimensions and levels	Invert Level	6.51m OD
	Soffit Level	9.59m OD
Manning's n	0.035	
How modelled	USBPR 1978 unit with FLAT soffit	
Model assumptions and limitations	Cross section is manually skewed using the Cosine of the skew angle 34˚.	

Name/ Model node label	Riverstown Bridge – 4GLA_3440Bu	
Type of structure	Road Bridge	
Description	Multi arch (4) stone road bridge	
Survey reference		
Irish Grid reference(s)		
Included in Model	Yes	
Photograph		
Model cross-section		
Dimensions and levels	Invert Level	6.48 mOD
	Springing Level	8.21 mOD
	Soffit Level	9.90 mOD
Manning's n	0.035	
How modelled	ARCH Bridge	
Model assumptions and limitations	No overtopping spill as it is constrained by footbridge. Overtopping of this structure is accounted for by the footbridge spill, which is in the 2D domain. No skew is applied as it is accounted for in the footbridge	

D Freeboard Calculation

River	Reach	Node	Hydraulic Freeboard: Flow	Roughness	AFX	Total	Superelevation Δy/2	Tidal Uncertainty	Construction Freeboard	Total Freeboard
Sallybrook	1	19GLAS00561	0.20	0.15	0.00	0.25				
		19GLAS00549	0.18	0.18	0.00	0.26				
		4GLA_5405	0.17	0.20	0.00	0.26				
		4GLA_5294	0.19	0.13	0.00	0.23				
					Maximum	0.26				0.26
	2	4GLA_5181	0.15	0.17	0.00	0.23	0.264			
		4GLA_5083	0.20	0.09	0.00	0.22				
		4GLA_5060INT	0.25	0.17	0.00	0.31				
		4GLA_5047D	0.33	0.19	0.00	0.39				
		4GLA_5017U	0.33	0.19	0.00	0.38				
		4GLA_5017D	0.34	0.20	0.00	0.40				
					Maximum	0.40	0.264			0.66
Hazelwood	1	4GLA_3995	0.64	0.37	0.20	0.76				
					Maximum	0.76				0.76
	2	4GLA_3995D	0.38	0.36	0.12	0.53				
		4GLA_3969	0.38	0.36	0.12	0.53				
		4GLA_3915	0.36	0.37	0.12	0.53				
		4GLA_3900	0.36	0.36	0.12	0.52				
		4GLA_3900D	0.33	0.39	0.11	0.52				
		4GLA_3879	0.32	0.38	0.10	0.51				
		19GLAS00385	0.31	0.40	0.10	0.51				
		4GLA_3804	0.29	0.31	0.10	0.44				
					Maximum	0.53				0.53
Meadowbrook	1	4GLA_3786D	0.25	0.33	0.00	0.42	0.325			
		4GLA_3715	0.26	0.33	0.00	0.42				
					Maximum	0.42	0.325			0.75
	2	4GLA_3575	0.27	0.36	0.00	0.45				
		4GLA_3457	0.28	0.10	0.00	0.30				
		19GLAS00347A	0.38	0.04	0.00	0.38				
			0.00		*Maximum*	0.45				0.45
The Grove	1	4GLA_2057	0.26	0.21	0.00	0.33				
		4GLA_2028INT	0.21	0.17	0.00	0.27				
		4GLA_2000INT	0.18	0.13	0.00	0.23				
		4GLA_1971INT	0.16	0.12	0.00	0.20				
					Maximum	0.33				0.33
	2	4GLA_1886	0.09	0.10	0.06	0.15				
		4GLA_1862	0.32	0.33	0.08	0.46				
			0.00		*Maximum*	0.46				0.46

Notes

Flow: Flow increased by 23.5% to account for uncertainty in the calculation of Qmed, the Growth Curve and the Q100 Rating

Roughness: Manning's *n* values are increased to the upper bounds limit of their classification

AFX: To account for the sensitivity of aflux at bridges the Cv valued were reduced to 0.8

Superelevation calculated using to the free vortex method (V.T. Chow 1973)

Tidal uncertainity from Lee CFRAM calculation of the downstream boundary

Total Freeboard =

$$F_B = \sqrt{\sum A_1^2 + A_2^2 + A_3^2 + \dots A_n^2}$$

where: A1 = Flow
A2 = Roughness
A3 = AFX

Copper Valley	19GLNM00064B	0.20	0.28	0.08	0.35		
	19GLNM00063	0.18	0.12	0.10	0.24		
	19GLNM00059	0.20	0.21	0.08	0.30		
	19GLNM00055A	0.21	0.20	0.09	0.30		
	19GLNM00054B	0.18	0.22	0.10	0.30		
	19GLNM00052	0.19	0.24	0.10	0.32		
				Maximum	0.35		0.35
Butlerstown	4BUT_571	0.24	0.08	0.05	0.26		
	4BUT_488	0.20	0.10	0.08	0.24		
	4BUT_468	0.23	0.06	0.06	0.24		
				Maximum	0.26		0.26
Estuary	4GLA_1628U	0.01	0.03	0.00	0.03	0.300	
	4GLA_1628D	0.01	0.03	0.00	0.03	0.300	
	4GLA_1626	0.01	0.03	0.00	0.03	0.300	
	4GLA_1518INT	0.00	0.02	0.00	0.02	0.300	
	4GLA_1418	0.00	0.00	0.00	0.00	0.300	
	4GLA_1320	0.01	0.01	0.00	0.01	0.300	
	4GLA_1146	0.01	0.01	0.00	0.01	0.300	
				Maximum	0.03	0.30	0.33

Registered Office

24 Grove Island
Corbally
Limerick
Ireland

t: +353 (0) 61 345463
e:info@jbaconsulting.com

JBA Consulting Engineers
and Scientists Limited

Registration number 444752

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