

South Western CFRAM Study

Hydraulics and Flood Mapping Appendices,
Unit of Management 19

January 2015

The Office of Public Works

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Oifig na nOibreacha Poiblí

SOUTH WESTERN CFRAM STUDY
CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT

Mott MacDonald

South Western CFRAM Study

Hydraulics and Flood Mapping Appendices, Unit of Management 19

January 2015

The Office of Public Works

Johnathan Swift Street,
Trim,
Co. Meath

Mott MacDonald, 5 Eastgate Avenue, Eastgate, Little Island, Cork, Ireland
T +353 (0)21 4809 800 **F** +353 (0)21 4809 801 **W** www.mottmac.com

Issue and revision record

Revision	Date	Originator	Checker	Approver	Description	Standard
A	July 2014	M Piggott	R Gamble B O'Connor	R Gamble	Draft	
B	January 2015	M Piggott	R Gamble B O'Connor	R Gamble	Draft Final	

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Appendices

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Appendix A. Ballingeary AFA Model Proformas

UOM	19		
AFA/ MPW Reach	AFA-Ballingeary and Inchigeelagh		
Focus	Ballingeary		
Model ID	I18BY		
Purpose of Model Build	Flood Mapping		
Main Watercourse	River Bunsheelin	FLUVIAL RISK	Yes
Length Modelled (km)	10km	COASTAL RISK	No
Area Modelled (km^2)	N/A	VULNERABLE TO WAVES	No

Input Data	
River Channel Topographic Data	River channel survey for the River Bunsheelin and Upper Lee was undertaken by Maltby's Survey Ltd in June 2007. 5UL1_KP_001, 5UL1_XS_001, 5ULE_KP_001-006, 5ULE_XS_001-013, 5ULE_XS_014-035, 5ULE_XS_036-045: surveyed in June 2007 (Upper Lee CFRAMS Study)
Floodplain Topographic Data	Filtered LIDAR DTM "I18BY_DTM_2m.asc" 2m grid resolution captured in August 2006 as part of the Lee Pilot CFRAM Study. The LIDAR DTM covered the AFA of Ballingeary, Inchigeelagh and Lough Allua in between.
Map data	1:5000 OSI mapping tiles were used. OS1006 & OS1206. The OSI mapping was found to include all current developments and was consistent with site observations, the river channel survey and aerial photography.

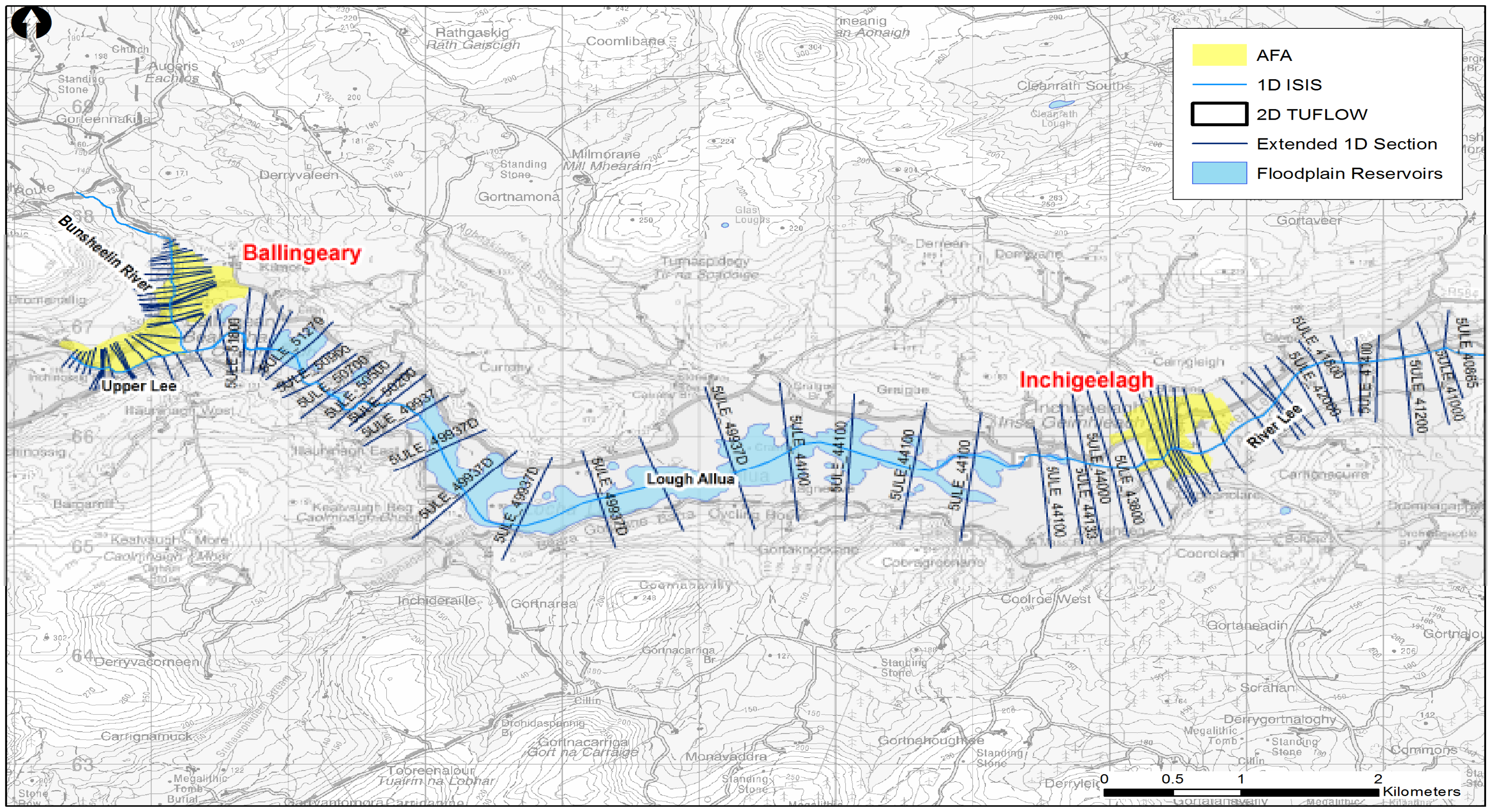
Model Build	
General Schematisation	Ballingeary and Inchigeelagh have been modelled in the same hydraulic model in order to fully consider the routing of flow through Lough Allua. A 1D approach has been taken for Ballingeary and Inchigeelagh AFAs because the flood water is dictated by the Lough Allua and limited to the narrow valley. Therefore the 1D approach is deemed sufficient to assess flood risk to the AFA. The 1D model represents the River Bunsheelin to its confluence with the River Lee and the River Lee through Ballingeary, Lough Allua and Inchigeelagh building upon the existing Lee Pilot CFRAMS model. Ballingeary changes: The major change is the application of rainfall runoff inflows and improved intermediate catchment distribution based on the revised design hydrology. The extension of the river channel sections has been based on the LIDAR DTM and slightly improved the orientation of the extension at Ballingeary to better estimate floodplain volumes. Version D2: The Manning's 'n' values for River Bunsheelin have been updated to better represent the frequency of flooding. The flood mapping of cross-sections downstream of the R584 have been revised to consider water levels on the floodplain where it spills out of bank and flows along Main Street (rather than enforcing lower levels from the confluence of the Bunsheelin-Lee further downstream).
Software Versions Used	ISIS version 3.6 TUFLOW version 2012-05-AC-iSP-w32
Total No of 1D nodes	**60**
Open channel (H)	85
Bridges (D)	4
Culverts (I)	0
Weirs (W)	0

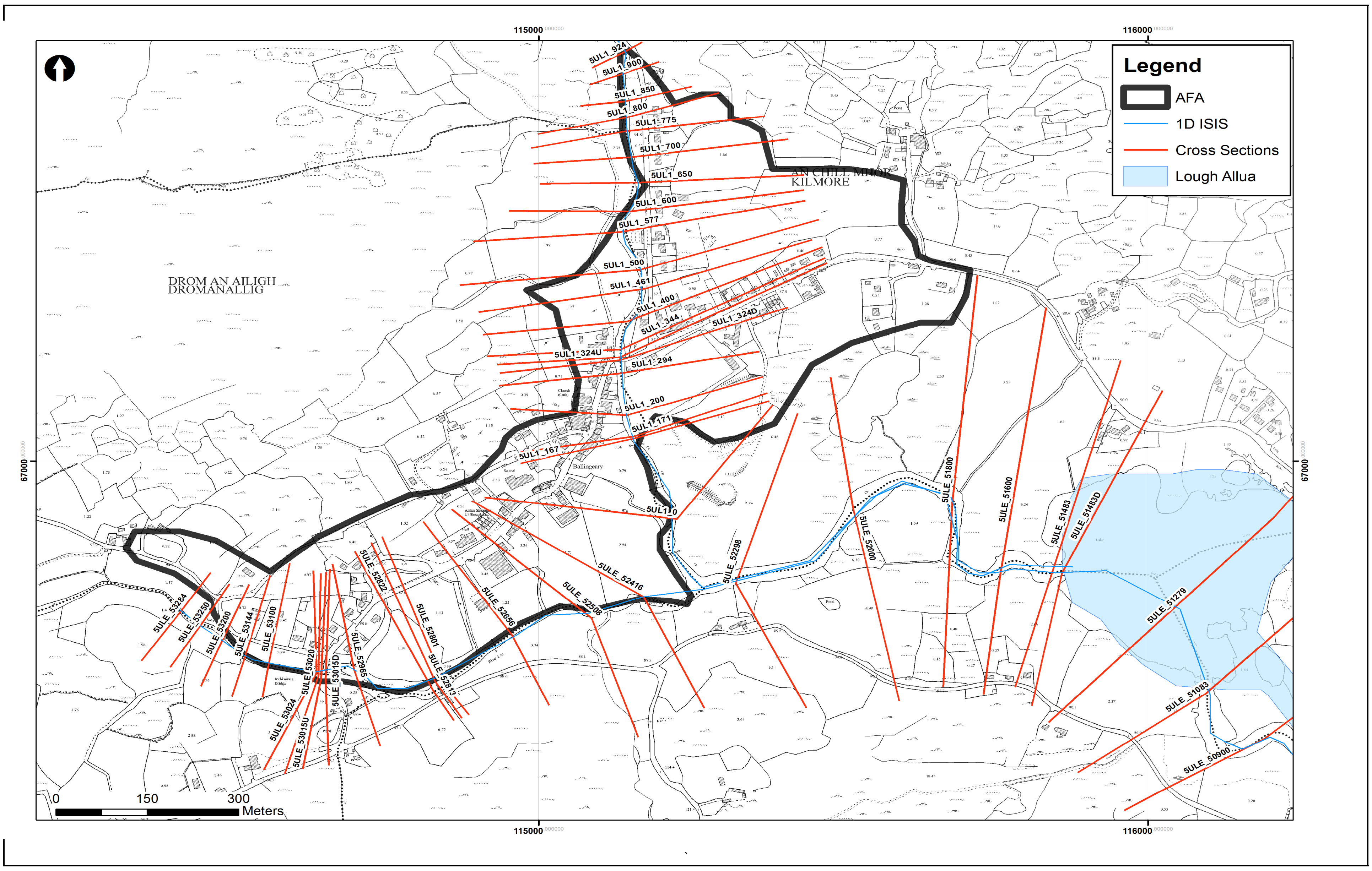
Model Extent	Reach/Feature	Upstream Limit (ING)	Downstream Limit (ING)
	River Bunsheelin	115142, 67766	115225, 66890
	River Lee	114407, 66715	125774, 66748

Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	River Bunsheelin	0.040	0.06-0.08	0.060	Schedule 1: Photographs
	River Bunsheelin downstream of Ballingeary Bridge 324D	0.060	0.06-0.08	0.060	Schedule 1: Photographs
	River Lee	0.040-0.055	0.040-0.055	0.060	Schedule 1: Photographs

Structures	See Schedule 2 for Hydraulic Structure Parameters
Upstream boundary	The Bunsheelin and Lee inflows upstream of the confluence were lumped at the upstream limit of the model because the intermediate catchment did not contribute significant flow. The River Bunsheelin upstream boundary was located at 19BUNS00274H at the upstream of the AFA at the site of a road bridge. The River Lee upstream boundary is 5ULE_53284.
Lateral inflows	The tributary inflow in Inchigeelagh was applied as rainfall runoff hydrograph unit directly to the upstream of Inchigeelagh Bridge where the tributary joins the River Lee. The hydrograph was delayed by 6.5 hours to meet the design flows through Inchigeelagh. The intermediate catchment between Ballingeary and Inchigeelagh was applied as flow-time (QT) boundary via a lateral inflow to sections located at 5ULE52298 and 5ULE51483 at natural overland flow paths. The lateral inflow was distributed evenly as the catchment area was approximately equal.
Downstream boundary	The downstream boundary of the model was located 3.8km downstream of the Inchigeelagh AFA (5ULE_39437) such that the assumptions at the downstream boundary did not affect flood risk in the two AFA. The gradient at this boundary was calculated using the local hydraulic gradient observed in the river channel survey.
Run Settings	Unsteady simulation over 50 hours to enable the routing of the full flow hydrograph from the 43hour storm event through Lough Allua. The model was started at -3 hours to allow any initial stabilisation before the hydrograph start. The 1D timestep was set to 10s which is appropriate to resolve the fluvial hydrograph whilst maintaining stability of the model. All other run parameters were set to default.

Model Geoschematics




Legend
AFA
1D ISIS
Cross Sections
Lough Allua
115000
116000
67000
DROM AN AILIGH
DROMANALLIG
AN CHILL MHOR
KILMORE
0
150
300
Meters

SCHEDULE 1 : PHOTOGRAPHS

Photo 1: Channel Upstream of AFA

Photo 2: In-Channel Bars Downstream of R584

Photo 3: Typical Vegetated Bank Uptream of AFA

Photo 4: Floodplain within Urban Area

SCHEDULE 2: Structures

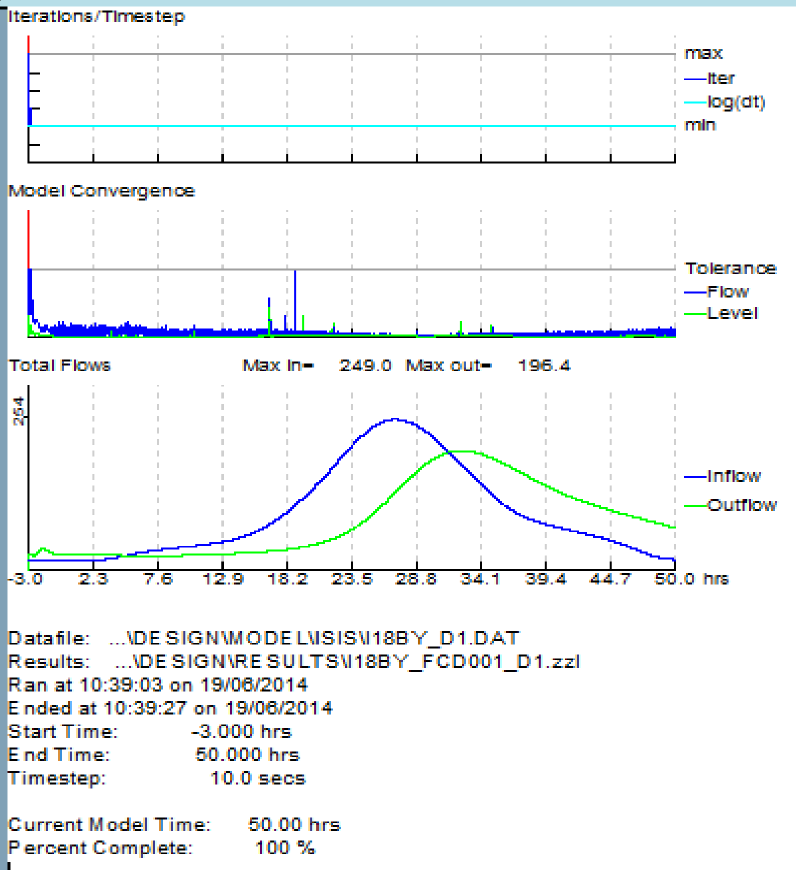
Data file P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I18BY_Ballingeary\DESIGN\model\ISIS\I18BY_D1.DAT

Node	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Culvert Parameters											Comments/ Justification
				Soffit Elevation (mAOD)	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation (mAOD)	Length	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation (mAOD)	Modular Limit	Weir Coeff.	Soffit level (mAOD)	Invert u/s (mAOD)	Invert d/s (mAOD)	Width/ area (m) (m2)	Length (m)	K	Ki	M	Trash Screen?	Trash Screen coefficient	
5UL1_324BU	115132	67193	Bridge (arched) + Spill	87.67	4	0	0.8	N/A	N/A	N/A	N/A	87.4	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Weir checked with revised survey received May 2011 Associated spill - 5UL1_324BSU Calibration coefficient reduced to 0.8 to simulate narrowing of flow and increased velocities of approach
5UL1_171BU	115157	67046	Ballingeary Bridge Bridge (arched) + Spill	86.01	1	0	2	N/A	N/A	N/A	N/A	85.534	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Footbridge with minial obstruction of channel until soffit reached. Calibration coefficient increased to represent greater blockage for vegetation at bridge banks during high flows to increase backwater effect upstream and increase frequency of flooding on Main Street in combination with increased Manning's 'n' to represent in-channel bars Associated spill - 5UL1_171SU
5ULE_53015BU	114655	66626	Inchigossig Bridge Bridge (arched) + Spill	88.16	4	0	1	N/A	N/A	N/A	N/A	86.572	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Associated spill - 5ULE53015BSU
5ULE_43278BU	122455	65871	Inchigeelagh Bridge Bridge (arched) + Spill	86.13	7	0	2	N/A	N/A	N/A	N/A	84.175	0.9	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Inchigeelagh Birdge as surveyrd with the bridge coefficient calibrated to meet the recorded levels in November 2009 Associated spill (5ULE43278BSU) represents flow over the road and parapet.
5ULE43278S	122455	65871	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	83.3	0.8	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Dummy spill to better simulate bed drop to 43259 with average bed level of 83.3 in channel at Inghigeelagh calibrated to meet the recorded November 2009 levels.
5ULE_49937D	119442	65738	Reservoir	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	Represents the volume of the main Lough Allua.

Ballingeary Model Performance

1D Convergence

Convergence Plot 0.1% AEP Fluvial Event



Comments	The 1D model components were convergent and within the recommended tolerances for the majority of the event. The initial poor convergence is associated with using average initial conditions as a common starting place for all scenarios. However this quickly stabilises within recommended tolerances within 0.25 hours and does not affect the peak.

2D Convergence (N/A)

Mass Balance Plot 0.1%AEP Fluvial Event	
Comments	

Hydrological Performance

Target Flows	HEP ID	Location	Model Node	10% AEP m3/s Design	10% AEP m3/s Modelled	10% AEP m3/s % Difference	1%AEP m3/s Design	1%AEP m3/s Modelled	1%AEP m3/s % Difference	0.1%AEP m3/s Design	0.1%AEP m3/s Modelled	0.1%AEP m3/s % Difference
	19_927_2	d/s Bunsheelin	5UL1_167	34.20	34.06	0%	51.00	50.81	0%	76.00	75.77	0%
	19_925_1	Downstream on Lee with Bunsheelin Confluence	5ULE_52298U	90.00	88.10	-2%	135.00	131.50	-3%	202.10	196.30	-3%
	19_1714_2	Lee outfall into Lough Allua	5ULE_51483	102.10	89.05	-13%	154.10	133.36	-13%	231.60	200.70	-13%

Comments	The modelled and design flows show good agreement through the modelled nodes. For both the Rivers Bunsheelin and Lee the flow at the upstream of the confluence of the two rivers was lumped at the upstream extent of the model. This was done as both reaches are small and there is little increase in flow along them. The above comparison shows that there is a -13% difference between the modelled and design flows for all return periods at the River Lee outfall in to Lough Allua. By analysing the flow progression between the Lee/ Bunsheelin confluence and Lough Allua it can be seen that the water level in the Lough is generating backwater up the River Lee (in the 0.1% AEP event this extends to node 5ULE_52801). This subsequently lowers the flow and can explain the discrepancy in values. The Bunsheelin catchment is steep so is not impacted to the same extent by this backwater effect.

Calibration Event 19/11/2009

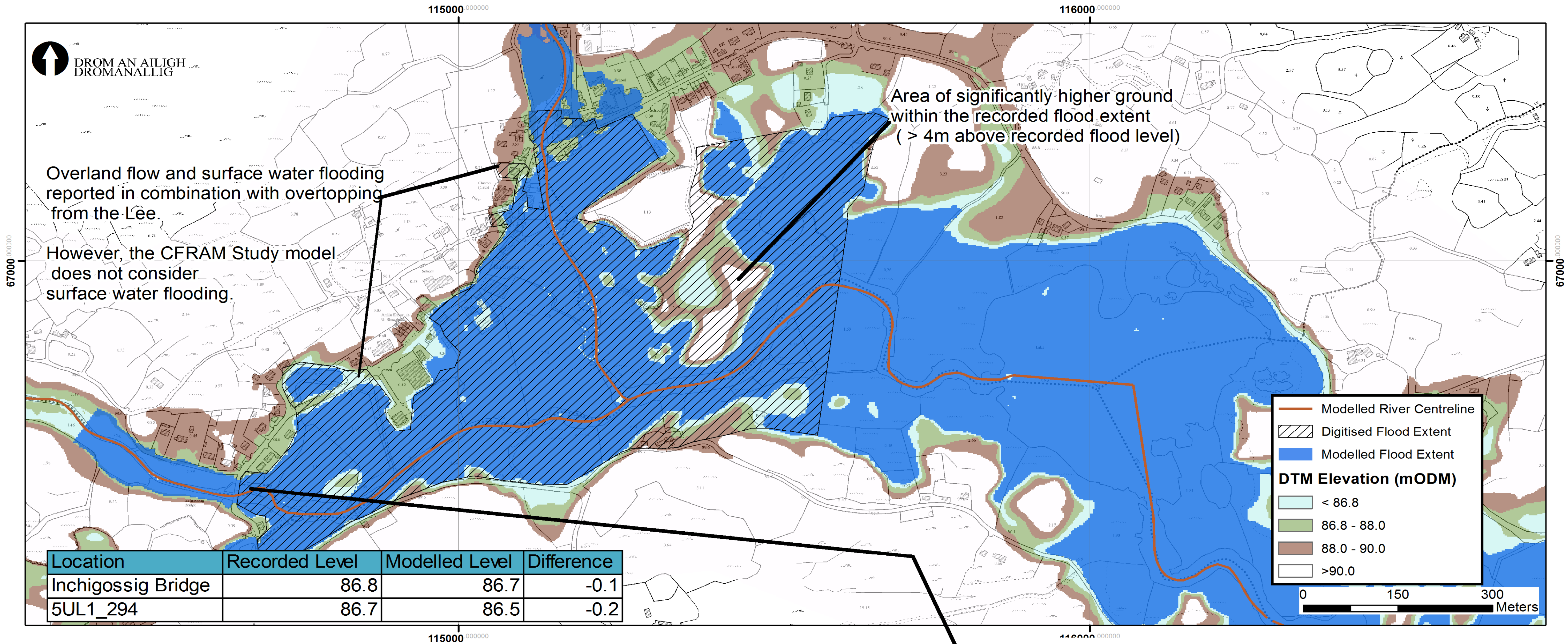
Model Run ID	I18BY_FCC_20091119_D1
Period Modelled	17/11/2009 00:00 to 23/11/2009 14:00
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	Calibrated Rainfall runoff FSSR units have been applied to the Upper Lee and Bunsheelin inflows based on observed rainfall in Ballingeary and 93% runoff calibrated to levels at Ballingeary and Inchigeelagh. The design downstream boundary gradient was used as it is locate sufficiently downstream so as not to affect flood risk in the AFAs.
Calibration Plot	See Schedule 3 - Calibration and Sensitivity
Comments	The model was calibrated to reproduce the recorded levels in Ballingeary and areas flooded based on the OPW and Béal Átha An Ghaorthaigh flood reports. The flood extent provided by the An Coiste Forbartha, Béal Átha An Ghaorthaigh indicates areas flooding within the extent which are significantly elevated above areas in the town which did not flood. These have been indicated on the figure. The rest of the extent has been used to calibrate the model bearing in mind that flooding along Árdan Seamus o'Shea was attributed to both surface water and fluvial flooding. However, surface water flooding is not considered by the CFRAM model. The hydrological model was calibrated to produce the observed percentage runoff and the spill and bridge coefficients at Inchigeelagh Bridge were also calibrated to reproduce the backwater within Lough Allua and flooding at Ballingeary. The modelled peak water level was within 0.1m of the recorded flooding at Inchigossig Bridge and 0.2m on Bunsheelin Stream by the Post Office. However the flood extent and depths matched well at the Post Office and towards Parochial House and Casadh Spride Park. The model predicted slightly less flooding upslope of the Church which was caused partly by surface water flowing down the steep valley sides. This overland flow has not been considered in the CFRAM model. Overall, the model calibrates well with the mechanism, levels and extent recorded in November 2009.

Sensitivity Test 1: Increased Flow

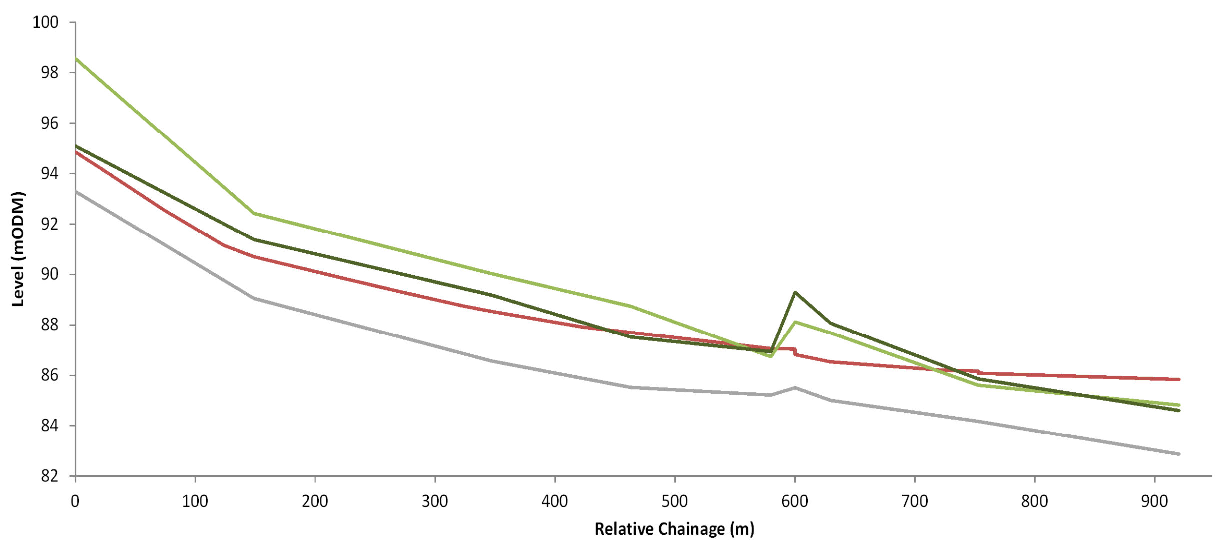
Model Run ID	I18BY_FHD010_D1
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	All inflows were increased by 30% for the 1%AEP fluvial current design event to account for the uncertainty in the derivation of QMED and the pooling group selected.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity

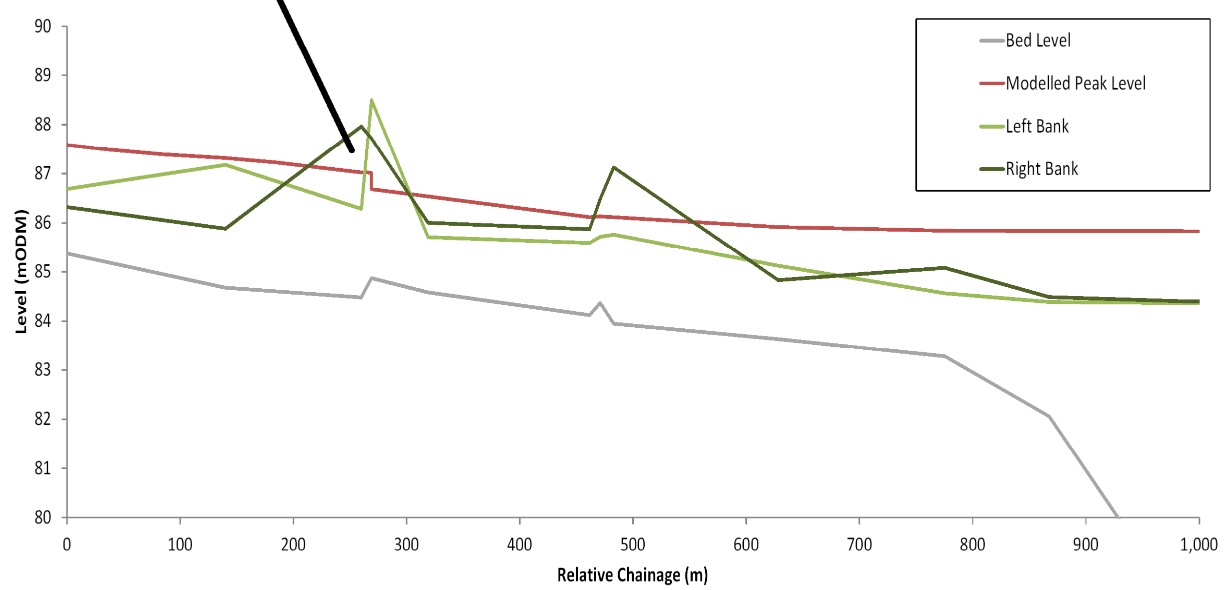
Comments	A 30% increase in flows resulted in a 0.36m water level increase on average as the 1%AEP design event already fill Lough Allua and the flooding is constrained to the narrow valley. This results in a greater backwater effect up to Ballingeary increasing flooding along the Main Street and overall levels and depths. However, the overall flood extent did not increase significantly as the design 1%AEP extent already filled the narrow valley. The design flow estimates and rainfall-runoff parameters have been calibrated to the severe flooding in 2009 and have been taken as a conservative estimate of current conditions. Although the test indicates sensitivity of flood levels and depths to inflows, it is worth noting here that the calibration undertaken increases confidence in the unadjusted inflows
Sensitivity Test 2: Increased Downstream Boundary	
Model Run ID	I18BY_FCSH01_D1
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	The gradient used in the Normal Depth Boundary at the downstream end of the model was reduced (made slacker) by a factor of two. No other hydrological inflows were modified.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increased downstream boundary did not significantly raise water levels through Inchigeelagh, Lough Allua and Ballingeary. Therefore flood risk was not deemed sensitive to the assumptions in the downstream boundary.
Sensitivity Test 3: Increased Manning's 'n'	
Model Run ID	I18BY_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 0.045 All river banks 0.060 to 0.075 Pasture / parkland / garden 0.060 to 0.080 Dense vegetation 0.085 to 0.100
Hydrological	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increase in roughness values resulted in a 0.10 m rise in water level in Ballingeary along both the Upper Lee and Bunsheelin Rivers. This resulted in a small increase in flooding along Ardan Seamus o'Shea and around the Garda Station because the 1%AEP already floods a large proportion of the valley. Therefore, the Ballingeary model was not deemed to be sensitive to Manning's 'n' at the 1%AEP. The Manning's 'n' values have been calibrated to the 2009 event to inform the design scenario. It should be noted that the assumptions taken for Manning's 'n' may have a more significant impact on resultant flood risk for smaller magnitude, higher frequency events where the channel capacity is less effected by backwater from Lough Allua.

Map A.1: Calibration to 19/11/2009 Flood Event

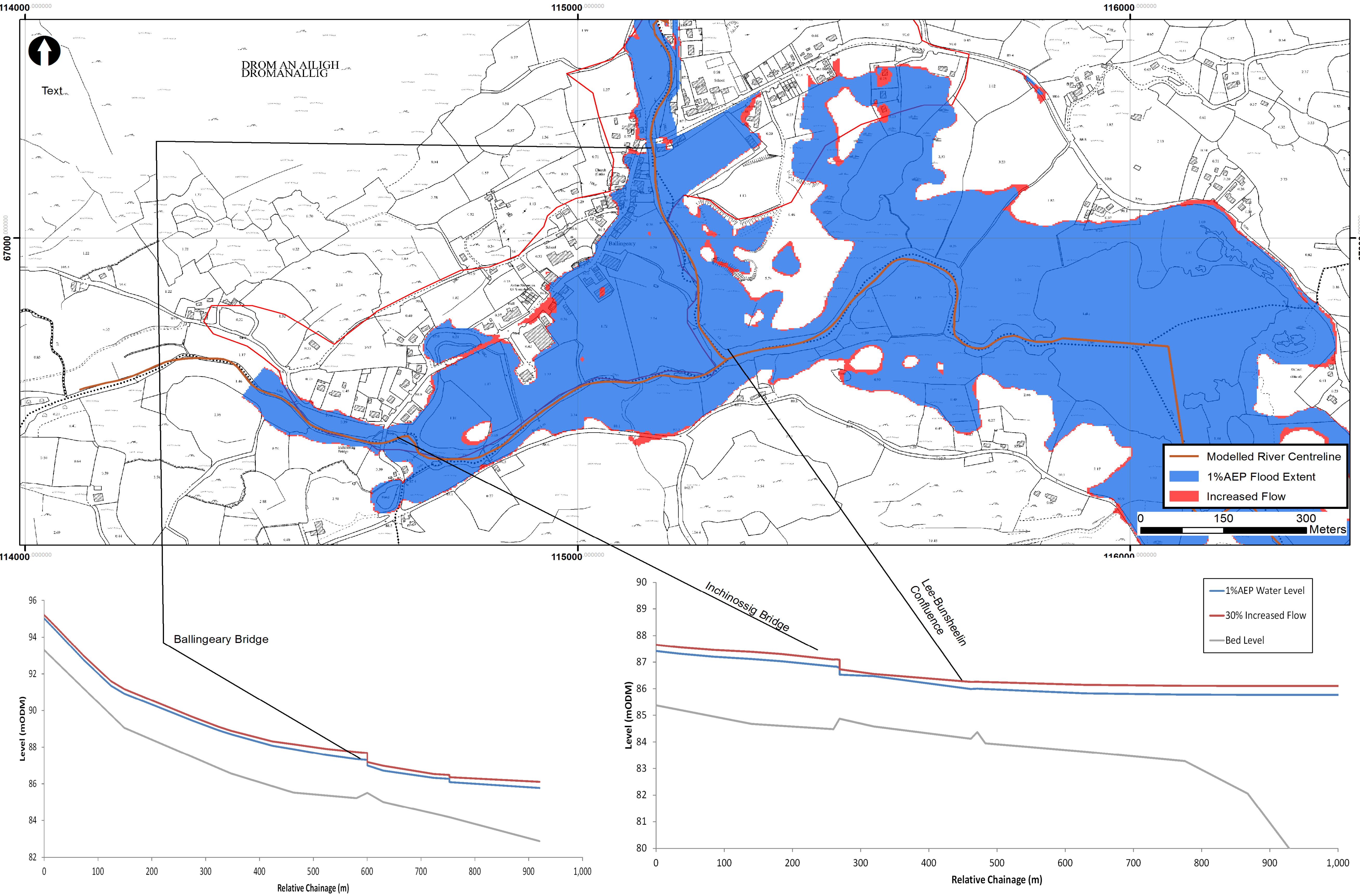


Location	Recorded Level	Modelled Level	Difference
Inchigossig Bridge	86.8	86.7	-0.1
5UL1_294	86.7	86.5	-0.2

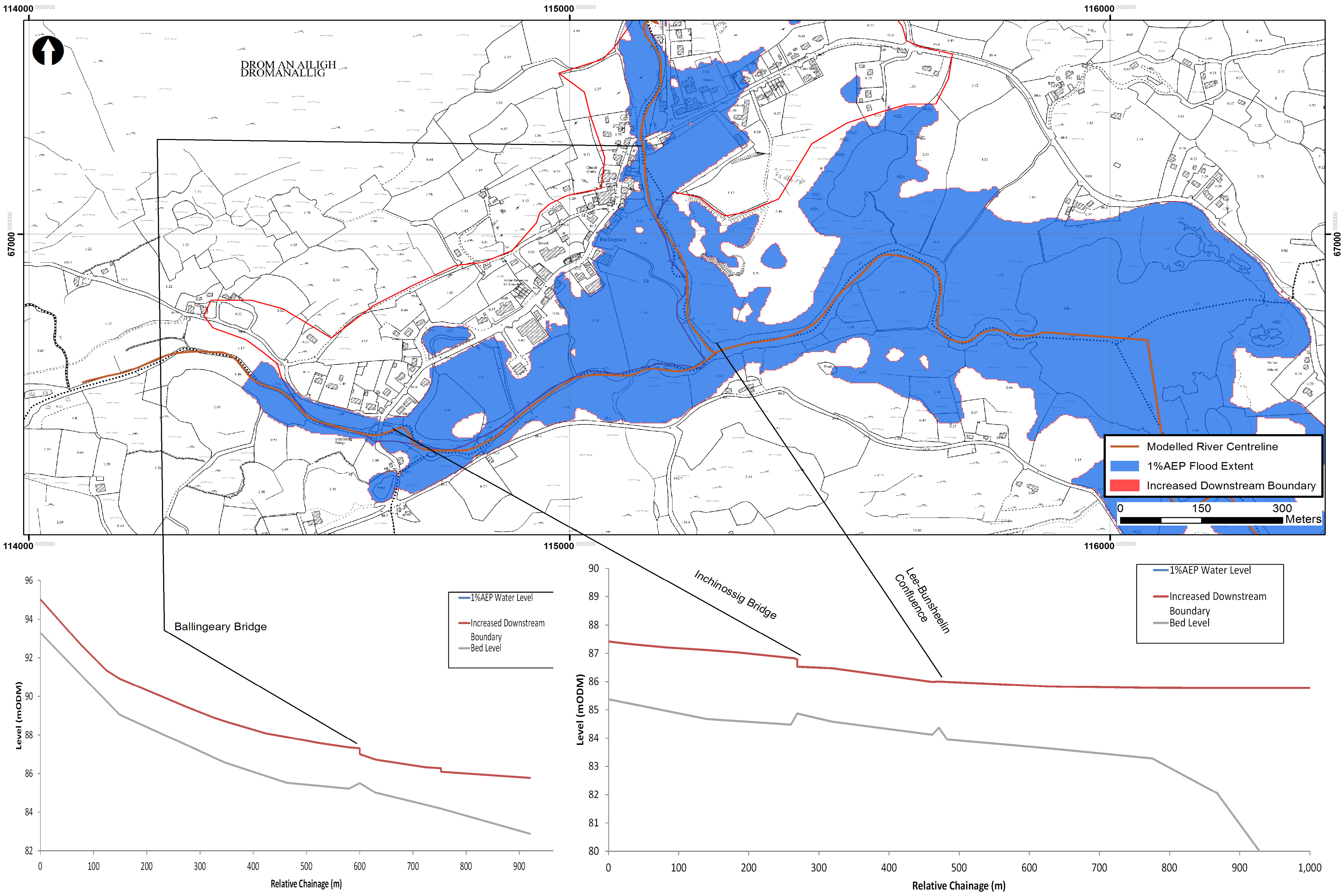




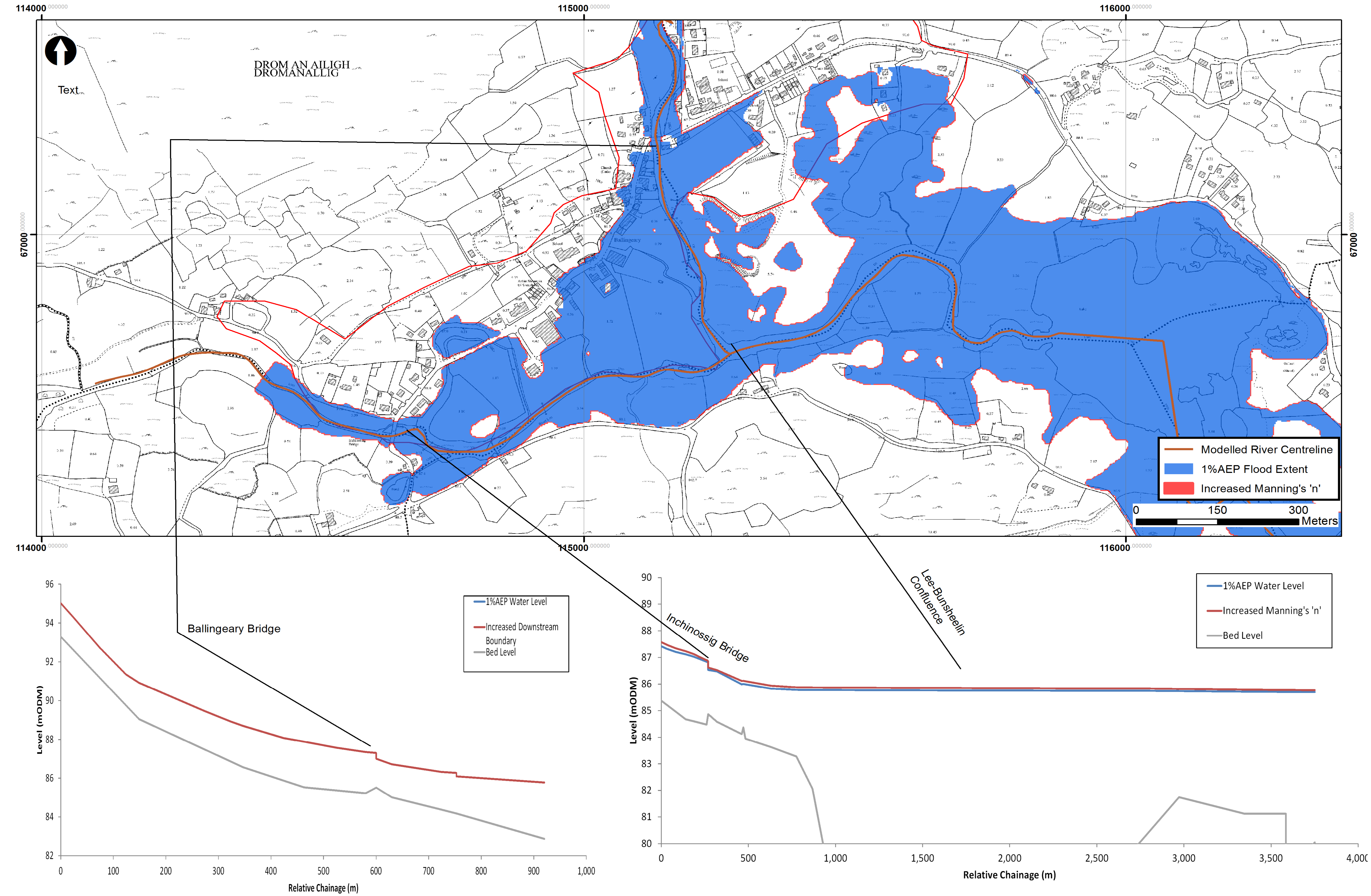
Map A.2: Sensitivity to 30% Increased Peak Flow



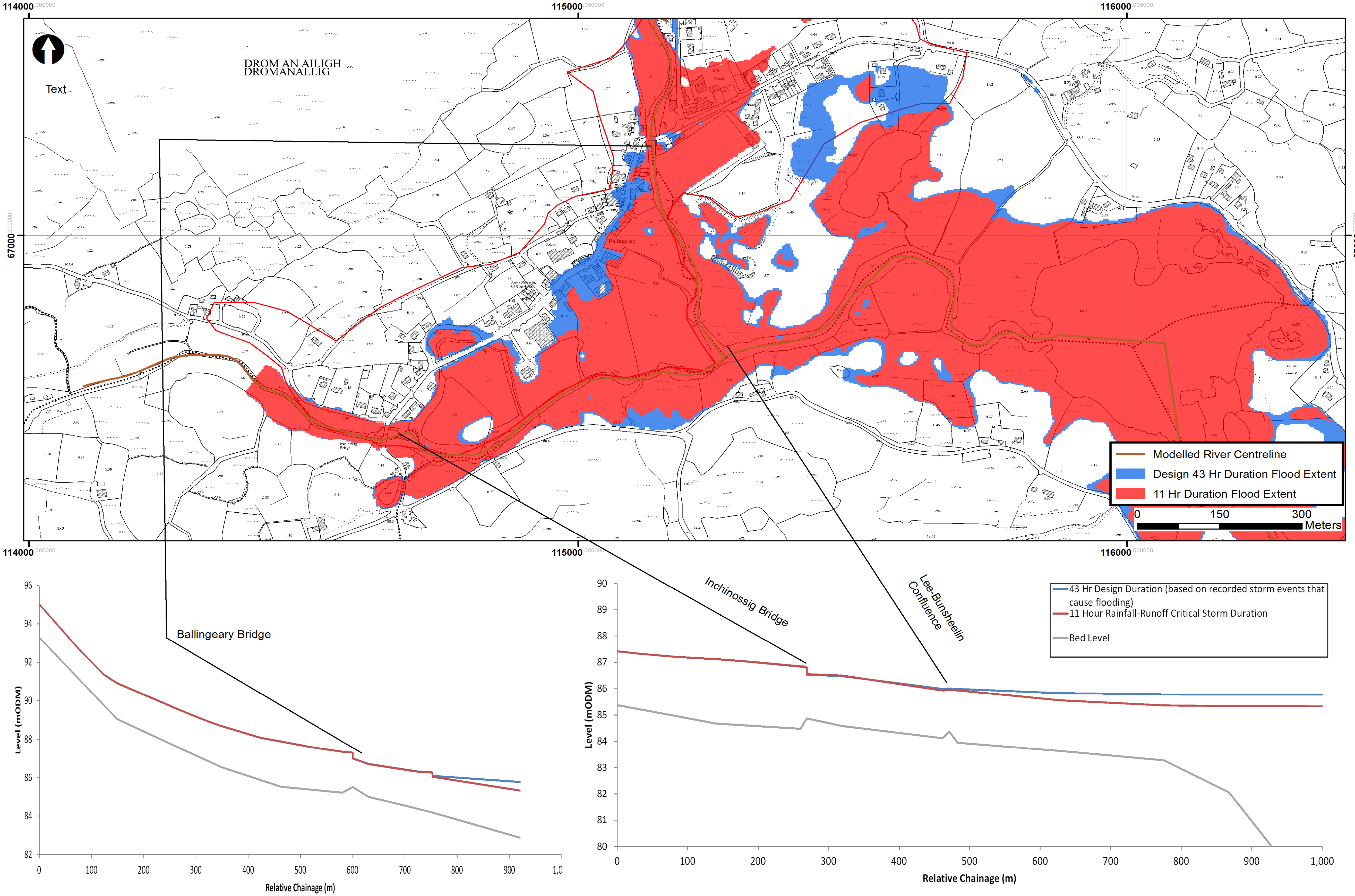
Map A.3: Sensitivity to assumptions in the downstream boundary



Map A.4: Sensitivity to Increased Manning's 'n'



Map A.5: Sensitivity to Storm Duration



Ballingeary Model Outputs	
Threshold of Property Flooding	The key thresholds and areas affected by flooding in Ballingeary are: - 50%AEP event floods the school sports pitch, Casadh Na Spride Park and floods up to the back of properties by the Post Office. This is caused by backwater in Lough Allua due to prolonged rainfall/successive events and limited capacity at Inchigeelagh Bridge. - 20% AEP event floods Main Street and properties by the post office to Saint Finbarr's and Saint Ronan's Church. This is caused by a combination of high flows along the Bunsheelin River and backwater in Lough Allua due to prolonged rainfall/successive events. - 20-10%AEP floods over the R584 upstream of Ballingeary Bridge from the Upper Lee in accordance with the recurring flood reports and flood events in 2004 and 2005.
Critical Structures for Flood Risk	The key flood mechanisms in Ballingeary are a combination of backwater from Lough Allua after prolonged rainfall and overland flow over saturated ground. However, the following also influence the severity of flood risk in Ballingeary: - Bed level/ channel capacity of the Bunsheelin and Lee Rivers downstream of the R584 to Lough Allua - Inchigeelagh Bridge downstream of Lough Allua which limits the outflow and therefore the backwater along Lough Allua to Ballingeary.
Areas affected by flooding	Flooding is expected to affect properties located by the Garda Station and along Main Street by the Post Office.
Risk to people	The greatest risk to life associated with deep flooding at the back of Post Office and high velocities by Ballingeary Bridge. The flashiness of the Bunsheelin catchment when saturated could mean a rapid rise in water levels with little warning.
Consideration for Flood Risk Management Options	- Increased conveyance of the Bunsheelin and Lee Rivers could reduce flood levels for small magnitude, more frequent events. Such measures are unlikely to increase flows (and flood risk) downstream as the additional flow would be small compared to the capacity of Lough Allua. - Flood warning would be ineffective for flooding caused by overland flow in the upper reaches of the Bunsheelin as this source of flood risk is driven by small flashy catchments. - However, flood warning would be more effective for flooding arising from backwater in Lough Allua where forecast rainfall is linked to the preceding level in the Lough.

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	I19HBY18_EXFCDEXF_D2		I19HBY18_DPFCD100_D2	I19HBY18_VLFCD100_D2	I19HBY18_HZFCD100_D1
Fluvial Current Design 1%AEP	I19HBY18_EXFCDEXF_D2	I19HBY18_ZN_D2	I19HBY18_DPFCD010_D2	I19HBY18_VLFCD010_D2	I19HBY18_HZFCD010_D1
Fluvial Current Design 0.1%AEP	I19HBY18_EXFCDEXF_D2	I19HBY18_ZN_D2	I19HBY18_DPFCD001_D2	I19HBY18_VLFCD001_D2	I19HBY18_HZFCD001_D1
Fluvial Mid Range Future Design 10%AEP	I19HBY18_EXFMDEXF_D2				
Fluvial Mid Range Future Design 1%AEP	I19HBY18_EXFMDEXF_D2				
Fluvial Mid Range Future Design 0.1%AEP	I19HBY18_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
Fluvial Current Design 50%AEP	I18BY_FCD500_D4.ief	50	50	I18EXFCD500D2		I18DPFCD500D2	I18VLFCD500D2	
Fluvial Current Design 20%AEP	I18BY_FCD200_D4.ief	20	20	I18EXFCD100D2		I18DPFCD100D2	I18VLFCD100D2	I12HZFCD100D2
Fluvial Current Design 10%AEP	I18BY_FCD100_D4.ief	10	10	I18EXFCD200D2		I18DPFCD200D2	I18VLFCD200D2	
Fluvial Current Design 5%AEP	I18BY_FCD050_D4.ief	5	5	I18EXFCD050D2		I18DPFCD050D2	I18VLFCD050D2	
Fluvial Current Design 2%AEP	I18BY_FCD020_D4.ief	2	2	I18EXFCD020D2		I18DPFCD020D2	I18VLFCD020D2	
Fluvial Current Design 1%AEP	I18BY_FCD010_D4.ief	1	1	I18EXFCD010D2	I18ZN_A_D2	I18DPFCD010D2	I18VLFCD010D2	I12HZFCD010D2
Fluvial Current Design 0.5%AEP	I18BY_FCD005_D4.ief	0.5	0.5	I18EXFCD005D2		I18DPFCD005D2	I18VLFCD005D2	
Fluvial Current Design 0.1%AEP	I18BY_FCD001_D4.ief	0.1	0.1	I18EXFCD001D2	I18ZN_B_D2	I18DPFCD001D2	I18VLFCD001D2	I12HZFCD001D2
Fluvial Mid Range Future Design 50%AEP	I18BY_FMD500_D4.ief	50	50	I18EXFMD500D2		I18DPFMD500D2		
Fluvial Mid Range Future Design 20%AEP	I18BY_FMD200_D4.ief	20	20	I18EXFMD100D2		I18DPFMD100D2		
Fluvial Mid Range Future Design 10%AEP	I18BY_FMD100_D4.ief	10	10	I18EXFMD200D2		I18DPFMD200D2		
Fluvial Mid Range Future Design 5%AEP	I18BY_FMD050_D4.ief	5	5	I18EXFMD050D2		I18DPFMD050D2		
Fluvial Mid Range Future Design 2%AEP	I18BY_FMD020_D4.ief	2	2	I18EXFMD020D2		I18DPFMD020D2		
Fluvial Mid Range Future Design 1%AEP	I18BY_FMD010_D4.ief	1	1	I18EXFMD010D2		I18DPFMD010D2		
Fluvial Mid Range Future Design 0.5%AEP	I18BY_FMD005_D4.ief	0.5	0.5	I18EXFMD005D2		I18DPFMD005D2		
Fluvial Mid Range Future Design 0.1%AEP	I18BY_FMD001_D4.ief	0.1	0.1	I18EXFMD001D2		I18DPFMD001D2		
Fluvial High End Future Design 10%AEP	I18BY_FHD100_D4.ief	10	10	I18EXFHD100D2		I18DPFHD100D2		
Fluvial High End Future Design 1%AEP	I18BY_FHD010_D4.ief	1	1	I18EXFHD010D2		I18DPFHD010D2		
Fluvial High End Future Design 0.1%AEP	I18BY_FHD001_D4.ief	0.1	0.1	I18EXFHD001D2		I18DPFHD001D2		

Note on CFRAM Studies Naming Conventions

Model File Naming Convention:

B MN ID _ S C R PPP _St N
B = River Basin District code: I for South Western (Iardheisceart)
MN = **M**odel **N**umber: A sequential number for all models across the SW CFRAM study area.
ID = Model **ID**entifier: The first and last letters of the model name e.g. Ballingeary is shortened to BY
S = **S**ource code: F=fluvial C=coastal W=wave overtopping
C = **Sc**enario code: C= current M= Mid Range Future Scenario H= High End Future Scenario
R = **R**un Type: D = design, C = Calibration O= Option Assessment Run
PPP= **P**robability , expressed as a X in 1000 chance e.g. 50%AEP = 500 , 0.5% AEP = 005
St = **St**atus , D = draft, F = final
N = Revision **N**umber a single digit revision number

Additional Map Naming Convention:
B UoM H MN _ TT S C R PPP _St N

Additional GIS Naming Convention:
B MN TT S C R PPP St N

Codes a**s** above with the addition of:
UoM= Unit of Management number e.g. 18 = River Blackwater catchment
H = **High** Priority Watercourse / **Medium** Priority Watercourse
TT = Map **T**ype Ex = Extent, ZN = Zone, DP = Depth, VL = Velocity, HZ = Hazard

Appendix B. Inchigeelagh AFA Model Proformas

UOM	**19**		
AFA/ MPW Reach	**AFA-Ballingeary and Inchigeelagh**		
Focus	**Inchigeelagh**		
Model ID	**I18BY**		
Purpose of Model Build	**Flood Mapping**		
Main Watercourse	**River Bunsheelin**	**FLUVIAL RISK**	Yes
Length Modelled (km)	**10km**	**COASTAL RISK**	No
Area Modelled (km^2)	**N/A**	**VULNERABLE TO WAVES**	No

Input Data	
River Channel Topographic Data	River channel survey for the River Bunsheelin and Upper Lee was undertaken by Maltby's Survey Ltd in June 2007. 5UL1_KP_001, 5UL1_XS_001, 5ULE_KP_001-006, 5ULE_XS_001-013, 5ULE_XS_014-035, 5ULE_XS_036-045: surveyed in June 2007 (Upper Lee CFRAMS Study)
Floodplain Topographic Data	Filtered LIDAR DTM "I18BY_DTM_2m.asc" 2m grid resolution captured in August 2006 as part of the Lee Pilot CFRAM Study. The LIDAR DTM covered the AFA of Ballingeary, Inchigeelagh and Lough Allua in between.
Map data	1:5000 OSI mapping tiles were used. OS1006 & OS1206. The OSI mapping was found to include all current developments and was consistent with site observations, the river channel survey and aerial photography.

Model Build	
General Schematisation	Ballingeary and Inchigeelagh have been modelled in the same hydraulic model in order to fully consider the routing of flow through Lough Allua. A 1D approach has been taken for Ballingeary and Inchigeelagh AFAs because the flood water is dictated by the Lough Allua and limited to the narrow valley. Therefore the 1D approach is deemed sufficient to assess flood risk to the AFA. The 1D model represents the River Bunsheelin to its confluence with the River Lee and the River Lee through Ballingeary, Lough Allua and Inchigeelagh building upon the existing Lee Pilot CFRAMS model. Inchigeelagh changes: The major change is the application of rainfall runoff inflows and improved intermediate catchment distribution based on the revised design hydrology. The natural drop in bed level at Inchigeelagh bridge is not modelled with a spill unit attached directly to the bridge to improve model configuration and stability in the downstream reach. Cork County Council and OPW indicated that there were suspected issues with the in-channel islands downstream of Inchigeelagh Bridge. Therefore manually interpolated sections from LIDAR have been combined with river channel survey to better represent the routing of out-of-bank flows in extreme event. The extension of the river channel sections has been based on the LIDAR DTM and slightly improved the orientation of the extension at Inchigeelagh to better estimate floodplain volumes. Version D2: The Manning's 'n' values for River Bunsheelin have been updated to better represent the frequency of flooding. The flood mapping of cross-sections downstream of the R584 in Ballingeary have been revised to consider water levels on the floodplain where it spills out of bank and flows along Main Street (rather than enforcing lower levels from the confluence of the Bunsheelin-Lee further downstream). No additional model or flood mapping changes were made in Inchigeelagh.
Software Versions Used	ISIS version 3.6 TUFLOW version 2012-05-AC-iSP-w32
Total No of 1D nodes	**60**
Open channel (H)	85
Bridges (D)	4
Culverts (I)	0
Weirs (W)	0

Model Extent

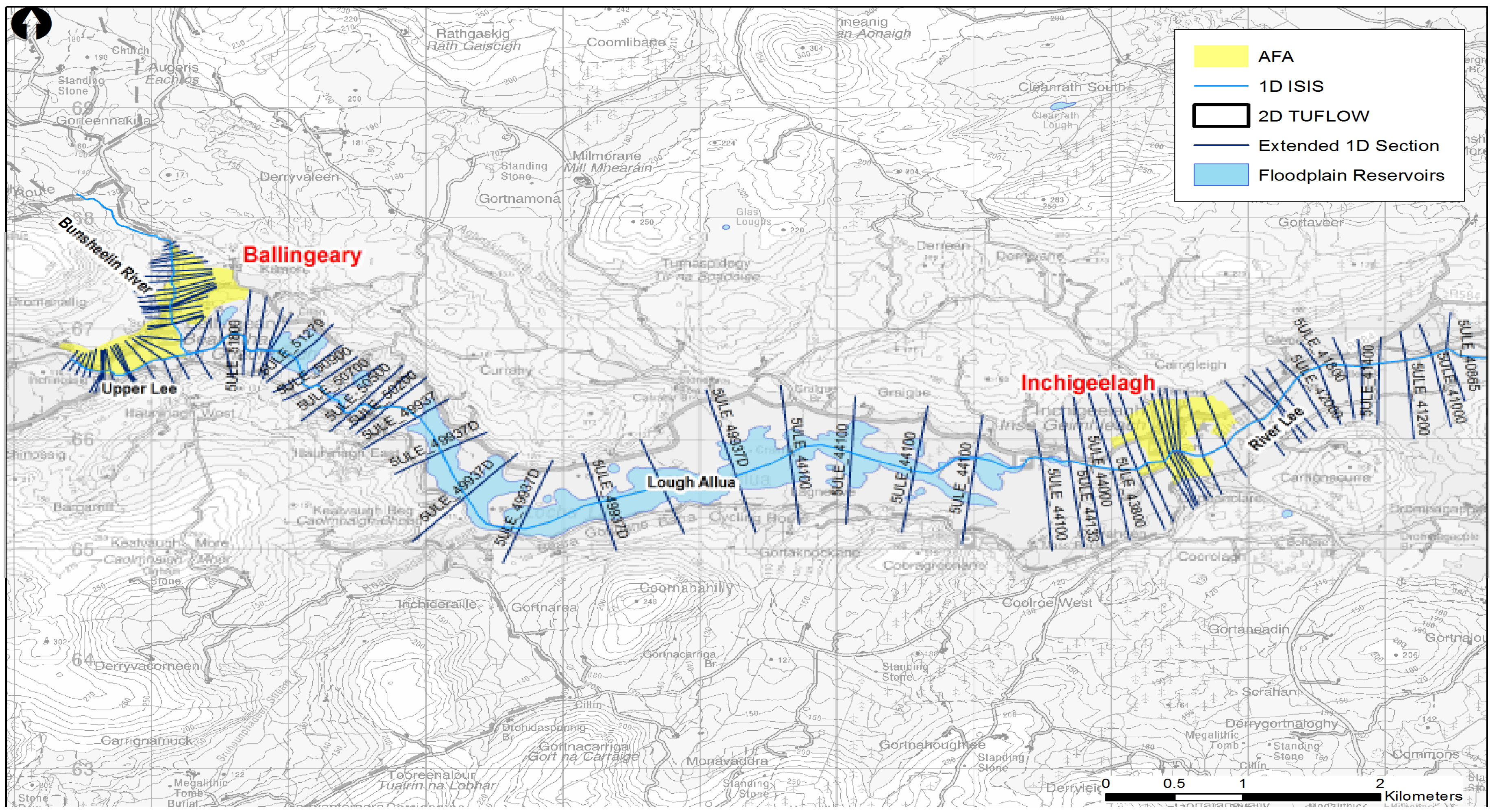
Reach/Feature	Upstream Limit (ING)	Downstream Limit (ING)
River Bunsheelin	115142, 67766	115225, 66890
River Lee	114407, 66715	125774, 66748

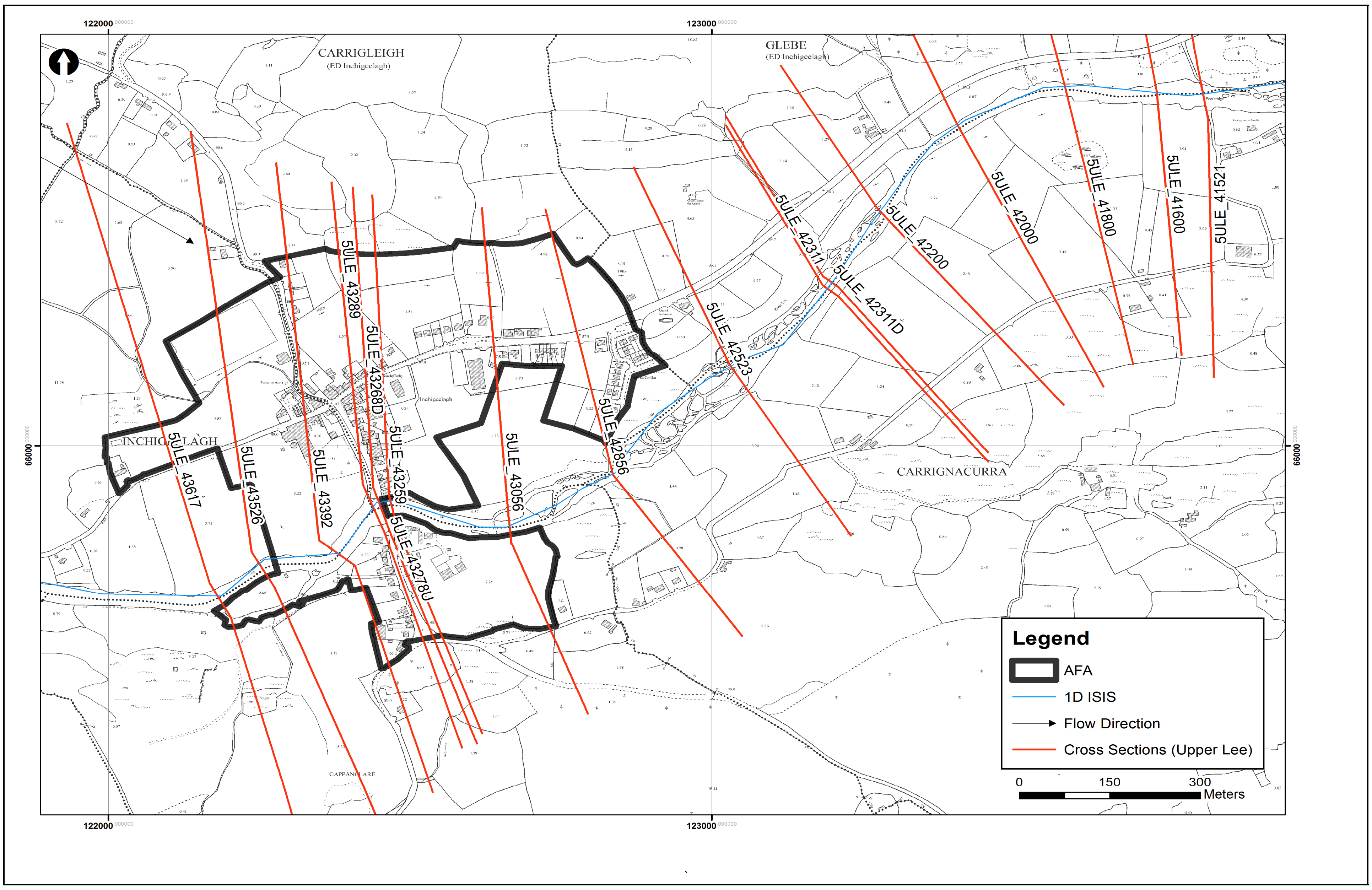
Roughness

Reach/Feature	Active Channel	River Banks	Floodplain	Source
River Bunsheelin	0.040	0.06-0.08	0.060	Schedule 1: Photographs
River Bunsheelin downstream of Ballingeary Bridge 324D	0.060	0.06-0.08	0.060	Schedule 1: Photographs
River Lee	0.040-0.055	0.040-0.055	0.060	Schedule 1: Photographs

Structures	See Schedule 2 for Hydraulic Structure Parameters
Upstream boundary	The Bunsheelin and Lee inflows upstream of the confluence were lumped at the upstream limit of the model because the intermediate catchment did not contribute significant flow. The River Bunsheelin upstream boundary was located at 19BUNS00274H at the upstream of the AFA at the site of a road bridge. The River Lee upstream boundary is 5ULE_53284.
Lateral inflows	The tributary inflow in Inchigeelagh was applied as rainfall runoff hydrograph unit directly to the upstream of Inchigeelagh Bridge where the tributary joins the River Lee. The hydrograph was delayed by 6.5 hours to meet the design flows through Inchigeelagh. The intermediate catchment between Ballingeary and Inchigeelagh was applied as flow-time (QT) boundary via a lateral inflow to sections located at 5ULE52298 and 5ULE51483 at natural overland flow paths. The lateral inflow was distributed evenly as the catchment area was approximately equal.
Downstream boundary	The downstream boundary of the model was located 3.8km downstream of the Inchigeelagh AFA (5ULE_39437) such that the assumptions at the downstream boundary did not affect flood risk in the two AFA. The gradient at this boundary was calculated using the local hydraulic gradient observed in the river channel survey.
Run Settings	Unsteady simulation over 50 hours to enable the routing of the full flow hydrograph from the 43hour storm event through Lough Allua. The model was started at -3 hours to allow any initial stabilisation before the hydrograph start. The 1D timestep was set to 10s which is appropriate to resolve the fluvial hydrograph whilst maintaining stability of the model. All other run parameters were set to default.

Model Geoschematics




CARRIGLEIGH
GLEBE
INCHIGEELAGH
CARRIGNACURRA
5ULE_43617
5ULE_43526
5ULE_43392
5ULE_43289
5ULE_43268D
5ULE_43259
5ULE_43278U
5ULE_43056
5ULE_42856
5ULE_42523
5ULE_42311
5ULE_42311D
5ULE_42200
5ULE_42000
5ULE_41800
5ULE_41600
5ULE_41521
122000
123000
66000
Legend
AFA
1D ISIS
Flow Direction
Cross Sections (Upper Lee)
0
150
300
Meters

SCHEDULE 1 : PHOTOGRAPHS
Photo 1: Channel Upstream of AFA

Photo 2: In-Channel Bars Downstream of R584

Photo 3: Typical Vegetated Bank Uptream of AFA

Photo 4: Floodplain within Urban Area


SCHEDULE 2: Structures

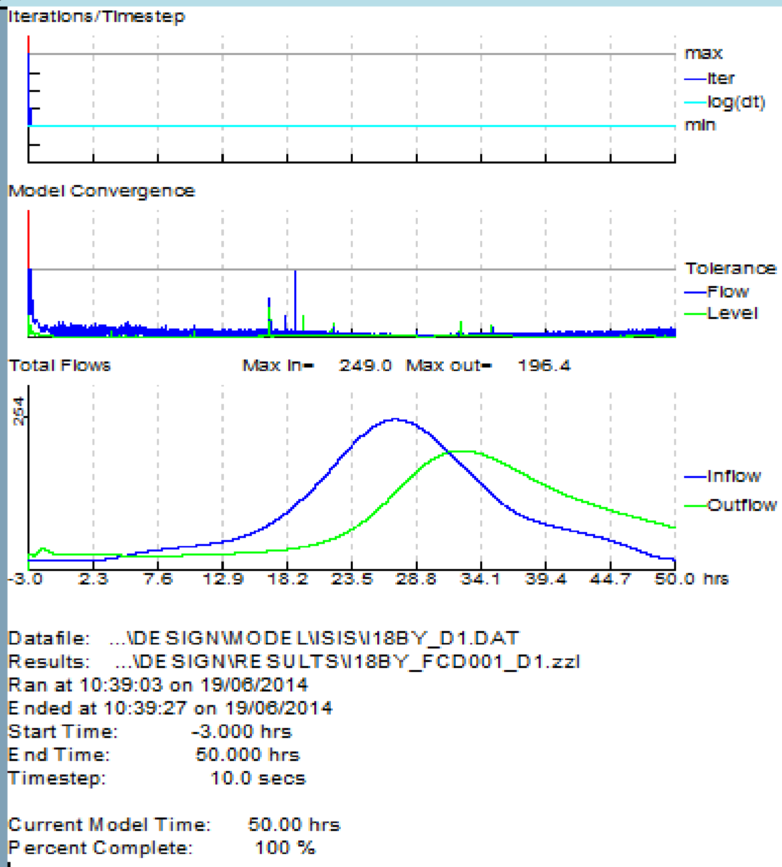
Data file: P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I18BY_Ballingeary\DESIGN\model\ISIS\I18BY_D1.DAT

Node	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Culvert Parameters										Comments/ Justification
				Soffit Elevation (mAOD)	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation (mAOD)	Length	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation (mAOD)	Modular Limit	Weir Coeff.	Soffit level (mAOD)	Invert u/s (mAOD)	Invert d/s (mAOD)	Width/ area (m) (m2)	Length (m)	K	Ki	M	Trash Screen?	Trash Screen coefficient	
5UL1_324BU	115132	67193	Bridge (arched) + Spill	87.67	4	0	0.8	N/A	N/A	N/A	N/A	87.4	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Weir checked with revised survey received May 2011 Associated spill - 5UL1_324BSU Calibration coefficient reduced to 0.8 to simulate narrowing of flow and increased velocities of approach
5UL1_171BU	115157	67046	Ballingeary Bridge Bridge (arched) + Spill	86.01	1	0	2	N/A	N/A	N/A	N/A	85.534	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Footbridge with minial obstruction of channel until soffit reached. Calibration coefficient increased to represent greater blockage for vegetation at bridge banks during high flows to increase backwater effect upstream and increase frequency of flooding on Main Street in combination with increased Manning's 'n' to represent in-channel bars Associated spill - 5UL1_171SU
5ULE_53015BU	114655	66626	Inchigossig Bridge Bridge (arched) + Spill	88.16	4	0	1	N/A	N/A	N/A	N/A	86.572	0.9	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Associated spill - 5ULE53015BSU
5ULE_43278BU	122455	65871	Inchigeelagh Bridge Bridge (arched) + Spill	86.13	7	0	2	N/A	N/A	N/A	N/A	84.175	0.9	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Inchigeelagh Birdge as surveyrd with the bridge coefficient calibrated to meet the recorded levels in November 2009 Associated spill (5ULE43278BSU) represents flow over the road and parapet.
5ULE43278S	122455	65871	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	83.3	0.8	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Dummy spill to better simulate bed drop to 43259 with average bed level of 83.3 in channel at Inghigeelagh calibrated to meet the recorded November 2009 levels.
5ULE_49937D	119442	65738	Reservoir	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	Represents the volume of the main Lough Allua.

Ballingeary Model Performance - Inchigeelagh

1D Convergence

Convergence Plot 0.1% AEP Fluvial Event



Comments: The 1D model components were convergent and within the recommended tolerances for the majority of the event. The initial poor convergence is associated with using average initial conditions as a common starting place for all scenarios. However this quickly stabilises within recommended tolerances within 0.25 hours and does not effect the peak.

2D Convergence (N/A)

Mass Balance Plot 0.1%AEP Fluvial Event

Comments

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
19_927_2	d/s Bunsheelin	5UL1_167	34.20	34.06	0%	51.00	50.81	0%	76.00	75.77	0%
19_925_1	Downstream on Lee with Bunsheelin Confluence	5ULE_52298U	90.00	88.10	-2%	135.00	131.50	-3%	202.10	196.30	-3%
19_1714_2	Lee outfall into Lough Allua	5ULE_51483	102.10	89.05	-13%	154.10	133.36	-13%	231.60	200.70	-13%

Comments: The modelled and design flows show good agreement through the modelled nodes. For both the Rivers Bunsheelin and Lee the flow at the upstream of the confluence of the two rivers was lumped at the upstream extent of the model. This was done as both reaches are small and there is little increase in flow along them.
The above comparison shows that there is a -13% difference between the modelled and design flows for all return periods at the River Lee outfall in to Lough Allua. By analysing the flow progression between the Lee/ Bunsheelin confluence and Lough Allua it can be seen that the water level in the Lough is generating backwater up the River Lee (in the 0.1% AEP event this extends to node 5ULE_52801). This subsequently lowers the flow and can explain the discrepancy in values. The Bunsheelin catchment is steep so is not impacted to the same extent by this backwater effect.

Calibration Event 19/11/2009

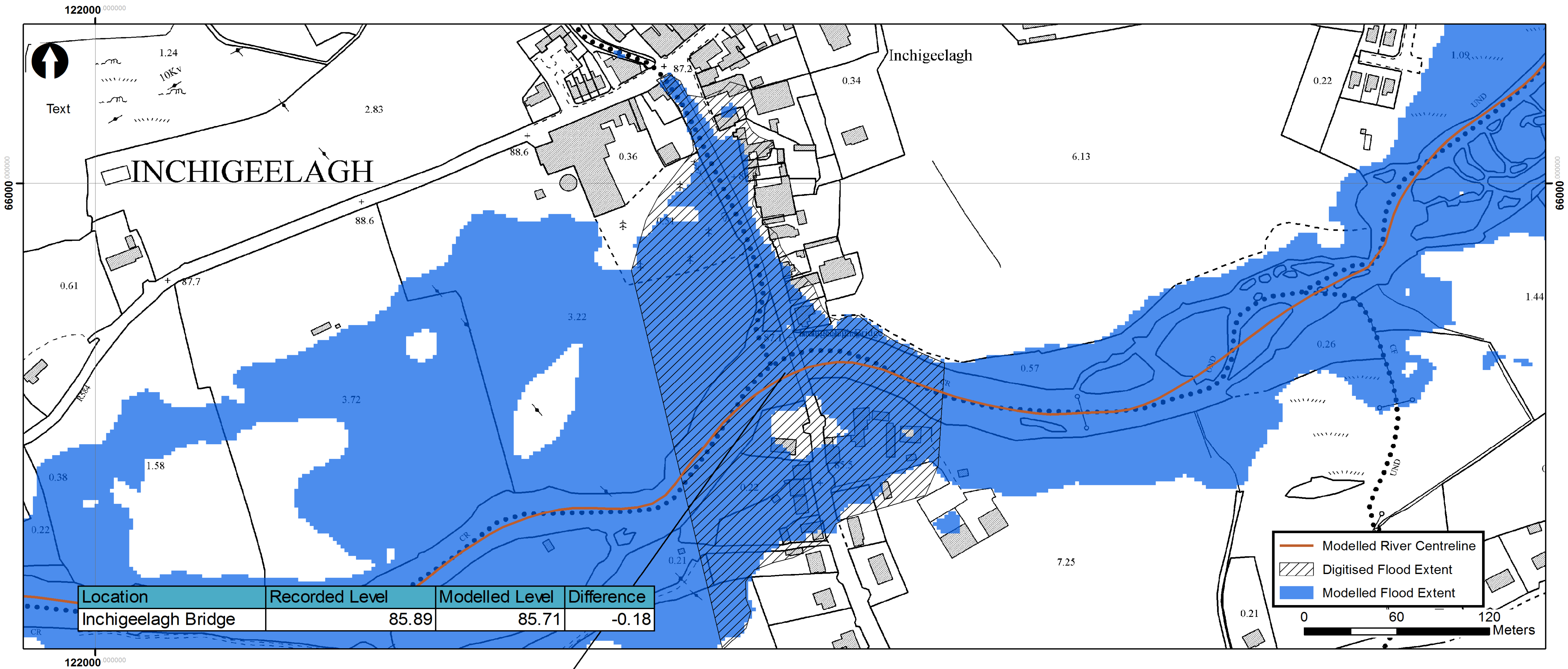
Model Run ID	I18BY_FCC_20091119_D1
Period Modelled	17/11/2009 00:00 to 23/11/2009 14:00
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	Calibrated Rainfall runoff FSSR units have been applied to the Upper Lee, Bunsheelin and Inchigeelagh tributary inflows based on observed rainfall in Ballingeary and 93% runoff calibrated to levels at Ballingeary and Inchigeelagh. The design downstream boundary gradient was used as it is located sufficiently downstream so as not to affect flood risk in the AFAs.
Calibration Plot	See Schedule 3 - Calibration and Sensitivity
Comments	The in-bank Manning's 'n', bridge and spill coefficients were calibrated to reproduce the extent of flooding and recorded level in Inchigeelagh. The flood extent provided was provided OPW and only covers the very centre of Inchigeelagh. It has been assumed that there was extensive flooding upstream in Lough Allua and downstream towards the footbridge crossing but it did not affect properties. The model predicted water backing-up from Inchigeelagh Bridge to overtop the road and flood properties. This is consistent with the OPW flood report. The flood level upstream of the bridge was within 0.2m of the recorded peak level. However the extent and depth of flooding at properties is consistent with the flood report. Therefore, the model calibrated well with the mechanisms and extent of flooding recorded in November 2009.

Sensitivity Test 1: Increased Flow

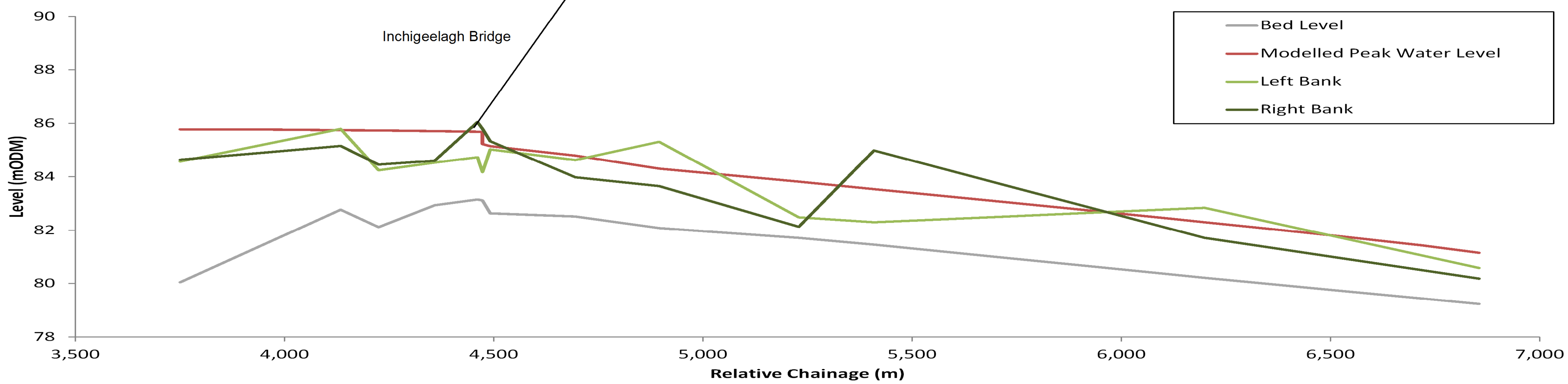
Model Run ID	I18BY_FHD010_D1
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	All inflows were increased by 30% for the 1%AEP fluvial current design event to account for the uncertainty in the derivation of QMED and the pooling group selected.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity

Comments	A 30% increase in flows resulted in a 0.33m water level increase on average through Inchigeelagh because the 1%AEP design event already filled Lough Allua and the flooding is constrained to the narrow valley. This results in a greater flood risk to properties along the L3404 towards Marian Terrace. Therefore flood risk in Inchigeelagh was found to be sensitive to the uncertainties in flow. The design flow estimates and rainfall-runoff parameters have been calibrated to the severe flooding in 2009 and have been taken as a conservative estimate of current conditions. Although the test indicates sensitivity of flood levels and depths to inflows, it is worth noting here that the calibration of inflows to historical rainfall profiles undertaken increases confidence in the unadjusted inflows.
Sensitivity Test 2: Increased Downstream Boundary	
Model Run ID	I18BY_FCSH01_D1
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	The gradient used in the Normal Depth Boundary at the downstream end of the model was reduced (made slacker) by a factor of two. No other hydrological inflows were modified.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increased downstream boundary did not significantly raise water levels through Inchigeelagh and upstream in Lough Allua . Therefore flood risk in Inchigeelagh was not deemed sensitive to the assumptions in the downstream boundary.
Sensitivity Test 3: Increased Manning's 'n'	
Model Run ID	I18BY_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 0.045, 0.045 to 0.50. Channel downstream of the bridge with in-channel islands 0.050 to 0.058 and 0.06 to 0.08. All river banks 0.060 to 0.080 Pasture / parkland / garden 0.060 to 0.080 Dense vegetation 0.085 to 0.100 This sensitivity test reduces the capacity of the channel downstream of Inchigeelagh Bridge as the in0channel islands and banks are assumed to be more vegetated. Therefore the Manning's 'n' sensitivity test also highlights the sensitivity of flood risk in Inchigeelagh to river cleaning works in this downstream reach.
Hydrological	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increase in roughness values resulted in a 0.10 m rise in water level through Inchigeelagh as a whole. The greatest increase in flood levels and therefore risk was along the reach of the Lee with in-bank channels (downstream of Inchigeelagh Bridge). However, the Manning's 'n' assumed did not affect flood levels and risk upstream of the bridge because the bridge capacity rather than channel roughness determines flood risk upstream at the 1%AEP. Therefore, flood risk at the 1%AEP was not deemed be sensitive to Manning's 'n' and the capacity of the island reach downstream of Inchigeelagh Bridge. However, flood levels and risk through the island-reach itself were found to be sensitive to the Manning's 'n' values used. The Manning's 'n' values have been calibrated and used for the design scenario.

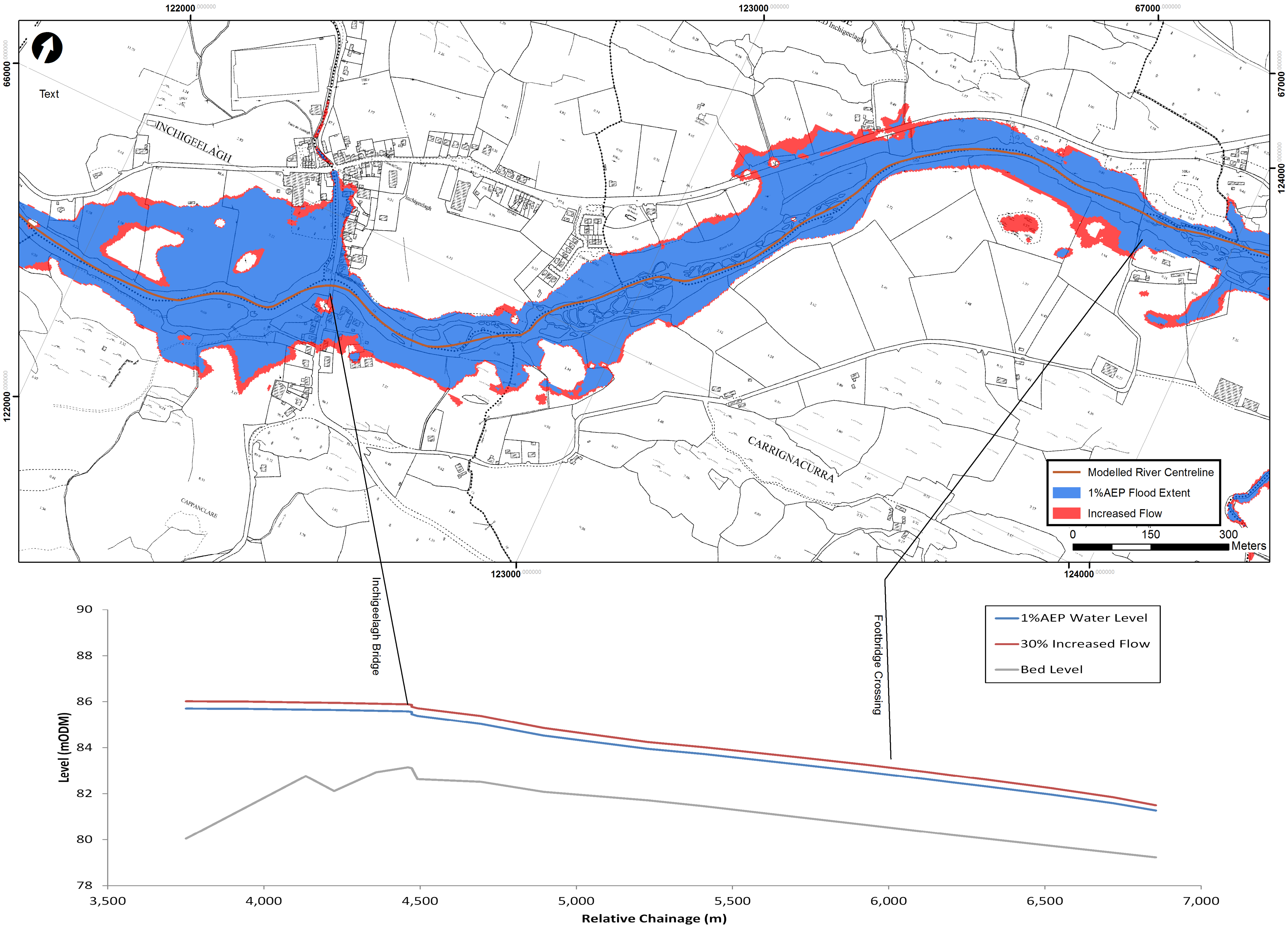
Map B.1: Calibration to 19/11/2009 Flood Event



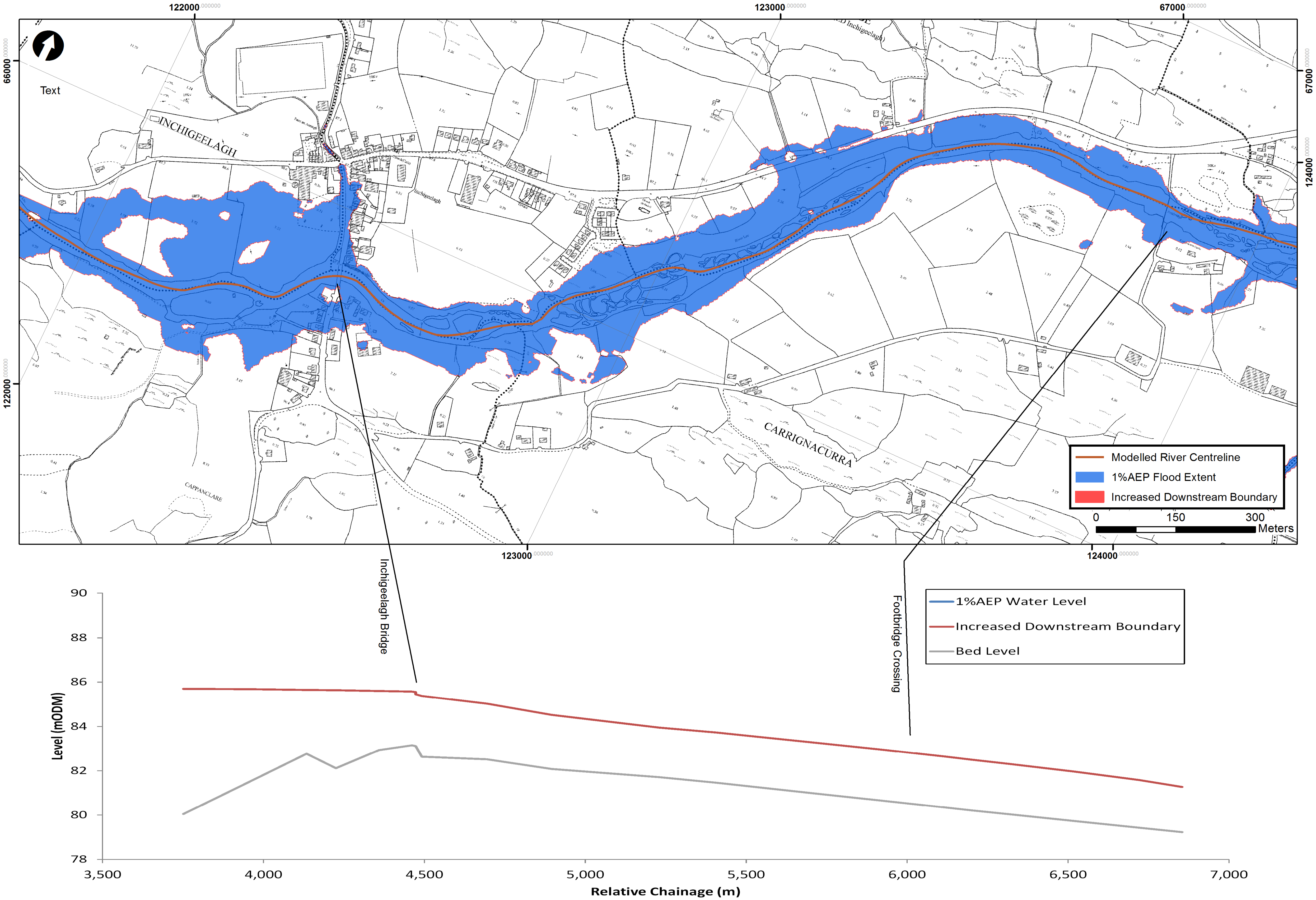
Location	Recorded Level	Modelled Level	Difference
Inchigeelagh Bridge	85.89	85.71	-0.18



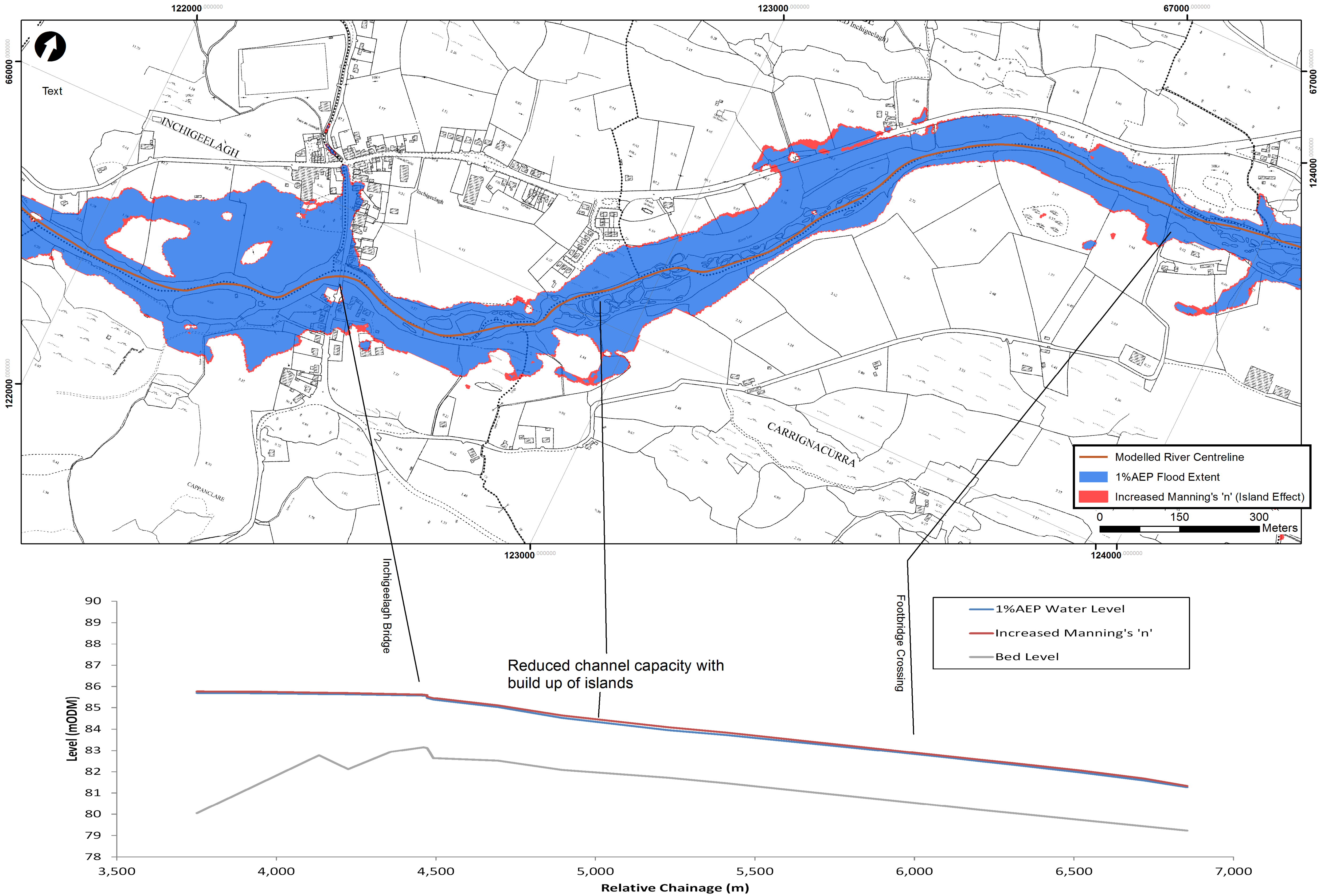
Map B.2: Sensitivity to 30% Increased Peak Flow



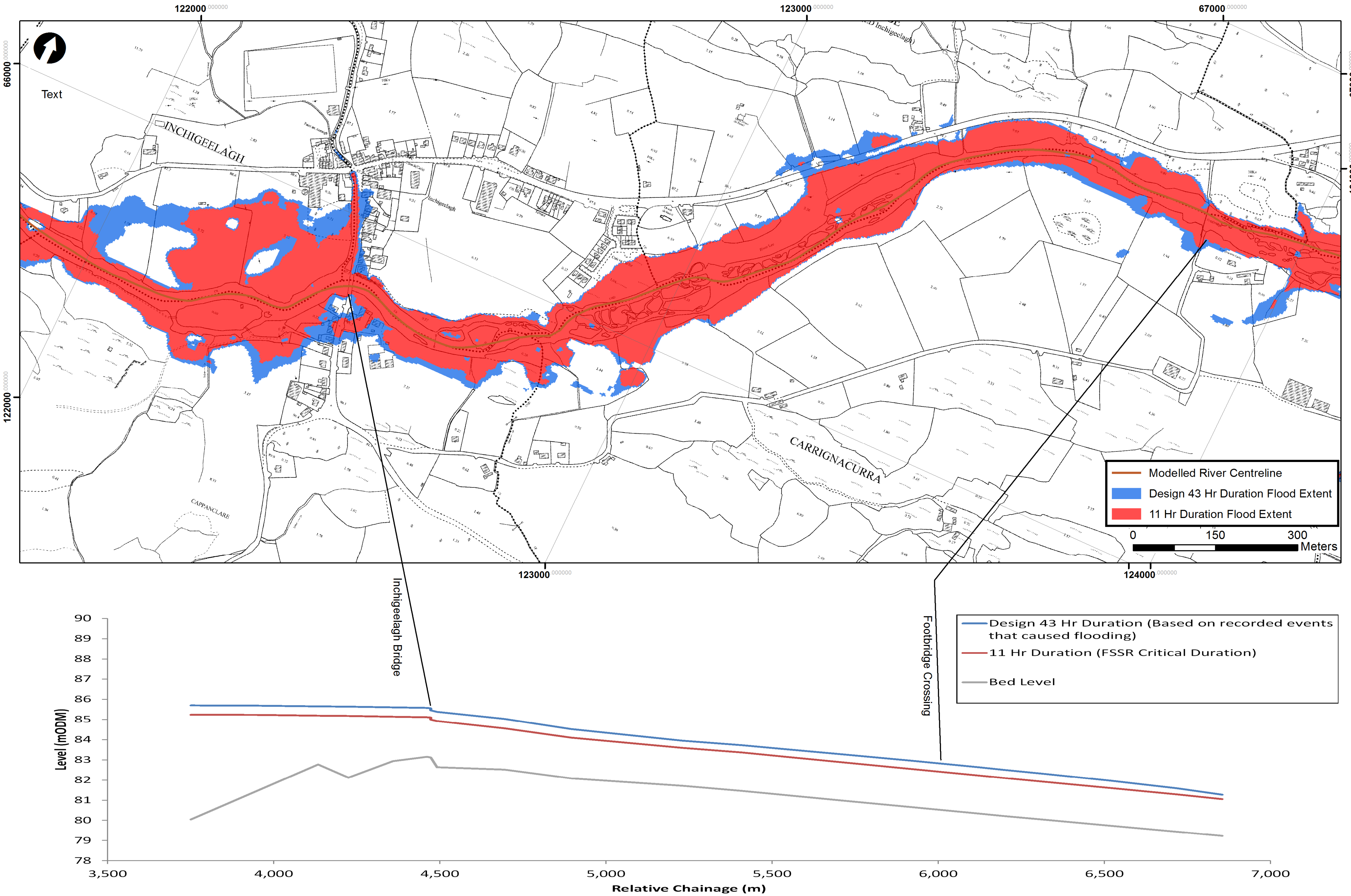
Map B.3: Sensitivity to assumptions in the downstream boundary



Map B.4: Sensitivity to Increased Manning's 'n'



Map B.5: Sensitivity to the Duration of the Flood Event



Inchigeelagh Outputs	
Threshold of Property Flooding	The key thresholds and areas affected by flooding in Inchigeelagh are: - 10%AEP event floods low lying areas at the back of Rose Cottage and flooding of the road by Inchigeelagh Bridge. - 2% to 5%AEP begins to cause flooding to properties at Rose Cottage on the right bank and Cuan Mhuire along the L3404 on the left bank as the bridge is bypassed.
Critical Structures for Flood Risk	The key flood mechanism in Inchigeelagh arises from high flows from Lough Allua after prolonged rainfall events. The outflow is limited by Inchigeelagh Bridge which causes water to back up and eventually flood over the road. The capacity of Inchigeelagh Bridge is critical to flood risk in Inchigeelagh.
Areas affected by flooding	Flooding is expected to Rose Cottages and properties located along the L3404 towards the Post Office.
Risk to people	The greatest risk to life is associated with deep flooding and high velocities upstream of Inchigeelagh Bridge and between the islands downstream of the bridge.
Consideration for Flood Risk Management Options	- Increased conveyance at Inchigeelagh Bridge could reduce levels upstream and flooding over the road and to properties. However, such measure could also increase flows (and flood risk) downstream. - Flood warning could be effective for flooding arising from the level of Lough Allua

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	I19HIH18_EXFCDEXF_D2		I19HIH18_DPFCD100_D2	I19HIH18_VLFCD100_D2	I19HBY18_HZFCD100_D1
Fluvial Current Design 1%AEP	I19HIH18_EXFCDEXF_D2	I19HIH18_ZN_D2	I19HIH18_DPFCD010_D2	I19HIH18_VLFCD010_D2	I19HBY18_HZFCD010_D1
Fluvial Current Design 0.1%AEP	I19HIH18_EXFCDEXF_D2	I19HIH18_ZN_D2	I19HIH18_DPFCD001_D2	I19HIH18_VLFCD001_D2	I19HBY18_HZFCD001_D1
Fluvial Mid Range Future Design 10%AEP	I19HIH18_EXFMDEXF_D2				
Fluvial Mid Range Future Design 1%AEP	I19HIH18_EXFMDEXF_D2				
Fluvial Mid Range Future Design 0.1%AEP	I19HIH18_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
Fluvial Current Design 50%AEP	I18BY_FCD500_D4.ief	50	50	I18EXFCD500D2		I18DPFCD500D2	I18VLFCD500D2	
Fluvial Current Design 20%AEP	I18BY_FCD200_D4.ief	20	20	I18EXFCD100D2		I18DPFCD100D2	I18VLFCD100D2	I12HZFCD100D2
Fluvial Current Design 10%AEP	I18BY_FCD100_D4.ief	10	10	I18EXFCD200D2		I18DPFCD200D2	I18VLFCD200D2	
Fluvial Current Design 5%AEP	I18BY_FCD050_D4.ief	5	5	I18EXFCD050D2		I18DPFCD050D2	I18VLFCD050D2	
Fluvial Current Design 2%AEP	I18BY_FCD020_D4.ief	2	2	I18EXFCD020D2		I18DPFCD020D2	I18VLFCD020D2	
Fluvial Current Design 1%AEP	I18BY_FCD010_D4.ief	1	1	I18EXFCD010D2	I18ZN_A_D2	I18DPFCD010D2	I18VLFCD010D2	I12HZFCD010D2
Fluvial Current Design 0.5%AEP	I18BY_FCD005_D4.ief	0.5	0.5	I18EXFCD005D2		I18DPFCD005D2	I18VLFCD005D2	
Fluvial Current Design 0.1%AEP	I18BY_FCD001_D4.ief	0.1	0.1	I18EXFCD001D2	I18ZN_B_D2	I18DPFCD001D2	I18VLFCD001D2	I12HZFCD001D2
Fluvial Mid Range Future Design 50%AEP	I18BY_FMD500_D4.ief	50	50	I18EXFMD500D2		I18DPFMD500D2		
Fluvial Mid Range Future Design 20%AEP	I18BY_FMD200_D4.ief	20	20	I18EXFMD100D2		I18DPFMD100D2		
Fluvial Mid Range Future Design 10%AEP	I18BY_FMD100_D4.ief	10	10	I18EXFMD200D2		I18DPFMD200D2		
Fluvial Mid Range Future Design 5%AEP	I18BY_FMD050_D4.ief	5	5	I18EXFMD050D2		I18DPFMD050D2		
Fluvial Mid Range Future Design 2%AEP	I18BY_FMD020_D4.ief	2	2	I18EXFMD020D2		I18DPFMD020D2		
Fluvial Mid Range Future Design 1%AEP	I18BY_FMD010_D4.ief	1	1	I18EXFMD010D2		I18DPFMD010D2		
Fluvial Mid Range Future Design 0.5%AEP	I18BY_FMD005_D4.ief	0.5	0.5	I18EXFMD005D2		I18DPFMD005D2		
Fluvial Mid Range Future Design 0.1%AEP	I18BY_FMD001_D4.ief	0.1	0.1	I18EXFMD001D2		I18DPFMD001D2		
Fluvial High End Future Design 10%AEP	I18BY_FHD100_D4.ief	10	10	I18EXFHD100D2		I18DPFHD100D2		
Fluvial High End Future Design 1%AEP	I18BY_FHD010_D4.ief	1	1	I18EXFHD010D2		I18DPFHD010D2		
Fluvial High End Future Design 0.1%AEP	I18BY_FHD001_D4.ief	0.1	0.1	I18EXFHD001D2		I18DPFHD001D2		

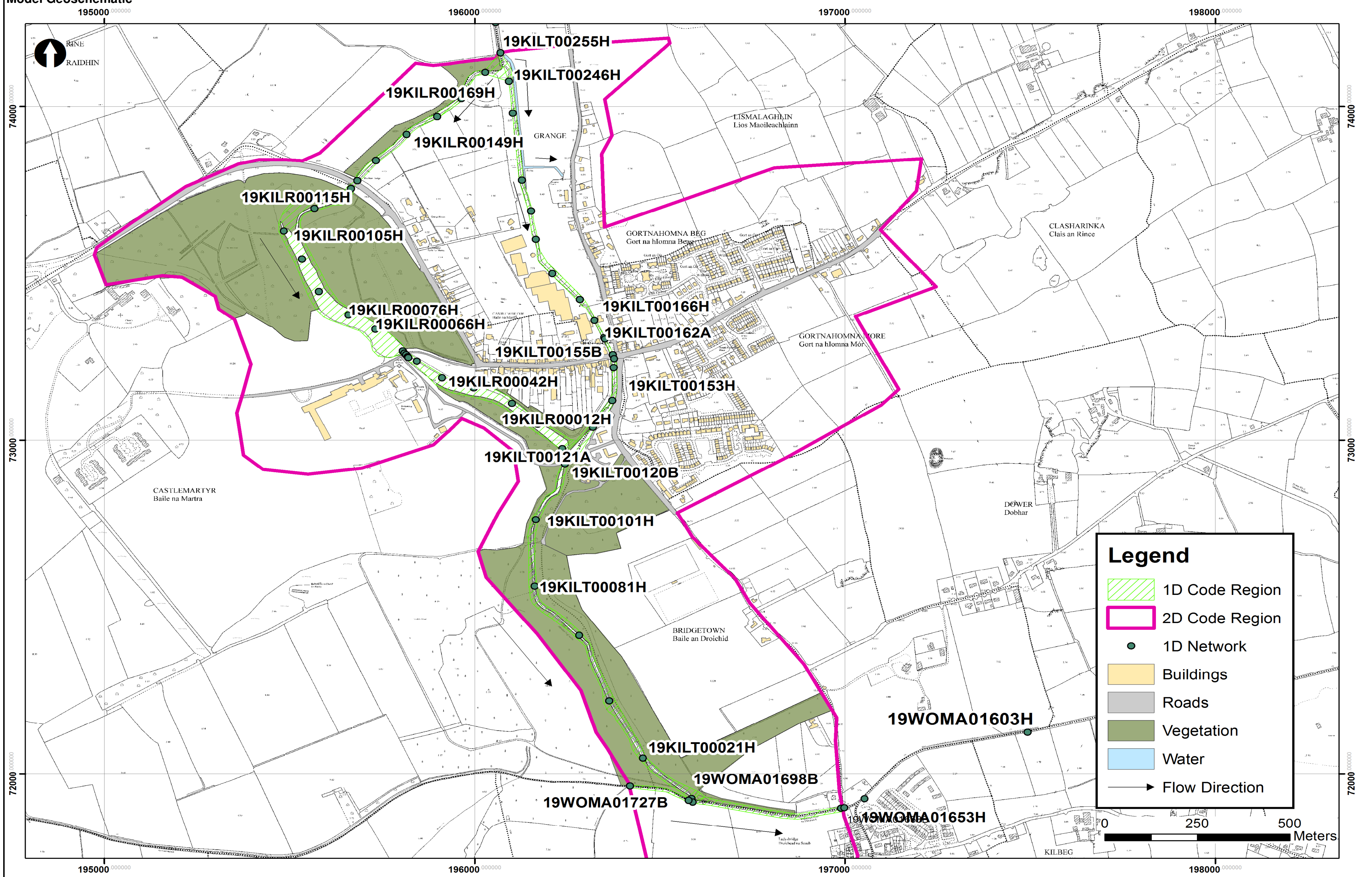
Appendix C. Castlemartyr AFA Model Proformas

UOM	**19**		
AFA/ MPW Reach	**AFA-Castlemartyr**		
Model ID	**I19CR**		
Purpose of Model Build	**Flood Mapping**		
Main Watercourse	**River Kiltha**	**FLUVIAL RISK**	Yes
Length Modelled (km)	**5.96**	**COASTAL RISK**	No
Area Modelled (km^2)	**2.57**	**VULNERABLE TO WAVES**	No

Input Data	
River Channel Topographic Data	River channel survey was undertaken by Murphy Surveys Limited as part of the CFRAM Study. 19KILT_Kiltha_V0 River Kiltha surveyed December 2012 : No errors or gaps were found within the survey. 19KILR_Kiltha_River_V0 Golf Course channel surveyed December 2012 : No errors or gaps were found within the survey. 19WOMA_Womanagh_V0 surveyed December 2012 : No errors or gaps were found within the survey.
Floodplain Topographic Data	Filtered LIDAR DTM "19CAS_DTM_2m.asc" 2m grid resolution captured in May 2012. The LIDAR DTM covered the entirety of the urban area
Map data	1:5000 OSI mapping tiles were used. The OSI mapping was found to include all current developments and was consistent with site observations, the river channel survey and aerial photography.

Model Build					
General Schematisation	A 1D/2D approach was taken to model Castlemartyr to accurately model flow along the main watercourses and head loss through hydraulic structures whilst enabling multidirectional flow across the urban areas. The 1D model represents the River Kiltha as the main watercourses which flows in a southerly direction towards the River Womanagh. The River Kiltha is modelled from the Water Treatment Works upstream to route of flow within the channel and model the interaction at the confluence. The 1D model of the Kiltha is hydrodynamically linked to a 2D model of the floodplain downstream of the confluence at 19KILT00255H through the town to the confluence with the Womanagh and down to Ladysbridge to consider the full interaction of flows and any backwater at the downstream confluence. The 2D domain covered the AFA extent to consider flood risk from the Kiltha and the Womanagh. The 2D model was set to a 5m grid size to represent the urban area without compromising run time. Buildings were raised above the floodplain by 0.15m to represent the threshold and then a high Manning's 'n' value of 0.2 applied to represent the storage of the building. This approach means accurate flood depths can be extracted for flood damage analysis. The design model assumes that additional flows enter the golf course channel once the right bank of the Kiltha overtops represented as a direct spill over the bank in 1D. The ditch on the left bank towards the Grange is assumed to flood once the Kiltha overtops the left bank. This ditch is enforced with a 3D breakline based on LiDAR and reduced Manning's 'n'. The reported swallow holes near the Enterprise Centre and behind the houses upstream of Castlemartyr Bridge have been assumed to be saturated as a conservative estimate of flood risk in Castlemartyr. Therefore, no flow has been abstracted from the model under design flood conditions.				
Software Versions Used	ISIS version 3.6 TUFLOW version 2012-05-AC-iSP-w32				
Total No of 1D nodes	**69**				
Open channel (H)	61				
Bridges (D)	6				
Culverts (I)	0				
Weirs (W)	2				
Model Extent	Reach/Feature	Upstream Limit (ING)	Downstream Limit (ING)		
	Kilthea	195998, 74642	196584, 71925		
	Kiltha	196028, 74101	196169, 73047		
	Womanagh	196419, 71962	197492, 72123		
Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	Kilthea	0.040-0.045	0.060-0 .085	0.060	Schedule 1: Photographs
	Kiltha	0.040-0.050	0.060-0 .085	0.060-0 .085	Schedule 1: Photographs
	Womanagh	0.040	0.060-0 .085	0.060	Schedule 1: Photographs
Structures	See Schedule 2 for Hydraulic Structure Parameters				
Upstream boundary	The River Kiltha upstream boundary was located at 19KILT00304H representing the inflow from the Kiltha upstream of the Killamucky tributary. The upstream of the golf course channel (KILR) has a sweetening flow applied to maintain stability in ISIS. This 0.1m3/s and does not affect the peak flow.				
Lateral inflows	Intermediate inflows upstream of the town have been lumped at the Killamucky tributary as a natural low point in the banks. Intermediate inflows have also been applied to the Womanagh to fully consider backwater effects at the Kiltha confluence.				
Downstream boundary	The downstream boundary of the 1D was located on the River Womanagh downstream from the confluence of the River Kiltha. The gradient of the stage-discharge relationship at this boundary was calculated using the local hydraulic gradient observed in the River Womanagh during the 0.1% AEP event based on model I21WH.				
Run Settings	Unsteady simulation between 28 and 60 hours to simulate the full flood flow hydrograph above baseflow. The 1D timestep was set to 1s which is divisible in to the 2D timestep of 2s which is less than half the grid cell size as recommended by TUFLOW. All other parameters set to default.				

Model Geoschematic



SCHEDULE 1 : PHOTOGRAPHS
Photo 1: Kiltha facing downstream

Photo 2: Kiltha immediately upstream of urban areas

Photo 3: Bridge and urban area on Kiltha

Photo 4: Downstream and non-urban area


SCHEDULE 2: Structures

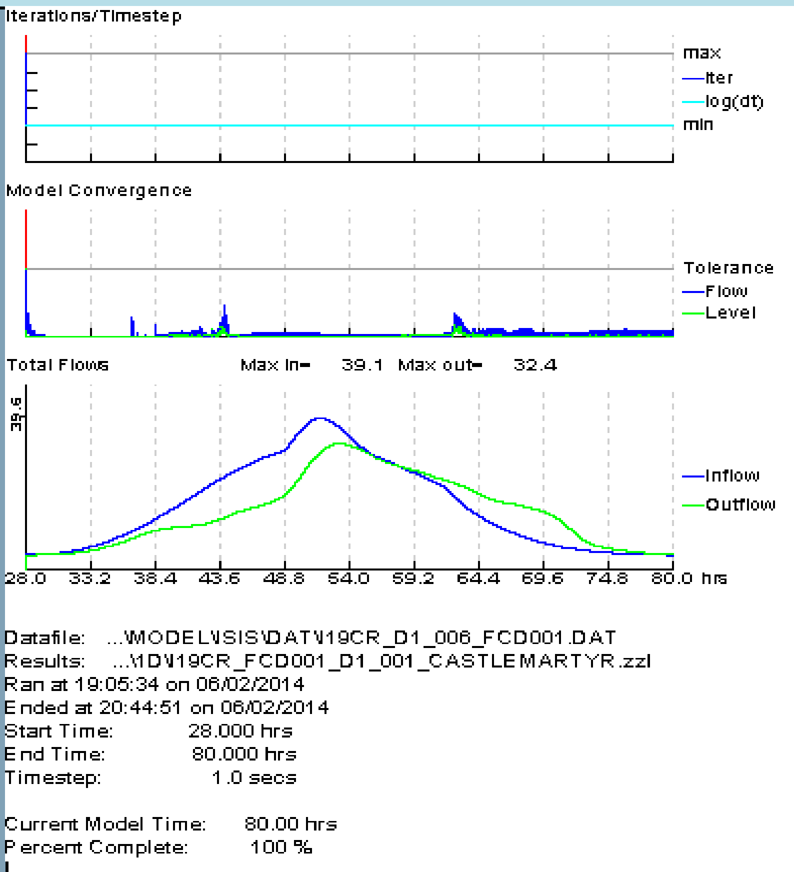
Data file P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I19CR_Castlemartyr\DESIGN\model\ISIS\I19CR_D1_006.DAT

Node	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Culvert Parameters										Comments/ Justification
				Soffit Elevation (mAOD)	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation (mAOD)	Length	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation (mAOD)	Modular Limit	Weir Coeff.	Soffit level (mAOD)	Invert u/s (mAOD)	Invert d/s (mAOD)	Width/ area (m) (m2)	Length (m)	K	Ki	M	Trash Screen?	Trash Screen coefficient	
19KILT00162D	196349	73307	USBPR Bridge	10.27	1	38.86	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	Access Bridge significantly skewed to direction of flow.
19KILT00121D	196249	72943	USBPR Bridge	10.03	1	39.76	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	Access bridge to Castlemartyr Resort significantly skewed to approach angle but does not obstruct low flows.
19KILT00156D	196376	73244	Bridge Arched	10.1	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	Castlemartyr road bridge
19WOMA01660D	196989	71896	Bridge Arched	6.99	1	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	Ladysbridge
19KILR00130D	795687	73790	Bridge Arched	12.63	1	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	New Bridge (N25 road bridge)
19KILR00055D	195806	73267	USBPR Bridge	11.78	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	Castlemartyr Resort entrance bridge
19KILR00054W	195814	73256	Weir	N/A	N/A	N/A	N/A	10.8	1	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	
19KILR00004W	196169	73047	Weir	N/A	N/A	N/A	N/A	9.057	6.29	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	
19KILT00162W	196349	73307	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.661	0.9	1.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Online spill representing bed drop through associated bridge - default online value of 1.7 used.
19KILT00162S	196349	73307	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10.567	0.9	1.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Spill over bridge deck to simulate the inefficiencies of flow over the relatively flat and unobstructed bridge deck.
19KILT00156S	196376	73244	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10.48	0.9	1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Spill over bridge deck to simulate the inefficiencies of flow over and around the bridge parapet.
19KILT00121S	196249	72943	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	11.019	0.9	1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Spill over bridge deck to simulate the inefficiencies of flow over and around the bridge parapet.
19WOMA01660S	196989	71896	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.61	0.9	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Spill over bridge deck to simulate the inefficiencies of flow over and around the bridge parapet and hedges along the floodplain spill over the road.
19KILR00130S	795687	73790	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	14.34	0.9	1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Spill over bridge deck to simulate the inefficiencies of flow over and around the bridge parapet.
19KILR00055S	195806	73267	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	11.998	0.9	1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Spill over bridge deck to simulate the inefficiencies of flow over the relatively flat and unobstructed bridge deck.
19KILT00255R	196169	73047	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	11.871	0.7	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Offline spill over the vegetated bank to golf course channel - Coefficient lowered to represent the inefficiencies of flow through the vegetated and angle of flow away from the main flow path along the Kiltha River.

Castlemartyr Model Performance

1D Convergence

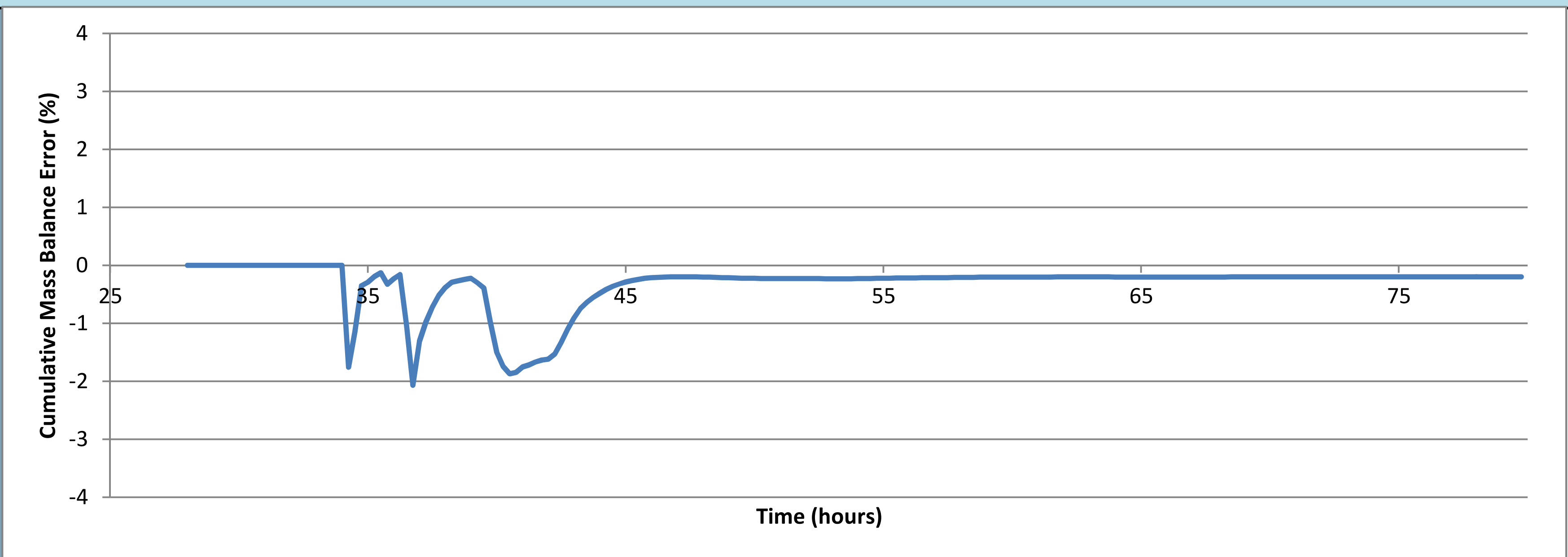
Convergence Plot 0.1% AEP Fluvial Event



Comments: The 1D model components were convergent and within the recommended tolerances for the majority of the event. The initial poor convergence is associated with using average initial conditions as a common starting place for all scenarios. However this quickly stabilises within recommended tolerances within 0.25 hours and does not affect the peak.

2D Convergence

Mass Balance Plot 0.1%AEP Fluvial Event



Comments: The total cumulative mass error of the model was -0.2% or -34974m^3. Greater mass error is experienced at the initial wetting of the 2D cells at 34 hours when water initially spills out of bank. However, the mass error is within the tolerance (+/-1%) before the peak at 52 hours . Therefore, the results are 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
19_909_11	Upstream Boundary	19KILT00304H	10.20	10.21	0%	15.50	15.53	0%	23.50	23.45	0%
19_1909_15	Kiltha at Downstream of Golf Course	19KILT00120E	12.40	10.94	-12%	18.86	16.95	-10%	28.49	24.80	-13%
19_1909_17	Kiltha at confluence with Womanagh	19KILT00041H	12.50	10.95	-12%	19.00	17.03	-10%	28.70	26.16	-9%

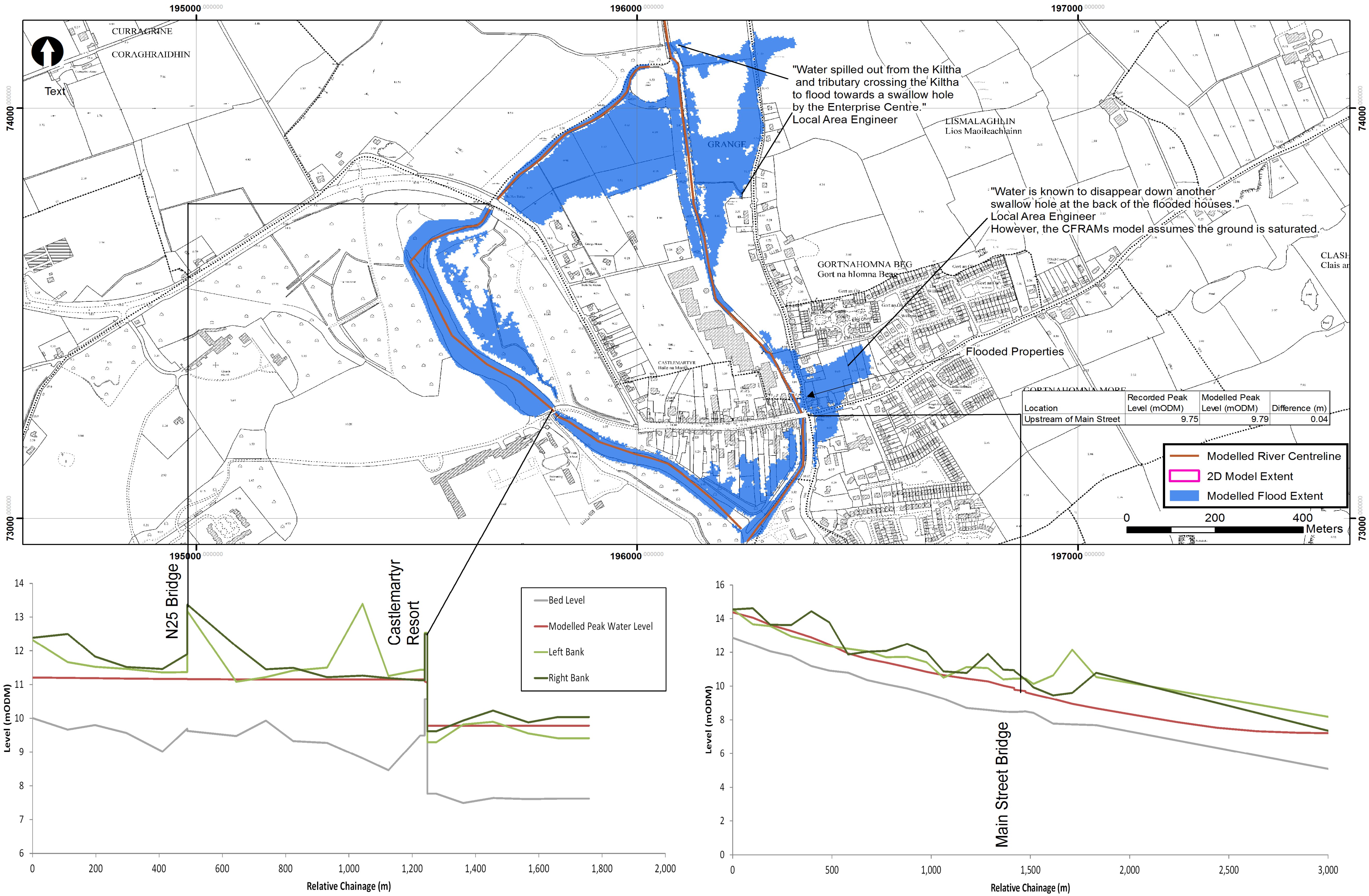
Comments: The flows in the 1D ISIS channel were combined with 2D flows parallel to the channel where there were out-of-bank flows and compared to the design hydrology.
The model tends to underestimate downstream of the AFA because 2m^3/s to 4m^3/s is attenuated at the Grange and through the Golf Course as reported by the Local Area Engineer. Therefore, the routing of flows represents reality.

Calibration Event

Model Run ID	i19cr_fcc_20091119_d1_001_castlemartyr
Period Modelled	18/11/2009 17:00 to 20/11/2009 03:00
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 Kiltha based on calibrated CWI and SPR at Ballyedmond gauge in a neighbouring catchment. The design downstream boundary gradient was used as the downstream assumption did not affect flooding in Castlemartyr.
Calibration Plot	See Schedule 3 - Calibration and Sensitivity
Comments	The model was calibrated to reproduce the extent of flooding and flow paths at the Grange and flooding of properties upstream of the Bridge. The flood level was within 0.05m of the recorded peak level but the flood extent was larger than recorded behind the houses. However, the local engineer noted that water disappeared down a sink hole behind the houses whereas the CFRAM model assumes this sink hole to be saturated as a conservative estimate of flood risk to Castlemartyr. Overall, the model calibrates well with the mechanisms recorded in November 2009.

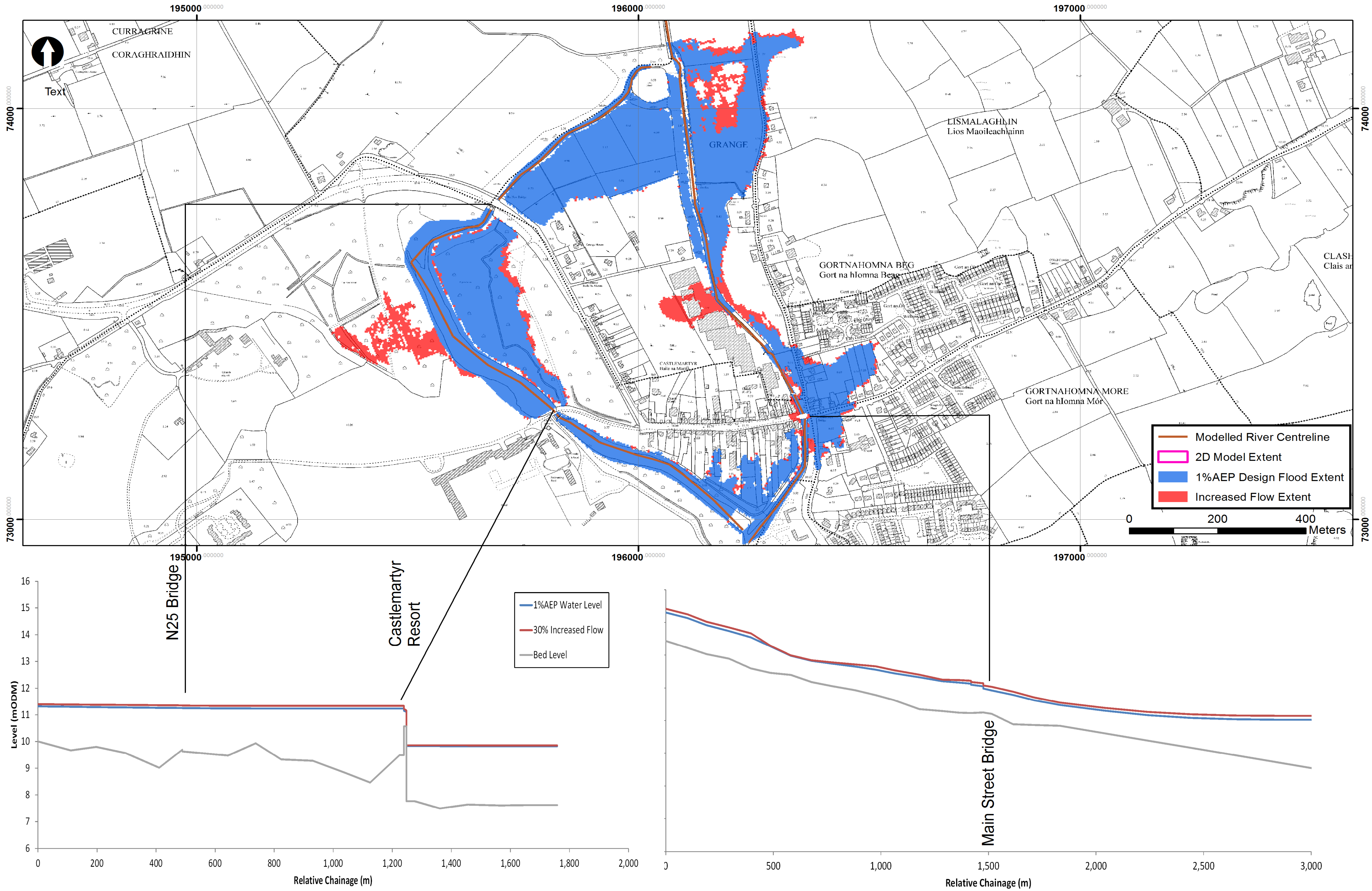
Sensitivity Test 1: Increased Flow	
Model Run ID	I19CR_FHD010_D1_001_CASTLEMARTYR
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	All inflows were increased by 30% for the 1%AEP fluvial current design event to account for the uncertainty in the derivation of QMED and the pooling group selected.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	A 30% increase in flows did not result in a significant increase in flood risk at Castlemartyr Bridge. However, the increased flow test did increase in flooding opposite Ladybrook house due to increased backwater from the access bridge downstream. Flooding also increased on the right bank in Castlemartyr Resort in the woodland areas towards the N25. Therefore flood risk in Castlemartyr was not deemed be sensitive to the uncertainties in flow because it did not significantly increase flood risk to existing properties.
Sensitivity Test 2: Increased Downstream Boundary	
Model Run ID	I19CR_FCSH01_D1_001_CASTLEMARTYR
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	The gradient used in the Stage-Discharge QH Boundary at the downstream end of the model was reduced (made slacker) by a factor of two. No other hydrological inflows were modified.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increase in downstream boundary did not significantly increase in flood risk at Castlemartyr Bridge with a small increase in shallow flooding upstream of the town bridges due to increased backwater from the access bridge downstream. However this did not flood the nearby properties. Therefore flood risk in Castlemartyr was not deemed be sensitive to the uncertainties in downstream boundary because it did not significantly increase flood risk to existing properties.
Sensitivity Test 3: Increased Manning's 'n'	
Model Run ID	I19CR_FCSN01_D1_001_CASTLEMARTYR
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 0.045 All river banks 0.060 to 0.075 Pasture / parkland / garden 0.060 to 0.080 Buildings 0.200 to 0.300 Roads 0.033 to 0.040 Dense vegetation 0.085 to 0.10
Hydrological	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increase in Manning's 'n' resulted in a small increase in flood extent and depths overall with the largest increases located at the Grange, Golf Course and LadsyBrook. However, no additional existing properties were flooded as a result of increasing Manning's 'n'. Therefore flood risk in Castlemartyr was not deemed be sensitive to the assumptions in Manning's 'n' because it did not significantly increase flood risk to existing properties.

Map C.1: Calibration to 19/11/2009 Flood Event



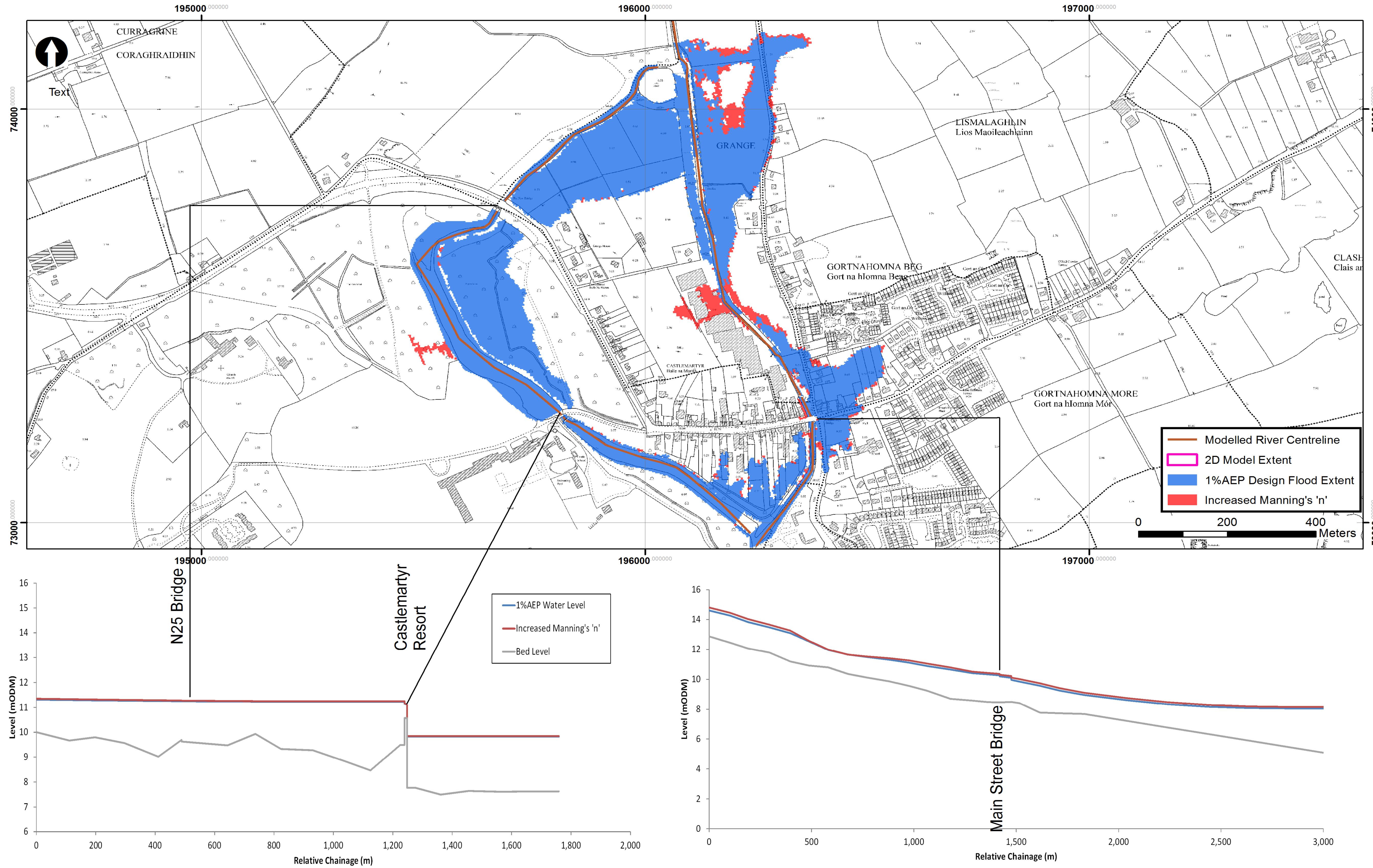
Location	Recorded Peak Level (mODM)	Modelled Peak Level (mODM)	Difference (m)
Upstream of Main Street	9.75	9.79	0.04

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



Map C.3: Sensitivity to assumptions in the downstream boundary

Map C.4: Sensitivity to Increased Manning's 'n'



Castlemartyr Model Outputs

Threshold of Property Flooding	The key thresholds and areas affected by flooding in Castlemartyr are: - 20%AEP causes extensive flooding of fields towards the Enterprise Centre although properties are not affected. - 20%AEP event flood properties upstream of Castlemartyr Bridge due to backwater from both the main bridge and access bridge upstream. - 10%AEP event floods over the N25 at Castlemartyr Bridge assuming the sink hole is saturated. - 0.5%AEP event floods properties opposite Ladysbrook House
Critical Structures for Flood Risk	The critical structures in determining flood risk include: - Bank levels at the Killamucky confluence - Access Bridge and Castlemartyr Bridge
Areas affected by flooding	Flooding is expected to affect properties upstream of Castlemartyr Bridge, fields at the Grange regularly. Properties opposite Ladysbrook House are also expected to flood in extreme events/
Risk to people	The greatest risk to life is associated with deep flooding upstream of Castlemartyr Bridge. Flooding over the N25 at Castlemartyr Bridge may form a hazard to road users.
Consideration for Flood Risk Management Options	- Increased conveyance and raised bank levels at the key structures identified are likely to reduce flood risk. - Flood warning on the River Kiltha is likely to be effective as the time to peak is over 6 hours. The soil moisture deficit conditions (i.e. saturation) should be considered for any potential flood risk mitigation measures in this karstic catchment.

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	I19HCR19_EXFCDEXF_D1		I19HCR19_DPFCD100_D1	I19HCR19_VLFCD100_D1	I19HCR19_HZFCD100_D1
Fluvial Current Design 1%AEP	I19HCR19_EXFCDEXF_D1	I19HCR19_ZN_D1	I19HCR19_DPFCD010_D1	I19HCR19_VLFCD010_D1	I19HCR19_HZFCD010_D1
Fluvial Current Design 0.1%AEP	I19HCR19_EXFCDEXF_D1	I19HCR19_ZN_D1	I19HCR19_DPFCD001_D1	I19HCR19_VLFCD001_D1	I19HCR19_HZFCD001_D1
Fluvial Mid Range Future Design 10%AEP	I19HCR19_EXFMDEXF_D1				
Fluvial Mid Range Future Design 1%AEP	I19HCR19_EXFMDEXF_D1				
Fluvial Mid Range Future Design 0.1%AEP	I19HCR19_EXFMDEXF_D1				

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
Fluvial Current Design 50%AEP	I19CR_FCD500_D1_001_Castlemartyr.ief	50	N/A	I19EXFCD500D1		I19DPFCD500D1	I19VLFCD500D1	I19HZFCD500D1
Fluvial Current Design 20%AEP	I19CR_FCD200_D1_001_Castlemartyr.ief	20	N/A	I19EXFCD100D1		I19DPFCD100D1	I19VLFCD100D1	I19HZFCD100D1
Fluvial Current Design 10%AEP	I19CR_FCD100_D1_001_Castlemartyr.ief	10	N/A	I19EXFCD200D1		I19DPFCD200D1	I19VLFCD200D1	I19HZFCD200D1
Fluvial Current Design 5%AEP	I19CR_FCD050_D1_001_Castlemartyr.ief	5	N/A	I19EXFCD050D1		I19DPFCD050D1	I19VLFCD050D1	I19HZFCD050D1
Fluvial Current Design 2%AEP	I19CR_FCD020_D1_001_Castlemartyr.ief	2	N/A	I19EXFCD020D1		I19DPFCD020D1	I19VLFCD020D1	I19HZFCD020D1
Fluvial Current Design 1%AEP	I19CR_FCD010_D1_001_Castlemartyr.ief	1	N/A	I19EXFCD010D1	I19ZN_A_D1	I19DPFCD010D1	I19VLFCD010D1	I19HZFCD010D1
Fluvial Current Design 0.5%AEP	I19CR_FCD005_D1_001_Castlemartyr.ief	0.5	N/A	I19EXFCD005D1		I19DPFCD005D1	I19VLFCD005D1	I19HZFCD005D1
Fluvial Current Design 0.1%AEP	I19CR_FCD001_D1_001_Castlemartyr.ief	0.1	N/A	I19EXFCD001D1	I19ZN_B_D1	I19DPFCD001D1	I19VLFCD001D1	I19HZFCD001D1
Fluvial Mid Range Future Design 50%AEP	I19CR_FMD500_D1_001_Castlemartyr.ief	50	N/A	I19EXFMD500D1		I19DPFMD500D1		
Fluvial Mid Range Future Design 20%AEP	I19CR_FMD200_D1_001_Castlemartyr.ief	20	N/A	I19EXFMD100D1		I19DPFMD100D1		
Fluvial Mid Range Future Design 10%AEP	I19CR_FMD100_D1_001_Castlemartyr.ief	10	N/A	I19EXFMD200D1		I19DPFMD200D1		
Fluvial Mid Range Future Design 5%AEP	I19CR_FMD050_D1_001_Castlemartyr.ief	5	N/A	I19EXFMD050D1		I19DPFMD050D1		
Fluvial Mid Range Future Design 2%AEP	I19CR_FMD020_D1_001_Castlemartyr.ief	2	N/A	I19EXFMD020D1		I19DPFMD020D1		
Fluvial Mid Range Future Design 1%AEP	I19CR_FMD010_D1_001_Castlemartyr.ief	1	N/A	I19EXFMD010D1		I19DPFMD010D1		
Fluvial Mid Range Future Design 0.5%AEP	I19CR_FMD005_D1_001_Castlemartyr.ief	0.5	N/A	I19EXFMD005D1		I19DPFMD005D1		
Fluvial Mid Range Future Design 0.1%AEP	I19CR_FMD001_D1_001_Castlemartyr.ief	0.1	N/A	I19EXFMD001D1		I19DPFMD001D1		
Fluvial High End Future Design 10%AEP	I19CR_FHD100_D1_001_Castlemartyr.ief	10	N/A	I19EXFHD100D1		I19DPFHD100D1		
Fluvial High End Future Design 1%AEP	I19CR_FHD010_D1_001_Castlemartyr.ief	1	N/A	I19EXFHD010D1		I19DPFHD010D1		
Fluvial High End Future Design 0.1%AEP	I19CR_FHD001_D1_001_Castlemartyr.ief	0.1	N/A	I19EXFHD001D1		I19DPFHD001D1		

Note on CFRAM Studies Naming Conventions

Model File Naming Convention:

B MN ID _ S C R PPP _St N
B = River Basin District code: I for South Western (Iardheisceart)
MN = **M**odel **N**umber: A sequential number for all models across the SW CFRAM study area.
ID = Model **ID**entifier: The first and last letters of the model name e.g. Ballingeary is shortened to BY
S = **S**ource code: F=fluvial C=coastal W=wave overtopping
C = **Sc**enario code: C= current M= Mid Range Future Scenario H= High End Future Scenario
R = **R**un Type: D = design, C = Calibration O= Option Assessment Run
PPP= **P**robability , expressed as a X in 1000 chance e.g. 50%AEP = 500 , 0.5% AEP = 005
St = **St**atus , D = draft, F = final
N = Revision **N**umber a single digit revision number

Additional Map Naming Convention:
B UoM H MN _ TT S C R PPP _St N

Additional GIS Naming Convention:
B MN TT S C R PPP St N

Codes a**s** above with the addition of:
UoM= Unit of Management number e.g. 18 = River Blackwater catchment
H = **High** Priority Watercourse / **Medium** Priority Watercourse
TT = Map **T**ype Ex = Extent, ZN = Zone, DP = Depth, VL = Velocity, HZ = Hazard

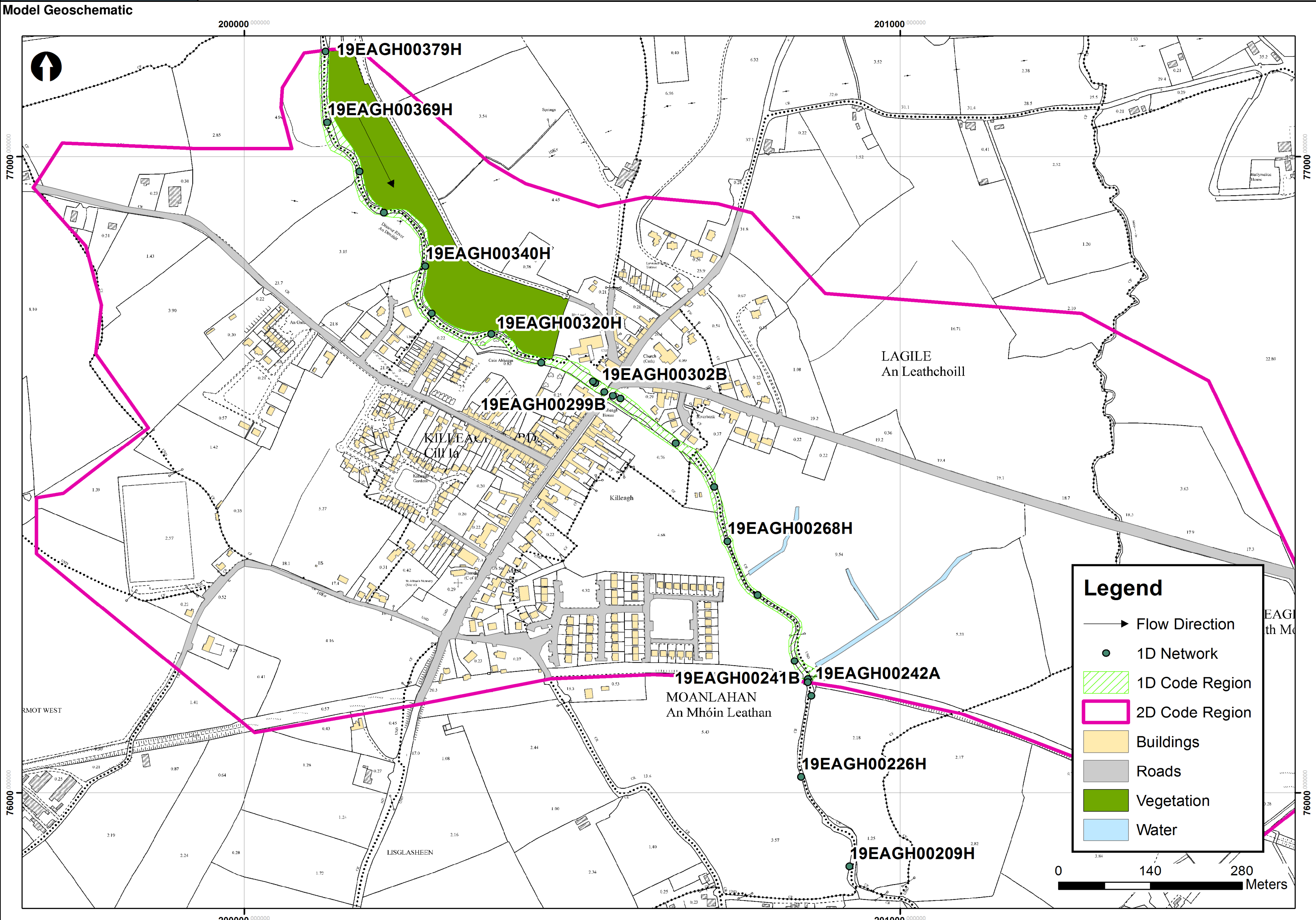
Appendix D. Killeagh AFA Model Proformas

UOM	19		
AFA/ MPW Reach	AFA-Killeagh		
Model ID	I20KL		
Purpose of Model Build	Flood Mapping		
Main Watercourse	River Dissour	FLUVIAL RISK	Yes
Length Modelled (km)	3.8	COASTAL RISK	No
Area Modelled (km^2)	1.4	VULNERABLE TO WAVES	No

Input Data	
River Channel Topographic Data	River channel survey was undertaken by Murphy Surveys Limited as part of the CFRAM Study. 19EAGH_Killeagh_V0 surveyed November 2012 : No errors or gaps were found within the survey.
Floodplain Topographic Data	Filtered LIDAR DTM "19KIL_DTM_2m.asc" 2m grid resolution captured in September 2012. The LIDAR DTM covered the entirety of the urban area
Map data	1:5000 OSI mapping tiles were used. There appears to be a new housing development along the new road 'Cois Abhanin' in the central area of Killeagh, that was not present in the previous survey. However, these properties were not predicted to be flooded in any of the design scenarios modelled. Therefore these missing buildings do not affect flood risk in Killeagh.

Model Build					
General Schematisation	A 1D/2D approach was taken to model Killeagh to accurately model flow along the main watercourses and head loss through hydraulic structures whilst enabling multidirectional flow across the urban areas. The 1D model represents the River Dissour as the main watercourse which flows in a southerly direction to. The River Dissour is modelled through the AFA from 19EAGH00379H and finishes at a 1D normal depth boundary at 19EAGH00002H where it enters the River Womanagh. The 2D element of the Dissour ends at the railway bridge (node 19EAGH00242A) where all flow passes through the structure. The 2D domain covered the AFA extent to consider flood risk from the Dissour. The 2D model was orientated in a broadly North-South direction to be parallel to the River Dissour within the AFA. The 2D grid size was set to 5m to model the flow pathway along the roads and be consistent with neighbouring AFAs in UoM19 and UoM18. Buildings footprints were raised by 0.15m above the floodplain level based on site observations of representative threshold levels in the AFA. A raised Manning's 'n' of 0.2 was then assigned to represent storage and flow inefficiencies through the building once flooded. This approach enables the extraction of representative flood depths for subsequent depth-damage calculations.				
Software Versions Used	ISIS version 3.6 TUFLOW version 2012-05-AC-iSP-w32				
Total No of 1D nodes	**35**				
Open channel (H)	31				
Bridges (D)	3				
Culverts (I)	0				
Weirs (W)	1				
Model Extent	Reach/Feature	Upstream Limit (ING)		Downstream Limit (ING)	
	River Dissour	200123, 77165		202189, 74768	
Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	River Dissour	0.040	0.040-0.085	0.060	Schedule 1: Photographs
	Open pasture	N/A	N/A	0.06	Schedule 1: Photographs
	Dense vegetation	N/A	N/A	0.085	Schedule 1: Photographs
	Buildings	N/A	N/A	0.2	Schedule 1: Photographs
	Roads	N/A	N/A	0.03	Schedule 1: Photographs
Structures	See Schedule 2 for Hydraulic Structure Parameters				
Upstream boundary	The River Dissour inflow was lumped at the upstream boundary as there was limited flows from the intermediate catchment through the town. The upstream boundary was located at 19EAGH00379H at the upstream of the AFA because this location captured all flow entering the AFA from upstream.				
Lateral inflows	Lateral inflows represent the intermediate catchment and tributary inflow from Ballymakeagh More Stream as single point inflow.				
Downstream boundary	The downstream boundary of the 1D was located on the River Dissour, 2km downstream of the AFA , at the confluence with the River Womanagh. The confluence of the Dissour and Womanagh is partially tidal influenced. A single QH boundary is not appropriate to describe the downstream levels on the Womanagh and any backwater arising from this reach. Therefore the water level - time (HT) series were extracted from the Womanagh model results and applied to downstream boundary of the Dissour to fully consider the backwater during high tide.				
Run Settings	Unsteady simulation of the 30 hours over the peak of the flood hydrograph allowing for the rising and recession limb. The model was started at 10 hours when the flood hydrograph first rises above baseflow. The 1D timestep was set to 1s which is divisible in to the 2D timestep of 2s which is less than half the grid cell size as recommended by TUFLOW. All other parameters set to default.				

Model Geoschematic



SCHEDULE 1 : PHOTOGRAPHS
Photo 1: Banks of the Dissour

Photo 2: Channel of the Dissour Upstream of Town Bridge

Photo 3: Channel of the Dissour Downstream of Town Bridge

Photo 4: Floodplain

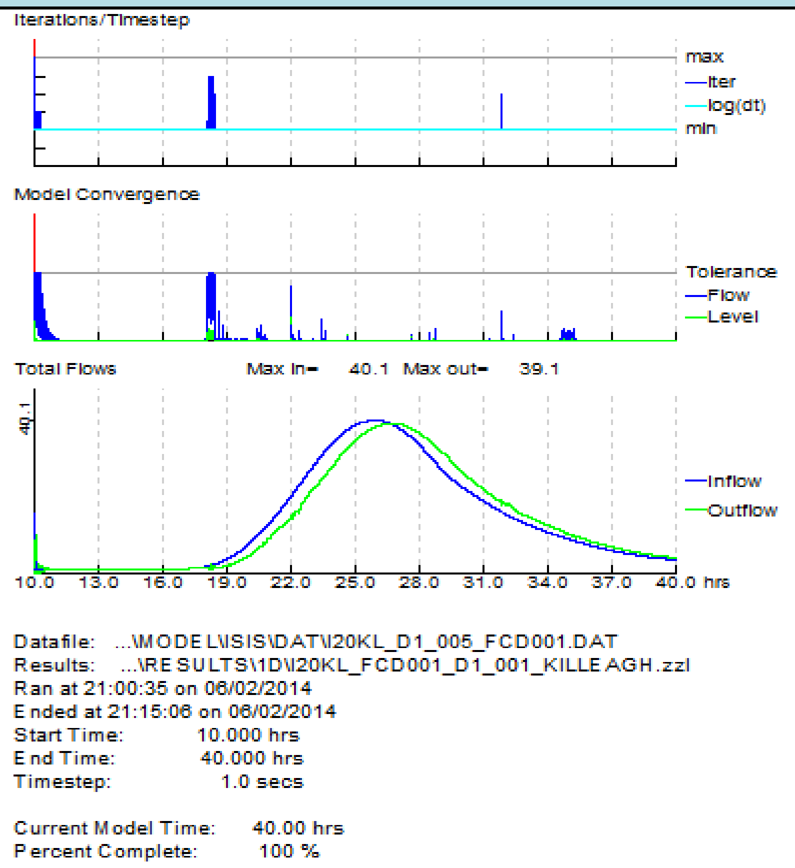
SCHEDULE 2: Structures

Data file	P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I20KL_Killeagh\DESIGN\model\ISIS\I20KL_D1_005.DAT																									
Node	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Culvert Parameters											Comments/ Justification
				Soffit Elevation (mAOD)	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation (mAOD)	Length	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation (mAOD)	Modular Limit	Weir Coeff.	Soffit level (mAOD)	Invert u/s (mAOD)	Invert d/s (mAOD)	Width/ area (m) (m2)	Length (m)	K	Ki	M	Trash Screen?	Trash Screen coefficient		
19EAGH00302W	200539	76645	Rock Weir WEIR+Spill	N/A	N/A	N/A	N/A	16.18	1	0.8	1.5	16.3	0.9	1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Formal weir structure represents the rock weir in channel and spill represents the river banks up to floodplain level. The weir and spill coefficients were calibrated to achieve the surveyed water profile at low flows.	
19EAGH00300D	200550	76632	Main Street Bridge Arched	17.19	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	No spill modelled over the parapet as the bridge is bypass before the parapet is overtopped.	
19EAGH00299E	200539	76645	Weir on the downstream of Main Street Bridge	N/A	N/A	N/A	N/A	15.43	4.88	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		
19EAGH00242D	200859	76178	Old Rail Bridge USBPR Bridge	13.96	3	37.12	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	No spill modelled over the parapet as the bridge soffit is not reached in any scenarios modelled.	
19EAGH00012D	202124	74837	USBPR Bridge	2.79	1	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		

Killeagh Model Performance

1D Convergence

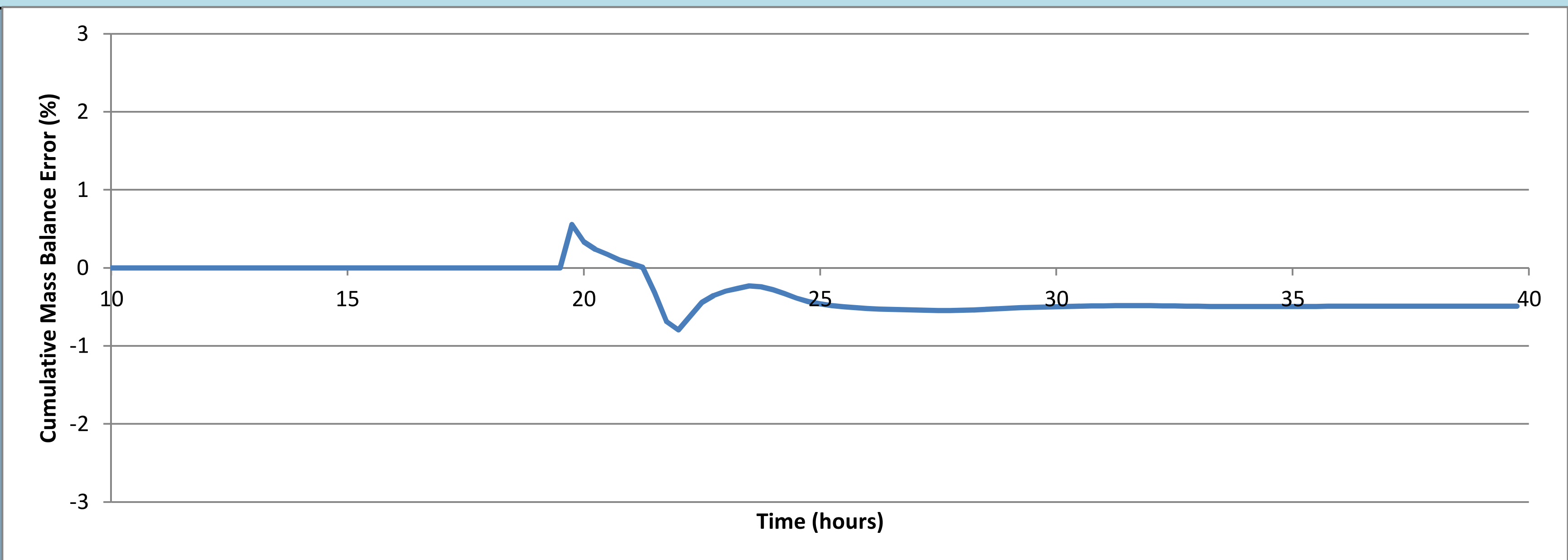
Convergence Plot 0.1% AEP Fluvial Event



Comments: The 1D model components were convergent and within the recommended tolerances for the majority of the event. The initial poor convergence is associated with using average initial conditions as a common starting place for all scenarios. However this quickly stabilises within recommended tolerances within 0.25 hours and does not affect

2D Convergence

Mass Balance Plot 0.1%AEP Fluvial Event



Comments: The cumulative mass error over the 0.1% AEP event was -0.5% or -8560 m^3. Greater mass error is experienced at the initial wetting of the 2D cells at 20 hours when water initially spills out of bank. However, the mass error is within the tolerance during the time of the peak and the results are 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
19_686_10	Dissour u/s Survey Extent	19EAGH00379H	13.30	13.54	2%	19.60	19.91	2%	29.00	29.40	1%
19_686_15	Dissour d/s Survey Extent - Moanlahan Bridge	19EAGH00242A	13.60	13.53	-1%	20.00	19.88	-1%	29.50	28.85	-2%
19_1798_3	Dissour u/s Womanagh	19EAGH00002H	18.40	18.26	-1%	27.10	26.78	-1%	40.10	39.10	-2%

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. All modelled flows are within 3% of the derived hydrology. The model tends to underestimate flow further downstream for the 0.1% event due to backwater from the Womanagh.

Validation to Historical Flood Evidence

Stakeholder Comments from Flood Risk Review: The Killeagh flood report for 2009 is not located within the Killeagh AFA. The source of the flood waters was a runoff (and the cause was surface water drainage). The flooding occurred in the Dower/Womanagh catchment. 300m of the local road L7836 and some pasture lands were flooded.

A member of staff at the Thatch Pub and Restaurant which is located adjacent to the bridge over the Dissour River in Killeagh stated that she had no recollection of any flooding to the premises. From discussion with a long term resident of Killeagh he confirmed that in his living memory there was no fluvial flooding in the village of Killeagh. He also stated that he can only remember the flood level of the river only ever reaching the eyes of the bridge and never overflowing. The Local Authority had no specific issues in relation to this site.

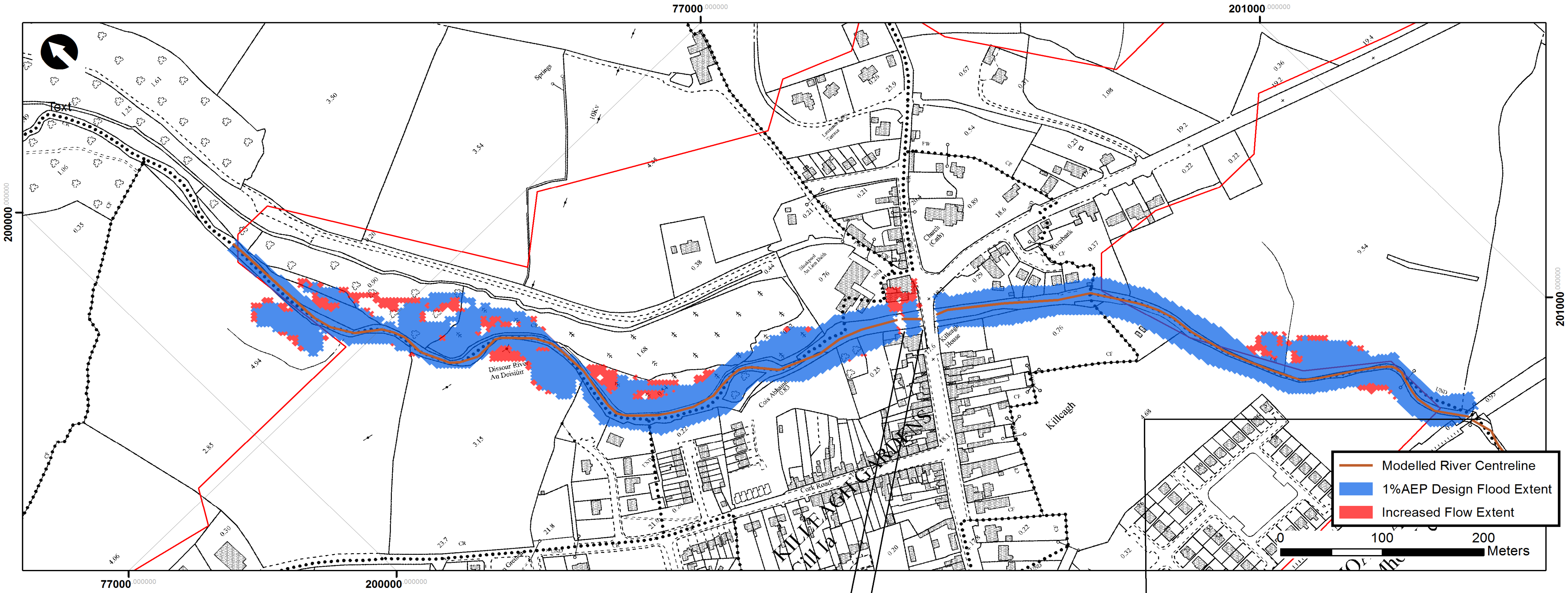
Model Results: The design flood outlines remain in-bank at the Bridge up to 0.1%AEP. This low frequency of flooding corresponds with the local resident's experience of no flooding in living memory at this location.

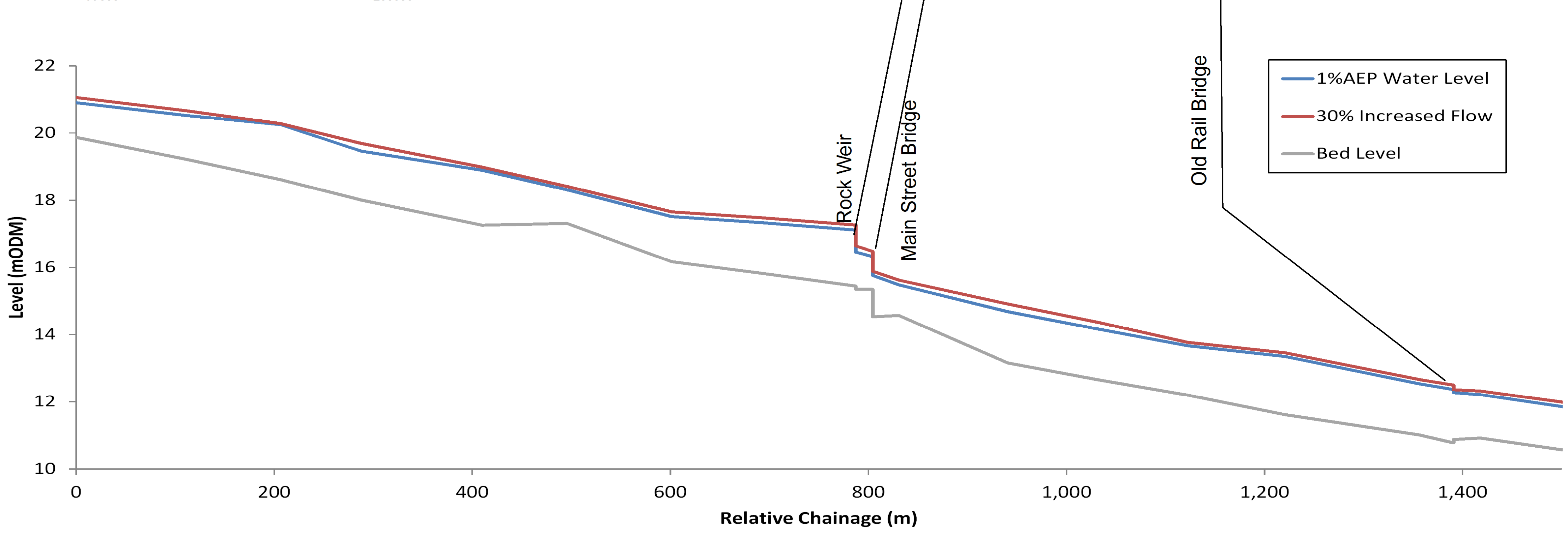
Sensitivity Test 1: Increased Flow

Model Run ID	i20kl_fhd010_d1_001_killeagh
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.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity

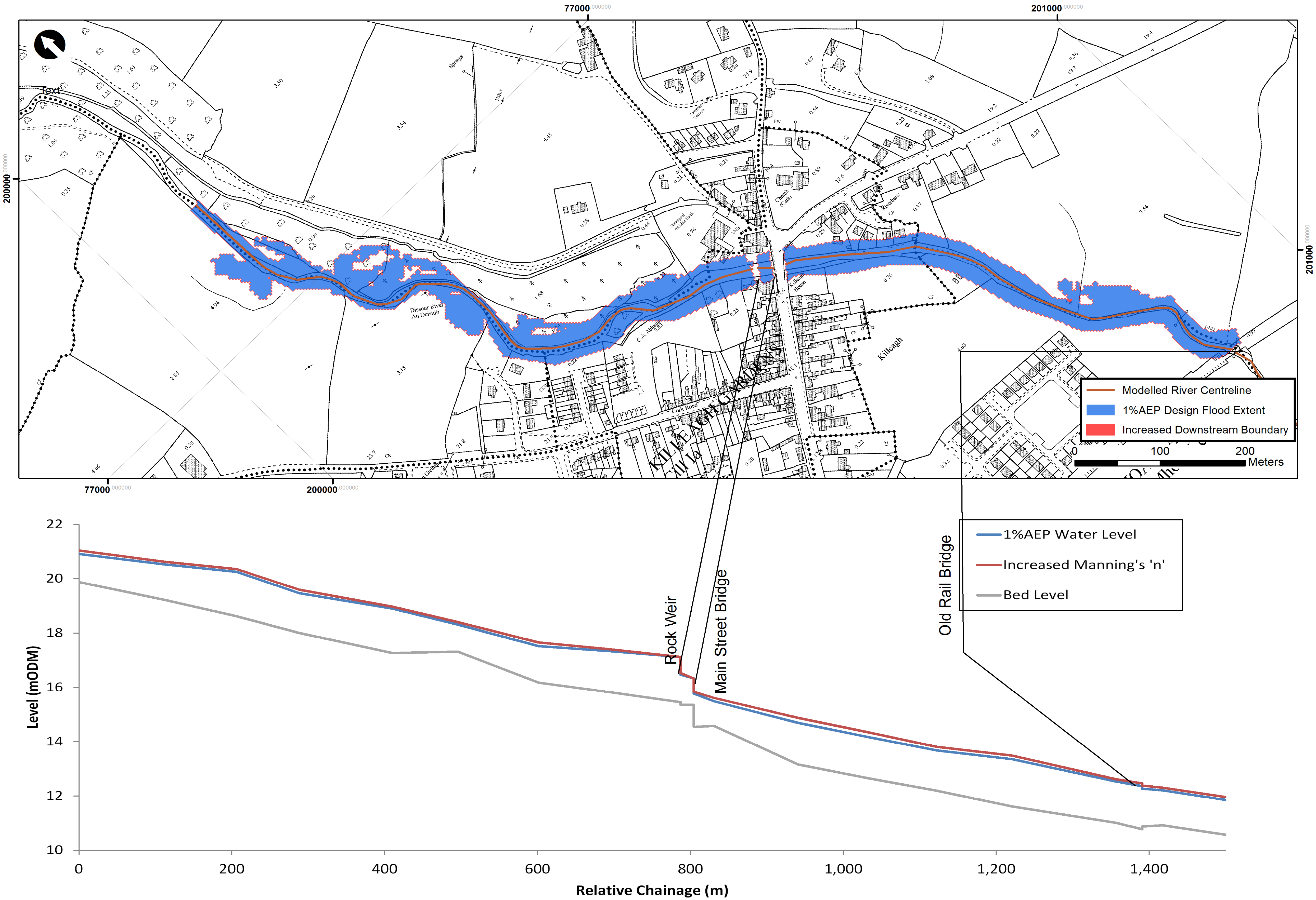
Comments	A 30% increase in flows resulted in a small increase in flood extent on the left bank upstream of Main Street Bridge affecting one property, the Old Thatch Pub. Flood levels and extent also increased upstream of the town but did not inundate properties. Therefore flood risk in Killeagh was not found to be sensitive to the uncertainties in flow given the relatively small increase in flood extent and risk.
Sensitivity Test 2: Increased Downstream Boundary	
Model Run ID	i20kl_fcsh01_d1_001_killeagh
Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	The water level in the downstream boundary (which represents the tidally influenced River Womanagh) was raised by 0.5m to represent uncertainties in the tidal estimation in line with Guidance Note 22. This approximate to the Mid-Range Future Scenario (MRFS). No other hydrological inflows were modified.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increased downstream boundary resulted in raised levels 600m upstream of the confluence with the Womanagh. However water levels and flood risk within the AFA was not affected. Therefore, flood risk in Killeagh was not deemed sensitive to the assumptions in the downstream boundary.
Sensitivity Test 3: Increased Manning's 'n'	
Model Run ID	i20kl_fcsn01_d1_001_killeagh
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 0.045 All river banks 0.060 to 0.075 Pasture / parkland / garden 0.060 to 0.080 Buildings 0.200 to 0.300 Roads 0.033 to 0.040 Dense vegetation 0.085 to 0.100
Hydrological	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 level and extent through the town. The increase in Manning's 'n' resulted in small increase upstream and downstream but did not affect properties. Therefore Killeagh is not deemed to be sensitive to the assumptions in Manning's 'n' values.

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

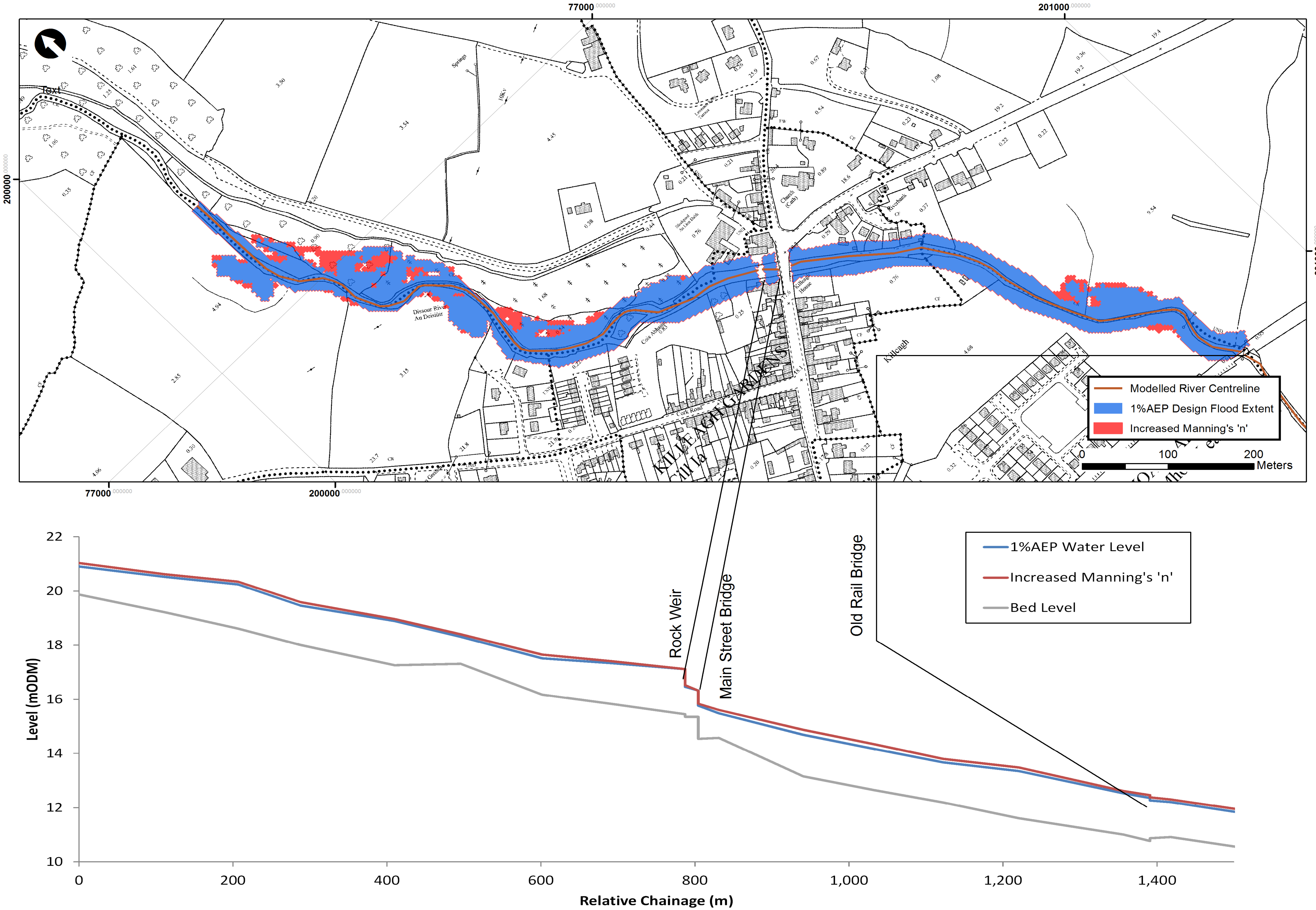




Map D.2: Sensitivity to assumptions in the downstream boundary



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



Killeagh Model Outputs	
Threshold of Flooding	The key thresholds and areas affected by flooding in Killeagh are: - 20%AEP event exceeds the capacity of channel upstream of the town and 100m upstream of the Old Rail Bridge to flood fields but does not affect properties. - 0.5%AEP event spills out-of-bank upstream of the Main Street Bridge to inundate the Old Thatch Pub but does not reach the soffit level or overtop the road.
Critical Structures for Flood Risk	The critical structures in determining flood risk include: - The rock weir and Main Street Bridge in extreme flood events.
Areas affected by flooding	The Old Thatch Pub area in extreme fluvial events only.
Risk to people	The greatest risk to life is associated with flooding at the Old Thatch Pub Area in extreme fluvial events. The flood hazard is classed as low to moderate due to the moderate depths of flooding and relatively low velocity of water.
Consideration for Flood Risk Management Options (where required)	Flood risk is generally low. However, the following measures are hydraulically and hydrologically feasible - Increased conveyance and/or bank levels at the Main Street Bridge identified are likely to reduce flood risk. - Flood warning on the Dissour is likely to be effective as the time to peak is over 6 hours.

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	I19HKL20_EXFCDEXF_D1		I19HKL20_DPFCD100_D1	I19HKL20_VLFCD100_D1	I19HKL20_HZFCD100_D1
Fluvial Current Design 1%AEP	I19HKL20_EXFCDEXF_D1	I19HKL20_ZN_D1	I19HKL20_DPFCD010_D1	I19HKL20_VLFCD010_D1	I19HKL20_HZFCD010_D1
Fluvial Current Design 0.1%AEP	I19HKL20_EXFCDEXF_D1	I19HKL20_ZN_D1	I19HKL20_DPFCD001_D1	I19HKL20_VLFCD001_D1	I19HKL20_HZFCD001_D1
Fluvial Mid Range Future Design 10%AEP	I19HKL20_EXFMDEXF_D1				
Fluvial Mid Range Future Design 1%AEP	I19HKL20_EXFMDEXF_D1				
Fluvial Mid Range Future Design 0.1%AEP	I19HKL20_EXFMDEXF_D1				

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
Fluvial Current Design 50%AEP	I20KL_FCD500_D1_001_Killeagh.ief	50	N/A	I20EXFCD500D1		I20DPFCD500D1	I20VLFCD500D1	I20HZFCD500D1
Fluvial Current Design 20%AEP	I20KL_FCD200_D1_001_Killeagh.ief	20	N/A	I20EXFCD100D1		I20DPFCD100D1	I20VLFCD100D1	I20HZFCD100D1
Fluvial Current Design 10%AEP	I20KL_FCD100_D1_001_Killeagh.ief	10	N/A	I20EXFCD200D1		I20DPFCD200D1	I20VLFCD200D1	I20HZFCD200D1
Fluvial Current Design 5%AEP	I20KL_FCD050_D1_001_Killeagh.ief	5	N/A	I20EXFCD050D1		I20DPFCD050D1	I20VLFCD050D1	I20HZFCD050D1
Fluvial Current Design 2%AEP	I20KL_FCD020_D1_001_Killeagh.ief	2	N/A	I20EXFCD020D1		I20DPFCD020D1	I20VLFCD020D1	I20HZFCD020D1
Fluvial Current Design 1%AEP	I20KL_FCD010_D1_001_Killeagh.ief	1	N/A	I20EXFCD010D1	I20ZN_A_D1	I20DPFCD010D1	I20VLFCD010D1	I20HZFCD010D1
Fluvial Current Design 0.5%AEP	I20KL_FCD005_D1_001_Killeagh.ief	0.5	N/A	I20EXFCD005D1		I20DPFCD005D1	I20VLFCD005D1	I20HZFCD005D1
Fluvial Current Design 0.1%AEP	I20KL_FCD001_D1_001_Killeagh.ief	0.1	N/A	I20EXFCD001D1	I20ZN_B_D1	I20DPFCD001D1	I20VLFCD001D1	I20HZFCD001D1
Fluvial Mid Range Future Design 50%AEP	I20KL_FMD500_D1_001_Killeagh.ief	50	N/A	I20EXFMD500D1		I20DPFMD500D1		
Fluvial Mid Range Future Design 20%AEP	I20KL_FMD200_D1_001_Killeagh.ief	20	N/A	I20EXFMD100D1		I20DPFMD100D1		
Fluvial Mid Range Future Design 10%AEP	I20KL_FMD100_D1_001_Killeagh.ief	10	N/A	I20EXFMD200D1		I20DPFMD200D1		
Fluvial Mid Range Future Design 5%AEP	I20KL_FMD050_D1_001_Killeagh.ief	5	N/A	I20EXFMD050D1		I20DPFMD050D1		
Fluvial Mid Range Future Design 2%AEP	I20KL_FMD020_D1_001_Killeagh.ief	2	N/A	I20EXFMD020D1		I20DPFMD020D1		
Fluvial Mid Range Future Design 1%AEP	I20KL_FMD010_D1_001_Killeagh.ief	1	N/A	I20EXFMD010D1		I20DPFMD010D1		
Fluvial Mid Range Future Design 0.5%AEP	I20KL_FMD005_D1_001_Killeagh.ief	0.5	N/A	I20EXFMD005D1		I20DPFMD005D1		
Fluvial Mid Range Future Design 0.1%AEP	I20KL_FMD001_D1_001_Killeagh.ief	0.1	N/A	I20EXFMD001D1		I20DPFMD001D1		
Fluvial High End Future Design 10%AEP	I20KL_FHD100_D1_001_Killeagh.ief	10	N/A	I20EXFHD100D1		I20DPFHD100D1		
Fluvial High End Future Design 1%AEP	I20KL_FHD010_D1_001_Killeagh.ief	1	N/A	I20EXFHD010D1		I20DPFHD010D1		
Fluvial High End Future Design 0.1%AEP	I20KL_FHD001_D1_001_Killeagh.ief	0.1	N/A	I20EXFHD001D1		I20DPFHD001D1		

Note on CFRAM Studies Naming Conventions

Model File Naming Convention:

B MN ID _ S C R PPP _St N
B = River Basin District code: I for South Western (Iardheisceart)
MN = **M**odel **N**umber: A sequential number for all models across the SW CFRAM study area.
ID = Model **ID**entifier: The first and last letters of the model name e.g. Ballingeary is shortened to BY
S = **S**ource code: F=fluvial C=coastal W=wave overtopping
C = **Sc**enario code: C= current M= Mid Range Future Scenario H= High End Future Scenario
R = **R**un Type: D = design, C = Calibration O= Option Assessment Run
PPP= **P**robability , expressed as a X in 1000 chance e.g. 50%AEP = 500 , 0.5% AEP = 005
St = **S**tatus , D = draft, F = final
N = Revision **N**umber a single digit revision number

Additional Map Naming Convention:
B UoM H MN _ TT S C R PPP _St N

Additional GIS Naming Convention:
B MN TT S C R PPP St N

Codes a**s** above with the addition of:
UoM= Unit of Management number e.g. 18 = River Blackwater catchment
H = **High** Priority Watercourse / **Medium** Priority Watercourse
TT = Map **T**ype Ex = Extent, ZN = Zone, DP = Depth, VL = Velocity, HZ = Hazard

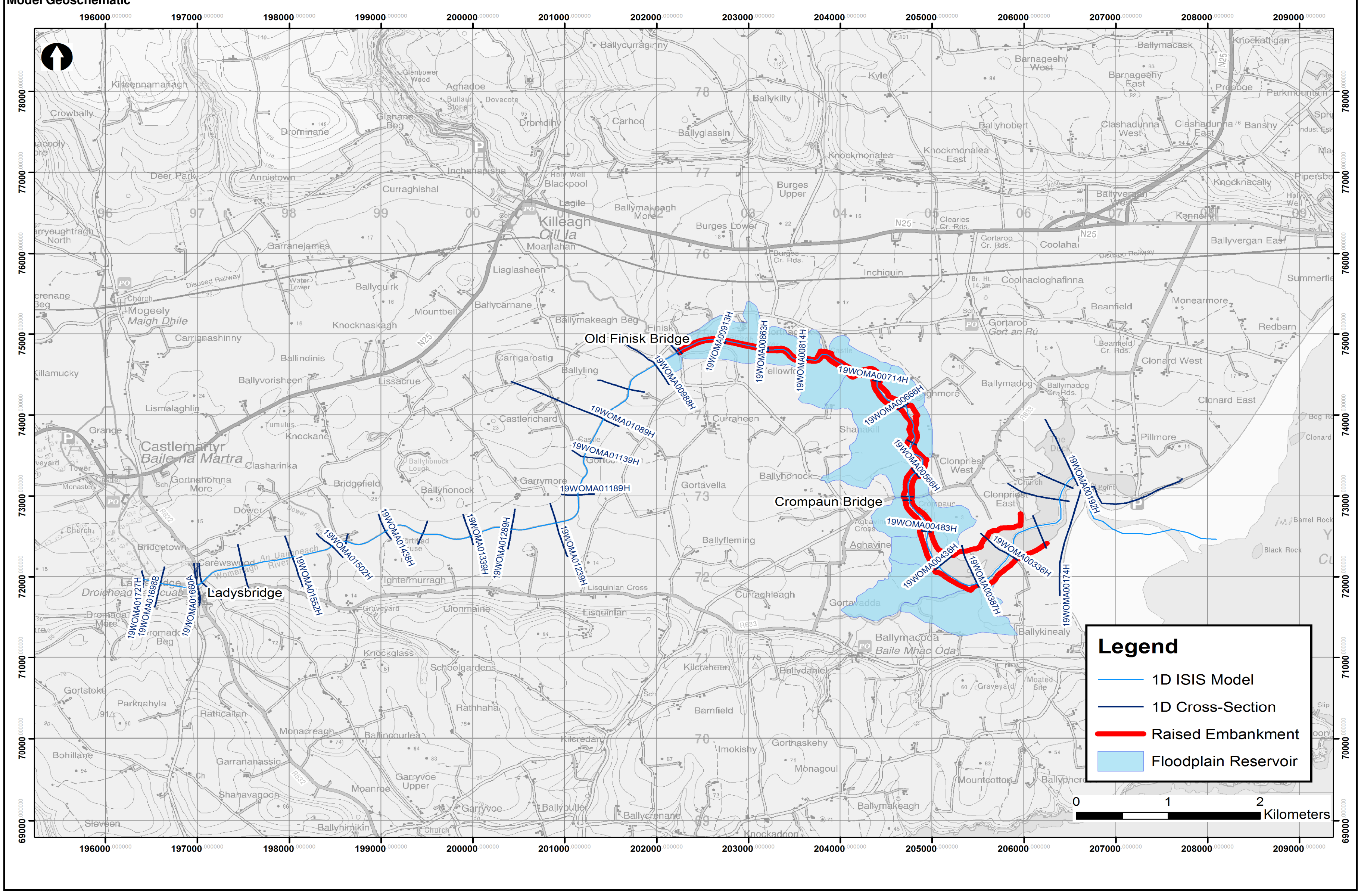
Appendix E. Womanagh MPW Model Proformas

UOM	19		
AFA/ MPW Reach	MPW-River Womanagh		
Model ID	I21WH		
Purpose of Model Build	Flood Mapping		
Main Watercourse	River Womanagh	FLUVIAL RISK	Yes
Length Modelled (km)	15.4	COASTAL RISK	Yes
Area Modelled (km^2)	N/A	VULNERABLE TO WAVES	No

Input Data	
River Channel Topographic Data	River channel survey was undertaken by Murphy Surveys Limited as part of the CFRAM Study. 19WOMA_Womanagh_V0 surveyed November 2012 : No errors or gaps were found within the survey.
Floodplain Topographic Data	Filtered LIDAR DTM covering the River Womanagh at the confluence with the River Kiltha "19CAS_DTM_2m.asc" 2m grid resolution captured in May 2012. Accuracy +/- 0.2m Filtered LIDAR DTM covering the River Womanagh at the confluence with the River Dissour "19KIL_DTM_2m.asc" 2m grid resolution captured in September 2012.Accuracy +/- 0.2m IFSAR OSi National DTM. Accuracy of +/- 2m and up to +/- 0.5m on flat ground. The River Womanagh is partially covered by LiDAR hence the OSI IFSAR based DTM has been combined with the LIDAR to develop a single DTM to extend 1D cross-sections and derive floodplain reservoir volumes. DTM Development (version 3) The IFSAR was adjusted by 0.5m based on the typical error to the river channel survey data and LiDAR on flat open ground. However, there artificially high elevations around the Dower Confluence caused by poor filtering of the IFSAR data where there are forestry plantations. These areas are marked as "liable to flooding" on the 1:5000 maps and caused inconsistent flood extents with upstream and downstream reaches. Therefore, the areas of high elevation were manually "smoothed" by interpolating from the more accurate LiDAR and topographic survey upstream and downstream of this area. This provided a more realistic and consistent flood extent however, there is greater uncertainty in flood depths as ground elevations are only interpolated and unlikely to pick up local variations. The final DTM "I21WH_DTM_LIDAR_SAR3.asc" is provided in the digital handover.
Map data	1:5000 OSI mapping tiles were used. There appears to be a new development to the west of Ladysbridge in the area of Dealgban ~100m south from the River Womanagh. This is the only difference between current OSI mapping and the original survey. This has been informed the Manning'n' 'n' value selected for the floodplain at this location but buildings have not explicitly modelled in 1D only MPW reaches.

Model Build					
General Schematisation	A 1D approach was deemed sufficient to derive flood extent and depth mapping for the Womanagh MPW. A 1D ISIS model was developed to simulate in-bank fluvial and tidal flows and extended to model the floodplain as discussed below: i) Upstream of Old Finisk Bridge, the surveyed river channel sections have been extended across the entire valley because the floodplain is connected with the river channel. ii) Downstream of Old Finisk Bridge, the raised embankments disconnect the tidally influenced river channel with the natural floodplain. Therefore, 1D floodplain reservoir units have been used to represent each floodplain cell based on the volume calculated from the combined DTM. However, the crest of the embankments are not necessarily picked up by the LiDAR and IFSAR data. Therefore, detailed defence asset survey of the embankment crests has been used to derive the spill levels in ISIS. A more detailed 2D modelling approach was not used for the lower Womanagh because the floodplain elevations are reliant on less accurate IFSAR data, and therefore a 2D approach would not significantly improve flood depth information.				
Software Versions Used	ISIS version 3.6 TUFLOW version 2012-05-AC-iSP-w32				
Total No of 1D nodes	**92**				
Open channel (H)	40				
Bridges (D)	3				
Spills (S)	35				
Floodplain Reservoirs	14				
Culverts (I)	0				
Weirs (W)	0				
Model Extent	Reach/Feature	Upstream Limit (ING)		Downstream Limit (ING)	
	River Womanagh	196419, 71965		206695, 73100	
Roughness	Reach/Feature	Active Channel	River Banks	Floodplain	Source
	River Womanagh	0.040	0.040-0.060	0.060	Schedule 1: Photographs
Structures	See Schedule 2 for Hydraulic Structure Parameters				
Upstream boundary	The River Womanagh upstream flow-time (QT) boundary was located at 19WOMA01727H at the downstream of the Womanagh-Kiltha confluence. It represents the combined inflow from the Upper Womanagh and River Kiltha.				
Lateral inflows	Major tributaries have been applied as flow-time (QT) boundary types based on the design hydrology and applied as a point inflow to the relevant cross-section using a lateral inflow unit. Flows from intermediate catchments have also been applied as flow-time (QT) boundaries distributed to the natural low bank points and overland flow pathways using a lateral inflow unit. The distribution of the intermediate inflows has been equally distributed because the catchment area increased approximately uniformly in this reach.				
Downstream boundary	The downstream boundary of the 1D was located on the River Womanagh, located at 19WOMA00174H at the mouth of the estuary. A head-time (HT) boundary was applied based on the design tidal conditions in order to accurately simulate backwater and tide-locking upstream. The tidal conditions were shifted by -3 hours in order to phase the fluvial peak with the peak tide.				
Run Settings	Unsteady simulation of the full 48 hour hydrograph. The model starts at -3 hours to start at low tide and align the tidal peak with the peak fluvial inflow at Old Finisk Bridge. The 1D timestep was set to 10s which is appropriate for to resolve the fluvial and tidal hydrograph without oscillations of water level over time and spatially along the model. All other run parameters were set to default.				

Model Geoschematic



SCHEDULE 1 : PHOTOGRAPHS

Photo 1: Channel downstream of Ladysbridge

Photo 3: Channel upstream of Ladysbridge

Photo 2: Channel towards Old Finisk Bridge

Photos 1 and 2. In-channel vegetation is summer growth for this reach is would die back during the winter months (i.e. flood season). Therefore 0.04 was deemed representative of winter conditions

Photo 4: Typical Flood plain

Photo 4: Floodplain is typically pasture land with hedges around field boundaries. Therefore a value of 0.06 has been used to represent the combined Manning's n' of mature crops and dense vegeation based on recommended industry ranges.

SCHEDULE 2: Structures

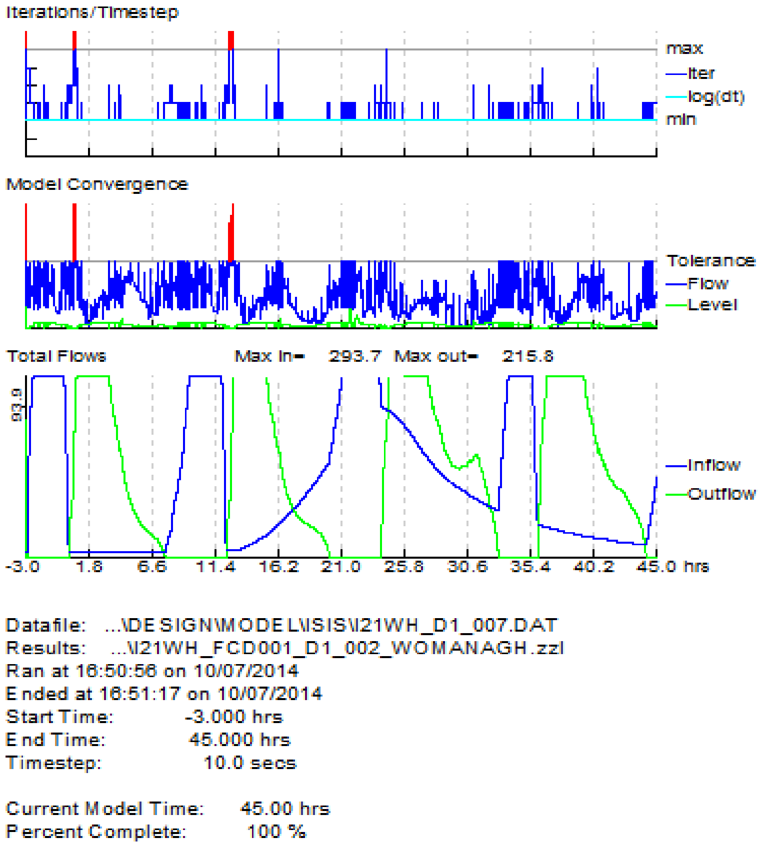
Data file P:\Cambridge\Demeter\EVT4\296241 S West CFRAMS EVT Code\Technical\Hydraulics\Build\I21WH_Womanagh\DESIGN\model\ISIS\I21WH_D1_007.DAT

Node	Easting	Northing	Structure Type	Bridge Parameters				Weir Parameters				Spill Parameters			Culvert Parameters										Comments/ Justification
				Soffit Elevation (mAOD)	No of Openings	Skew Angle	Calibration Coefficients	Crest Elevation (mAOD)	Length	Modular Limit	Velocity Coeff.	Minimum. Crest Elevation (mAOD)	Modular Limit	Weir Coeff.	Soffit level (mAOD)	Invert u/s (mAOD)	Invert d/s (mAOD)	Width/ area (m) (m2)	Length (m)	K	Ki	M	Trash Screen?	Trash Screen coefficient	
19WOMA01660D	196989	71896	Ladysbridge Arched Bridge	6.99	1	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	Arched opening represented as an arched bridge
19WOMA01660S	196989	71896	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.6	0.9	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Spill over parapet and road for bridge unit 19WOMA01660D
19WOMA00967D	202222	74775	Old Finisk Bride Arched Bridge	3.98	1	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	Arched opening represented as an arched bridge
19WOMA00967S	202222	74775	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.92	0.9	1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Spill over parapet and road for bridge unit 19WOMA00967D
19WOMA00533D	204739	72993	Crompaun Bridge USBPR	2.06	1	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	Flat soffit bridge with railings above deck modelled as USBPR bridge.
19WOMA00533S	204739	72993	Spill	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.16	0.7	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Spill over bridge deck and road for bridge unit 19WOMA00533D
RES_00988R	202156.1 7	4619.314	Reservoir	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	Floodplain reservoir on right bank upstream of Old Finisk Bridge
RES_00964R	202877.37	74757.141	Reservoir	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	Floodplain reservoir on the right bank immeadiately downstream of Old Finisk Bridge
RES_00964L	203072.25	74984.975	Reservoir	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	Floodplain reservoir on the left bank immeadiately downstream of Old Finisk Bridge to Gortnagark
RES_00814R	203781.35	74413.776	Reservoir	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	Floodplain reservoir on the right bank at Shanakil.
RES_00763R	204362.02	73723.923	Reservoir	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	Floodplain reservoir on the right bank from Shanakil to Crompaun Bridge.
RES_00530R	204612.31	72701.104	Reservoir	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	Floodplain reservoir on the right bank from Crompaun Bridge to Aghavine.
RES_00483R	204764.54	72306.606	Reservoir	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	Floodplain reservoir on the right bank at Aghavine.
RES_00436R	204660.1 7	1817.126	Reservoir	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	Floodplain reservoir on the right bank from Aghavine to the Ballmacoda Stream
RES_00387R	205342.87	71564.96	Reservoir	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	Floodplain reservoir on the right bank at the Ballymacoda Stream
RES_00763L	204170.69	74714.079	Reservoir	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	Floodplain reservoir on the left bank at Creighmore.
RES_00714L	204676.13	74331.643	Reservoir	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	Floodplain reservoir on the left bank at Ballymadog.
RES_00666L	204909.35	73763.508	Reservoir	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	Floodplain reservoir on the left bank downstream of Ballymadog.
RES_00566L	204866.81	73106.044	Reservoir	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	Floodplain reservoir on the left bank upstream of Crompaun Bridge
RES_00530L	205141.21	72670.864	Reservoir	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	Floodplain reservoir on the left bank downstream of Crompaun Bridge. The embankments have been breached as part of coastal restoration and this areas floods on every tide.

River Womanagh Model Performance

1D Convergence

Convergence Plot 0.1% AEP Fluvial Event



Comments: The 1D model components were convergent and within the recommended tolerances for the majority of the event. The initial poor convergence is associated with using average initial conditions as a common starting place for all scenarios.
The spikes in poor convergence at 0.5 and 12 hours are attributed to rapid flow through the narrow opening in the spill into the set-back area downstream of Crompaun Bridge (530L reservoir) at the changing of the tide during low fluvial flow. However, this occurs before the peak flood and does not affect peak level.

2D Convergence (Not Applicable.1D only approach used)

Mass Balance Plot

Comments

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
19_705_1	River Womanagh Upstream	19WOMA01727H	16.7	16.67	0%	25.1	25.1	0%	37.7	37.8	0%
19_1823_1	Womanagh downstream Ladysbridge	19WOMA01658B	18.2	17.84	-2%	27.4	26.4	-4%	41.2	39.1	-5%
19_1833_1	Womanagh downstream Dower	19WOMA01502H	23	22.18	-4%	34.7	32.3	-7%	52.1	47.4	-9%
19_1793_1	Womanagh downstream Ballying	19WOMA01038H	27.4	23.71	-13%	41.3	33.9	-18%	62.1	49.4	-20%
19_1794_1	Womanagh downstream Dissour (Finisk Bridge)	19WOMA00964B	43.9	33.53	-24%	66.1	46.2	-30%	99.3	66.5	-33%
19_1941_2+	River Womanagh (Crompaun Bridge)	19WOMA00534A	46.8	37.65	-20%	70.5	40.2	-43%	105.9	50.9	-52%

Comments: At the upstream of the River Womanagh design and modelled flows agree within 10%. However, the model tends to underestimate downstream of the Balling confluence in the current scenario as the tidal influence limits the fluvial discharge. The design hydrology assumes free-flow conditions. Therefore, there is an expected discrepancy between the design and hydraulically modelled flows in the lower reaches.

Validation to Historic Flood Evidence

Known areas of flooding: "Land flooding in vicinity of Crompaun Bridge. Flooding upstream and downstream on both sides of bridge. Womanagh River. Flood ID 2208"
This refers to tidal flooding in October 2004. The peak water level in Youghal was 2.92mOD for the Oct 2004, which is greater than the 0.1%AEP according to the ICPSS total tide

Comments: The 0.1%AEP coastal current event inundates the floodplain areas upstream and downstream of Crompaun Bridge but does not overtop the bridge itself as described by the local engineer reports.

The relative flood frequency of this coastal event could be improved by a review of Ballycotton tidal gauge data as the longer record becomes available. However, a review of the total tide plus surge flood frequency is beyond the scope of this study at this time.

Sensitivity Test 1: Increased Flow

Model Run ID: I21WH_FHD010_D1_002_Womanagh

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 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 in accordance with Guidance note 22.
However, this incorporates a 1.05m rise in sea level associated with predicted sea level rise and isostatic readjustment. Therefore results downstream of Old Finisk Bridge are not representative of solely increased flow and have not be compared.

Sensitivity Plot: See Schedule 3 - Calibration and Sensitivity

Comments: A 30% increase in flows resulted in water level is located upstream of Ladysbridge, where the stage increases by roughly 0.5m due to the backwater effect of the bridge, increasing flood risk on the lower reaches of the Kiltha. Level typically increases by 0.2m downstream of Ladysbridge to Old Finisk Bridge due to the increase in peak flow.

This equates to a small increase in flood extent as the design 1%AEP outline already fill the majority of the river valley.
Therefore flood risk along the Womanagh was not found to be sensitive to the uncertainties in flow upstream of Old Finisk Bridge.

Sensitivity Test 2: Increased Downstream Boundary

Model Run ID: I21WH_CMD010_D1_002_Womanagh

Hydraulic Modification to Design Model	No hydraulic modifications were made to the design model.
Hydrological inflows	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.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increased downstream boundary resulted in raised levels up the Womanagh. The tidal influence extends up to the Ballying under design conditions. However the increased downstream boundary extends tidal influence a further 3km towards the Dower confluence. This equates to a significant increase in flood extent as the total tide plus surge level now overtops the right bank downstream of Crompaun Bridge and both banks upstream of Crompaun Bridge Therefore flood risk along the Womanagh was found to be sensitive to the assumptions in the downstream boundary, particularly around Crompaun Bridge. The ICPSS total tide plus surge levels have been applied as the design downstream conditions in accordance with the CFRAM brief.
Sensitivity Test 3: Increased Manning's 'n'	
Model Run ID	I21WH_FCSN01_D1_002_Womanagh
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 0.045 All river banks 0.060 to 0.075 Pasture / parkland / garden 0.060 to 0.080 Dense vegetation 0.085 to 0.100
Hydrological	No modifications were made to the design inflows.
Sensitivity Plot	See Schedule 3 - Calibration and Sensitivity
Comments	An increase in the roughness values raised water levels upstream of Finisk Bridge. The model is most sensitive to the Manning's n change prior to Ladysbridge where water levels increased by 0.2m. Downstream from the Ladysbridge the effects of Manning's n on the stage appears to lessen as the floodplain area increases. Water levels in this reach only increased by 0.1m on average. Where the River Womanagh becomes tidally dominated (Finisk Bridge), sensitivity to Manning's n is much less causing little or no difference to the stage. Therefore the Womanagh was not deemed to be sensitive to the assumptions in Manning's 'n' values in the fluvial reaches.

Figure E.1: Sensitivity to 30% Increased Peak Flow

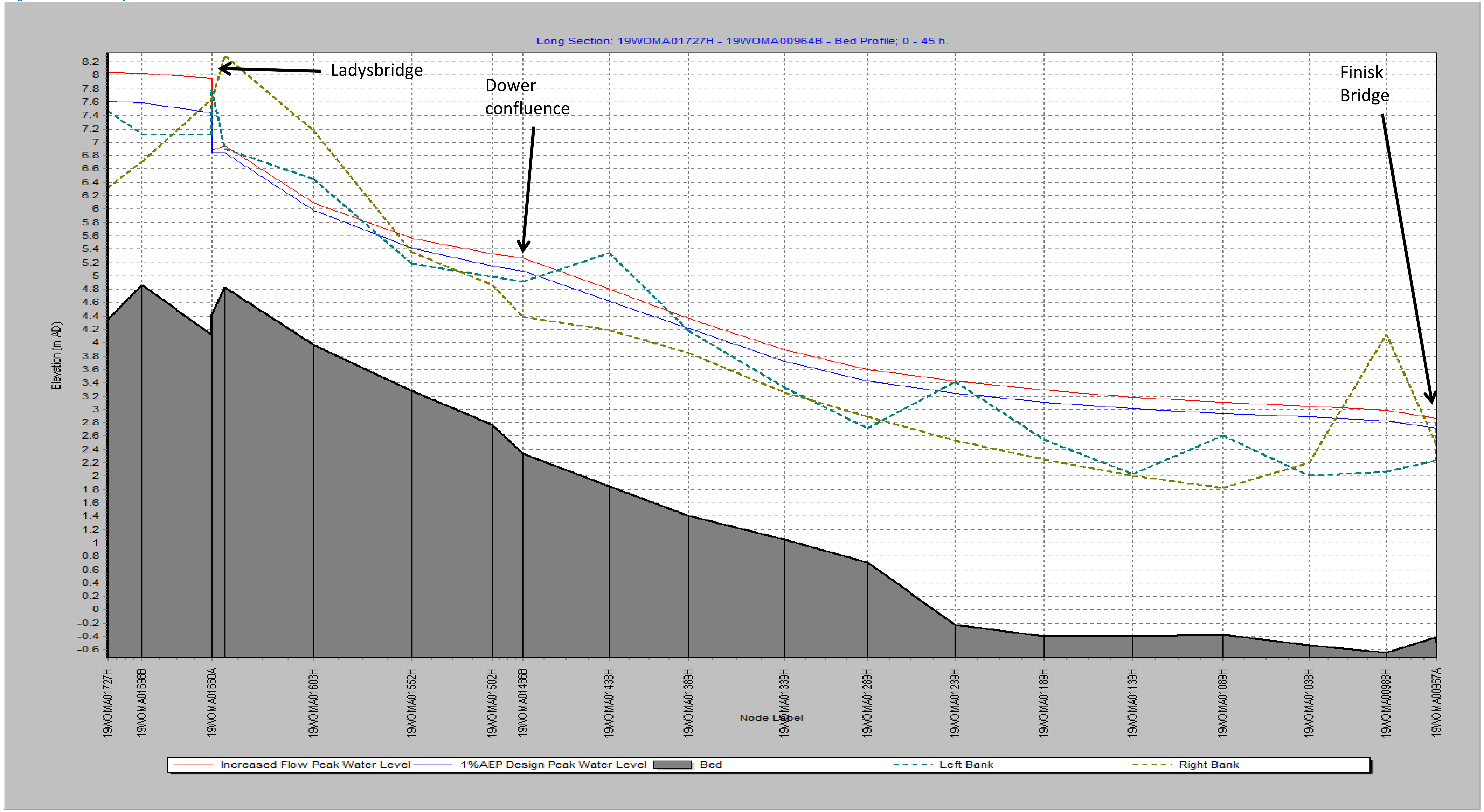


Figure E.2: Sensitivity to assumptions in the downstream boundary

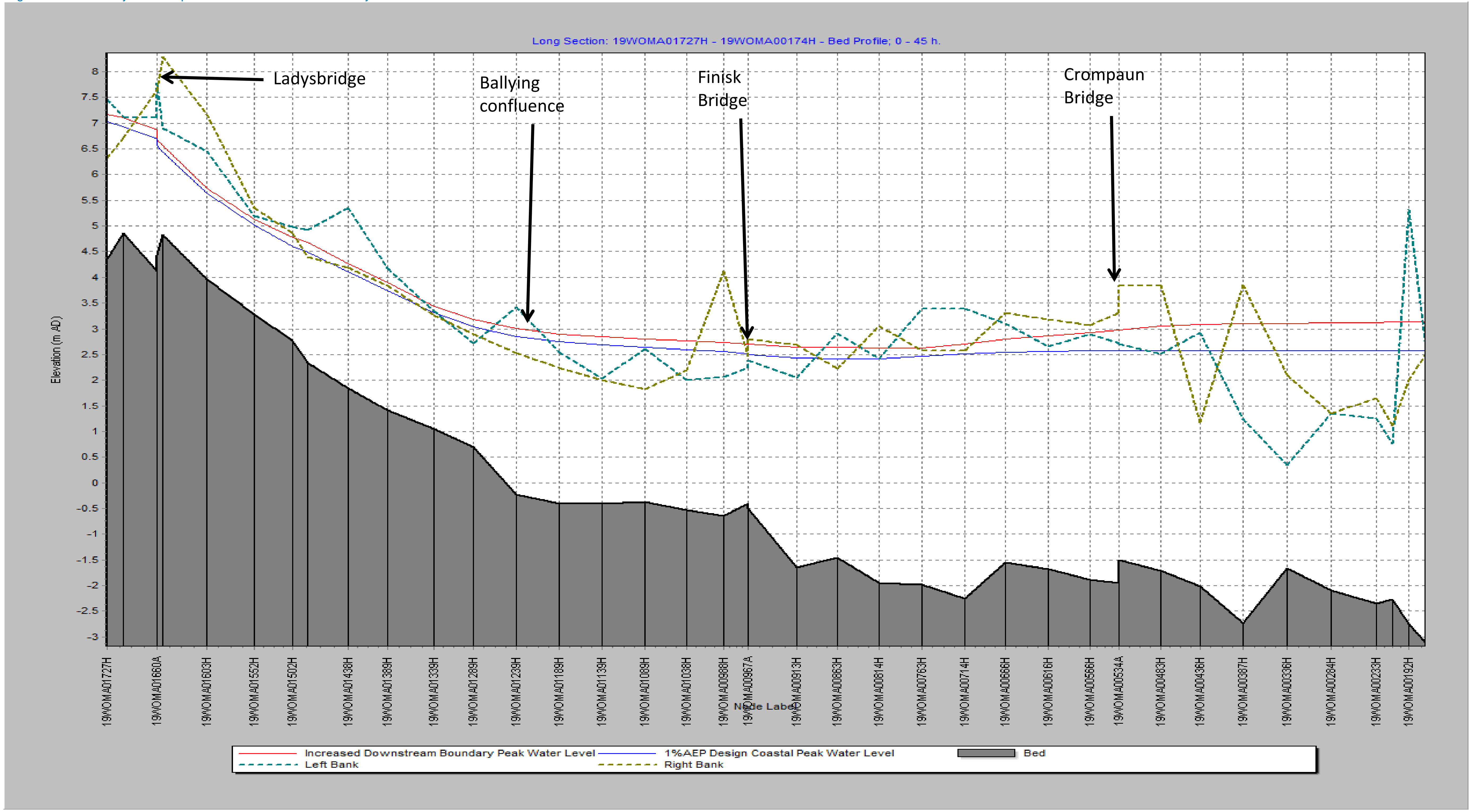
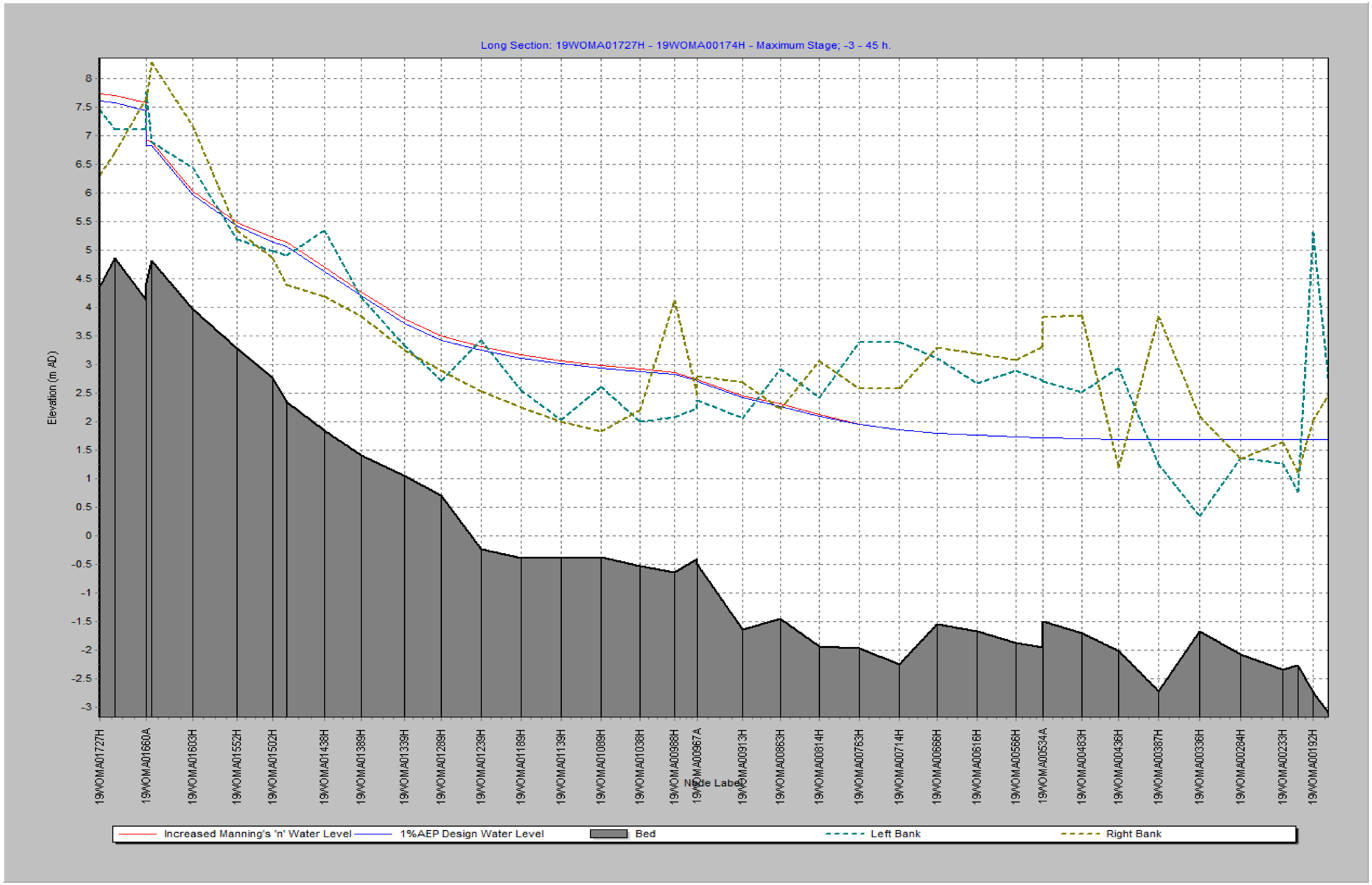


Figure E.3: Sensitivity to Increased Manning's 'n'



River Womanagh Model Outputs	
Threshold of Property Flooding	The key thresholds and areas affected by flooding are: - 50%AEP fluvial current event floods fields upstream of Ladysbridge to the areas immediately downstream of Old Finisk Bridge but does not affect property. - 1%AEP fluvial current overtops the right bank near Yellowford to flood the low lying areas of the coastal floodplain. - 0.1%AEP fluvial current events overtops the road at Ladysbridge - 50%AEP coastal current event floods the set-back areas downstream of Crompaun and the banks immediately downstream of Old Finisk Bridge - 20%AEP coastal current event overtops the raised embankment at Yellowford to flood the coastal floodplain - 0.1%AEP coastal current event overtops the raised embankments between Craihnmore to Clonpriest West. - Less than 5 buildings are affected by both fluvial and coastal flooding along the Womanagh MPW.
Critical Structures for Flood Risk	The critical structures in determining flood risk include: - Ladysbridge - The raised embankments downstream of Old Finisk Bridge
Areas affected by flooding	Fields around Ladysbridge, Old Finisk Bridge and Crompaun Bridge.
Risk to people	Risk to life has not been assessed for MPWs
Consideration for Flood Risk Management Options	- The condition of embankments and location of low spots along the embanked system should be reviewed along with the benefit of defending these areas from coastal flooding to establish a sustainable maintenance regime for the future.

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	I19MWH21_EXFCDEXF_D2		I19MWH21_DPFCD100_D2	Not Required for MPW	Not Required for MPW
Fluvial Current Design 1%AEP	I19MWH21_EXFCDEXF_D2	I19MWH21_ZN_D2	I19MWH21_DPFCD010_D2		
Fluvial Current Design 0.1%AEP	I19MWH21_EXFCDEXF_D2	I19MWH21_ZN_D2	I19MWH21_DPFCD001_D2		
Fluvial Mid Range Future Design 10%AEP	I19MWH21_EXFMDEXF_D2				
Fluvial Mid Range Future Design 1%AEP	I19MWH21_EXFMDEXF_D2				
Fluvial Mid Range Future Design 0.1%AEP	I19MWH21_EXFMDEXF_D2				
Coastal Current Design 10%AEP	I19MWH21_EXCCDEXC_D2		I19MWH21_DPCCD100_D2	Not Required for MPW	Not Required for MPW
Coastal Current Design 1%AEP	I19MWH21_EXCCDEXC_D2	I19MWH21_ZN_D2	I19MWH21_DPCCD010_D2		
Coastal Current Design 0.1%AEP	I19MWH21_EXCCDEXC_D2	I19MWH21_ZN_D2	I19MWH21_DPCCD001_D2		
Coastal Mid Range Future Design 10%AEP	I19MWH21_EXCMDEXC_D2				
Coastal Mid Range Future Design 1%AEP	I19MWH21_EXCMDEXC_D2				
Coastal Mid Range Future Design 0.1%AEP	I19MWH21_EXCMDEXC_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	Coastal %AEP	Flood Extent Polygon	Flood Zone Polygon	Flood Depth Grid	Flood Velocity Grid	Flood Hazard Grid
Fluvial Current Design 50%AEP	I20KL_FCD500_D1_002_Womanagh.ief	50	MHWS	I21EXFCD500D2		I21DPFCD500D2	Not Required for MPW	Not Required for MPW
Fluvial Current Design 20%AEP	I20KL_FCD200_D1_002_Womanagh.ief	20	MHWS	I21EXFCD200D2		I21DPFCD200D2		
Fluvial Current Design 10%AEP	I20KL_FCD100_D1_002_Womanagh.ief	10	MHWS	I21EXFCD100D2		I21DPFCD100D2		
Fluvial Current Design 5%AEP	I20KL_FCD050_D1_002_Womanagh.ief	5	MHWS	I21EXFCD050D2		I21DPFCD050D2		
Fluvial Current Design 2%AEP	I20KL_FCD020_D1_002_Womanagh.ief	2	MHWS	I21EXFCD020D2		I21DPFCD020D2		
Fluvial Current Design 1%AEP	I20KL_FCD010_D1_002_Womanagh.ief	1	MHWS	I21EXFCD010D2	I21ZN_A_D2	I21DPFCD010D2		
Fluvial Current Design 0.5%AEP	I20KL_FCD005_D1_002_Womanagh.ief	0.5	MHWS	I21EXFCD005D2		I21DPFCD005D2		
Fluvial Current Design 0.1%AEP	I20KL_FCD001_D1_002_Womanagh.ief	0.1	MHWS	I21EXFCD001D2	I21ZN_B_D2	I21DPFCD001D2		
Fluvial Mid Range Future Design 50%AEP	I20KL_FMD500_D1_002_Womanagh.ief	50	MHWS	I21EXFMD500D2		I21DPFMD500D2		
Fluvial Mid Range Future Design 20%AEP	I20KL_FMD200_D1_002_Womanagh.ief	20	MHWS	I21EXFMD200D2		I21DPFMD200D2		
Fluvial Mid Range Future Design 10%AEP	I20KL_FMD100_D1_002_Womanagh.ief	10	MHWS	I21EXFMD100D2		I21DPFMD100D2		
Fluvial Mid Range Future Design 5%AEP	I20KL_FMD050_D1_002_Womanagh.ief	5	MHWS	I21EXFMD050D2		I21DPFMD050D2		
Fluvial Mid Range Future Design 2%AEP	I20KL_FMD020_D1_002_Womanagh.ief	2	MHWS	I21EXFMD020D2		I21DPFMD020D2		
Fluvial Mid Range Future Design 1%AEP	I20KL_FMD010_D1_002_Womanagh.ief	1	MHWS	I21EXFMD010D2		I21DPFMD010D2		
Fluvial Mid Range Future Design 0.5%AEP	I20KL_FMD005_D1_002_Womanagh.ief	0.5	MHWS	I21EXFMD005D2		I21DPFMD005D2		
Fluvial Mid Range Future Design 0.1%AEP	I20KL_FMD001_D1_002_Womanagh.ief	0.1	MHWS	I21EXFMD001D2		I21DPFMD001D2		
Fluvial High End Future Design 10%AEP	I20KL_FHD100_D1_002_Womanagh.ief	10	MHWS	I21EXFHD100D2		I21DPFHD100D2		
Fluvial High End Future Design 1%AEP	I20KL_FHD010_D1_002_Womanagh.ief	1	MHWS	I21EXFHD010D2		I21DPFHD010D2		
Fluvial High End Future Design 0.1%AEP	I20KL_FHD001_D1_002_Womanagh.ief	0.1	MHWS	I21EXFHD001D2		I21DPFHD001D2		
Coastal Current Design 50%AEP	I20KL_CCD500_D1_002_Womanagh.ief	50-70	50	I21EXCCD500D2		I21DPCCD500D2		
Coastal Current Design 20%AEP	I20KL_CCD200_D1_002_Womanagh.ief	50-70	20	I21EXCCD200D2		I21DPCCD200D2		
Coastal Current Design 10%AEP	I20KL_CCD100_D1_002_Womanagh.ief	50-70	10	I21EXCCD100D2		I21DPCCD100D2		
Coastal Current Design 5%AEP	I20KL_CCD050_D1_002_Womanagh.ief	50-70	5	I21EXCCD050D2		I21DPCCD050D2		
Coastal Current Design 2%AEP	I20KL_CCD020_D1_002_Womanagh.ief	50-70	2	I21EXCCD020D2		I21DPCCD020D2		
Coastal Current Design 1%AEP	I20KL_CCD010_D1_002_Womanagh.ief	50-70	1	I21EXCCD010D2	I21ZN_A_D2	I21DPCCD010D2		
Coastal Current Design 0.5%AEP	I20KL_CCD005_D1_002_Womanagh.ief	50-70	0.5	I21EXCCD005D2		I21DPCCD005D2		
Coastal Current Design 0.1%AEP	I20KL_CCD001_D1_002_Womanagh.ief	50-70	0.1	I21EXCCD001D2	I21ZN_B_D2	I21DPCCD001D2		
Coastal Mid Range Future Design 50%AEP	I20KL_CMD500_D1_002_Womanagh.ief	50-70	50	I21EXCMD500D2		I21DPCMD500D2		
Coastal Mid Range Future Design 20%AEP	I20KL_CMD200_D1_002_Womanagh.ief	50-70	20	I21EXCMD200D2		I21DPCMD200D2		
Coastal Mid Range Future Design 10%AEP	I20KL_CMD100_D1_002_Womanagh.ief	50-70	10	I21EXCMD100D2		I21DPCMD100D2		
Coastal Mid Range Future Design 5%AEP	I20KL_CMD050_D1_002_Womanagh.ief	50-70	5	I21EXCMD050D2		I21DPCMD050D2		
Coastal Mid Range Future Design 2%AEP	I20KL_CMD020_D1_002_Womanagh.ief	50-70	2	I21EXCMD020D2		I21DPCMD020D2		
Coastal Mid Range Future Design 1%AEP	I20KL_CMD010_D1_002_Womanagh.ief	50-70	1	I21EXCMD010D2		I21DPCMD010D2		
Coastal Mid Range Future Design 0.5%AEP	I20KL_CMD005_D1_002_Womanagh.ief	50-70	0.5	I21EXCMD005D2		I21DPCMD005D2		
Coastal Mid Range Future Design 0.1%AEP	I20KL_CMD001_D1_002_Womanagh.ief	50-70	0.1	I21EXCMD001D2		I21DPCMD001D2		
Coastal High End Future Design 10%AEP	I20KL_CHD100_D1_002_Womanagh.ief	50-70	10	I21EXCHD100D2		I21DPCHD100D2		
Coastal High End Future Design 0.5%AEP	I20KL_CHD010_D1_002_Womanagh.ief	50-70	0.5	I21EXCHD010D2		I21DPCHD010D2		
Coastal High End Future Design 0.1%AEP	I20KL_CHD001_D1_002_Womanagh.ief	50-70	0.1	I21EXCHD001D2		I21DPCHD001D2		

Note on CFRAM Studies Naming Conventions

Model File Naming Convention:

B MN ID _ S C R PPP _St N
B = River Basin District code: I for South Western (Iardheisceart)
MN = **M**odel **N**umber: A sequential number for all models across the SW CFRAM study area.
ID = Model **ID**entifier: The first and last letters of the model name e.g. Ballingeary is shortened to BY
S = **S**ource code: F=fluvial C=coastal W=wave overtopping
C = S**c**enario code: C= current M= Mid Range Future Scenario H= High End Future Scenario
R = **R**un Type: D = design, C = Calibration O= Option Assessment Run
PPP= **P**robability , expressed as a X in 1000 chance e.g. 50%AEP = 500 , 0.5% AEP = 005
St = **St**atus , D = draft, F = final
N = Revision **N**umber a single digit revision number

Additional Map Naming Convention:
B UoM H MN _ TT S C R PPP _St N

Additional GIS Naming Convention:
B MN TT S C R PPP St N

Codes a**s** above with the addition of:
UoM= Unit of Management number e.g. 18 = River Blackwater catchment
H = **High** Priority Watercourse / **Medium** Priority Watercourse
TT = Map **T**ype Ex = Extent, ZN = Zone, DP = Depth, VL = Velocity, HZ = Hazard