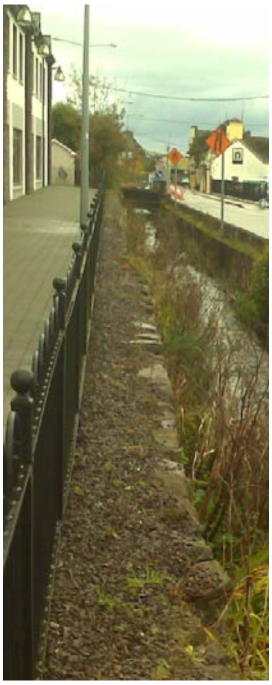

South Western CFRAM Study

Hydraulics and Flood Mapping Appendices,
Unit of Management 22

September 2014

The Office of Public Works

OPW
The Office of Public Works
Oifig na nOibreacha Poiblí

SOUTH WESTERN CFRAM STUDY
CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT

Mott MacDonald

Issue and revision record

Revision	Date	Originator	Checker	Approver	Description	Standard
A	June 2014	M Piggott	R Gamble B O'Connor	R Gamble	Draft	
B	Setpember 2014	M Piggott	R Gamble B O 'Connor	R Gamble	Draft Final	

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Mott MacDonald

Appendices

Appendix A. Castleisland AFA Model Proformas

UOM	**22**		
AFA/ MPW Reach	**Castleisland**		
Model ID	**I33CD**		
Purpose of Model Build	**Flood Mapping**		
Main Watercourse	**River Maine**	**FLUVIAL RISK**	Yes
Length Modelled (km)	**10**	**COASTAL RISK**	No
Area Modelled (km^2)	**47**	**VULNERABLE TO WAVES**	No

Input Data	
River Channel Topographic Data	Topographic survey by Murphy Surveys Limited. Data captured in September 2012. Refer to Drawing 4674_22MAIN_XS_6
Floodplain Topographic Data	2m DTM LIDAR provided by OPW converted from ITM to ING. Elevations on hard standing were compared with river channel survey and found to be within 0.2 m.
Map data	Ordnance Survey Ireland 1:1000, 1:2500 and 1:5000 and 1:50000 data Vector mapping at 1:1000, 1:2500 and 1:5000 were converted from DWG/DXF to GIS files for modelling purposes

Model Build	
General Schematisation	A 1D/2D ISIS/TUFLOW approach was taken for Castleisland to accurately model flow along the main watercourses and head loss through hydraulic structures whilst enabling multidirectional flow and backwater on the flow through the complex urban floodplain. The local area engineers reported a regular flow route from the Glenshearoon to Anglore Stream during flood when high flows overtop the Glanshearoon right bank, spill into a swallow hole , through Crag Cave and re emrge at the springs at the upstream of Anglore Stream leading to additional flooding at Tullig. A spill unit, set at Glenshearoon surveyed bank level, has been attached to the Glenshearoon sections by the swallow hole and to the upstream section of the Anglore river to simulate the flow route by assuming any water overtopping the right bank of the Glenshearoon by the swallow hole is immediately transferred to the Anglore Stream. The road embankment and dismantled railway have been explicitly enforced in the 2D domain based on LIDAR crest level as they are raised above the floodplain. Site visits to Casteisland and discussions with the local area engineers did not identify any major openingins opther than the rivers which are represented in the 1D model and 2D QH boundaries. Buildings thresholds have been raised by 0.15m above the DTM level based on site observations and a higher Manning's 'n' value applied to the building footprints to simulate the storage of water once flooded. The 2D floodplain was set to 5m to represent the urban area without compromising run time. Version D2: Improved representation at key structures to better match frequency of flooding discussed with local area engineers. See Schedule 2.
Software Versions Used	ISIS version 6.6 TUFLOW version 2012-05-AC-iSP-w32
Total No of 1D nodes	**110**
Routing Units	0
Open channel (H)	75
Bridges (D)	34
Culverts (I)	0
Weirs (W)	1

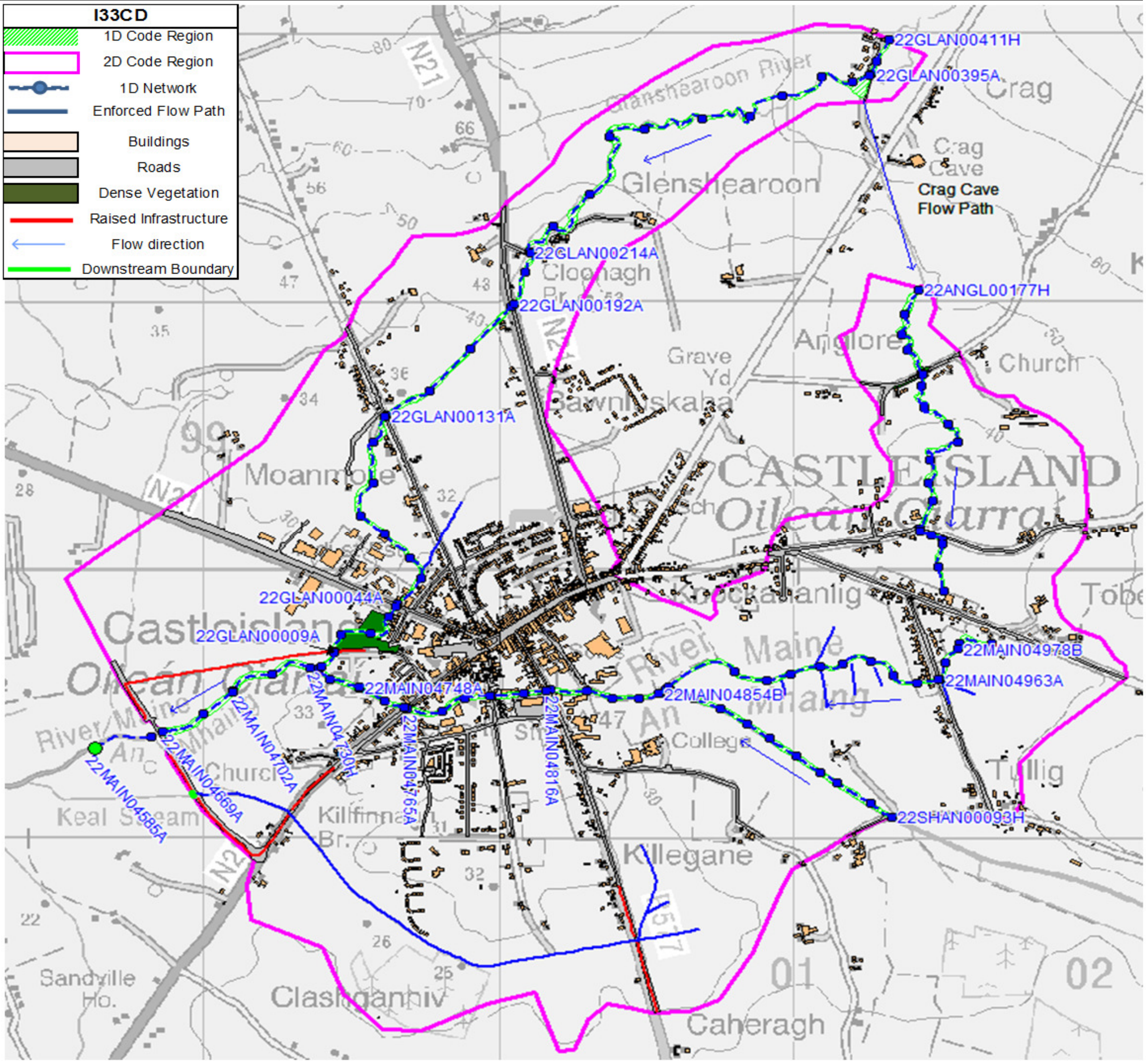
Model Extent	Reach/Feature	Upstream Limit (ING)	Downstrem Limit (ING)
	Shanowen	101333, 109071	100574, 109550
	Maine	101667, 109721	98629, 109333
	Anglore	101418, 111040	101549, 109701
	Glenshearoon	101320, 111974	099403, 109635

Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	Shanowen	0.040	0.060	N/A	Schedule 1: Photographs
	Maine	0.040 to 0.045	0.060	N/A	Schedule 1: Photographs
	Anglore	0.048	0.085	N/A	Schedule 1: Photographs
	Glenshearoon	0.040	0.060	N/A	Schedule 1: Photographs
	Open pasture	N/A	N/A	0.060	Schedule 1: Photographs
	Dense vegetation	N/A	N/A	0.085	Schedule 1: Photographs
	Buildings	N/A	N/A	0.200	Schedule 1: Photographs
	Roads	N/A	N/A	0.030	Schedule 1: Photographs

Structures	See Schedule 2 for Hydraulic Structure Parameters
Upstream boundary	Shanowen is the main inflow. This has been located on the downstream of Tullig road bridge taking a conservative assumption that all flows will flow through the bridge or over the road. The Glenshearoon inflow has been applied directly to the upstream limit of the open channel section. The proportion flowing into Crag Cave is determined hydraulically by the left bank spill at the swallow hole. The Anglore inflow was applied directly to the upstream limit of the Anglore Stream but was also attached to the downstream of the Crag Cave spill to enable transfer of flows from the Glenshearoon catchment once the left bank by the swallow hole entrance became overtopped.

Lateral inflows	Lateral inflows QT hydrographs were distributed equally across open channel sections between the confluences of Shanowen and Glenshearoon (MAIN_M_IC) as there were no obvious natural flow paths into the channel. The intermediate inflow along the Glenshearoon was applied equally at the minor tributaries located at 22GLAN00228 and 22GLAN00059.
Downstream boundary	A NCBDY has been applied in the 1D downstream of the bridge based on the bed level as representative of the longer reach of the River Maine. An automatic HQ has been applied at the d/s limit of Kealgorm stream based on the floodplain slope to allow a small amount of flow under the N23 at this location.
Run Settings	Unsteady simulation of full 45 hour hydrograph. 2.5s timestep Minimum flows of 1m3/s on Glan, 0.3m3/s on Anglore and 1.7m3/s on Shanowne/Maine to maintain stability at low flows. This takes up less than 10% of the channel capacity and does not reduce the volume available for flood storage. All other parameters set to default. The model was run for the design flood along the Maine River (M for main river model runs) and the design flood along the Glanshearoon River (T for tributary runs). These have then been combined to produce the final flood extent, depth , velocity and hazard results.

Model Geoschematic



SCHEDULE 1 : PHOTOGRAPHS

Photo 1: Shanowen Active Channel

ING 100748, 109478 - captured on 27/09/2012

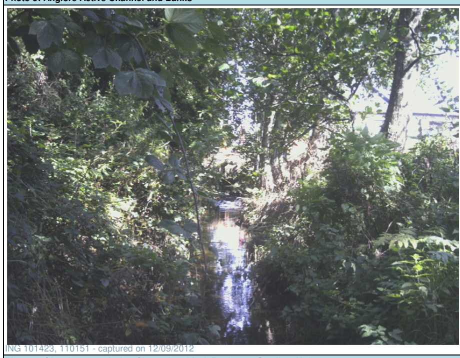
Phote 6: Pasture Floodplain

Photo 2: Maine Active Channel and Banks

ING 100468, 109518 - captured on 12/09/2012

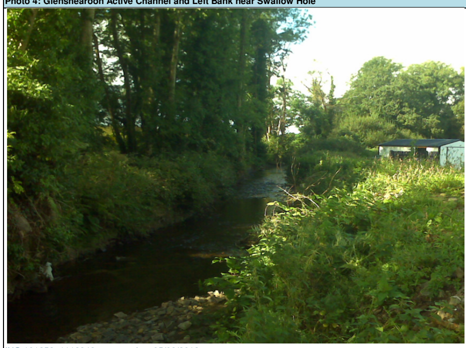
Photo 7: Roads and Urban Floodplain

Photo 3: Anglore Active Channel and Banks



ING 101423, 110151 - captured on 12/09/2012

Photo 4: Glenshearoon Active Channel and Left Bank near Swallow Hole



ING 101252, 1112848 - captured on 05/09/2012

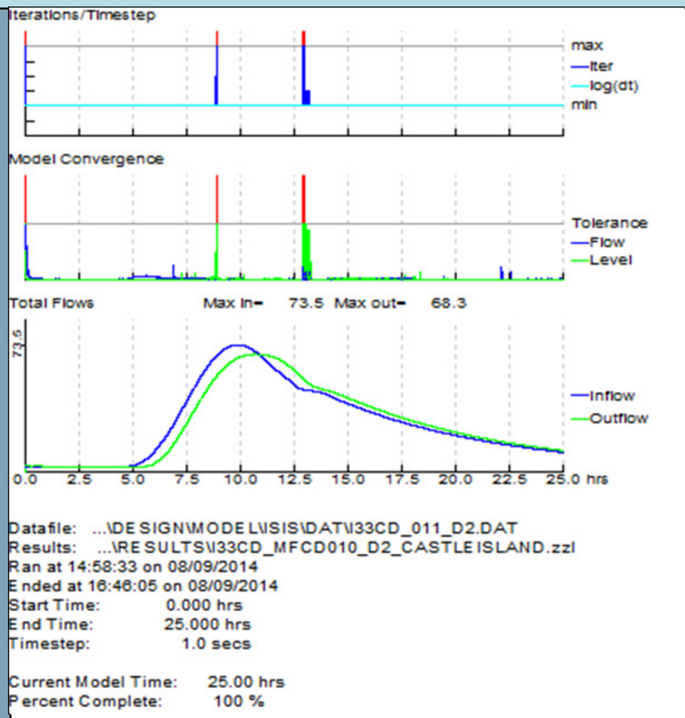
SCHEDULE 2: Structures

Node(s)	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Culvert Parameters													Comments/ Justification
Data file	P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I33CD_Castleisland\DESIGN\model\ISIS\I33CD_D1_010.DAT																											
				Soffit Elevation	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation	Breadth	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation	Modular Limit	Weir Coeff.	Soffit level (mAOD)	No of Openings	Invert u/s (mAOD)	Invert d/s (mAOD)	Area (m²)	Nominal Width (m)	Length (m)	K	Ki	M	Trash Screen	Trash Screen coefficient	Flapped	
22ANGL00021I	101500	109928	Tullig Culvert RECTANGULAR CULVERT+ ORIFICE												31.375	1	29.82	28.749	2.076	1.4 Narrowing to 1.2 under the road	214.922	0.9	0.5	0.7	NO		NO	Rectangular culvert under Tullig Road mdoelled with orifice at upstream to stabilise transition to orifice flow. Culvert is known to reduce in width under the road. Therefore a width of 1.2m was assumed based on discussions with local area engineers and in the absence of confined spaces survey. Additional inlet losses and bend lossed added to reproduce the freqeuncy of flooding reported.
22MAIN0477W MAIN04747SR MAIN04747SL	99524	109555	Gauge Weir RN Weir + Spill units					22.275	9.508		1	22.878	0.9	1.7														RN Weir representing the formal gauging weir at lwo flows and spills representing the banks up to bankfull. The weir and spill coefficients wer calibrated to the spot gaugings upstream.
22GLAN00394S	101254	111842	Crag Cave flow route River Bank Spill									58.837	0.9	1.0														Left bank elevations defining the spill into swallow hole which is directly linked to the upstream of Anglore Stream 22ANGL000177H. Spill coefficient represents both the offline flow over the bank and flow through the cave calibrated to reproduce observed flooding on Anglore Stream.
22ANGL00081A	101456	110408	General Head Loss																									General head loss applied to help stabilise low flows over rapid bed changes along the steep Anglore Stream
22MAIN04854D	100539	109540	Old Chapel Lane Footbridge FLAT Bridge	28.22	3	0	1					29.71	0.9	1.5														Flat bridge with three openings. Spill represents flow over the flat wall on the bridge at high flows.
22MAIN04816D	100168	109548	Church Street Bridge ARCH Bridge	26.93	2	0	1					28.42	0.9	1.5														Stone arched bridge with two openings applying HR Wallingford Arch equations. Spill represents flow over the flat wall on the bridge at high flows.
22MAIN04797D	99969	109528	Barrack Street Bridge FLAT Bridge	25.69	3	0	1					27.07	0.9	1.5														Flat soffit bridge with 3 openings.Soffit lowered by the utility pipe that crosses below the soffit. Spill represents flow over the flat wall on the bridge at high flows.
22MAIN04765D	99687	109479	Killarney Road Bridge ARCH Bridge	25.18	2	45	1					27.15	0.9	1.5														Upstream face is a a single rectangular opening but downstream face is two arched openings therefore arched bridge approach applied. The downstream arches were applied as most important flow control. Soffit lowered to consider the utility pipe corssing. Survey adjusted to be in line bridge rather and skew angle added to the bridge structure.
22MAIN04700D	99098	109538	Farm Access Bridge FLAT Bridge	23.12	2	0	1					23.57	0.9	1.5														Farm Access bridge modelled as a flat bridge with spil represnet flow over the track
22MAIN04669D	98863	109380	N23 Highways Bridge FLAT Bridge	23.49	1	0	2					24.94	0.9	1.5														Flat highways bridge with spill representing any flow over the road in extreme events
22ANGL00136D	101427	110732	Glebe House Bridge FLAT Bridge	37.98	1	0	1					39.2	0.9	1.5														Flat box bridge under Glebe House Road with spill representing flow over flat wall.
22ANGL00052D	101423	110151	Knockane Bridge FLAT Bridge	32.82	1	0	1					33.38	0.9	1.5														Flat box bridge at Knockane with spill representing flow over flat wall. 2D represents spill over road either side.
22MAIN04963D	101490	109586	Tullig Bridge FLAT Bridge	30.76	2	0	1					31.97	0.9	1.5														Flat soffit bridge under Tullig Road with spill representing flow over flat wall.
22GLAN00395D	101254	111842	Bridge by Crag Cottages FLAT Bridge	59.94	1	0	1					61.238	0.9	1.5														Flat soffit bridge with spill representing flow over flat wall.
22GLAN00214D	100142	111185	Access Bridge FLAT Bridge	41	1	0	1					42.164	0.9	1.5														Flat soffit bridge with spill representing flow over flat wall.
22GLAN00192D	100045	110986	Cloonagh Bridge ARCH Bridge	39.26	2	0	1					40.83	0.9	1.5														HR Wallingofrd Arched methdo usedto better represent arch obstruction with spill representing flow over flat wall.
22GLAN00131D	99615	110572	FLAT Bridge	33.25	2	0	1					34.48	0.9	1.5														Flat soffit bridge with spill representing flow over flat wall.
22GLAN00044D	99616	110569	Tralee Road Bridge ARCH Bridge	27.22	1	0	1					34.96	0.9	1.5														Arched bridge under Tralee Road with spill representing flow over flat wall.
22GLAN00009D	99440	109692	Old Railway Bridge FLAT Bridge	25.24	2	0	1					25.46	0.9	1.5														Flat soffit bridge with spill representing flow over flat wall.

Castleisland Model Performance

1D Convergence

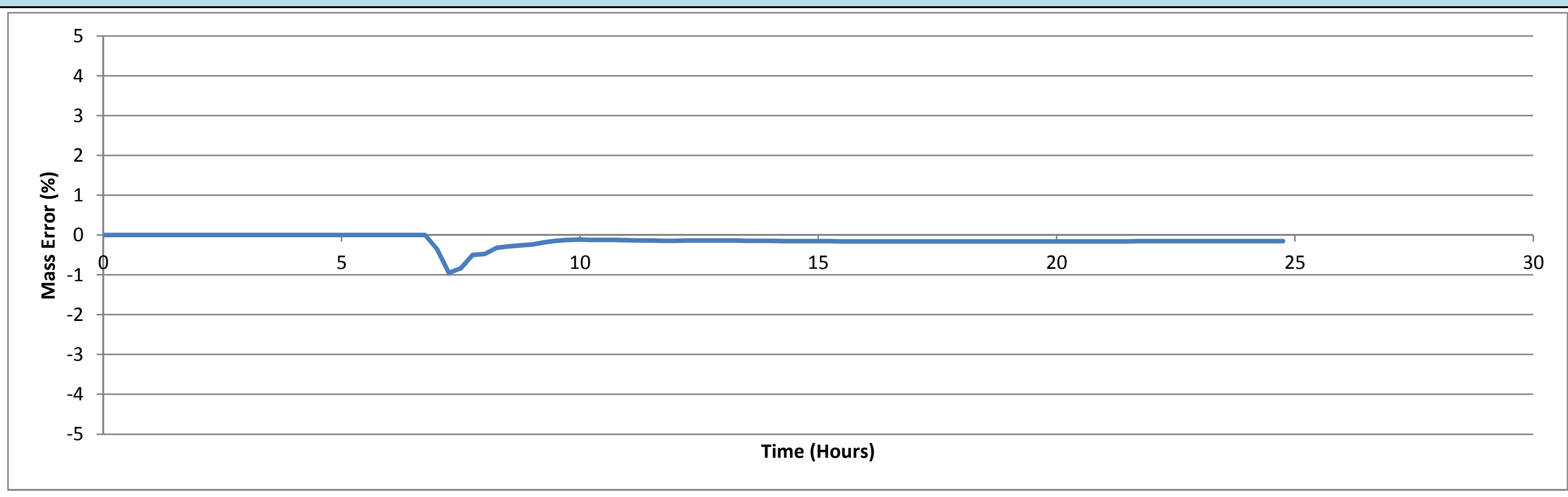
Convergence Plot
1% AEP Fluvial Event



Comments
The 1D model components were convergent and within the recommended tolerances for the majority of the event.
The short periods of instability at 9 and 12 hours occur as the water hits the soffit of the smaller culvert at the downstream of Anglore. however, the culvert is already bypassed and does not affect the flood extent.

2D Convergence

Mass Balance Plot
1%AEP Fluvial Event



Comments
The final cumulative mass balance error was 0.2% or 3381 m^3. The 2D model remains within the recommended tolerance throughout the event. There is a spike at 7 hours to -0.99% associated with the wetting of cell but it back to -0.1% before the peak at 10 hours.

The intial negative percentage mass error at 7 hours is exaggerated because there are very few active 2D cells as the water first spills out of bank. However, as flooding increases the mass error reduces to -0.01% by the peak. Therefore, the mass balance of volume entering and leaving the model is accurate within recommended tolerances at the peak and flood depth, velocity and extent can be deemed to be reliable.

Hydrological Performance

Target Flows

HEP ID	Location	Model Node	10% AEP m^3/s			1%AEP m^3/s			0.1%AEP m^3/s		
			Design	Modelled	% Difference	Design	Modelled	% Difference	Design	Modelled	% Difference
22_1589_3	Shanowen downstream	22SHAN00002A	37.2	37.1	0%	54.2	54.8	1%	79.4	80.5	1%
22_1587_3	22014 Castleisland Gauge	22MAIN04748H	43.6	41.5	-5%	61.8	57.6	-7%	91.8	71.2	-22%
	22014 Castleisland Gauge+ flow exiting catchment	22MAIN04748H	43.6	41.5	-5%	61.8	58.8	-5%	91.8	88.4	-4%
22_2098_3	Maine downstream	22MAIN04669A	56.9	51.4	-10%	80.7	75.4	-7%	119.9	113.2	-6%
22_360_2	Glenshearoon downstream	22GLAN00002H	12.6	11.0	-12%	18.7	15.8	-16%	27.8	22.4	-19%
22_1756_3	Anglore downstream	22ANGL00021I	3.3	3.7	12%	4.7	5.7	21%	7.0	8.3	19%

Comments
The flows in the 1D ISIS channel were combined with the 2D flow parallel to the channel where there was out-of-bank flows and compared to the design hydrology.

The modelled flow tended to underestimate flows at the gauge compared to the design peak flows in the extreme flood events because some flow was exiting the catchment along the R577 effectively bypassing the gauge. The modelled flows is within 5% (3m^3/s) of the design flows when this exit flow is included in the total flow estimate at the gauge as shown.

The modelled flows tended to underestimate the design flows on the Glenshearoon and overestimate the flows on the Anglore Stream because flow exited the Glenshearoon catchment and were transferred to the Anglore Stream catchment.

Calibration Event 1

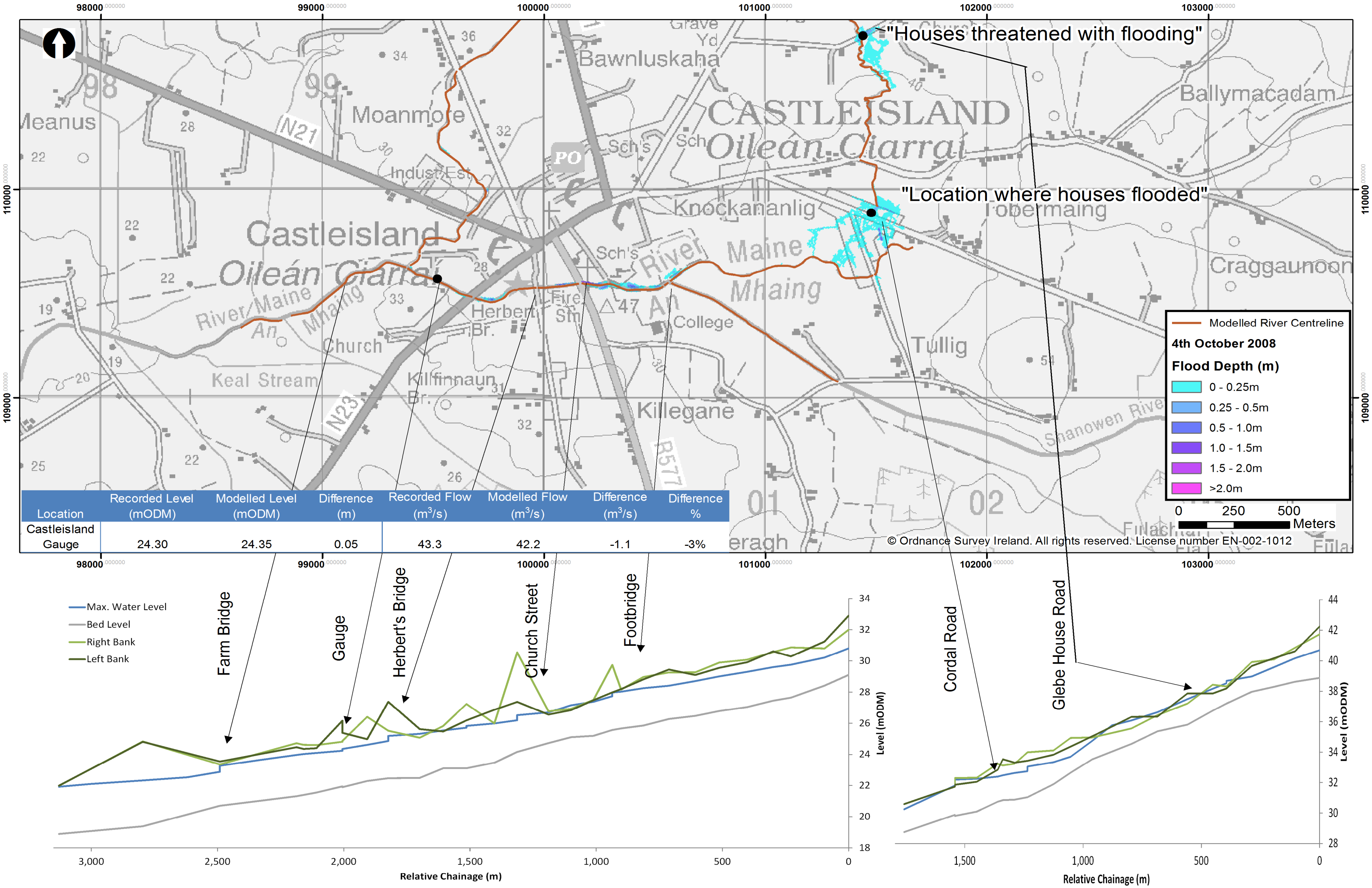
Model Run ID	I33CD_FCC20081004_D1
Period Modelled	04/10/2008 11:30 to 06/10/2008 02:45 with the peak at 04/10/2008 20:00
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	Rainfall runoff FSSR units have been applied to the Glenshearoon, Anglore and Shanowen inflows based on the catchment average rianfall adjusted from Valentia Observatory and calibrated percentage runoff to achieve the flows at the gauge.
Calibration Plot	See Schedule 3 - Calibration and Sensitivity
Comments	The model was calibrated to reproduce the recorded flow route through Crag Cave and flooding along the Anglore Stream by calibrating the spill coefficient of the spill at the swallow hole to 1.0. The resultant flood extent matches well with the reported flooding at Glebe House Road and the property flooding at Tullig as the excess flows cause the Anglore to exceed the capacity of Glebe House Bridge and the Tullig culvert. The water level at the gauge was 0.05m higher than recorded which is within the calibration tolerance of +/- 0.1m. Overall, the model calibrates well with the mechanisms and extents recorded in the 2008 event.

Verification Checks

Locations of known flooding	Flooding was observed around Church Street Bridge and Tullig on 24th January 2014. This event occurred after the model calibration exercise had been completed. Therefore, the photographs provided were used to verify and common sense check flow paths and frequency of flooding.
Available Gauge Data	The Castleisland gauge was not active for this event. Gauge data was obtained from Riverville but the flow was less than the 50%AEP estimate. The extent of flooding in Castleisland has not been observed as frequently as the 50%AEP (1 in 2 year). Therefore, flows at Riverville are not representative of flood conditions in Castleisland for this event.
Verification Plot	See Schedule 3 - Calibration and Sensitivity

Comparison with Design Flood	The photographs verify the flow paths across Tullig Road and on the rigth bank at Church Street.The extent of flooding at Tullig and around Church Street would be consistent with the 2%AEP design flood extent.
Sensitivity Test 1: Increased Flow	
Model Run ID	I33CD_FHD010_D1
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	All inflows were increased by 30% for the 1%AEP fluvial current design event to account for the uncertainty in the derivation of QMED and the pooling group selected. This is broadly equivalent to the HEFS 1%AEP as the increase in urban extent has less the 1% impact on peak flow. Therefore, the HEFS 1%AEP results (FHD010) have been used as the sensitivity test results.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	A 30% increase in flows resulted in a significant increase in the flow exiting the Maine catchment along the R277 and therefore an increase in flood extent in this area. The flow increase resulted in flooding along the N21 from the Glenshearoon and flooding at the sewage treatment works at the confluence. The flood extent also increased along Anglore Stream with greater excess flows being transferred from the Glenshearoon catchment. Therefore flood risk in the Castleisland was found to be sensitive to the uncertainties in flow. The design flows were selected based on the best fit to Castleisland gauge data and relative flood frequency of historic events. An allowance should be made when interpreting the design flood outlines and the in the sizing of any flood risk management option due to this uncertainty in flood level and extent caused by the uncertainties in flow.
Sensitivity Test 2: Increased Downstream Level	
Model Run ID	
Hydraulic Modification to Design Model	The downstream stage-flow boundary was increased from 1 in 670 to 1 in 1000 to represent greater backwater from the Maine catchment downstream of the N23.
Hydrological inflows	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	The increased backwater from the downstream boundary only affected water levels up to the Glenshearoon confluence and did not significantly increase flood extent. Therefore, the Castleisland model is not sensitive to the assumptions taken for the downstream boundary.
Sensitivity Test 3: Increased Manning's 'n'	
Model Run ID	I33CD_FCSN01_D1
Hydraulic Modification to Design Model	The Manning's 'n' values were increased to the upper limit of the industry recommended ranges. All active channels 0.040 to 0.050 All river banks 0.060 to 0.080 Pasture / parkland / garden 0.060 to 0.080 Buildings 0.200 to 0.300 Roads 0.033 to 0.040
Hydrological inflows	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increase in roughness values in bank and out-of-bank increased flooding on the left bank of the Shanowen and Maine resulting in a larger flood extent along the R277 flow path. The Manning's 'n' values along the Shanowen and Maine were calibrated for the October 2008 event and spot gaugings at Castlisland gauge. The calibrated Manning's 'n' values were selected as the design values. Water level was also raised along Anglore Stream. However, this did not result in large increase in flood extent given that the 1%AEP already exceeds the capacity of the critical bridges and culverts. The Manning's 'n' values along Anglore Stream were calibrated for the October 2008 event. The calibrated Manning's 'n' values were selected as the design values. An allowance should be made when interpreting the design flood outlines and the in the maintenance of any flood risk management option on the Shanowen and Maine channels due seasonal changes in roughness.

Map A.1: Calibration of the Castleisland Model to 4th Ocotber 2008 Fluvial Flood Event

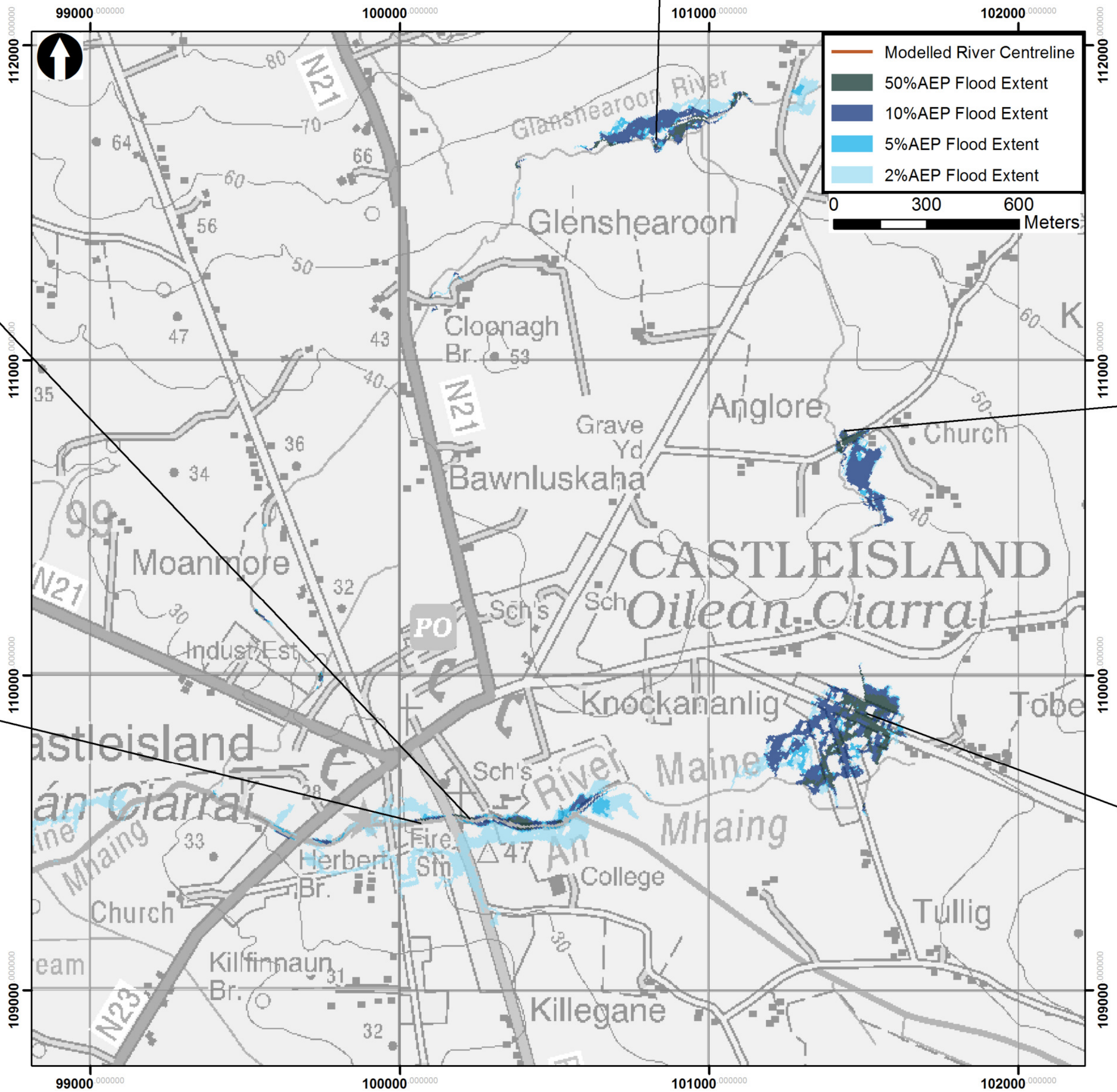


Location	Recorded Level (mODM)	Modelled Level (mODM)	Difference (m)	Recorded Flow (m^3/s)	Modelled Flow (m^3/s)	Difference (m^3/s)	Difference %
Castleisland Gauge	24.30	24.35	0.05	43.3	42.2	-1.1	-3%

Map A.2: Validation of Flooded Areas in 24th January 2014 with Design Flood Outlines

River Walk Upstream of Church Street Bridge

Downstream of Church Street Bridge

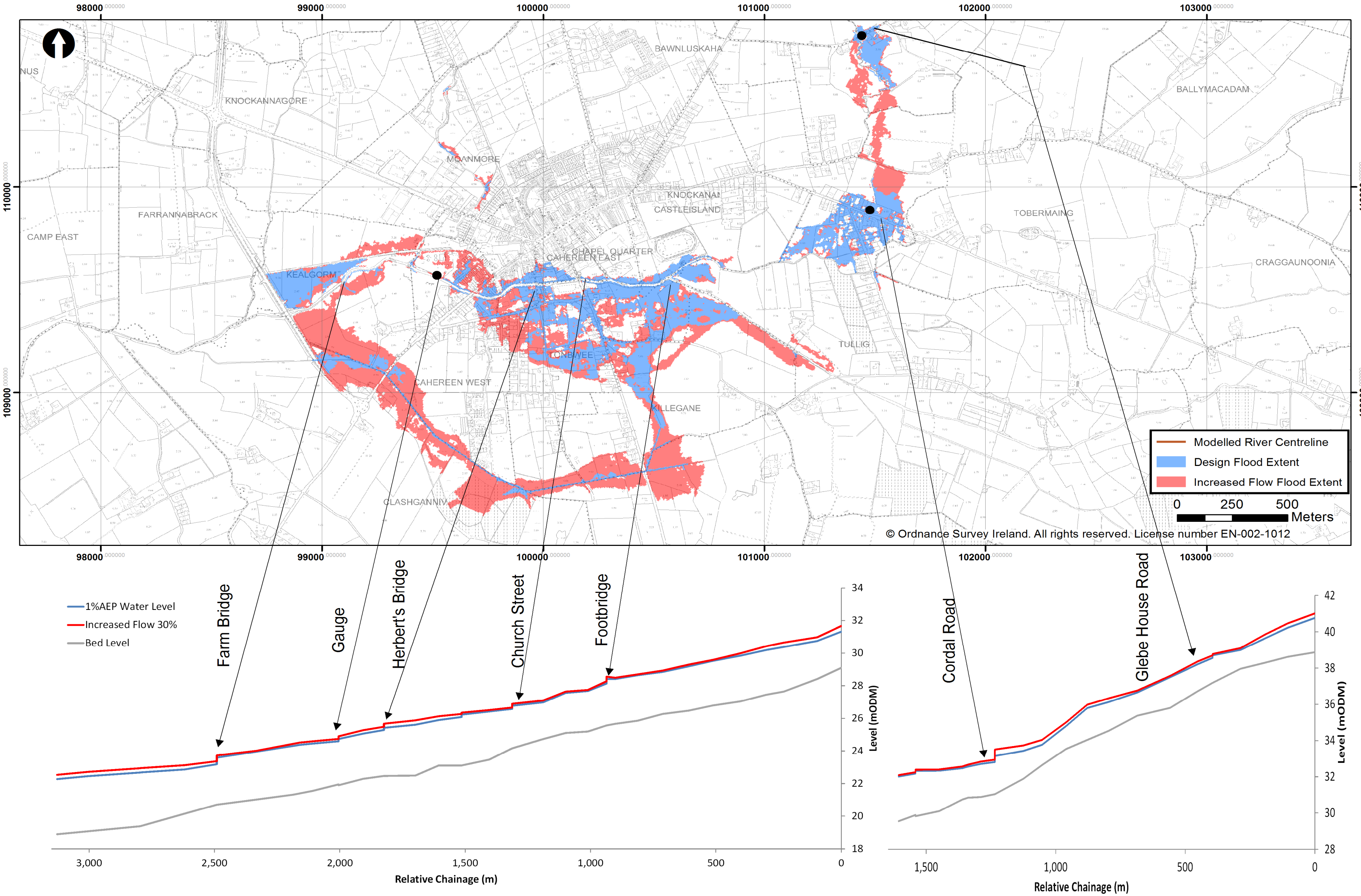


Water spilling out of Glenshearoon into swallow hole area

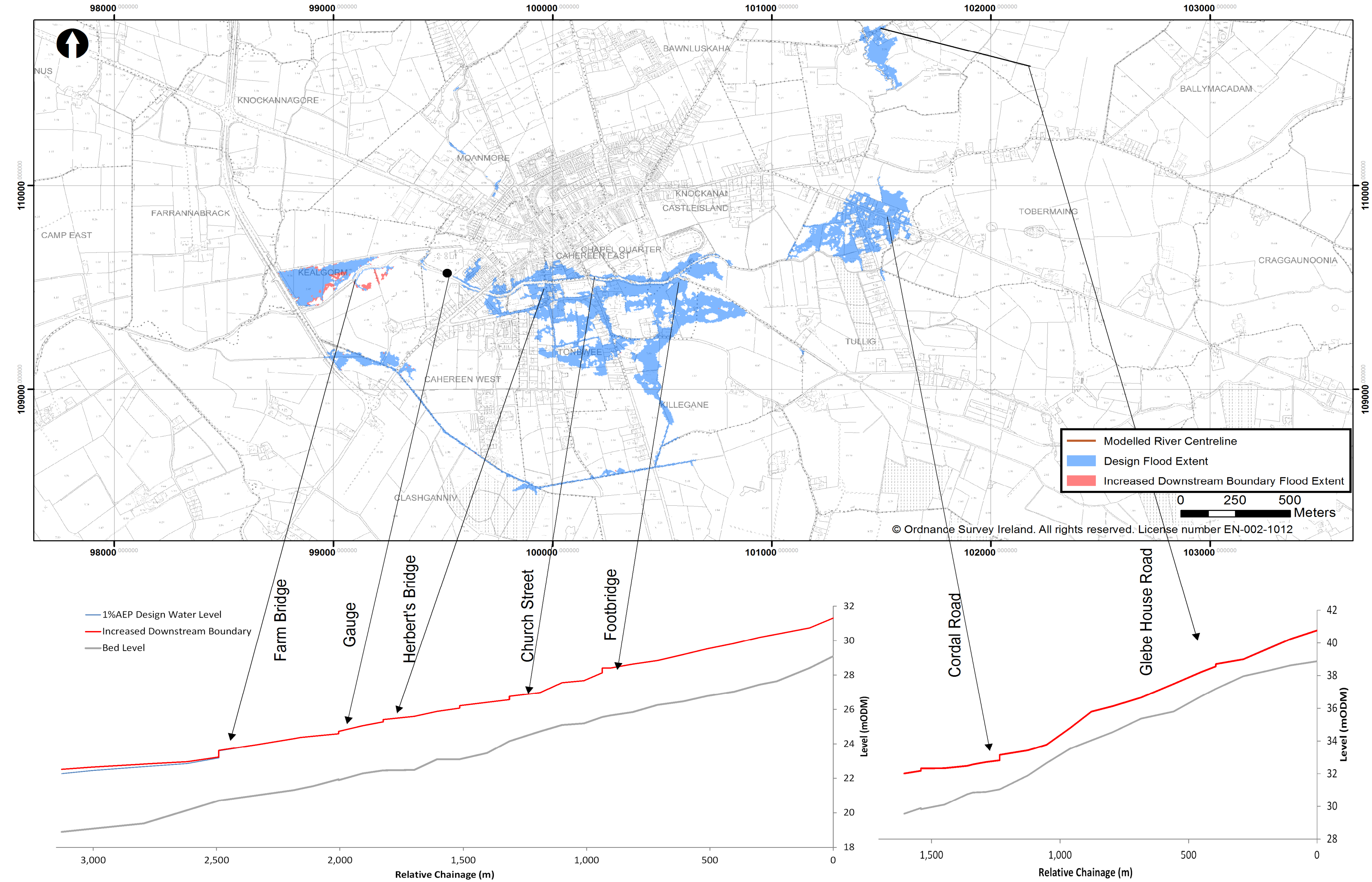
Upstream of Glebe House Birdge after flooding subsided

Walsh Machinery, Tullig

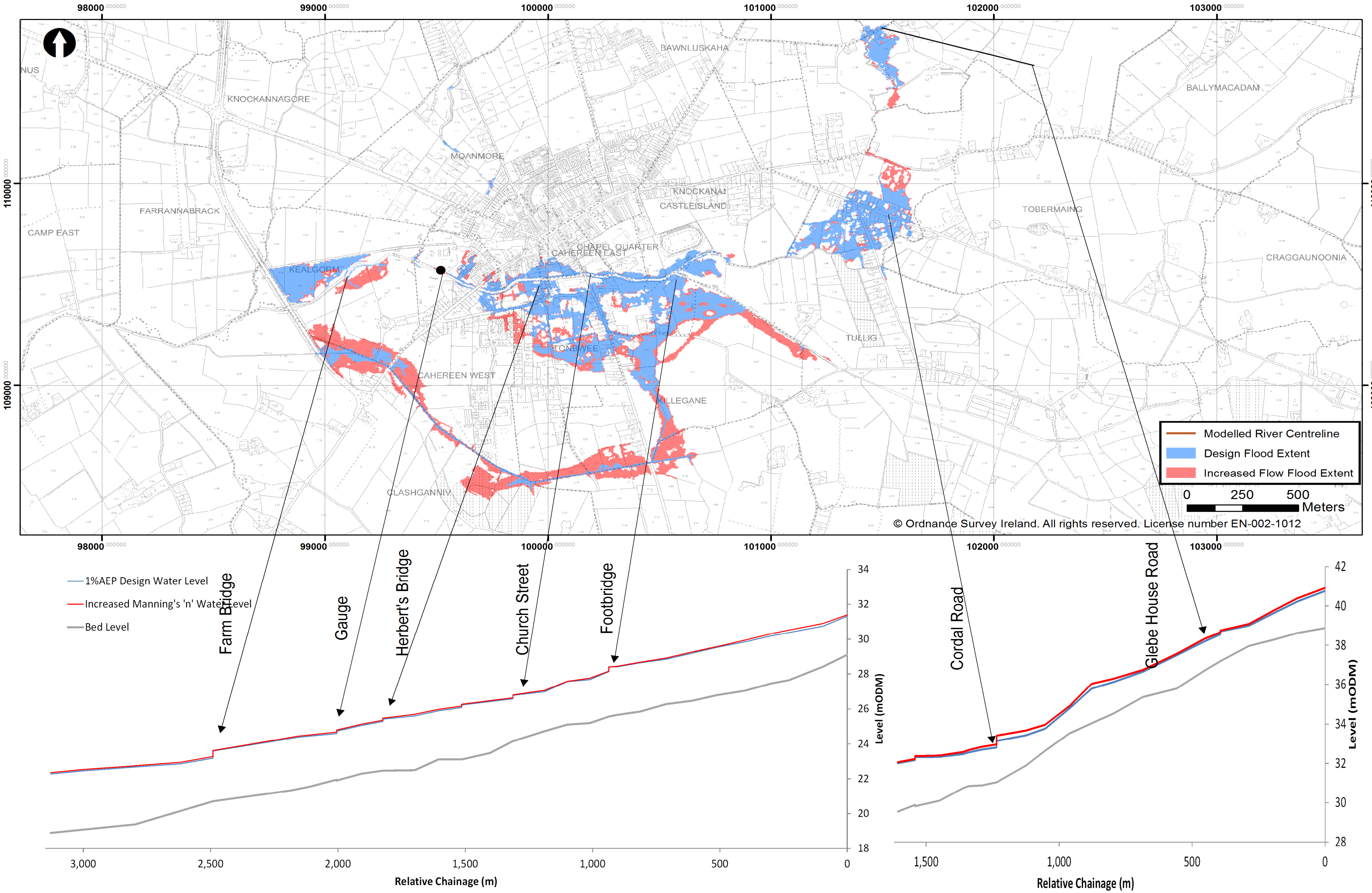
Map A.3: Sensitivity to 30% Increased Peak Flow



Map A.4: Sensitivity to Increased Downstream Boundary



Map A.5: Sensitivity to Increased Manning's 'n'



Castleisland Model Outputs	
Threshold of Flooding	The key thresholds and areas affected by flooding in Castleisland are: - 50%AEP event overtops the left bank at the swallow hole to Crag Cave on Glanshearoon - 50%AEP event exceeds the capacity of the downstream culvert on Anglore, flooding properties at Tullig - 10%AEP event exceeds the capacity of Glebe House Bridge causing water to flow over the road and threaten properties on the left bank. - 2%AEP floods riverside areas along the Maine upstream and downstream of Church Street - 1%AEP event floods the Technical College, Cahereen East and West areas of Castleisland from the Maine. Surface water flooding is not considered. - 1%AEP flows across the catchment boundary along the R277 - 0.1%AEP exceeds the capacity of the N21 Bridge on the Glenshearoon to flood Castleview Drive and the sewage treatment works - Approximately 200 properties are affected by the 1%AEP fluvial event. It should be noted that the CFRAM Study assumes saturated ground conditions as a worst-case scenario for the design flows. The saturation of the catchment preceding the event should be carefully considered when interpreting the flood maps in Castleisland due to karstic geology.
Critical Structures for Flood Risk	The critical structures in determining flood risk include: - Left bank levels on the Glenshearoon and the flow route through Crag Cave during saturated conditions - Glebe House Bridge on the Anglore Stream - Downstream culvert on the Anglore Stream at Tullig - Church Street Bridge on the Maine - Herbert's Bridge on the Maine - Farm access bridge downstream of the Maine-Glenshearoon confluence.
Areas affected by flooding	The greatest risk to life is associated with deep fast flowing water upstream of Herbert's Bridge and Church Street Bridge on the right bank.
Risk to people	There is significant and extreme risk to people for the 2%AEP and larger magnitude events.
Consideration for Flood Risk Management Options	- Increased conveyance at the key structures idenifitied are likely to reduce flood risk. - Bank works on the Glenshearoon to limit how much flow can enter the swallow hole may reduce excess flows and flooding on the Anglore Stream. - Flood warning on the Shanowen/Maine catchment is likely to be effective as there would several hours before the peak flow at the Castleisland Gauge. This gauge is a good indicator of the expected flow when combined with observations at the swallow hole on Glenshearoon to predict flooding at Tullig and within the town.

Flood Map Outputs

The following table outlines the print-ready flood mapping deliverables provided in the accompanying digitial data.

Scenario	Flood Extent Map	Flood Zone Map	Flood Depth Map	Flood Velocity Map	Flood Hazard Map
Fluvial Current Design 10%AEP	I21HCD33_EXFCDEXF_D2		I21HCD33_DPFCD100_D2	I21HCD33_VLFCD100_D2	I21HCD33_HZFCD100_D2
Fluvial Current Design 1%AEP	I21HCD33_EXFCDEXF_D2	I21HCD33_ZN_D2	I21HCD33_DPFCD010_D2	I21HCD33_VLFCD010_D2	I21HCD33_HZFCD010_D2
Fluvial Current Design 0.1%AEP	I21HCD33_EXFCDEXF_D2	I21HCD33_ZN_D2	I21HCD33_DPFCD001_D2	I21HCD33_VLFCD001_D2	I21HCD33_HZFCD001_D2
Fluvial Mid Range Future Design 10%AEP	I21HCD33_EXFMDEXF_D2				
Fluvial Mid Range Future Design 1%AEP	I21HCD33_EXFMDEXF_D2				
Fluvial Mid Range Future Design 0.1%AEP	I21HCD33_EXFMDEXF_D2				

GIS Outputs

The following table outlines the GIS deliverables and model run files provided in the accompanying digital handover.

Scenario	Model Run	Main River %AEP	Tributary River %AEP	Flood Extent Polygon	Flood Zone Polygon	Flood Depth Grid	Flood Velocity Grid	Flood Hazard Grid
	I33CD_MFCD500_D2_Castleisland.ief	50	50					
Fluvial Current Design 50%AEP	I33CD_TFCD500_D2_Castleisland.ief	50	50	I33EXFCD500D2		I33DPFCD500D2	I33VLFCD500D2	I33HZFCD500D2
	I33CD_MFCD200_D2_Castleisland.ief	20	50					
Fluvial Current Design 20%AEP	I33CD_TFCD200_D2_Castleisland.ief	50	20	I33EXFCD200D2		I33DPFCD200D2	I33VLFCD200D2	I33HZFCD200D2
	I33CD_MFCD100_D2_Castleisland.ief	10	20					
Fluvial Current Design 10%AEP	I33CD_TFCD100_D2_Castleisland.ief	20	10	I33EXFCD100D2		I33DPFCD100D2	I33VLFCD100D2	I33HZFCD100D2
	I33CD_MFCD050_D2_Castleisland.ief	5	20					
Fluvial Current Design 5%AEP	I33CD_TFCD050_D2_Castleisland.ief	20	5	I33EXFCD050D2		I33DPFCD050D2	I33VLFCD050D2	I33HZFCD050D2
	I33CD_MFCD020_D2_Castleisland.ief	2	10					
Fluvial Current Design 2%AEP	I33CD_TFCD020_D2_Castleisland.ief	10	2	I33EXFCD020D2		I33DPFCD020D2	I33VLFCD020D2	I33HZFCD020D2
	I33CD_MFCD010_D2_Castleisland.ief	1	5					
Fluvial Current Design 1%AEP	I33CD_TFCD010_D2_Castleisland.ief	5	1	I33EXFCD010D2	I33ZN_A_D2	I33DPFCD010D2	I33VLFCD010D2	I33HZFCD010D2
	I33CD_MFCD005_D2_Castleisland.ief	0.5	5					
Fluvial Current Design 0.5%AEP	I33CD_TFCD005_D2_Castleisland.ief	5	0.5	I33EXFCD005D2		I33DPFCD005D2	I33VLFCD005D2	I33HZFCD005D2
	I33CD_MFCD001_D2_Castleisland.ief	0.1	1					
Fluvial Current Design 0.1%AEP	I33CD_TFCD001_D2_Castleisland.ief	1	0.1	I33EXFCD001D2	I33ZN_B_D2	I33DPFCD001D2	I33VLFCD001D2	I33HZFCD001D2
	I33CD_MFMD500_D2_Castleisland.ief	50	50					
Fluvial Mid Range Future Design 50%AEP	I33CD_TFMD500_D2_Castleisland.ief	50	50	I33EXFMD500D2		I33DPFMD500D2		
	I33CD_MFMD200_D2_Castleisland.ief	20	50					
Fluvial Mid Range Future Design 20%AEP	I33CD_TFMD200_D2_Castleisland.ief	50	20	I33EXFMD200D2		I33DPFMD200D2		
	I33CD_MFMD100_D2_Castleisland.ief	10	20					
Fluvial Mid Range Future Design 10%AEP	I33CD_TFMD100_D2_Castleisland.ief	20	10	I33EXFMD100D2		I33DPFMD100D2		
	I33CD_MFMD050_D2_Castleisland.ief	5	20					
Fluvial Mid Range Future Design 5%AEP	I33CD_TFMD050_D2_Castleisland.ief	20	5	I33EXFMD050D2		I33DPFMD050D2		
	I33CD_MFMD020_D2_Castleisland.ief	2	10					
Fluvial Mid Range Future Design 2%AEP	I33CD_TFMD020_D2_Castleisland.ief	10	2	I33EXFMD020D2		I33DPFMD020D2		
	I33CD_MFMD010_D2_Castleisland.ief	1	5					
Fluvial Mid Range Future Design 1%AEP	I33CD_TFMD010_D2_Castleisland.ief	5	1	I33EXFMD010D2		I33DPFMD010D2		
	I33CD_MFMD005_D2_Castleisland.ief	0.5	5					
Fluvial Mid Range Future Design 0.5%AEP	I33CD_TFMD005_D2_Castleisland.ief	5	0.5	I33EXFMD005D2		I33DPFMD005D2		
	I33CD_MFMD001_D2_Castleisland.ief	0.1	1					
Fluvial Mid Range Future Design 0.1%AEP	I33CD_TFMD001_D2_Castleisland.ief	1	0.1	I33EXFMD001D2		I33DPFMD001D2		
	I33CD_MFHD100_D2_Castleisland.ief	10	20					
Fluvial High End Future Design 10%AEP	I33CD_TFHD100_D2_Castleisland.ief	20	10	I33EXFHD100D2		I33DPFHD100D2		
	I33CD_MFHD010_D2_Castleisland.ief	1	5					
Fluvial High End Future Design 1%AEP	I33CD_TFHD010_D2_Castleisland.ief	5	1	I33EXFHD010D2		I33DPFHD010D2		
	I33CD_MFHD001_D2_Castleisland.ief	0.1	1					
Fluvial High End Future Design 0.1%AEP	I33CD_TFHD001_D2_Castleisland.ief	1	0.1	I33EXFHD001D2		I33DPFHD001D2		

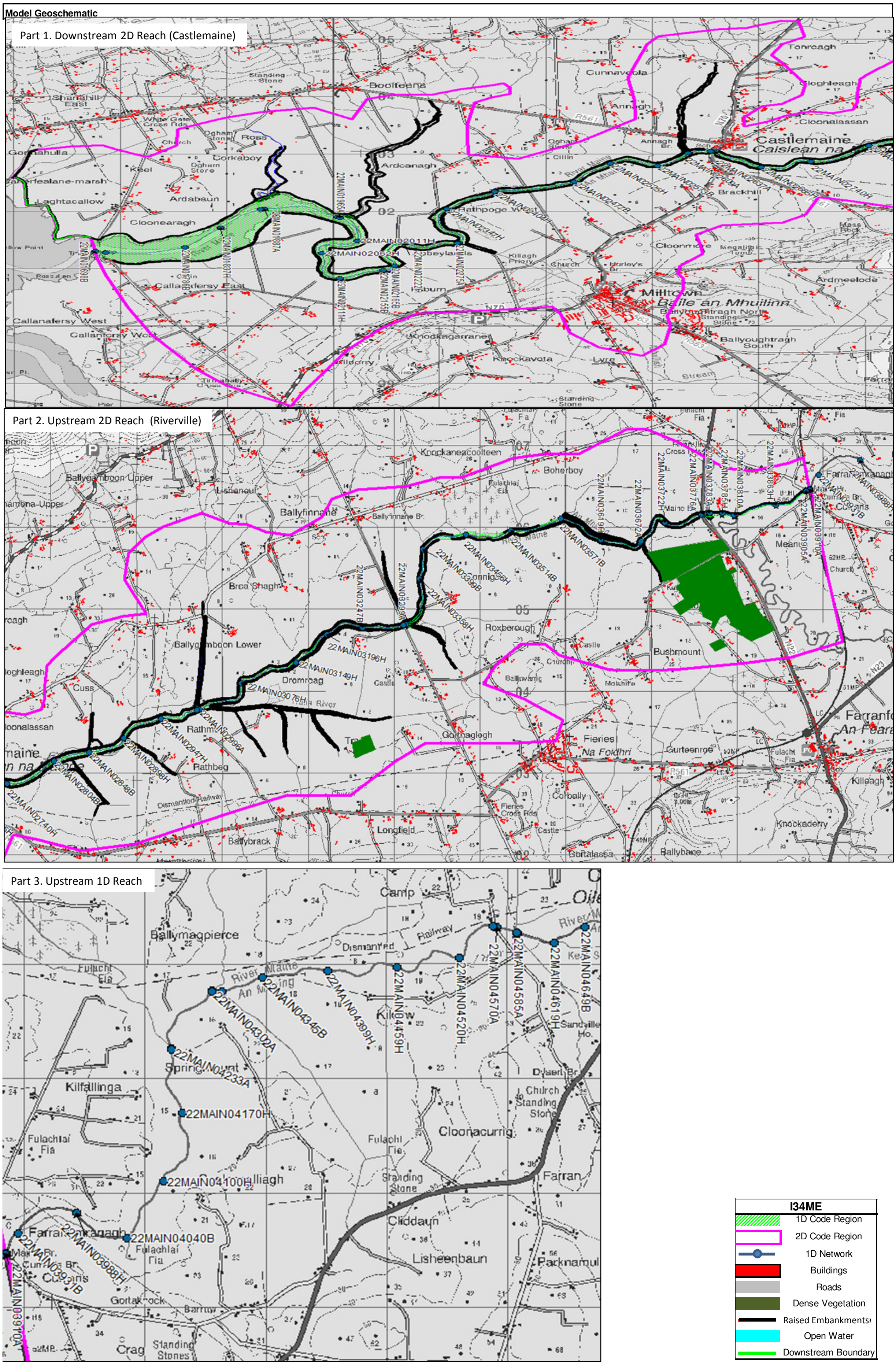
Appendix B. Maine MPW Model Proformas

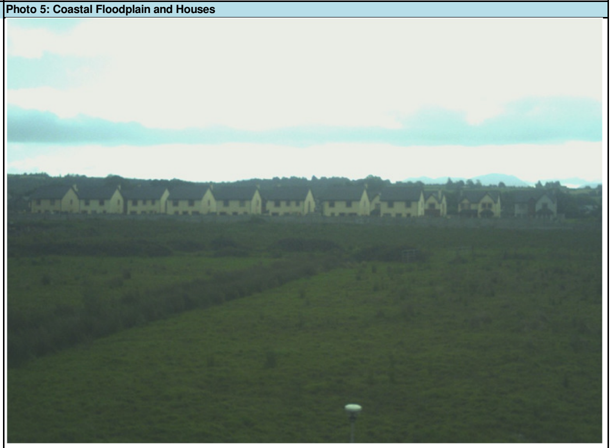
UOM	**22**		
AFA/ MPW Reach	**Maine**		
Model ID	**I34ME**		
Purpose of Model Build	**Flood Mapping**		
Main Watercourse	**River Maine**	**FLUVIAL RISK**	Yes
Length Modelled (km)	**29.5**	**COASTAL RISK**	Yes
Area Modelled (km^2)	**54.1**	**VULNERABLE TO WAVES**	No

Input Data	
River Channel Topographic Data	Topographic survey by Murphy Surveys Limited. Data captured in October 2012. Refer to Drawing 22MAIN_Maine_V1.dwg
Floodplain Topographic Data	2m DTM LIDAR provided by OPW converted from ITM to ING. Elevations on hard standing were compared with river channel survey and found to be within 0.2 m.
Map data	Ordnance Survey Ireland 1:1000, 1:2500 and 1:5000 and 1:50000 data Vector mapping at 1:1000, 1:2500 and 1:5000 were converted from DWG/DXF to GIS files for modelling purposes

Model Build					
General Schematisation	A 1D ISIS approach with extended sections over the floodplain was taken for the MPW Maine between the N23 at Castleisland to the Currans Bridge because the floodplain is fully connected with the river channel and 1D approach was deemed sufficient to provide flood extent and depth mapping for this reach. The survey indicates that the river bank is not conistently above the fldooplain between the cross sections i.e. there are low spots inbetween connecting the river channel and floodplain. Therefore it would not be appropriate to assume the floodplain was fully disconnected. A higher Manning's 'n' has been applied to simulate the inefficient flow over the banks. Downstream of Currans Bridge, a 1D/2D approach was taken to better represent the disconnected floodplain from the channel due to the raised embankments . A 2D approach is also better suited to simulate the multidirectional flow paths across the floodplain during coastal flooding. The 2D floodplain was set to a 10m grid resolution to improve run time over a large coastal floodplain whilst maintaining accuracy suitable for a MPW reach. Defended scenarios: The raised embankments have been enforced in the 2D domain based on the flood defence asset survey and form the interface between the 1D and 2D components. Undefended scenarios (for flood zone mapping): The raised embankments have been removed from the 2D domain based on surveyed elevations at the based embankments to smooth teh river banks to floodplain level and form the interface between the 1D and 2D components. Buildings thresholds have been raised by 0.15m above the DTM level based on site observations and a higher Manning's 'n' value applied to the building footprints to simulate the storage of water once flooded. Areas of dense tree plantation or densely vegetated bog have been assigned a higher manning's 'n' value to represent the increased roughness.				
Software Versions Used	ISIS version 6.6 TUFLOW version 2012-05-AC-iSP-w32				
Total No of 1D nodes	**101**				
Routing Units	0				
Open channel (H)	82				
Bridges (D)	7				
Spill (S)	7				
Culverts (I)	0				
Weirs (W)	5				
Model Extent	Reach/Feature	Upstream Limit (ING)		Downstrem Limit (ING)	
	Maine	98629, 109333		77744, 101293	
	Annagh Beg	83595, 104612		83326, 103013	
Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	Maine Upstream of Currans	0.040 to 0.045	0.08 to 0.1	0.1 Used to represent inefficient flows on floodplain and wooded areas to meet hydrological routing.	Schedule 1: Photographs
	Maine downstream of Currans	0.040 to 0.045	0.06 to 0.08	N/A	Schedule 1: Photographs
	Annagh and other open channels	0.040 to 0.045	N/A	N/A	Schedule 1: Photographs
	Open pasture	N/A	N/A	0.060	Schedule 1: Photographs
	Dense vegetation	N/A	N/A	0.085	Schedule 1: Photographs
	Buildings	N/A	N/A	0.200	Schedule 1: Photographs
	Roads	N/A	N/A	0.030	Schedule 1: Photographs
Structures	See Schedule 2 for Hydraulic Structure Parameters				
Upstream boundary	The upstream inflow from Castleisland and tributary inflows have been applied directly to 1D ISIS model, as per FSU WP 3.4 guidelines, which simplify the interaction at confluences. However, this approach is deemed sufficient to assess the flood extent and depth of flooding from the Maine which the classified MPW in this reach.				
Lateral inflows	Lateral inflows QT hydrographs were distributed at low points in the banks between the confluences of key tributaries.				
Downstream boundary	A full level-time (HT)tidal boundary has been applied directly to the outfall of the Maine into Castelmaine Harbour (estuary) based on the design tidal conditions transferred from Inch Spit based on Admiralty Prediction Points. The HT boundary extends along the coastal defence on the right bank of the Maine to Gortnahulla to model any interaction with tidal overtopping along this reach. The peak tide has been phased to coincide with the peak fluvial flow at Castlemaine in this MPW reach.				
Run Settings	Unsteady simulation for 65 hours to enable the fluvial flood to reach the outfall and covering 5 tidal cycles (2 before and after the peak tide) 2.5s timestep All other parameters set to default.				

Model Geoschematic



SCHEDULE 1 : PHOTOGRAPHS	
Photo 1: Maine Active Channel and River Banks	Photo 4: Upper Maine Floodplain
	
Photo 2: Densely Wooded River Banks	Photo 5: Coastal Floodplain and Houses
	
Photo 3: Lower Maine Near Castlemaine	
	

SCHEDULE 2: Structures

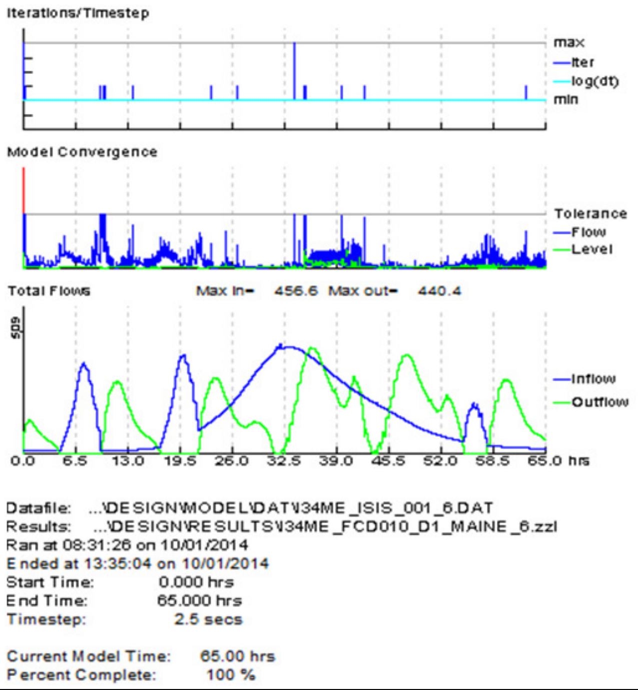
Data file P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I34ME_Maine\DESIGN\model\ISIS\I34ME_ISIS_001_6.DAT

Node(s)	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Culvert Parameters													Comments/ Justification
				Soffit Elevation	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation	Breadth	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation	Modular Limit	Weir Coeff.	Soffit level (mAOD)	No of Openings	Invert u/s (mAOD)	Invert d/s (mAOD)	Area (m²)	Nominal Width (m)	Length (m)	K	Ki	M	Trash Screen	Trash Screen coefficient	Flapped	
22MAIN04570D	97901	109330	Ahaclare Bridge USBPR Bridge	20.29	2	22.5	1	N/A	N/A	N/A	N/A	20.26	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Spill represents flow over parapet and acorss road on floodplain in 1D approach
22MAIN03905D	93805	106451	Currans Bridge USBPR Bridge	13.49	3	44.8	1	N/A	N/A	N/A	N/A	14.55	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Lowered soffit to account for the pipe influence. Soffit without pipe 13.63 to 13.76mODM
22MAIN03783D	92668	106152	N22 bridge USBPR Bridge	14.15	3	0	1	N/A	N/A	N/A	N/A	15.38	0.9	1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
22MAIN03297D	89147	104787	Cloonmealane Road Bridge USBPR Bridge	6.12	3	0	1	N/A	N/A	N/A	N/A	7.04	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
22MAIN02636D	83569	103009	Castlemaine N70 Bridge USBPR Bridge	3.4	3	0	1	N/A	N/A	N/A	N/A	4.32	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
22MAIN03910D	93833	106469	Rail bridge ARCH Bridge	18.78	3	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No spill over the bridge modelled because the maximum water level modelled is lower than the soffit and nearly 7m lower than minimum spill elevation (21.48mODM).
22MAIN03776D	92598	106150	Maine Road Bridge ARCH Bridge	14.02	3	0	1	8.02	23.19	N/A	0.8	14.43	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Arched bridge downstream of Riverville gauge. Weir represents bed drop across the section calibrated to match the gauge rating curve.The spill represents flow over the parapet.
MAINE03785W1 to 4	92672	106163	Riverville Weir RN WEIR and SPILL	N/A	N/A	N/A	N/A	9.14 9.16 9.19 9.14	5.92 5.11 5.73 6.26	N/A	1	9.38	0.7	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Four formal weirs represented by the RN WEIR units. Intervening structures and river banks in 1D represented by SPILL unit. Coeffient represents inefficient flow over vegeated banks.
(22_3102_14 Inflow)	92570	106165	Riverville Bypass Culvert Hydrological assumption No hydraulic structure	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	The Riverville bypass takes excess flows from the Brown Flesk via a weir at 093072,105680 and under the N22 in a rectangular culvert to outfall into the Maine downstream of the arched bridge and gauge. There is a short gauge record of flows this bypass which was used to establish the distribution between the Brown Flesk and bypass culvert. THis structure has not been hdyraulically modelled because the Brown Flesk is not a classified MPW and is beyond the scope of this study.

Maine (MPW) Model Performance

1D Convergence

Convergence Plot
1% AEP Fluvial Event

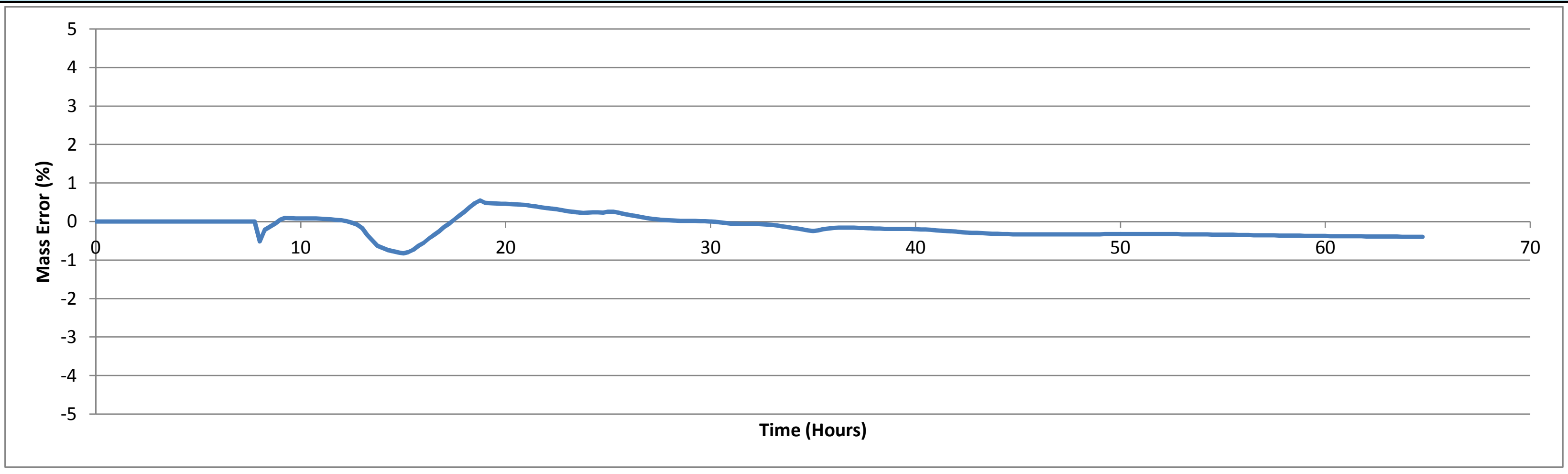


Comments

The 1D model components were convergent and within the recommended tolerances for the majority of the event. The higher number of iterations used at the start of the simulation quickly stabilise within 0.5 hours and do not affected the flood event.
The inflow peaks at approximately 7hrs, 20hrs and 56hrs represent the the incoming tide along the lower maine. The fluvial flood event extends over several hours and peaks at approxiamtely 33 hours.

2D Convergence

Mass Balance Plot
1%AEP Fluvial Event



Comments

The final cumulative mass balance error was -0.4% or 287367 m^3. The 2D model remains within the recommended tolerance throughout the event. The mass error temporarily increases between 8 and 20 hours as the 2D cells start to wet but remaiins within +/- 1% tolerance. The mass error then reduces to less than +/-0.1% 10 hours before the fluvial peak.
A negative mass balance means that there is less volume in the model than expected from the volume entering and leaving the 2D domain so depth could be under predicted at the initial wetting of cells as the 2D cells are rapidly wetting and the flow through the model is relatively small such as at the start of flooding.
The negative percentage mass error is exaggerated because there are very few active 2D cells as the first cells wet however, as flooding increases the mass error reduces to -0.05% by the peak. Therefore, the mass balance of volume entering and leaving the model is accurate within recommended tolerances at the peak and flood depth, velocity and extent can be deemed to be reliable.

Hydrological Performance

Target Flows – Fluvial events

HEP ID	Location	Model Node	10% AEP m^3/s Design	10% AEP Modelled	10% AEP % Difference	1%AEP m^3/s Design	1%AEP Modelled	1%AEP % Difference	0.1%AEP m^3/s Design	0.1%AEP Modelled	0.1%AEP % Difference
1D only reach											
22_721_1	Maine downstream of Brogheen	22MAIN04585B	99	98.6	0%	159.1	151.2	-5%	262.7	244.7	-7%
22_2090_1	Maine downstream of Ballymacpierce	22MAIN04302B	110.6	104.3	-6%	177.6	170.9	-4%	293.3	265.4	-10%
22_3375_1	Maine downstream of Little Maine	22MAIN04233B	144.3	126.6	-12%	231.7	230.7	0%	382.6	300.9	-21%
1D-2D reach (hydrodynamically linked to 1D only reach upstream)											
22_3101_1	22003 Riverville Gauge	22MAIN03780B	209.5	199.8	-5%	334.8	333.2	0%	550.2	553.0	1%
22_3306_1	Maine downstream of Inchinveema	22MAIN03672B	222.7	189.9	-15%	357.7	307.7	-14%	590.7	468.3	-21%
22_3754_1	Maine downstream of Coolmealane (Coolmealane Bridge)	22MAIN03291B	242	189.8	-22%	388.7	306.7	-21%	641.8	525.0	-18%
22_3970_3	Maine downstream of Annagh (Castlemaine)	22MAIN02609B	276.4	204.2	-26%	444	220.9	-50%	733.1	269.7	-63%
22_3958_1	Maine Downstream	22MAIN01698B	304.3	407.0	34%	488.9	431.0	-12%	807.3	454.0	-44%

Comments

The 1D flows were compared directly with the design flows upstream of Currans Bridge in 1D only reach.
Downstream of Currans Bridge, the flows in the 1D ISIS channel were combined with the 2D flow parallel to the channel where there was out-of-bank flows and compared to the design hydrology.
The modelled flows at Riverville Gauge were calculated using the 1D flows in the gauge sections, the flows along the bypass culvert and any 2D out-of-bank flow to be comparable with the design flow assumptions.

The modelled flows were within 10% of the design flows upstream and including Riverville Gauge which are entirely fluvially-dominated.
The modelled fluvial flows increasingly underestimated the design flows downstream of inchiveema due to the following:
1. Water stored on the floodplain and unable to re-enter the channel due to the raised embankment. i.e. the floodplain is attenuating the peak flow
2. An increasing tidal influence effectively tide-locking the Lower Maine and reducing peak flows.

The flows at the outfall 22_3948_1 are entirely tidally dominated and the peak flows represent tidal race on the turn of the tide rather than the fluvial flood. Therefore, the peak flows are not comparable with the design flood flows which assume free flow and fluvial dominance.

Calibration: There are no detailed flood reports available to calibrate flood extent along the Maine MPW due to the limited property that could be affected. However, gauge information was used to calibrate in-bank flows for two events.

Calibration Event 1

Model Run ID	I34CD_FCC20081004_D1
Period Modelled	04/10/2008 11:30 to 06/10/2008 02:45 with the peak at 04/10/2008 20:00
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	Rainfall runoff FSSR units have been applied based on the catchment average rainfall adjusted from Valentia Observatory and calibrated percentage runoff to achieve the flows at the riverville. The rainfall and calibrated rainfall paramaters were than trasnferred to the tributary inflows based on daily rain gauge totals.
Calibration Plot	See Schedule 3 - Calibration and Sensitivity
Comments	The model was calibrated to reproduce the water level and flow at Riverville gauge (22003). No Gauge information was available at Castlemaine 22061 for this event. The resultant gauge and long profile plots are included Schedule 3. The modelled peak flow at Riverville gauge was within 0.5% and peak water levels were within 0.02m at Riverville. No out of bank flooding was reported along the Lower Maine during this period and the model confirms this. Overall, the model calibrates well with the gauge data available for 4th October 2008.

Calibration Event 2

Model Run ID	I34CD_FCC20100112_D1
Period Modelled	12/01/2010 00:00 to 14/01/2010 23:45 with the peak at 12/01/2010 19:45 at Riverville
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.

Hydrological inflows	This event is less than QMED/ 50%AEP. It was selected to calibrate in-bank with concurrent gauge information at Riverville and Castlemaine. The observed rainfall at Valentia was transferred to various HEPS based on the daily rainfall gauge totals and the flood hydrograph derived and apply to the HEP inflows and lateral inflows. The astronomic predicted tide was derived for Castlemaine Harbour and applied directly to the downstream of the Maine model. The surge residual at Castletown Bearhaven was less than 0.1m therefore surge was not considered.
Calibration Plot	See Schedule 3 - Calibration and Sensitivity
Comments	The model was calibrated to reproduce the water level and flow at Riverville gauge (22003) and the level at the tidally influence Castlemaine gauge (22061). The resultant gauge and long profile plots are included Schedule 3. The modelled peak flow at Riverville gauge was within 0.5% and peak water levels were within 0.03m at both gauges. No out of bank flooding was reported during this period and the model confirms this. Overall, the model calibrates well with the gauge data available for 12th January 2010.
Verification to Anecdotal Flood Information	
Locations of known flooding	Recurring flooding was reported at observed around Church Street Bridge and Tullig on 24th January 2014. This event occurred after the model calibration exercise had been completed. Therefore, the photographs provided were used to verify and common sense check flow paths and frequency of flooding.
Available Gauge Data	The Castleisland gauge was not active for this event. Gauge data was obtained from Riverville but the flow was less than the 50%AEP estimate. The extent of flooding in Castleisland has not been observed as frequently as the 50%AEP (1 in 2 year). Therefore, flows at Riverville are not representative of flood conditions in Castleisland for this event.
Verification Plot	See Schedule 3 - Calibration and Sensitivity
Comparison with Design Flood	The photographs verify the flow paths across Tullig Road and on the rigth bank at Church Street.The extent of flooding at Tullig and around Church Street would be consistent with the 2%AEP design flood extent.
Sensitivity Test 1: Increased Flow	
Model Run ID	I34ME_FHD010_D1
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	All inflows were increased by 30% for the 1%AEP fluvial current design event to account for the uncertainty in the derivation of QMED and the pooling group selected. This is broadly equivalent to the HEFS 1%AEP as the increase in urban extent has less the 1% impact on peak flow. Therefore, the HEFS 1%AEP results (FHD010) have been used as the sensitivity test results.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	A 30% increase in flows resulted in a 0.2m increase in water level typically along the fluvial dominated reach. However this did not significantly increase flood extent and risk upstream of the Tralia confluence becasue the desigg 1%AEP flood extent already inundates the floodplain to the valley sides. Downstream of the Tralia confluence, water level was increased by approximately 0.4m due to the increase in flows. This resulted in a significant increase in flood extent upstream and downstream of Castlemaine although flood extent through the town of Castlemaine did not change becuas ehte town is on slightly higher ground.. Therefore flood risk upstream of the Traila confluence and within Castlemaine itself is not found to be sensitive to the uncertainties in flow. However, flood risk between Tralia and Castlemaine and downstream of Castlemaine was found to sensitive to uncertainites in flow. The design flows were selected based on the best fit to to Riverville gauge data and water levels at Castlemaine gauge. An allowance should be made when interpreting the design flood outlines and the in the sizing of any flood risk management option due to this uncertainty in flood level and extent caused by the uncertainties in flow.
Sensitivity Test 2: Increased Downstream Level	
Model Run ID	I34ME_CMD010_D1
Hydraulic Modification to Design Model	A 0.5m increase in water level was applied to the downstream boundary. This is broadly equivalent to the MRFS which increases sea level by 0.55m. Therefore, the MRFS 1%AEP results (CMD010) have been used to conduct the sensitivity test.
Hydrological inflows	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	A 0.5m increase in level resulted in a significant increase in flood extent along the Lower Maine up to Riverville. However flood extent did not signfincalt change in Castlmaine because the town is on higher ground. Flood risk upstream Riverville did not significantly change as it is fluvially dominated. Therefore flood risk at the suspension bridge and downstream of the Cromwell's Bridge on the Finnihy was deemed to be sensitive to the uncertainties in level. Flood risk upstream of Cromwell's Bridge was deemed to be insensitive to the downstream level. An allowance should be made when interpreting the design flood outlines and the in the sizing of any flood risk management option due to this uncertainty in flood level and extent caused by the uncertainties in levels.
Sensitivity Test 3: Increased Manning's 'n'	
Model Run ID	I34ME_FCN010_D1
Hydraulic Modification to Design Model	The Manning's 'n' values were increased to the upper limit of the industry recommended ranges. All active channels 0.040 to 0.050 All river banks 0.080 to 0.100 Pasture / parkland / garden 0.060 to 0.080 Buildings 0.200 to 0.300 Roads 0.033 to 0.040
Hydrological inflows	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	The increase in Mannng's 'n' did not signficantly increased flood extent as the 1%AEP design extent already fils the floodplain where it overtops the defences. The increase in Manning's 'n' did not significantly increase water level and locations where the embankments overtopped. Therefore. the Maine model is not deemed sensitive to assumptions in Manning's 'n' at the 1%AEP.

Figure B.1 In-Bank Calibration of the Maine Model to 4th October 2008 Fluvial Flood Event

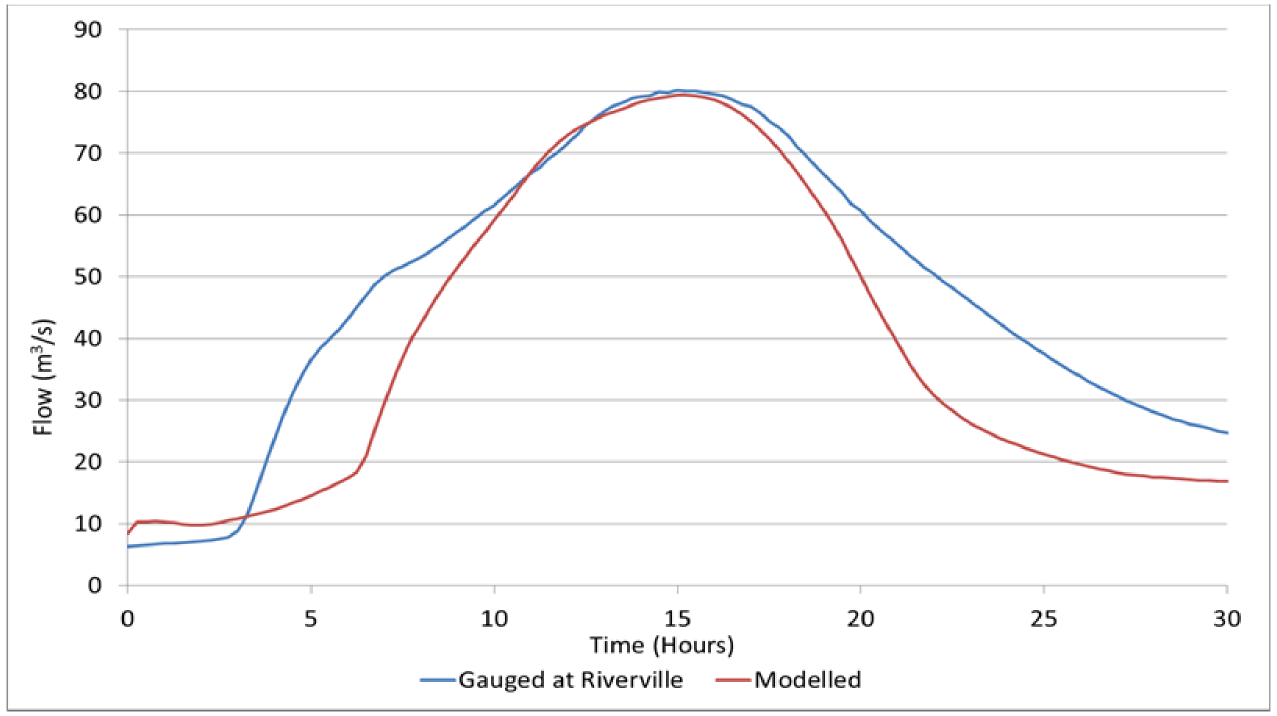
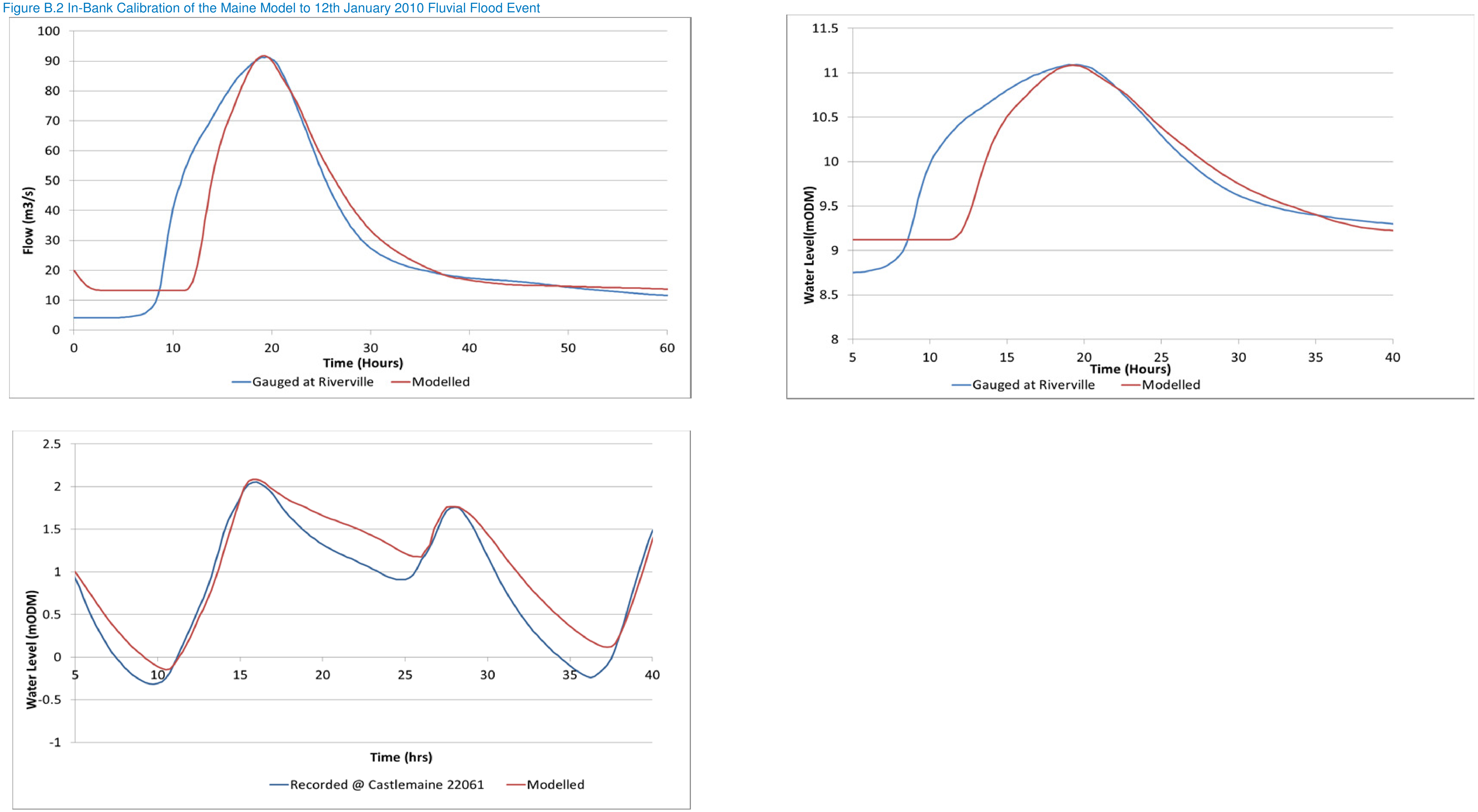
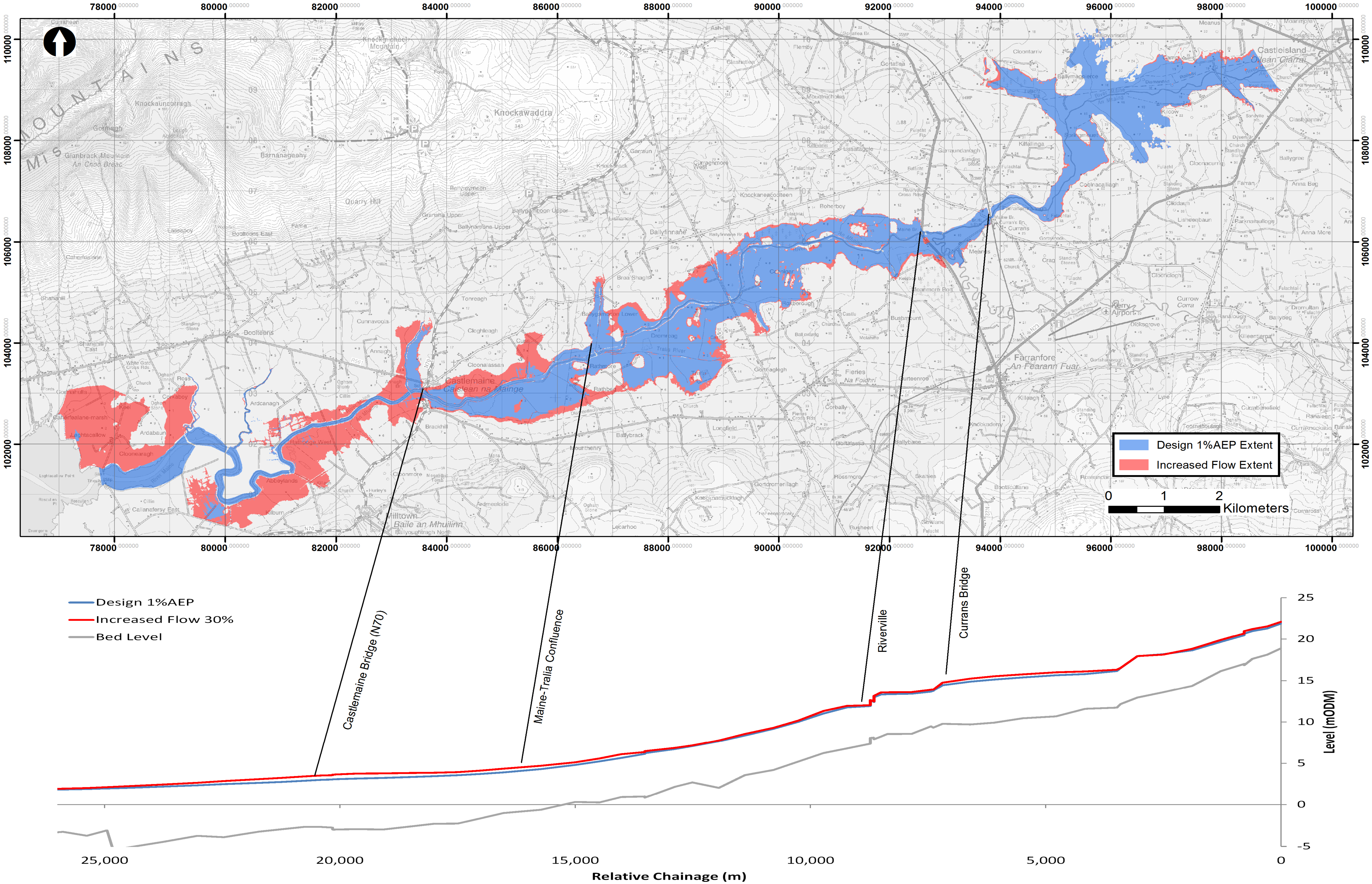


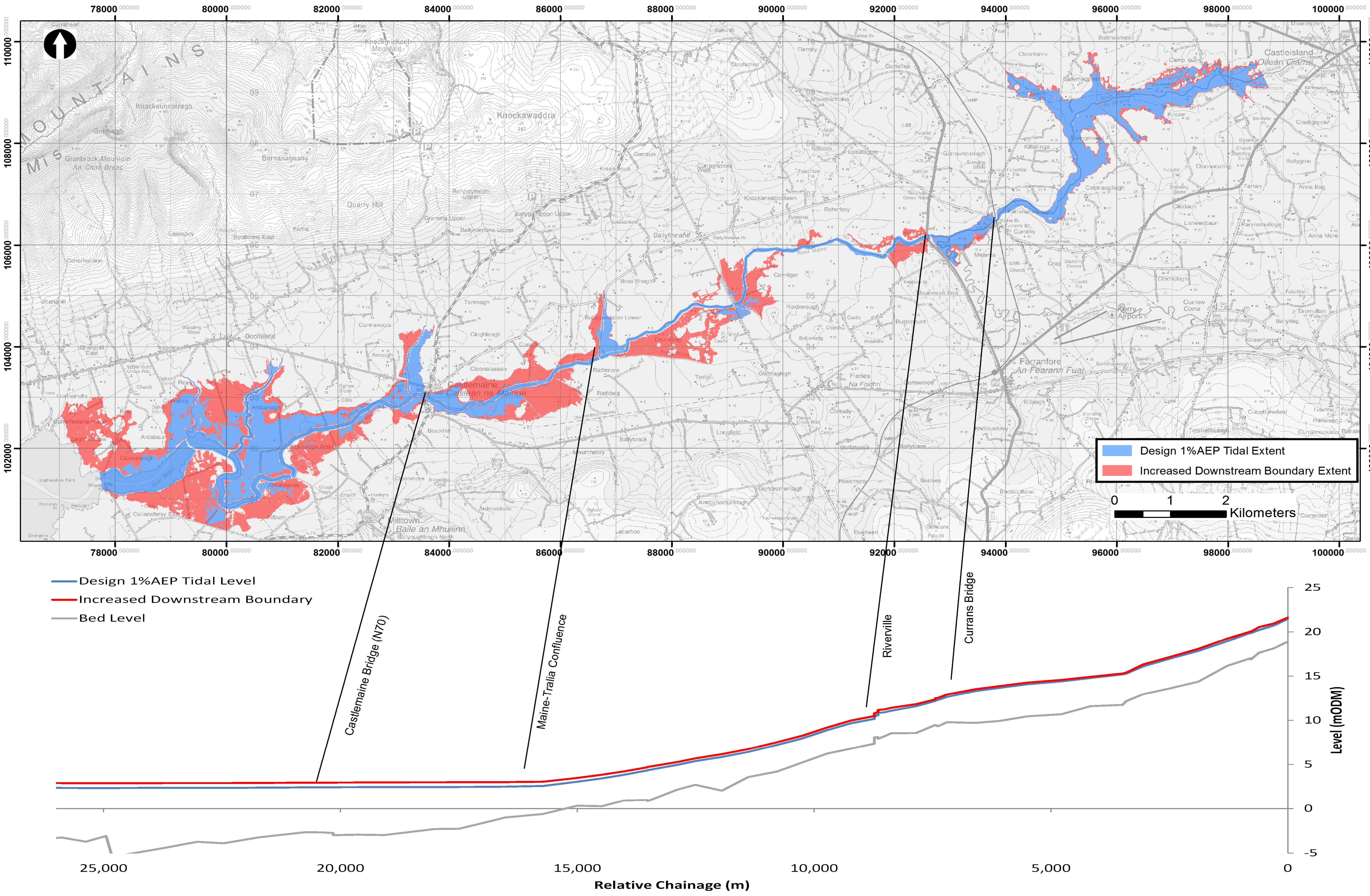
Figure B.2 In-Bank Calibration of the Maine Model to 12th January 2010 Fluvial Flood Event



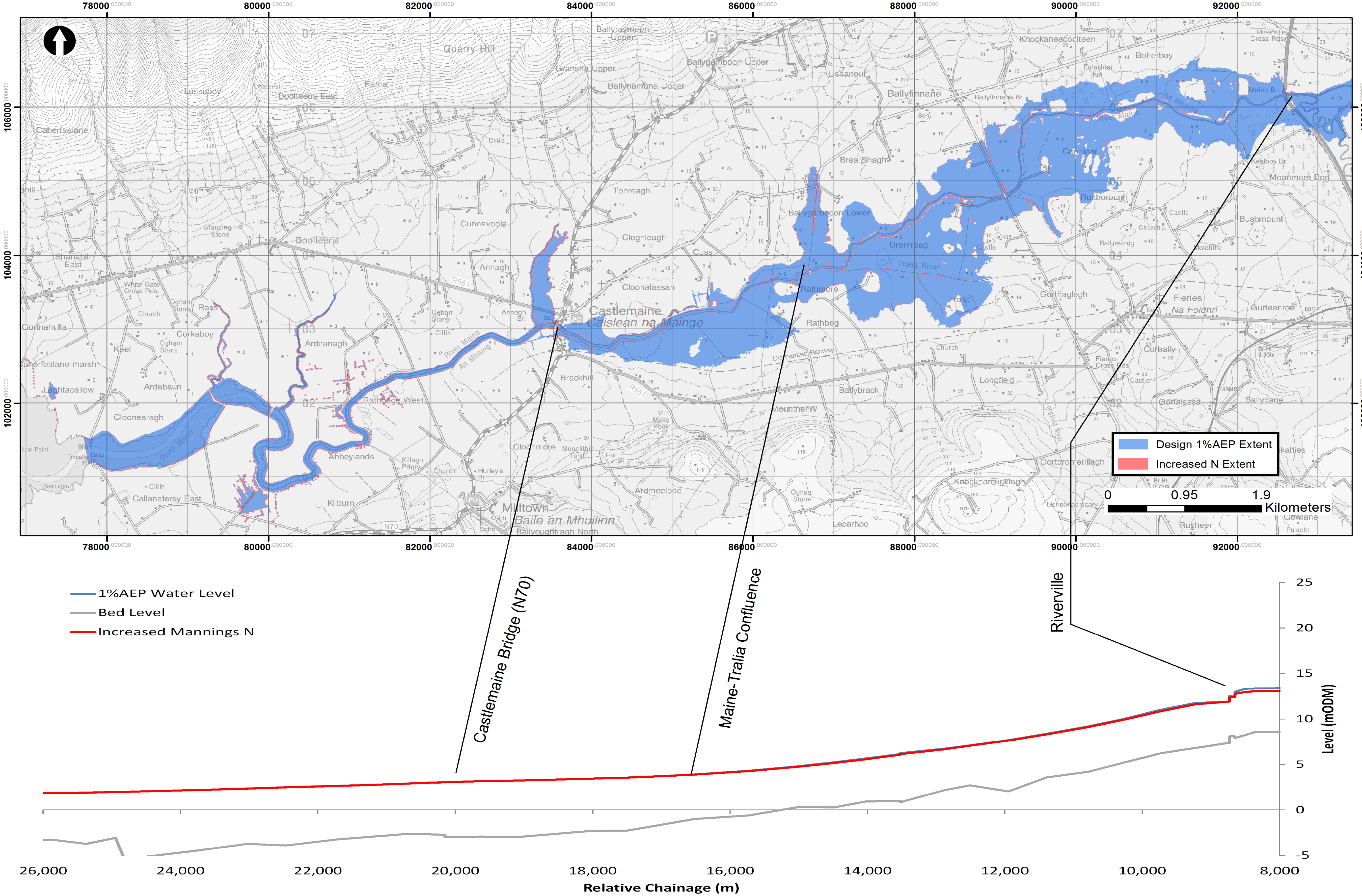
Map B.1: Sensitivity to 30% Increased Peak Flow



Map B.2: Sensitivity to Increased Downstream Boundary



Map B.3: Sensitivity to Increased Manning's 'n'



Maine Model Outputs

Threshold of Property Flooding	The key thresholds and areas affected by tidal flooding along the Maine MPW are: - 50%AEP tidal event exceeds the raised embankment at 080903,101921 to flooded the right bank towards Ardcanagh. - 50%AEP tidal event overtops the left bank of the Annagh River on the outskirts of Castlemaine - 10%AEP tidal event overtops the bank upstream of Castlemaine, at Rathpoge West and near Ardabaun causing extensive flooding on the right bank - 5%AEP tidal event overtops the left embankment at 80605,101151 flooding towards the Abbeylands - Less than 15 properties are affected by the 0.5%AEP tidal event. The key thresholds and areas affected by fluvial flooding along the Maine MPW are: - 50% AEP floods the confluence of the Maine and Brown Flesk but does not overtop the N22 - 20%AEP floods fields downstream of Riverville and around Coolmealane Bridge to Tralia River. - 2%AEP overtops the left bank downstream of Tralia River to Castlemaine - 1%AEP overtops the right bank upstream of Castlemaine - 1%AEP bypasses the Riverville Culvert to overtop the N22. - 0.5%AEP spills over the N70 upstream of Castlemaine to flood areas on the left bank downstream of Castlemaine - Less than 60 properties are affected by the 1%AEP fluvial event.
Critical Structures for Flood Risk	The critical structures along the Maine include: - The raised embankments and channel capacity downstream of Riverville determine flood risk to the lower Maine - The weir and bridge structures at Riverville control backwater and flooding over the N22 - Currans Bridge controls backwater upstream but flooding does not necessarily affect properties.
Areas affected by flooding	The majority of fluvial and tidal flooding is constrained to the agricultural and pastoral fields at Riverville, Castlemaine and the downstream Ferry Crossing once the raised embankments are overtopped. The impact of pumped drainage in removing water is not considered for this study as worst case scenario. Fluvial flooding also occurs around the Little Maine confluence. Limited properties are affected by flooding as this reach is relatively unpopulated and the largest town of Castlemaine is on raised ground compared with the surrounding floodplain.
Risk to people	Flood hazard is not calculacted for MPW reaches. However, the deepest tidal flooding occurs near Ardcanagh and the deepest fluvial flooding occurs between Coolmealane and Tralia. In both cases flooding exceeds 2m deep.
Consideration for Flood Risk Management Options	- Increased channel capacity in riased-embankent section - Raising of the embankment levels at low points identified by the survey/modelling. - Flood warning on the Maine catchment is likely to be effective as there is > 12 hours lead time at Riverville.

Flood Map Outputs

The following table outlines the print-ready flood mapping deliverables provided in the accompanying digitial data.

Scenario	Flood Extent Map	Flood Zone Map	Flood Depth Map	Flood Velocity Map	Flood Hazard Map
Fluvial Current Design 10%AEP	I21HME34_EXFCDEXF_D2		I21HME34_DPFCD100_D1		
Fluvial Current Design 1%AEP	I21HME34_EXFCDEXF_D2	I21HME34_ZN_D2	I21HME34_DPFCD010_D1		
Fluvial Current Design 0.1%AEP	I21HME34_EXFCDEXF_D2	I21HME34_ZN_D2	I21HME34_DPFCD001_D1		
Fluvial Mid Range Future Design 10%AEP	I21HME34_EXFMDEXF_D2				
Fluvial Mid Range Future Design 1%AEP	I21HME34_EXFMDEXF_D2				
Fluvial Mid Range Future Design 0.1%AEP	I21HME34_EXFMDEXF_D2				
Coastal Current Design 10%AEP	I34HME34_EXCCD_D2		I34HME34_DPCCD200_D1		
Coastal Current Design 0.5%AEP	I34HME34_EXCCD_D2		I34HME34_DPCCD005_D1		
Coastal Current Design 0.1%AEP	I34HME34_EXCCD_D2		I34HME34_DPCCD001_D1		
Coastal Mid Range Future Design 10%AEP	I34HME34_EXCMD_D2				
Coastal Mid Range Future Design 0.5%AEP	I34HME34_EXCMD_D2				
Coastal Mid Range Future Design 0.1%AEP	I34HME34_EXCMD_D2			Flood Velocity Maps are not required along MPW reaches	Flood Hazard Maps are not required along MPW reaches

GIS Outputs

The following table outlines the GIS deliverables and model run files provided in the accompanying digital handover.

Scenario	Model Run	Main River %AEP	Coastal %AEP	Flood Extent Polygon	Flood Zone Polygon	Flood Depth Grid	Flood Velocity Grid	Flood Hazard Grid
Fluvial Current Design 50%AEP	I34ME_FCD500_D1_Maine.ief	50	MHWS	I34EXFCD500D1		I34DPFCD500D1		
Fluvial Current Design 20%AEP	I34ME_FCD200_D1_Maine.ief	20	MHWS	I34EXFCD200D1		I34DPFCD200D1		
Fluvial Current Design 10%AEP	I34ME_FCD100_D1_Maine.ief	10	MHWS	I34EXFCD100D1		I34DPFCD100D1		
Fluvial Current Design 5%AEP	I34ME_FCD050_D1_Maine.ief	5	MHWS	I34EXFCD050D1		I34DPFCD050D1		
Fluvial Current Design 2%AEP	I34ME_FCD020_D1_Maine.ief	2	MHWS	I34EXFCD020D1		I34DPFCD020D1		
Fluvial Current Design 1%AEP	I34ME_FCD010_D1_Maine.ief	1	MHWS	I34EXFCD010D1	I34ZN_A_D2	I34DPFCD010D1		
Fluvial Current Design 0.5%AEP	I34ME_FCD005_D1_Maine.ief	0.5	MHWS	I34EXFCD005D1		I34DPFCD005D1		
Fluvial Current Design 0.1%AEP	I34ME_FCD001_D1_Maine.ief	0.1	MHWS	I34EXFCD001D1	I34ZN_B_D2	I34DPFCD001D1		
Fluvial Mid Range Future Design 50%AEP	I34ME_FMD500_D1_Maine.ief	50	MHWS	I34EXFMD500D1		I34DPFMD500D1		
Fluvial Mid Range Future Design 20%AEP	I34ME_FMD200_D1_Maine.ief	20	MHWS	I34EXFMD200D1		I34DPFMD200D1		
Fluvial Mid Range Future Design 10%AEP	I34ME_FMD100_D1_Maine.ief	10	MHWS	I34EXFMD100D1		I34DPFMD100D1		
Fluvial Mid Range Future Design 5%AEP	I34ME_FMD050_D1_Maine.ief	5	MHWS	I34EXFMD050D1		I34DPFMD050D1		
Fluvial Mid Range Future Design 2%AEP	I34ME_FMD020_D1_Maine.ief	2	MHWS	I34EXFMD020D1		I34DPFMD020D1		
Fluvial Mid Range Future Design 1%AEP	I34ME_FMD010_D1_Maine.ief	1	MHWS	I34EXFMD010D1		I34DPFMD010D1		
Fluvial Mid Range Future Design 0.5%AEP	I34ME_FMD005_D1_Maine.ief	0.5	MHWS	I34EXFMD005D1		I34DPFMD005D1		
Fluvial Mid Range Future Design 0.1%AEP	I34ME_FMD001_D1_Maine.ief	0.1	MHWS	I34EXFMD001D1		I34DPFMD001D1		
Fluvial High End Future Design 10%AEP	I34ME_FHD100_D1_Maine.ief	10	MHWS	I34EXFHD100D1		I34DPFHD100D1		
Fluvial High End Future Design 1%AEP	I34ME_FHD010_D1_Maine.ief	1	MHWS	I34EXFHD010D1		I34DPFHD010D1		

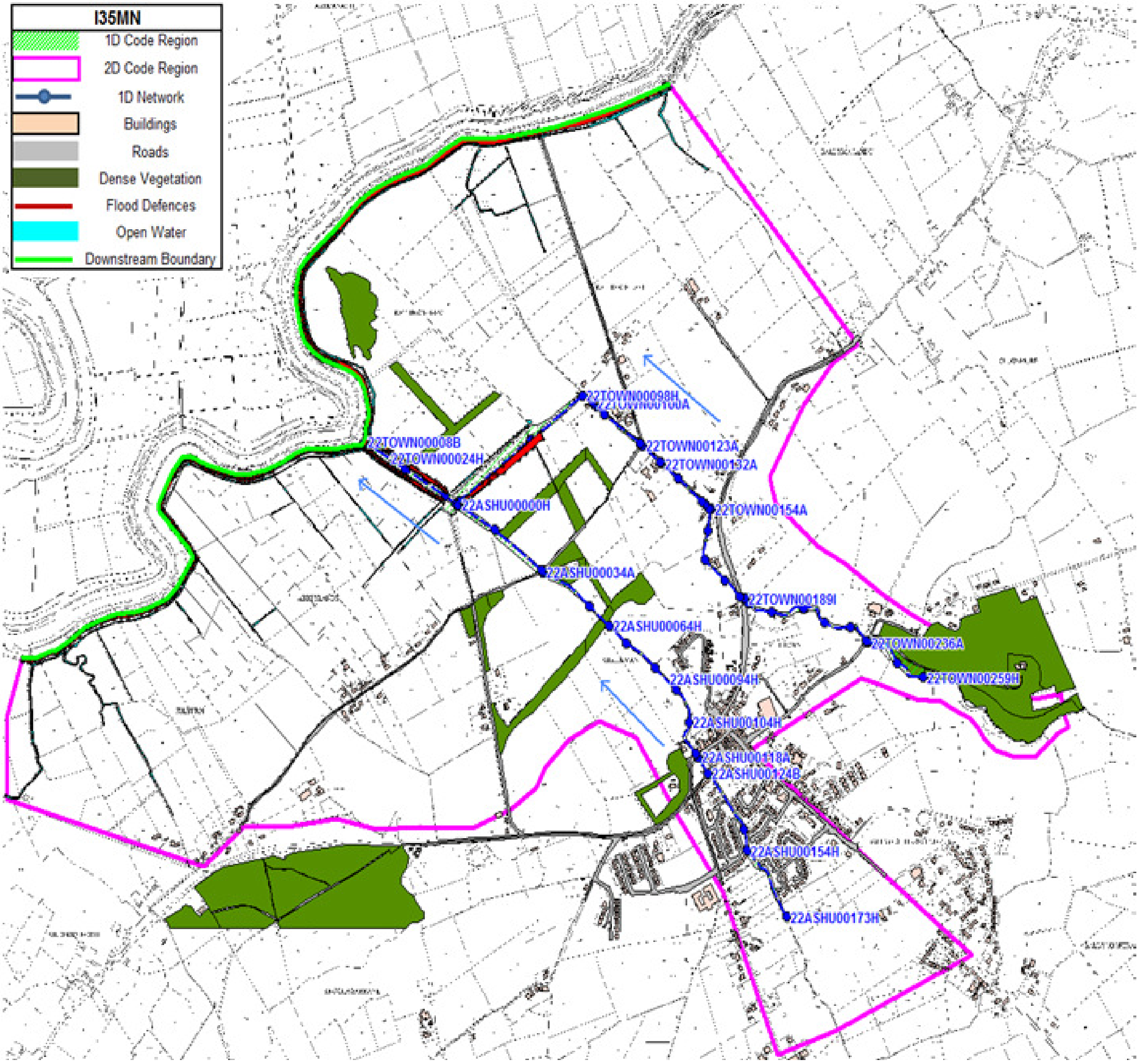
Appendix C. Milltown AFA Model Proformas

UOM	**22**		
AFA/ MPW Reach	**Milltown**		
Model ID	**I35MN**		
Purpose of Model Build	**Flood Mapping**		
Main Watercourses	**Ashullish and Ballyoughtrough Streams**	**FLUVIAL RISK**	Yes
Length Modelled (km)	**4.4**	**COASTAL RISK**	No (Tidal risk to lower end of catchment considered in Maine model)
Area Modelled (km^2)	**4.6**	**VULNERABLE TO WAVES**	No

Input Data	
River Channel Topographic Data	Topographic survey by Murphy Surveys Limited. Data captured in October 2012. Refer to Drawing 22AHSU_Ashullish_V1.dwg and 22TOWN_Milltown_V1.dwg
Floodplain Topographic Data	2m DTM LIDAR provided by OPW converted from ITM to ING. Elevations on hard standing were compared with river channel survey and found to be within 0.2 m.
Map data	Ordnance Survey Ireland 1:1000, 1:2500 and 1:5000 and 1:50000 data Vector mapping at 1:1000, 1:2500 and 1:5000 were converted from DWG/DXF to GIS files for modelling purposes

Model Build					
General Schematisation	A 1D/2D ISIS/TUFLOW approach was taken for Milltown to accurately model flow along the main watercourses and head loss through hydraulic structures whilst enabling multidirectional flow across the wide floodplain downstream of the N70. Building thresholds have been raised by 0.15m above the DTM level based on site observations and a higher Manning's 'n' value applied to the building footprints to simulate the storage of water once flooded. Areas of dense vegetation and plantations have been assigned higher Manning's 'n' to represent the increased roughness. the drainage channels with standing water were assigned with a lower Manning's 'n' to ensure these acted as flow pathways based on OSI mapping and site visit observations The 2D floodplain was set to 5m to represent the urban area without compromising run time. Version D2: Improved representation at culverts to better match local area engineer's comments. Improved representation of absolute flood defence crest and 1D extent.				
Software Versions Used	ISIS version 6.6 TUFLOW version 2012-05-AC-iSP-w32				
Total No of 1D nodes	**120**				
Routing Units	0				
Open channel (H)	54				
Bridges (D)	4				
Culverts (I)	6 structures using 50 culvert units (inlet, conduit and outlet)				
Penstock (P)	1				
Weirs (W)	0				
Model Extent	Reach/Feature	Upstream Limit (ING)		Downstream Limit (ING)	
	Ashullish	08265, 100032		081685, 101169	
	Ballyoughtrough (TOWN)	083164, 100739		081237, 101431	
Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	Ashullish and Ballyoughtrough	0.040	0.060	N/A	Schedule 1: Photographs
	Open pasture	N/A	N/A	0.060	Schedule 1: Photographs
	Dense vegetation	N/A	N/A	0.085	Schedule 1: Photographs
	Standing Water	N/A	N/A	0.04	Schedule 1: Photographs
	Buildings	N/A	N/A	0.200	Schedule 1: Photographs
	Roads	N/A	N/A	0.030	Schedule 1: Photographs
Structures	See Schedule 2 for Hydraulic Structure Parameters				
Upstream boundary	The design inflows were applied directly to the Ashullish and Ballyoughtrough upstream limits of the model as flow-time inflows QT.				
Lateral inflows	Lateral inflows were distributed evenly across the rest of the catchment at low points in the bank.				
Downstream boundary	The water level-time (HT) series extracted from the Maine MPW model was applied at the downstream of the flapped penstock to accurately simulate the period of tide-locking. The same HT boundary was applied along the banks of the River Maine to permit outflow from the model if flood levels exceed the embankment crest. The banks of teh River Maine form teh downstream limit of the active 2D code region (2D domain).				

Run Settings	Unsteady simulation of full 45 hour hydrograph. 2.5s timestep Minimum flows of 0.86m^3/s on the Ashullish Stream and 0.38m^3/s on the Ballyoughtrough (TOWN) were applied to maintain stability at low flows. This minimum flow is comparable to the calculated base flow.
Model Geoschematic	



SCHEDULE 1 : PHOTOGRAPHS

Photo 1: Ashullish Active Channel and Banks

Photo 2: Ballyoughtrough Channel and Banks

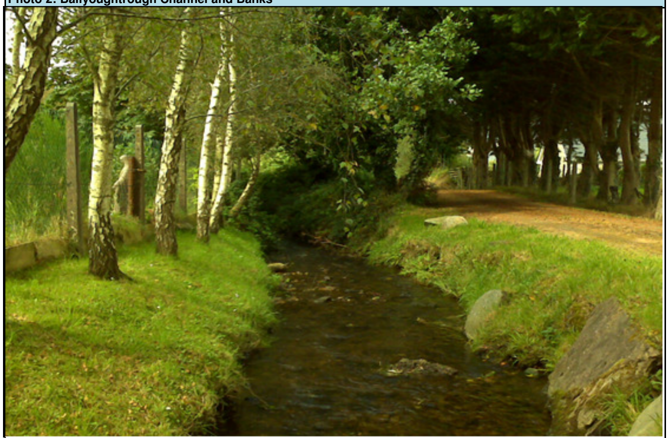


Photo 3: Pasture and Wooded Floodplain

Photo 4: Urban Floodplain, Roads and Buildings

SCHEDULE 2: Structures

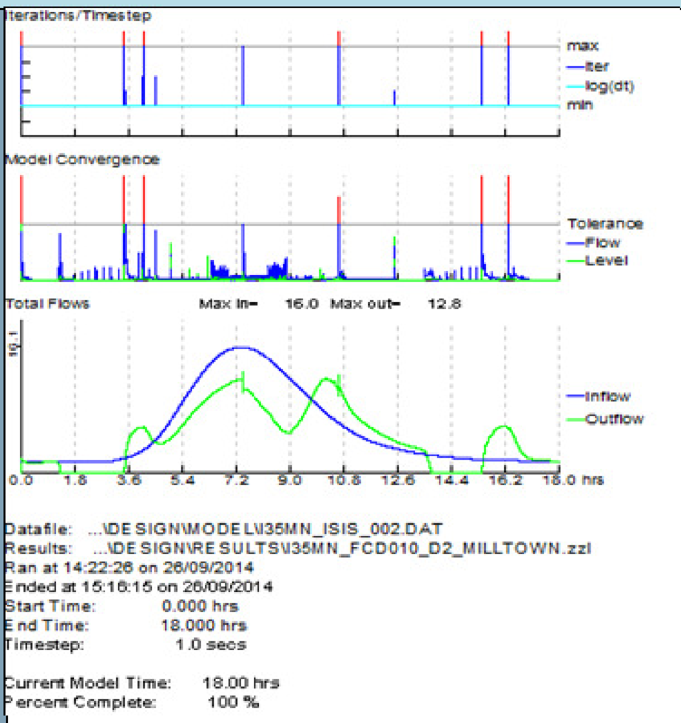
Data file: P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I35MN_Milltown\DESIGN\model\I35MN.DAT

Node(s)	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Culvert Parameters													Comments/ Justification
				Soffit Elevation	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation	Breadth	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation	Modular Limit	Weir Coeff.	Soffit level (mAOD)	No of Openings	Invert u/s (mAOD)	Invert d/s (mAOD)	Area (m²)	Nominal Width (m)	Length (m)	K	Ki	M	Trash Screen	Trash Screen coefficient	Flapped	
22ASHU00124D	82425	100457	Footbridge USBPR Bridge	15.64	1	0	1	N/A	N/A	N/A	N/A	15.476	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22ASHU00124D is a flat soffit footbridge wihtin only 0.2m differnce between the soffits on the left and right banks. It is not possible to model a sloping/ asymetircal soffit in the bridge geomerty therefore a symetrical soffit has been assumed for ISIS.
22ASHU00118D	82390	100504	N70 Town Bridge ARCH Bridge	15.67	2	0	1.2	N/A	N/A	N/A	N/A	17.011	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	d/s arched face used to the constricting point as old bridge rather than the rectangular us face from widening
22ASHU00034D	81852	101050	Access Bridge ARCH Bridge	3.22	1	0	1	N/A	N/A	N/A	N/A	3.62	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22ASHU00034D has been modelled with an ARCH bridge unit as the survey drawing and photos show an arched bridge with a springing height of at least 0.5m
TOWN00236O1 and 2	82966	100844	Chapel Bridge ORIFICE	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	21.21	0.9	1	20.305 20.265	2	19.371	19.359	2.109 0.715	2.23 0.80	5.9	0.7	0.5	0.7	N/A	N/A	N/A	Two low soffit rectangular bridge openings modelled as orifice units because the bridge would be orifice mode in the 50%AEP event and the length across the bridge is < 10m. Increased loss with inlet coefficeint (k) to better match blockage reported by local area engineer.
22TOWN00189I	82550	100971	N70 Culvert SPRUNG ARCH CONDUIT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12.74	1	10.864	10.981	3.202	2.8	18.255	0.7	0.7	0.75	N/A	N/A	N/A	Sprung arch conduit under N70 which sharp 90 degree bend near entrance. A culvert bend unit has been added to simulate the loss around the bend using a loss coefficient of 0.5. Increased inlet losses to better match local area engineer comments
22TOWN00154I	82432	101235	Culvert under access bridge CIRCULAR CULVERT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10.421	0.9	1	8.74	3	8.37	8.47	2.5434	0.9	6.1	0.1	0.5	2	N/A	N/A	N/A	Triple circular culvert with flat headwall Increased inlet losses to better match local area engineer comments
22TOWN00151I	82411	101251	Culvert under access bridge RECTANGULAR CULVERT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9.34	0.9	1	9.227	1	8.12	8.02	2.5484	2.3	10.166	0.7	0.5	0.667	N/A	N/A	N/A	Single rectangular corrugated culvert Increased inlet losses to better match local area engineer comments
22TOWN00132I	82263	101370	Culvert under access bridge RECTANGULAR CULVERT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.69	0.9	1	8.43	2	7.739	7.415	1.31 0.73	1.4 0.79	7.558	0.7	0.5	0.667	N/A	N/A	N/A	Double rectangular corrugated culvert Increased inlet losses to better match local area engineer comments
22TOWN00123I	82195	101423	Culvert under access bridge CIRCULAR CULVERT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.05	0.9	1	7.85	3	6.95	6.88	2.5434	0.9	6.757	0.1	0.5	2	N/A	N/A	N/A	Triple circular culvert with flat headwall Increased inlet losses to better match local area engineer comments
22TOWN00100I	82030	101548	Culvert under access bridge CIRCULAR CULVERT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.81	0.9	1	5.57	2	4.67	4.851	2.5434	0.9	5.378	0.1	0.5	2	N/A	N/A	N/A	Double circular culvert with flat headwall Increased inlet losses to better match local area engineer comments
TOWN00010O1 and 2	81259	101423	Outfall Penstock ORIFICE	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.32 0.32	2	-1.13 -1.13	-1.15 -1.24	1.67 1.53	1.15 1.07	22.3	1	0.5	0.7	N/A	N/A	FLAPPED	Flapped penstocks under the embankment. Dimensions estimated from upstream face as downstream was submerged during survey.

Milltown Model Performance

1D Convergence

Convergence Plot 1% AEP Fluvial Event

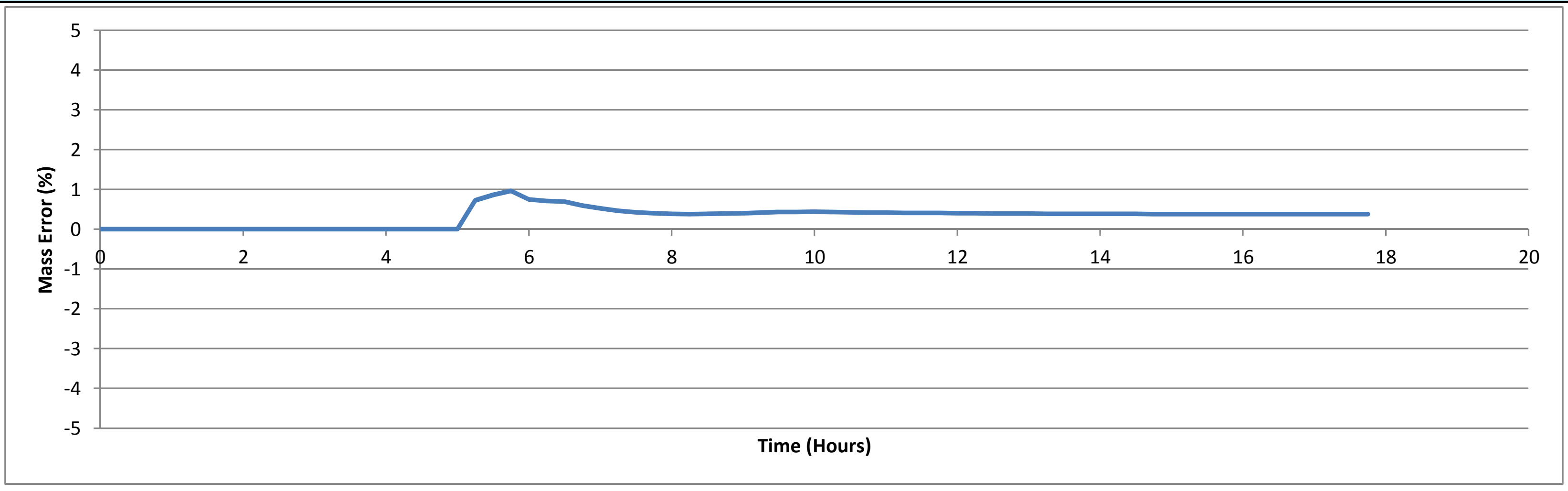


Comments

The 1D model components were convergent and within the recommended tolerances for the majority of the event.
The outflow varies due to the influence of the tide in the Maine preventing free flow at the outfall.
The brief 'spikes' of poor convergence at 3.5, 4, 6.5, 11.5,15.5 and 16.25hours are attributed to the opening and closing of the flapped outfall in to the Maine. These spikes do not impact the peak level or flood duration and therefore acceptable.

2D Convergence

Mass Balance Plot 1%AEP Fluvial Event



Comments

The final cumulative mass balance error was 0.4% or 1261 m3. The mass error rises to a maximum of 1% as the cells wet at 6 hours. However mass error reduces to less than the 0.4% at the peak (8hours). Therefore the mass error is within the +/- 1% recommended tolerance and is therefore acceptable.

A positive mass balance means that there is more volume in the model than expected from the volume entering and leaving the 2D domain so depth could be over predicted at the initial wetting of cells as the 2D cells are rapidly wetting and the flow through the model is relatively small such as at the start of flooding.
The positive percentage mass error is exaggerated because there are very few active 2D cells as the first cells wet at 5 to 6 hours however, as flooding increases the mass error reduces to to less than 1% by the peak. Therefore, the mass balance of volume entering and leaving the model is accurate within recommended tolerances at the peak and flood depth, velocity and extent can be deemed to be reliable.

Hydrological Performance

Target Flows

			10% AEP m3/s			1%AEP m3/s			0.1%AEP m3/s		
HEP ID	Location	Model Node	Design	Modelled	% Difference	Design	Modelled	% Difference	Design	Modelled	% Difference
22_3116_1	Ashullish-Ashullish Trib d/s	22ASHU00144H	3.3	3.2	-2%	5	4.9	-1%	7.5	7.4	-1%
22_3116_4	Ashullish- Ballyoughtragh U/s	22ASHU00000H	5.6	5.4	-4%	8.5	8.2	-4%	12.9	12.1	-6%
22_3617_1	Ashullish- Ballyoughtragh D/s	22TOWN00046B	9.8	10.1	3%	14.9	12.6	-15%	22.5	15.5	-31%
22_3958_2	Ashullish Stream d/s	22TOWN00010A	10.6	11.9	12%	16.1	14.1	-13%	24.3	15.4	-37%
22_3425_9	Ballyoughtragh Stream D/S	22TOWN00100A	4.2	4.0	-4%	6.4	6.2	-4%	9.8	9.1	-7%

Comments

The flows in the 1D ISIS channel were combined with 2D flows parallel to the channel where there were out-of-bank flows and compared to the design hydrology.

The modelled flow tended to underestimate flows at the HEP locations compared to the design peak flows in all flood events. Flows taken from the two downstream locations on the Ashullish Stream (22_3617_1 and 22_3958_2) both show significant under- and over-estimation of flow across these three return periods. These nodes are both influenced by backwater from the River Maine. which becomes more significant in the higher return periods, thereby explaining these discrepancies.

Verification Checks

Locations of known flooding

Flooding was observed from the Ballyoughtragh Stream downstream of Hurley's bridge on the N70 on 4th January 2008 and from the Ashullish Stream along the N70 at Bridge Street between 1998-2000. No specific details for these events were available so photographs provided were used to verify and common sense check flow paths and frequency of flooding.

Available Gauge Data

None in vicinity

Verification Plot

See Schedule 3 - Validation of flooded areas

Comparison with Design Flood

The photographs and discussion verify the modelled flood extents at the locations discussed above. The extent of flooding from the Ballyoughtragh Stream is consistent with a modelled 10% AEP flood event.

Sensitivity Test 1: Increased Flow

Model Run ID

I35MN_FHD010_D1_MILLTOWN_3

Hydraulic Modification to Design Model

No hydraulic modifications were made to the design model.

Hydrological inflows

All inflows were increased by 30% for the 1%AEP fluvial current design event to account for the uncertainty in the derivation of QMED and the pooling group selected.

This is broadly equivalent to the HEFS 1%AEP as the increase in urban extent has less the 1% impact on peak flow. Therefore, the HEFS 1%AEP results (FHD010) have been used as the sensitivity test results.

Sensitivity Plot

See Schedule 3 - Calibration and Sensitivity

Comments

A 30% increase in flows resulted in flooding along the Ashullish Stream and Ballyoughtragh Stream immediately south of the N70 where before it was minimal. These two sources both increased the overall flood extent as the additional flow resulted in new flow paths being utilised.

The increase in downstream water level increases the period of tide locking for this lower section. The increased downstream level was not of sufficient length or magnitude to induce a backwater impact in Milltown. It instead caused additional flooding in the floodplain from additional spill from the lower Ashullish Stream.

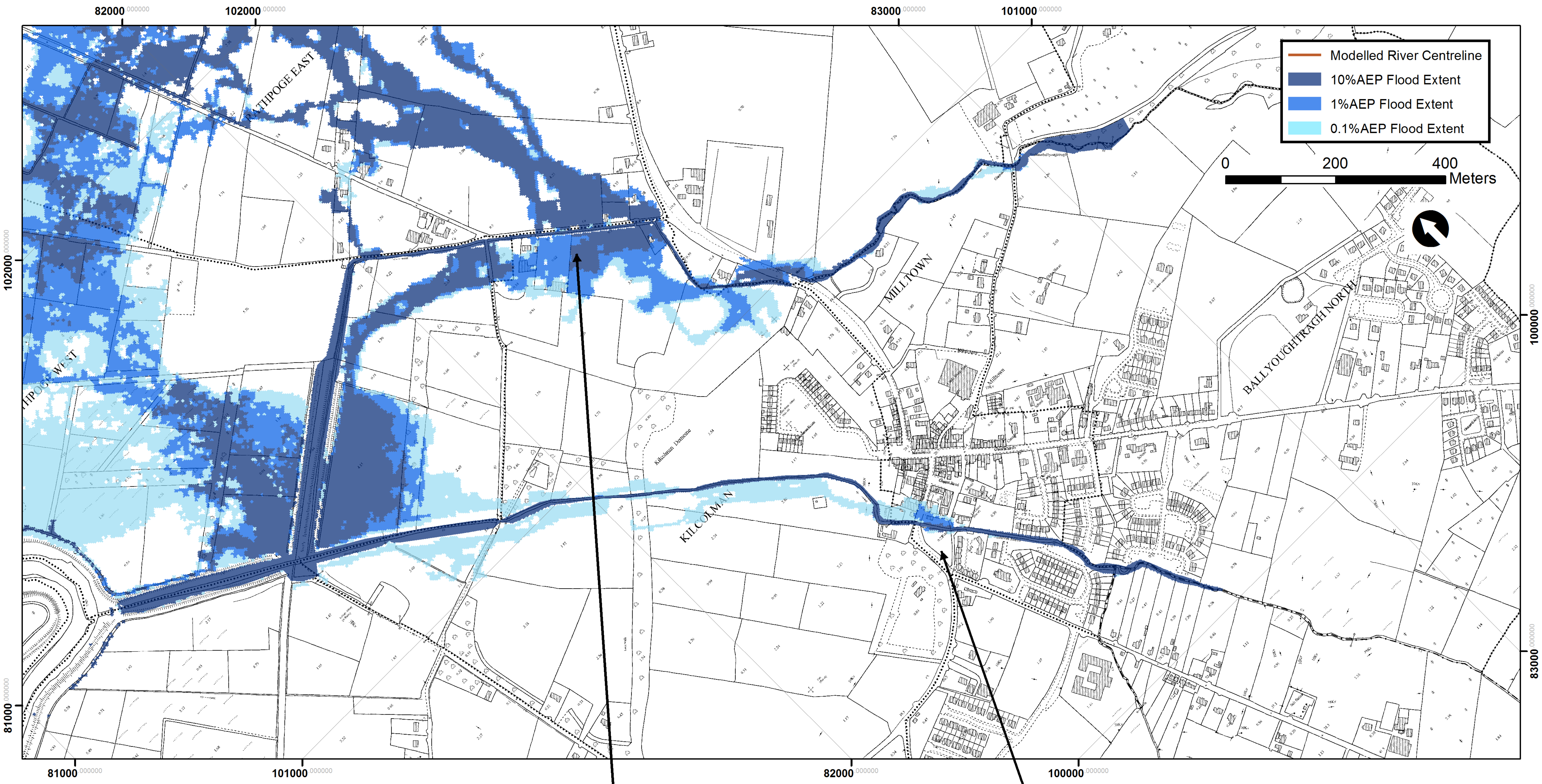
Therefore flood risk in Milltown was found to be sensitive to the uncertainties in flow.

An allowance should be made when interpreting the design flood outlines and in the sizing of any flood risk management option due to this uncertainty in flood level and extent caused by the uncertainties in flow.

Sensitivity Test 2: Increased Manning's 'n'	
Model Run ID	I35MN_FCN010_D1_MILLTOWN_3
Hydraulic Modification to Design Model	The Manning's 'n' values were increased to the upper limit of the industry recommended ranges. All active channels 0.040 to 0.048 All river banks 0.060 to 0.070 Pasture / parkland / garden 0.060 to 0.070 Buildings 0.200 to 0.300 Roads 0.033 to 0.040 Dense vegetation 0.085 to 0.1 Standing water 0.04 to 0.045
Hydrological inflows	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increase in roughness values in bank and out-of-bank has a minimal impact on the flood extent from the Ashullish Stream but did result in more extensive flooding from the Ashullish Stream downstream of the N70. The most notable impact of this is immediately downstream of Hurley's Bridge where the increased roughness results in water spilling out from the Ballyoughtragh Stream in a westerly direction. In general the increase in roughness did not have a notable impact on water level in both streams. Therefore the model is not deemed sensitive to the assumptions in assigning Manning 's 'n'.

Sensitivity Test 3: Increased culvert parameters	
Model Run ID	I35MN_FCS010_D1_MILLTOWN_3
Hydraulic Modification to Design Model	The Manning's 'n' values attached to the culvert sections were increased from 0.025 to 0.03. Culvert inlet parameters were also modified to represent a 20% increase in accordance with Table 6.4 CIRIA C689 Culvert Design and Operation Guide (2010).
Hydrological inflows	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	A change in the culvert parameters resulted in only minor changes to the maximum level and flood extent because the 1%AEP is already out of bank. However, the stage plot shows that there is a greater head loss on the rising and falling limb causing water to spill out-of-bank earlier and flood duration to be longer. Therefore the Milltown model is not deemed sensitive to the culvert coefficients at the 1%AEP but would be more sensitive for less severe events on threshold of flooding along Old Station Road.

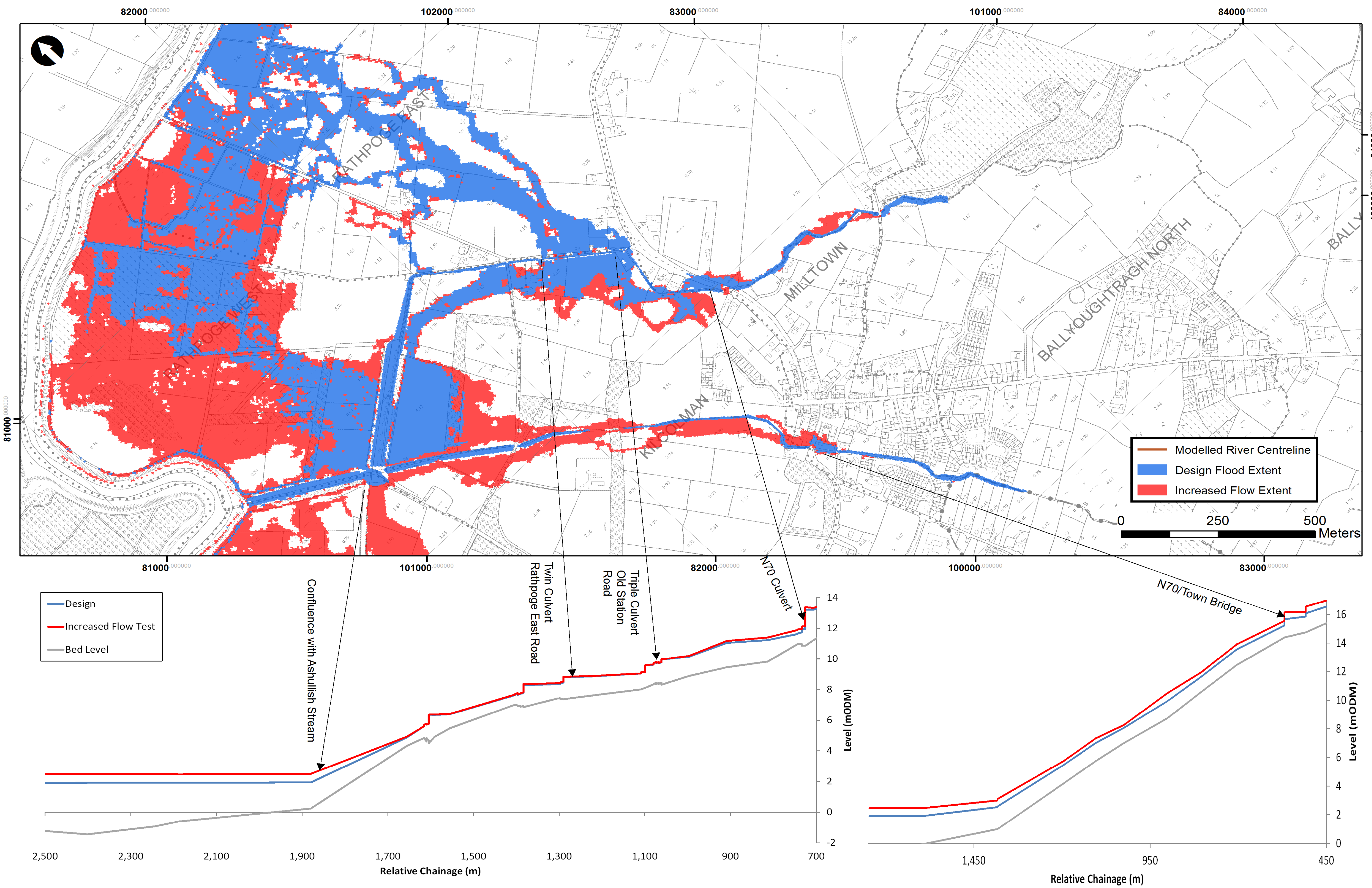
Map C.1: Validation of Flooded Areas in January 2008 with Design Flood Outlines



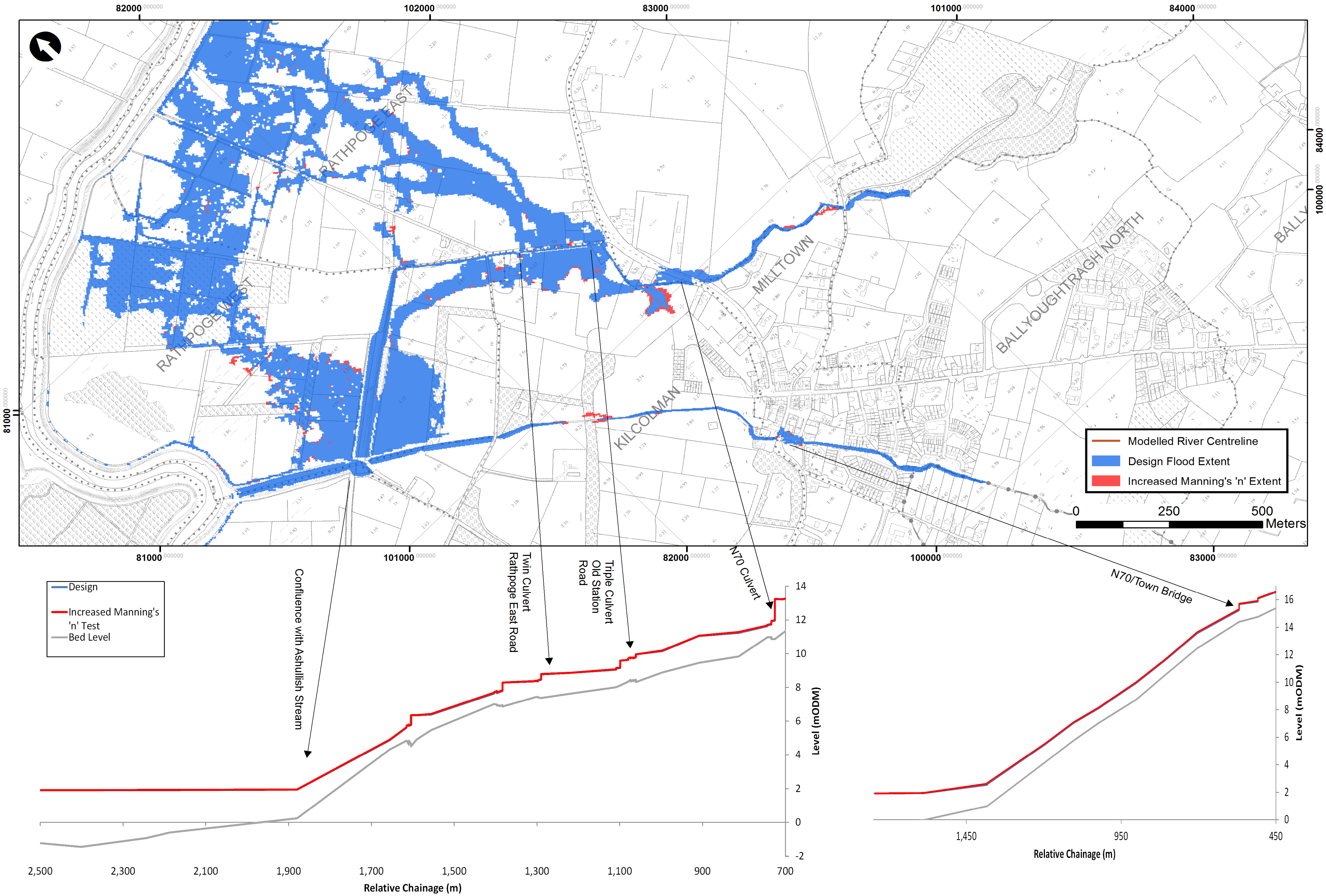
Flooding reported at these properties betwwen 1998-2000

Flooding reported both in JBA report (2011) and anecdotally along this road in January 2008.

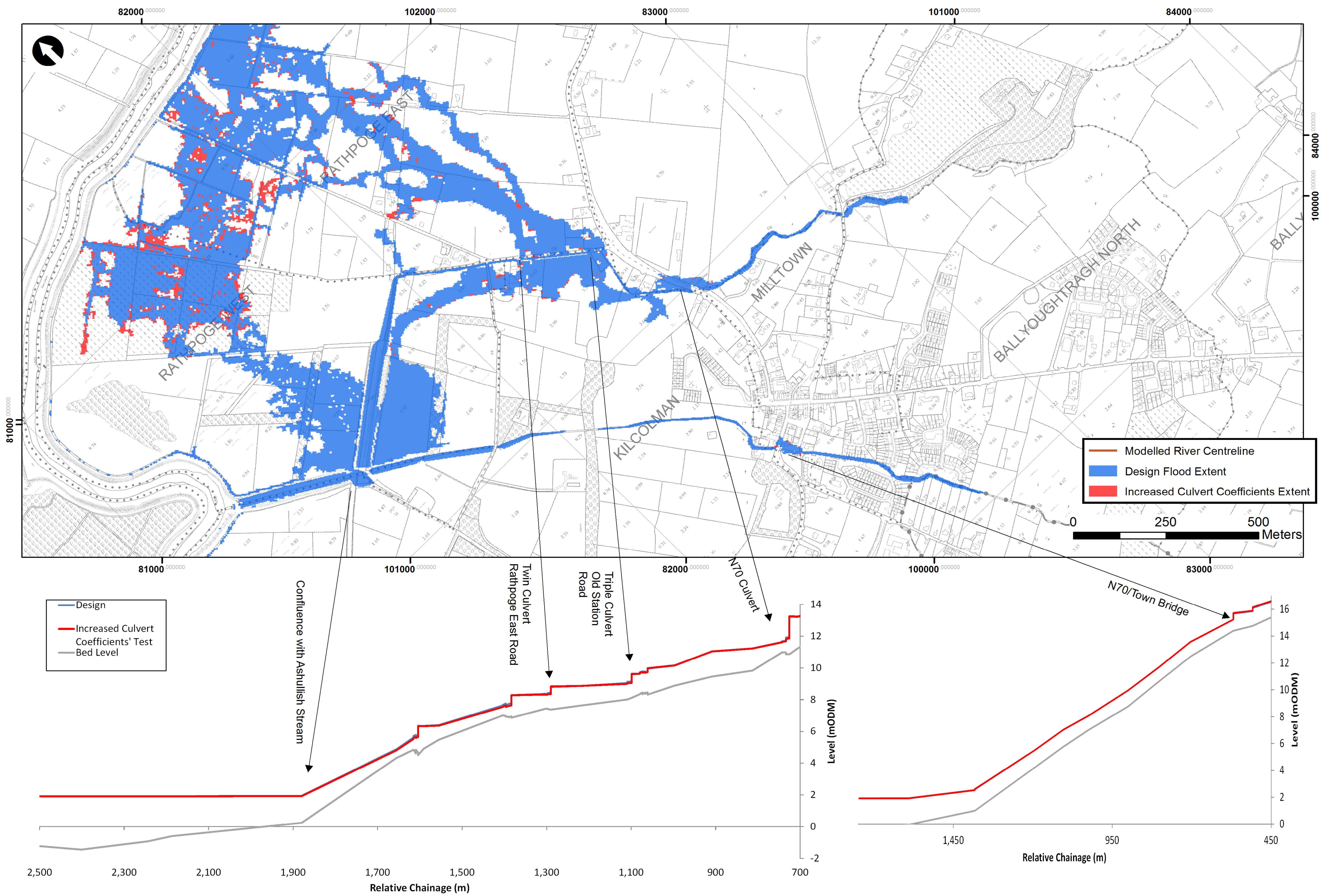
Map C.2: Sensitivity to 30% Increased Peak Flow



Map C.3: Sensitivity to Increased Manning's 'n'



Map C.4: Sensitivity to increased culvert parameters



Milltown Model Outputs	
Threshold of Property Flooding	The key thresholds and areas affected by flooding in Milltown are: - 50%AEP event exceeds the capacity of the Ballyoughtragh Stream downstream of the N70 causing water to spill over the right bank in two locations . This is modelled to impact a single property. -50%AEP overtops at the confluence of the Ballyoughtragh an Ashusliish Streams at low points in the embankments to flood fields. -10%AEP causes shallow floing by the N70 at Hurley's Bridge. - 2%AEP event causes additional sections of the Ballyoughtragh Stream downstream of the N70 to spill, impacting additional properties. - 1%AEP event floods the N70 at Town Bridge on the Ashullish Stream - 0.5%AEP event bypasses town bridge - Approximately 17 properties are affected by the 1%AEP fluvial event. It should be noted that the drainage system and tributaries towards Cloonmore and Kilburn has not been modelled as part of the CFRAM study as these are not MPW or HPWs.
Critical Structures for Flood Risk	The critical structures in determining flood risk include: - N70 bridge on Bridge Street, Ashullish Stream - Hurley's Bridge, Ballyoughtragh Stream - The several small culverts on the Ballyoughtragh Stream downstream of Hurley's Bridge.
Areas affected by flooding	The floodplain areas downstream of the N70 on both streams are modelled to be affected most from flooding. The greatest impact on property and infrastructure is modelled to be along the access tracks leading west off the N70.
Risk to people	The greatest risk to life is associated with deep fast flowing water in channel and along the Ballyoughtragh Stream downstream of the N70 where risk from overland flow would be highest. There is also risk along Bridge Street in the 0.1%AEP magnitude event.
Consideration for Flood Risk Management Options	- Increased conveyance at the key structures identified are likely to reduce flood risk.

Flood Map Outputs

The following table outlines the print-ready flood mapping deliverables provided in the accompanying digital data.

Scenario	Flood Extent Map	Flood Zone Map	Flood Depth Map	Flood Velocity Map	Flood Hazard Map
Fluvial Current Design 10%AEP	I22HMN35_EXFCDEXF_D2		I22HMN35_DPFCD100_D2	I22HMN35_VLFCD100_D2	I22HMN35_HZFCD100_D2
Fluvial Current Design 1%AEP	I22HMN35_EXFCDEXF_D2	I22HMN35_ZN_D2	I22HMN35_DPFCD010_D2	I22HMN35_VLFCD010_D2	I22HMN35_HZFCD010_D2
Fluvial Current Design 0.1%AEP	I22HMN35_EXFCDEXF_D2	I22HMN35_ZN_D2	I22HMN35_DPFCD001_D2	I22HMN35_VLFCD001_D2	I22HMN35_HZFCD001_D2
Fluvial Mid Range Future Design 10%AEP	I22HMN35_EXFMDEXF_D2				
Fluvial Mid Range Future Design 1%AEP	I22HMN35_EXFMDEXF_D2				
Fluvial Mid Range Future Design 0.1%AEP	I22HMN35_EXFMDEXF_D2				

GIS Outputs

The following table outlines the GIS deliverables and model run files provided in the accompanying digital handover.

Scenario	Model Run File	Main River %AEP	Tributary River %AEP	Flood Extent Polygon and Nodes	Flood Zone Polygon	Flood Depth Grid	Flood Velocity Grid	Flood Hazard Grid
Fluvial Current Design 50%AEP	I35MN_FCD500_D2_MILLTOWN.ief	50	50	I35EXFCD500D2		I35DPFCD500D2	I35VLFCD500D2	I35HZFCD500D2
Fluvial Current Design 20%AEP	I35MN_FCD200_D2_MILLTOWN.ief	20	20	I35EXFCD100D2		I35DPFCD100D2	I35VLFCD100D2	I35HZFCD100D2
Fluvial Current Design 10%AEP	I35MN_FCD100_D2_MILLTOWN.ief	10	10	I35EXFCD100D2		I35DPFCD100D2	I35VLFCD100D2	I35HZFCD100D2
Fluvial Current Design 5%AEP	I35MN_FCD050_D2_MILLTOWN.ief	5	5	I35EXFCD050D2		I35DPFCD050D2	I35VLFCD050D2	I35HZFCD050D2
Fluvial Current Design 2%AEP	I35MN_FCD020_D2_MILLTOWN.ief	2	2	I35EXFCD020D2		I35DPFCD020D2	I35VLFCD020D2	I35HZFCD020D2
Fluvial Current Design 1%AEP	I35MN_FCD010_D2_MILLTOWN.ief	1	1	I35EXFCD010D2	I35ZN_A_D2	I35DPFCD010D2	I35VLFCD010D2	I35HZFCD010D2
Fluvial Current Design 0.5%AEP	I35MN_FCD005_D2_MILLTOWN.ief	0.5	0.5	I35EXFCD005D2		I35DPFCD005D2	I35VLFCD005D2	I35HZFCD005D2
Fluvial Current Design 0.1%AEP	I35MN_FCD001_D2_MILLTOWN.ief	0.1	0.1	I35EXFCD001D2	I35ZN_B_D2	I35DPFCD001D2	I35VLFCD001D2	I35HZFCD001D2
Fluvial Mid Range Future Design 50%AEP	I35MN_FMD500_D2_MILLTOWN.ief	50	50	I35EXFMD500D2		I35DPFMD500D2		
Fluvial Mid Range Future Design 20%AEP	I35MN_FMD200_D2_MILLTOWN.ief	20	20	I35EXFMD100D2		I35DPFMD100D2		
Fluvial Mid Range Future Design 10%AEP	I35MN_FMD100_D2_MILLTOWN.ief	10	10	I35EXFMD100D2		I35DPFMD100D2		
Fluvial Mid Range Future Design 5%AEP	I35MN_FMD050_D2_MILLTOWN.ief	5	5	I35EXFMD050D2		I35DPFMD050D2		
Fluvial Mid Range Future Design 2%AEP	I35MN_FMD020_D2_MILLTOWN.ief	2	2	I35EXFMD020D2		I35DPFMD020D2		
Fluvial Mid Range Future Design 1%AEP	I35MN_FMD010_D2_MILLTOWN.ief	1	1	I35EXFMD010D2		I35DPFMD010D2		
Fluvial Mid Range Future Design 0.5%AEP	I35MN_FMD005_D2_MILLTOWN.ief	0.5	0.5	I35EXFMD005D2		I35DPFMD005D2		
Fluvial Mid Range Future Design 0.1%AEP	I35MN_FMD001_D2_MILLTOWN.ief	0.1	0.1	I35EXFMD001D2		I35DPFMD001D2		
Fluvial High End Future Design 10%AEP	I35MN_FHD100_D2_MILLTOWN.ief	10	10	I35EXFHD100D2		I35DPFHD100D2		
Fluvial High End Future Design 1%AEP	I35MN_FHD010_D2_MILLTOWN.ief	1	1	I35EXFHD010D2		I35DPFHD010D2		
Fluvial High End Future Design 0.1%AEP	I35MN_FHD001_D2_MILLTOWN.ief	0.1	0.1	I35EXFHD001D2		I35DPFHD001D2		