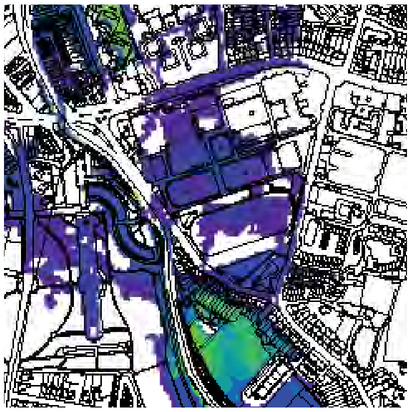
RPS

NORTH WESTERN
NEAGH BANN
CFRAM
STUDY
CATCHMENT FLOOD RISK
ASSESSMENT AND MANAGEMENT

North Western - Neagh Bann CFRAM Study

UoM 01 Hydraulics Report
4.4 Bunbeg-Derrybeg

IBE0700Rp0011



OPW
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Photographs of flooding on cover provided by Rivers Agency

NWNB CFRAM Study

HA01 Hydraulics Report

Bunbeg - Derrybeg Model

DOCUMENT CONTROL SHEET

Client	OPW
Project Title	NWNB CFRAM Study
Document Title	IBE0700Rp0011_HA01 Hydraulics Report
Model Name	Bunbeg - Derrybeg

Rev.	Status	Author(s)	Modeller	Reviewed by	Approved By	Office of Origin	Issue Date
D01	Draft	Various	I. Bentley	I. Bentley	G. Glasgow	Limerick/Belfast	06/06/2014
F01	Draft Final	Various	Various	L. Arbuckle	G. Glasgow	Belfast	22/01/15
F02	Draft Final	Various	Various	L. Arbuckle	G. Glasgow	Belfast	13/08/2015
F03	Draft Final	Various	J. Deery	S. Patterson	G. Glasgow	Belfast	08/07/2016

Table of Reference Reports

Report	**Issue Date**	**Report Reference**	**Relevant Section**
North Western Neagh Bann CFRAM Study Flood Risk Review	May 2012	**2011s5232 NW&NB CFRAM FRR Report**	Table 1
North Western Neagh Bann CFRAM Study UoM01 Inception Report	February 2013	**IBE0700Rp0002_UoM 01 Inception Report**	4.3.2
North Western Neagh Bann CFRAM Study Hydrology Report UoM01	July 2013	**IBE0700Rp0006_UoM 01 Hydrology Report**	4.15
North Western Neagh Bann CFRAM HA01_06_36 Survey Contract Report	October 2013	**IBE0700Rp0007_HA01_06_36 NWNB_CFRAM_Survey Contract Report**	ALL

4 HYDRAULIC MODEL DETAILS

4.4 BUNBEG – DERRYBEG MODEL

4.4.1 General Hydraulic Model Information

(1) Introduction:

The NWNB CFRAM Flood Risk Review (2011s5232 NW&NB CFRAM FRR Report_Final_v2.0) highlighted Bunbeg - Derrybeg as an AFA for 'mechanism 1 tidal' and fluvial flooding, based on a review of historic flooding and the extents of flood risk determined during the PFRA.

The Bunbeg – Derrybeg model represents the watercourses affecting both villages in the Gweedore area of north west Donegal. Two watercourse systems have been identified as requiring analysis under the CFRAM study, the Clady River with a total catchment area of 89km^2 and the Catheen River representing a total catchment of 8km^2. Both catchments are fairly steep and both are predominantly peat (>75%). The Clady River catchment however is heavily attenuated through Loughs Nacung (Upper and Lower) and Dunlewy with the control structure being the ESB owned and operated dam less than 2km upstream of the model extents. This dam is part of a system that diverts water to the south through a diversion channel where it then passes through a hydro-electric electricity generation station which discharges to the Gweedore River to the south of the AFA at Dore.

There are no gauging stations available within the modelled extents of the Clady or Catheen Rivers. There is some flow information available at the ESB dam control upstream of the modelled extents on the Clady River (38002 – ESB). The data at this station was not given a rating classification under FSU. Initially it was not clear whether this data included flows through the power generation facility or whether these flows were instantaneous or averaged over time. Additional data later received from ESB indicated that the flow data provided represented all inflows to the Clady River upstream of the AFA. The flow data is presented in the form of monthly and yearly maximum and minimums of the daily flow series from Lough Nacung. However it was confirmed that this daily flow series is made up of average values rather than maximum values and is therefore inadequate for estimation of design peak flow values. As would be expected, the Q_{med} value (peak flow value) based on catchment descriptors is significantly larger than the median from the series of observed values (daily averaged flow values) and is taken forward as the index flow. The Catheen catchment was considered against the national list of pivotal sites but none was found to have a high degree of hydrological similarity. No pattern was observed from sites listed as the most geographically and hydrologically similar to suggest that the catchment descriptor equation was over or underestimating for the Catheen catchment. The FSU ungauged catchment estimates of Q_{med} have not been adjusted based on a pivotal site, refer to UoM 01 Hydrology Report, Chapter 4.4 (Rp0006_F01) for full details on hydrology estimation.

All of the watercourses in the Bunbeg - Derrybeg model are HPWs and have therefore been modelled as 1D/2D using ISIS 2D. Since the Clady and Catheen rivers drain independently to the sea and flood flows do not interact, the model was divided into two separate 1D models with associated 2D active areas. This

reduced the size of the models and hence run times. A southern active area incorporates the Clady River (0115M), while a northern active area includes the watercourses Catheen River (0116M) and Derrybeg River (0117M), and also their two tributaries 0116A and 0117A, respectively. The coastal flood extents were determined using these 1D/2D models and extended using a separate ISIS 2D model.

In channel flow has been modelled in ISIS 1D, refer to Chapter 3 and Section 4.4.2 for further details. The approach to overtopping of structures is discussed in Section 3.3.4.

(2) Model Reference:	HA01_BUN15 (Model 15)
(3) AFAs included in the model:	Bunbeg - Derrybeg

(4) Primary Watercourses / Water Bodies (including local names):

Reach ID	**Name**
0115M	CLADY RIVER
0116M	CATHEEN RIVER
0116A	CATHEEN RIVER TRIB 1
0117M	DERRYBEG
0117A	DERRYBEG TRIB 1

(5) Software Type (and version):

(a) 1D Domain:	**(b) 2D Domain:**	**(c) Other model elements:**
ISIS v3.7.1	ISIS 2D v3.7.1 ('Mechanism 1 tidal' and fluvial flooding)	N/A

4.4.2 Hydraulic Model Schematisation

(1) Map of Model Extents:

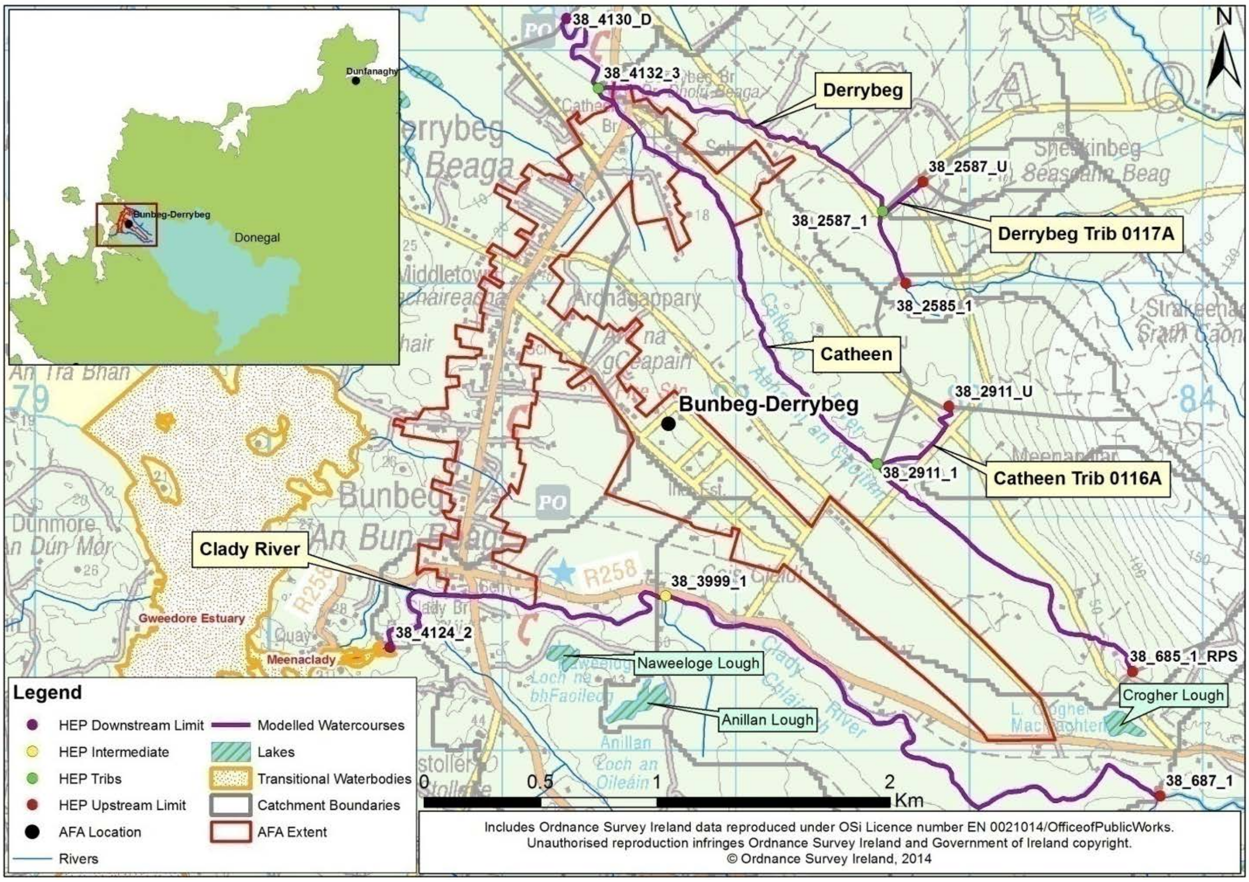


Figure 4.4.1: Overview Map of Model Extents – Bunbeg - Derrybeg End Models

Figure 4.4.1 illustrates the extent of the modelled catchment and river centre lines, HEP locations, the transitional waterbodies (Meenaclady / Gweedore Estuary) receiving the Clady River and AFA extents. There are two separate models, one representing the Clady River and one representing the Catheen and Derrybeg system. The Clady River model has 1no. Upstream Limit HEP, 1no. Intermediate HEP and 1no. Downstream Limit HEP. The Catheen /Derrybeg model contains 4no. Upstream Limit HEPs, 3no. Tributary HEPs (model check points, refer to Appendix A.3 for details) and 1no. Downstream Limit HEP. There are no Gauging Station HEPs.

In channel flow was modelled in ISIS 1D (refer to Chapter 3). The 1D model has been linked with ISIS 2D, with any overtopping flow passing into ISIS 2D to simulate the floodplain flow. In defining the left and right channel banks in ISIS 1D an assessment was made of the surveyed channel data to estimate where out of bank flow would occur. The 1D reaches and the 2D domain have been linked by means of 1D/2D links which are defined as polyline shapefiles. These shapefiles contain attribute fields that define the ISIS 1D model nodes that the 2D model links with. All modelled watercourses have been modelled as 1D in bank with the floodplain element in 2D.

(2) x-y Coordinates of River (Upstream extent):

River Name		x	y
0115M	CLADY RIVER	183814.049	422795.568
0116M	CATHEEN RIVER	183694.986	423337.965
0116A	CATHEEN RIVER TRIB 1	182914.464	424467.738
0117M	DERRYBEG	182726.609	424994.26
0117A	DERRYBEG TRIB 1	182792.755	4253244.99

(3) Total Modelled Watercourse Length:		0115M 5m ISIS 2D grid, 5.0km 0116M 5m ISIS 2D grid, 4.2km 0116A 5m ISIS 2D grid, 0.5km 0117M 5m ISIS 2D grid, 1.8km 0117A 5m ISIS 2D grid, 0.2km	
(4) 1D Domain only Watercourse Length:	0 (km)	**(5) 1D-2D Domain Watercourse Length:**	11.7 (km)
(6) 2D Domain Mesh Type / Resolution / Area:		(ISIS 2D) 16.19km^2	

(7) 2D Domain Model Extent:

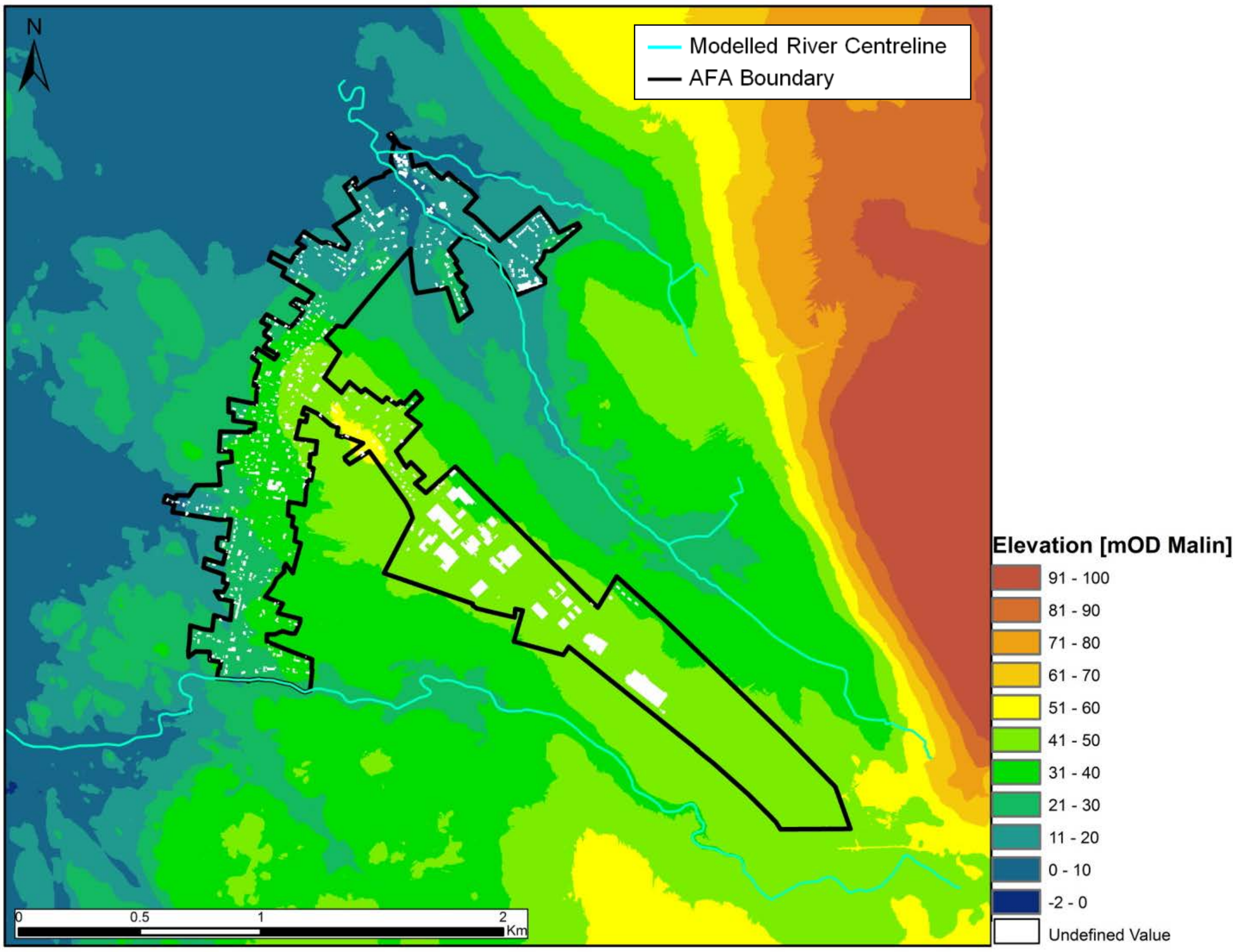


Figure 4.4.2: 2D Model Domain - Bunbeg-Derrybeg

Figure 4.4.2 illustrates the model extents and general topography. The spatial extent of the AFA boundary is outlined in black. The reach centre-lines are presented in light-blue which also represents the 1D modelled extent that is within the 2D area. Buildings are excluded from the mesh and therefore represented as white spaces - refer to Chapter 3.3.2 for details on representation of buildings in the model.

Figure 4.4.3 shows an overview drawing of the model schematisation. Figures 4.4.4 to Figure 4.4.7 show detailed views. The overview diagram covers the model extents, showing the surveyed cross-section locations, AFA boundary and river centreline. It also shows the area covered by the 2D model domain. The detailed views are provided where there is the most significant risk of flooding. These diagrams include the surveyed cross-section locations, AFA boundary and river centrelines. It also shows the location of critical structures as discussed in Section 4.4.3(1), along with the location and extent of the links between the 1D and 2D models. For clarity in viewing cross-section locations, the model schematisation diagram shows the full extent of the surveyed cross-sections. Note that the 1D model considers only the cross-section between the 1D-2D links.

The Catheen/Derrybeg model includes the River Catheen and Derrybeg (Reach IDs 0116M and 0117M respectively). This model represents Derrybeg and discharges into Maghera Strand. The Clady River model (Reach ID 0115M), represents Bunbeg and discharges to the Gweedore River.

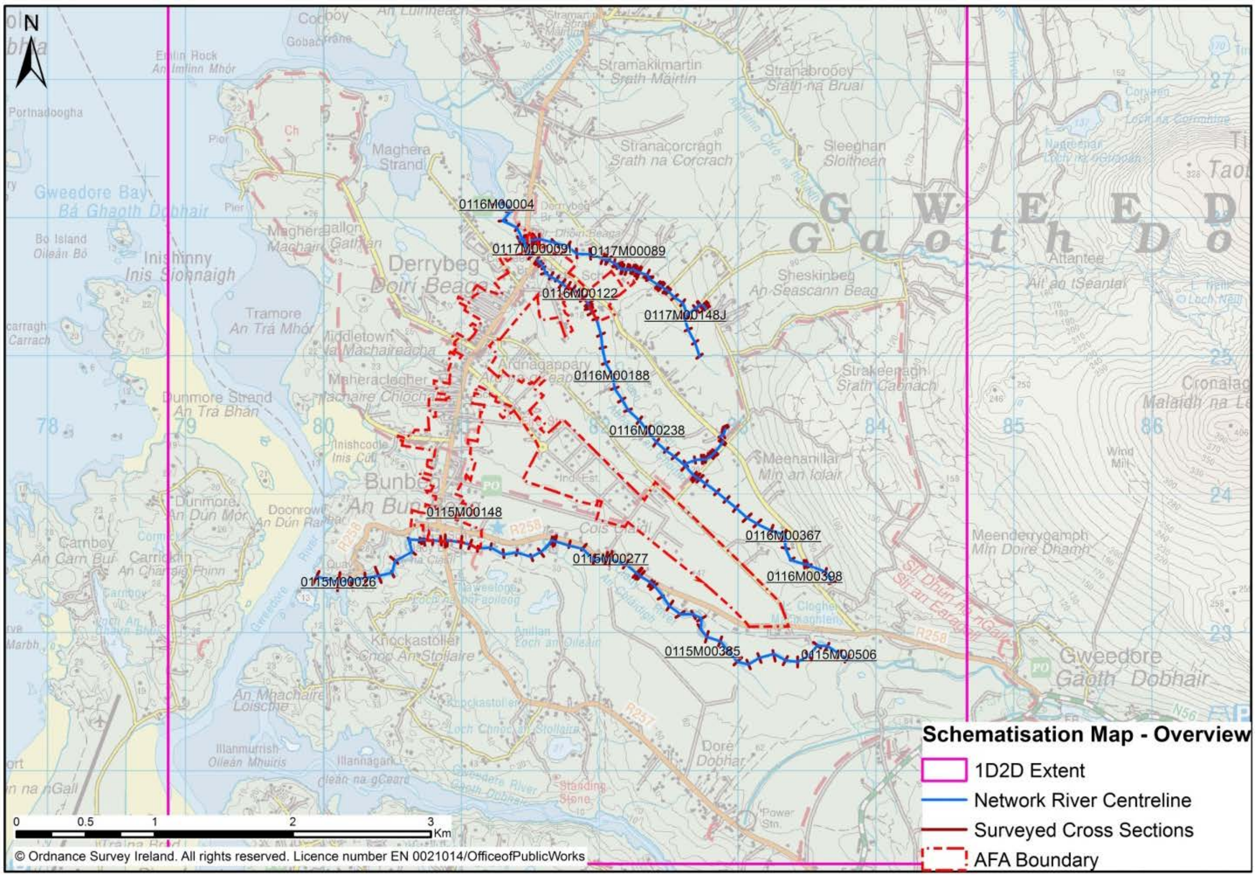


Figure 4.4.3: Model Schematisation Overview - Bunbeg (Clady River Model) and Derrybeg (Catheen River / Derrybeg Model)

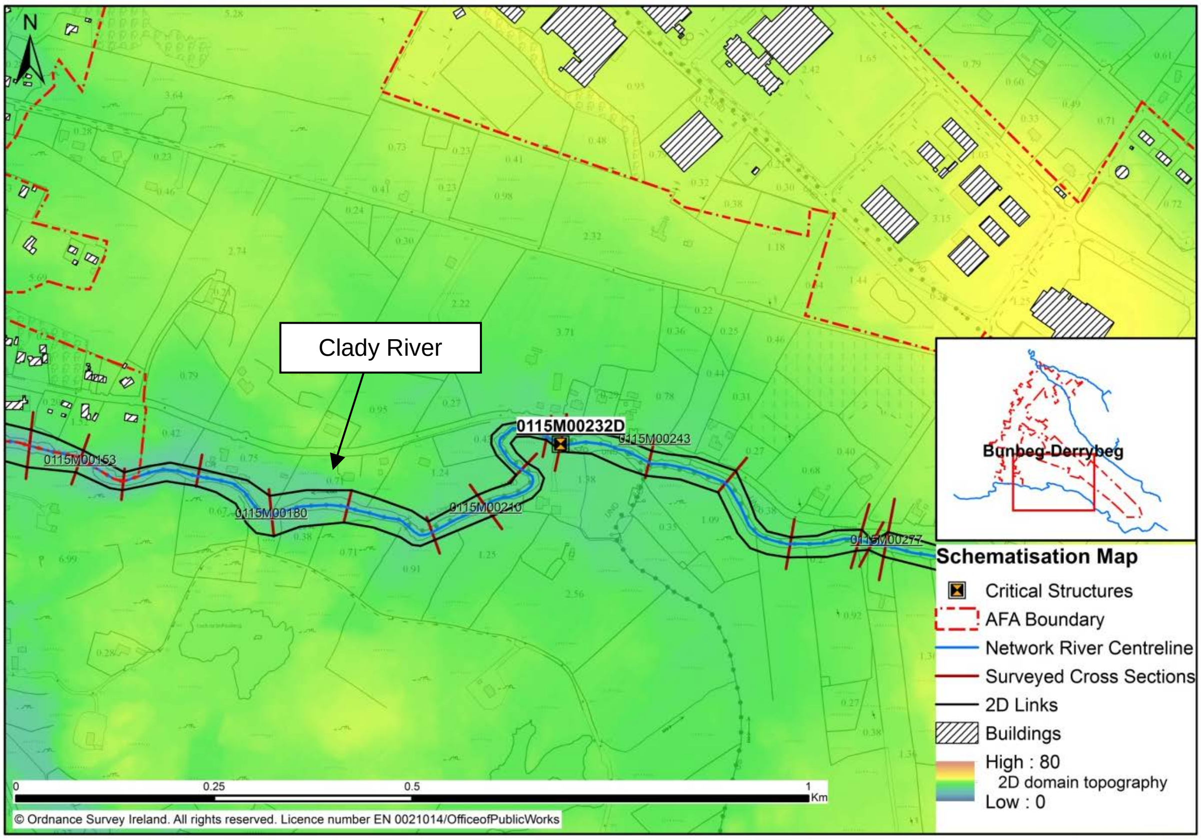


Figure 4.4.4: Detailed Area of Model Schematisation showing Critical Structures on the Clady River*

For clarity in viewing cross-section locations, the model schematisation diagram shows the full extent of the surveyed cross-sections. Note that the 1D model considers only the cross-section between the 1D-2D links.

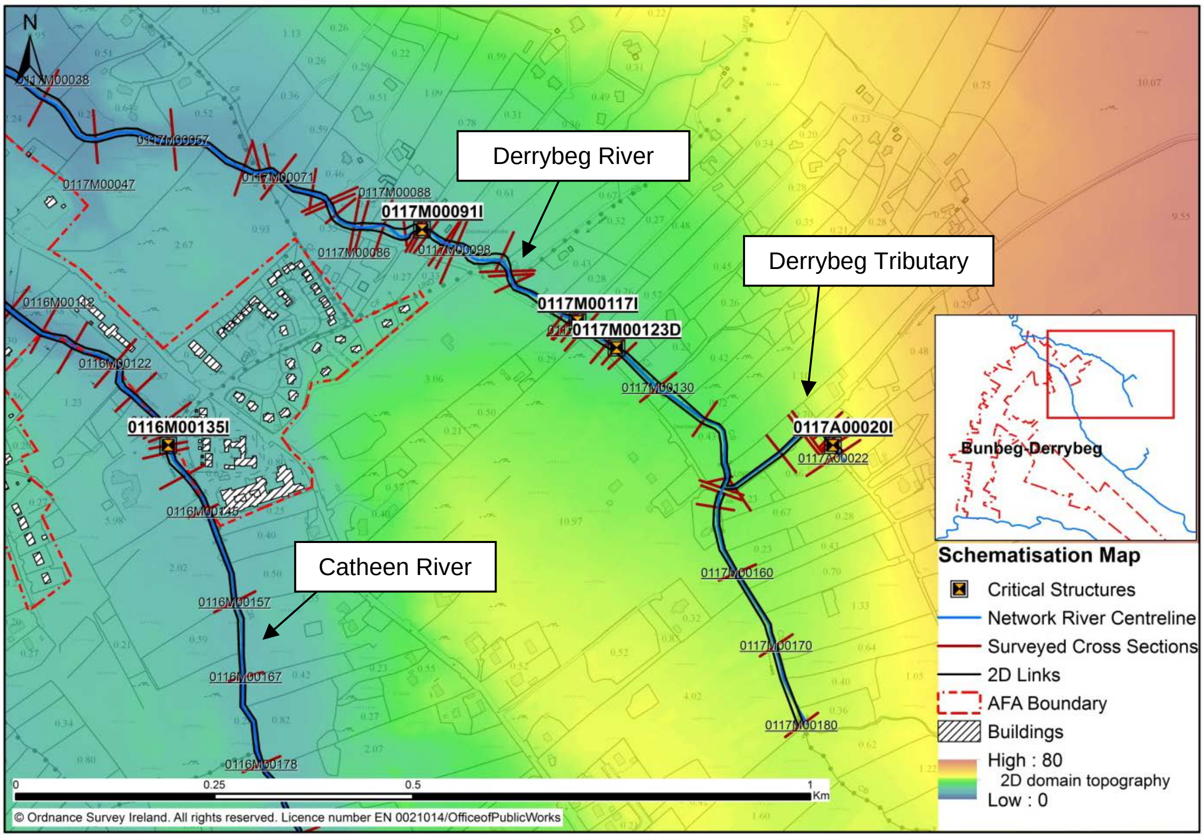


Figure 4.4.5: Detailed Area of Model Schematisation showing Critical Structures on the Catheen, Derrybeg and Derrybeg Tributary.

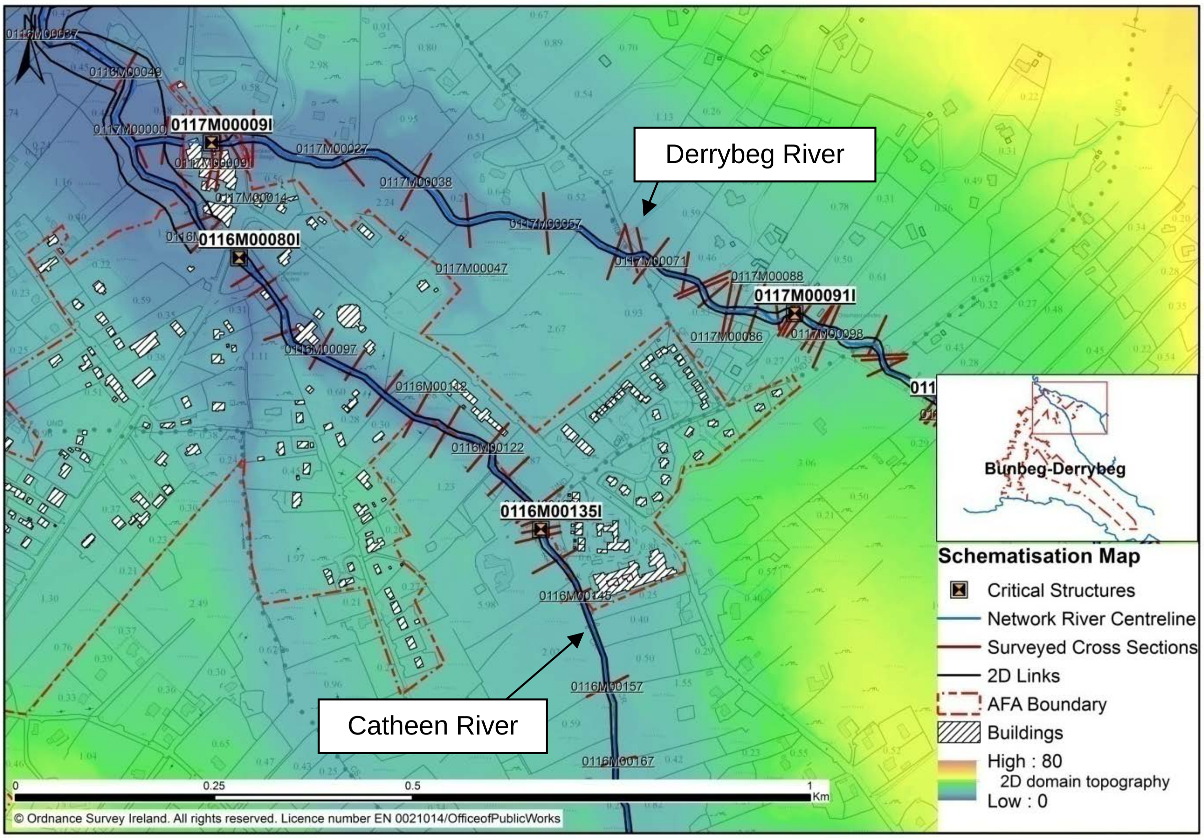


Figure 4.4.6: Detailed Area of Model Schematisation showing Critical Structures on the Catheen and Derrybeg Watercourses

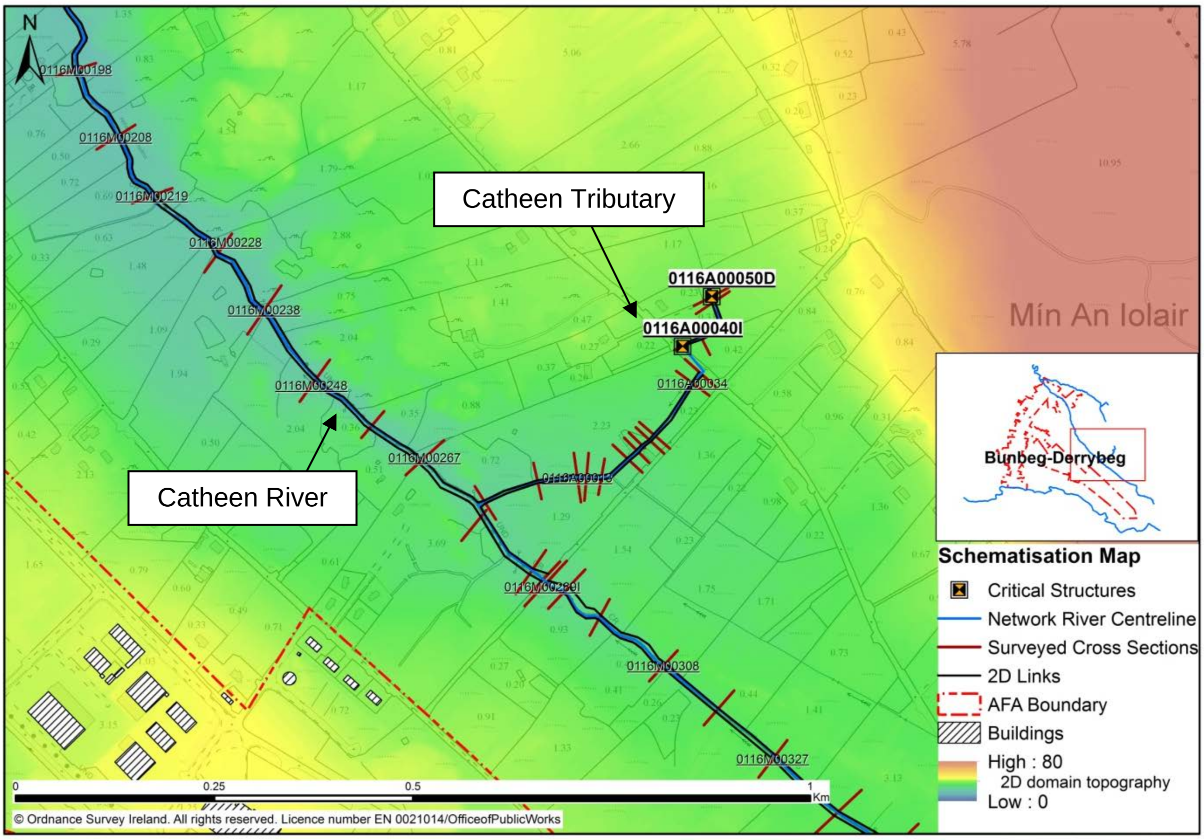


Figure 4.4.7: Detailed Area of Model Schematisation showing Critical Structures on the Catheen Tributary

(8) Survey Information

(a) Survey Folder Structure:

First Level Folder	**Second Level Folder**	**Third Level Folder**
Murphy_NW1_M15_WP5_0115M_V1_130510 Bunbeg - Derrybeg Murphy: Surveyor Name NW1: North Western CFRAM Study Area, Hydrometric Area 1 M15: Model Number 15 0115M: River Reference WP5 : Work Package 5 Version: V1 *130510*: Date Issued (10th MAY 2013)	V1_20130510_Ascii	
	V0_20130508_GIS	Flood_Plain_Photos_and_Shapefile
		Structure_Register
		Surveyed_Cross_Section_Lines
		Watercourse_Register
	V0_20130508_Photos	
	Photos *(Naming convention is in the format of Cross-Section ID and orientation - upstream, downstream, left bank or right bank)*	

(b) Survey Folder References:		
Reach ID	**Name**	**File Referencea**
0115M	CLADY RIVER	*Murphy_NW1_M15_WP5_0115M_V1_130510*
0116M	CATHEEN RIVER	Murphy_NW1_M15_WP5_0116M_V1_130410
0116A	CATHEEN RIVER TRIB 1	Murphy_NW1_M15_WP5_0116A_V1_130410
0117M	DERRYBEG	Murphy_NW1_M15_WP5_0117M_V1_130410
0117A	DERRYBEG TRIB 1	Murphy_NW1_M15_WP5_0117A_V1_130410

(9) Survey Issues:

None.

4.4.3 Hydraulic Model Construction

(1) 1D Structures (in-channel along modelled watercourses):	17 Bridges 10 Culverts 3 Weirs Note: Detailed information on the chainage of these structures and how they have been represented within the hydraulic model is presented in Appendix A.1. The locations of critical structures included in the model are presented in Figure 4.4.8 to Figure 4.4.17. Details of these structures are also presented in Appendix A.1.

The survey information recorded includes a photograph of each structure, which has been used to determine the Manning's n value. Further details are included in Chapter 3.5.1. A discussion on the way structures have been modelled in ISIS is included in Chapter 3.4.3. Figures 4.4.8 to 4.4.17 discuss the critical structures as follows (refer to draft final flood extent and depth maps and Section 4.4.5 for illustration of any flooding described).

Structure 0115M00232D (Figure 4.4.8, Ch 2841m) is a bridge on the River Clady which floods out of bank and the adjacent area during all simulated % AEP scenarios. This structure is located close to a meander and restricts flow causing out of bank flooding and reduction of flow downstream.

Figure 4.4.8: Bridge Structure 0115M00232D on River Clady

Piped culvert 0116M00135I (Figure 4.4.9, Ch 294m) on the Catheen River becomes surcharged causing out of bank flow during the simulated 1% and 0.1% AEP fluvial events. This affects the rear gardens of some properties within the Áras Bhríde housing development.

Figure 4.4.9: Culvert 0116M00135I on Catheen River

Out of bank flow is identified at culvert 0116M00080I (Figure 4.4.10, Ch 3487m) on the Catheen River during the simulated 10%, 1% and 0.1% AEP events. For the 0.1% AEP the Gweedore Parish Church on the right bank of the Catheen River is flooded with maximum flood depths of 0.6m to 0.8m to the north west of the building.

Figure 4.4.10: Culvert 0116M00080I on Catheen River

Culvert 0116A00050D (Figure 4.4.11, Ch 15m) on Catheen Tributary has insufficient capacity for the 10% AEP event, with bypassing occurring via the right hand bank affecting one property. During the 1% AEP event the culvert at cross section 0116A00040I (Figure 4.4.12, Ch 91m) also has insufficient capacity with flood waters overtopping an unnamed road between the R257 and the Gweedore Parish Church.

Figure 4.4.11: Culvert 0116A00050D on Catheen Tributary

Figure 4.4.12: Culvert 0116A00040I on Catheen Tributary

Bridges at cross sections 0117M00123D (Figure 4.4.13, Ch 573m) and 0117M00117I (Figure 4.4.14, Ch 632m) have insufficient capacity for the 1% AEP event with bypassing occurring via the right bank.

Figure 4.4.13: Culvert 0117M00123D on Derrybeg Watercourse

Figure 4.4.14: Culvert 0117M00117I on Derrybeg Watercourse

Culvert 0117M00091I (Figure 4.4.15, Ch 876m) on the Derrybeg watercourse has insufficient capacity for the ≥1% AEP event with overtopping of both banks occurring.

Figure 4.4.15: Culvert 0117M00091I on Derrybeg Watercourse

The dual piped culvert 0117M00009I (Figure 4.4.16, Ch 1708m) on the Derrybeg watercourse is surcharged during the ≥10% AEP event, with overtopping of the left bank occurring.

Figure 4.4.16: Piped Culvert 0117M00009I on Derrybeg Watercourse

Afflux caused by the culvert at cross-section 0117A00020I (Figure 4.4.17, Ch 24m) on the Derrybeg tributary results in flow bypass on the left bank during ≥1% AEP design events. One property is affected by this mechanism during the 0.1% AEP event.

Figure 4.4.17: Culvert 0117A00020I on Derrybeg Tributary

(2) 1D Structures in the 2D domain (beyond the modelled watercourses):	None
(3) 2D Model structures:	None
(4) Standard of Protection of Existing Formal Defences:	None

(5) Model Boundaries - Inflows:

Full details of the flow estimates are provided in the Hydrology Report (IBE0700Rp0006_UoM 01 Hydrology Report_D01-Section 4.15 and Appendix D) using the methodology detailed in Section 2.3.3 of the same report. The boundary conditions implemented in the model are shown in Table 4.4.1.

Table 4.4.1: Model Boundary Conditions

	Boundary Type	Branch Name	Boundary HEP
1	Upstream	Clady	38_687_1
2	Lateral	Clady	38_999_1 and 38_4124_2
3	Upstream	Catheen	38_685_1_RPS
4	Lateral	Catheen	38_685_1_RPS and 38_4130_D
5	Upstream	Catheen	38_2911_U
6	Lateral	Catheen	38_2911_U and 38_2911_1
7	Upstream	Derrybeg	38_2585_1
8	Lateral	Derrybeg	38_2585_1 and 38_4132_3
9	Upstream	Derrybeg	38_2587_U
10	Lateral	Derrybeg	38_2587_U and 38_2587_1

Figure 4.4.18 shows the upstream inflow hydrographs on the modelled watercourses for a 0.1% AEP fluvial event. The model flow at checkpoints was examined during initial development runs and adjustment of timing of inflow hydrographs was not required for anchoring of the model to estimated flows. Appendix A.3 contains further details of comparison of estimated flows with simulated flows in the model.

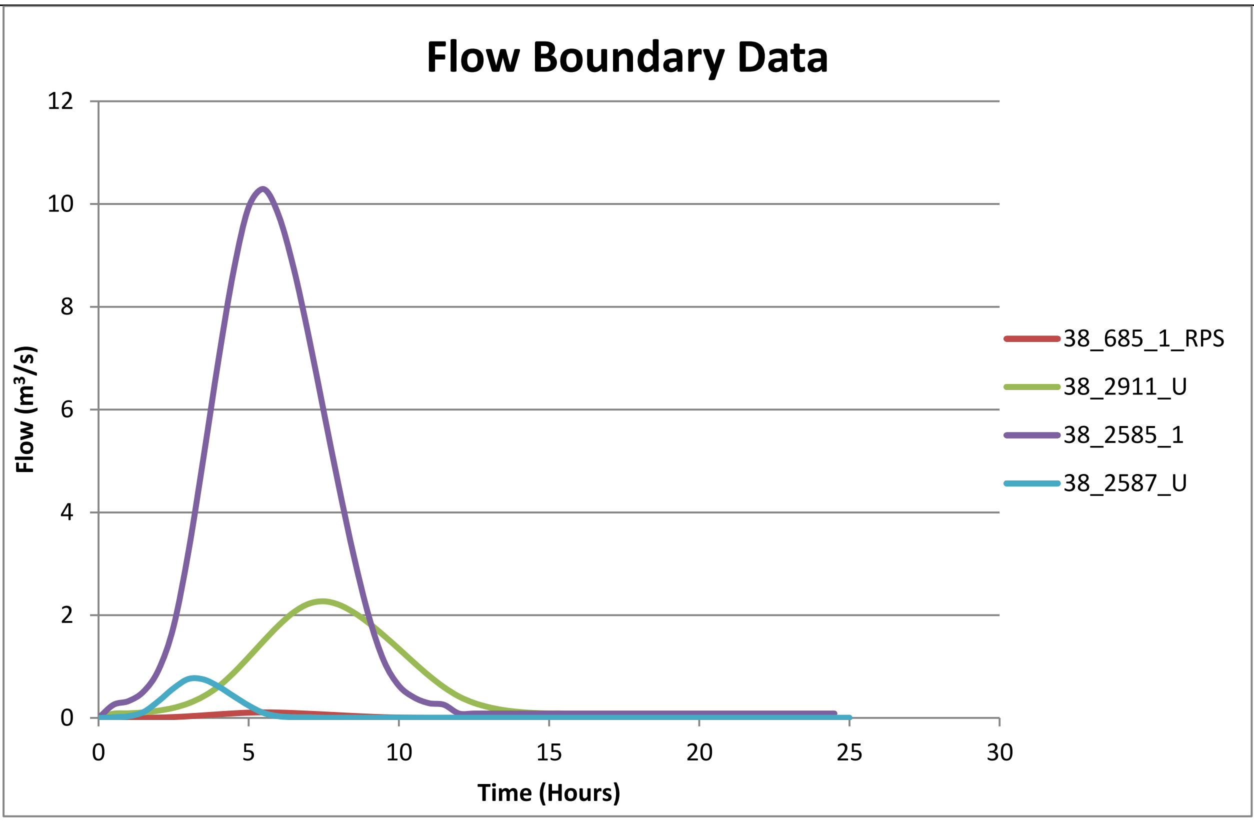


Figure 4.4.18: Upstream Inputs

To determine the worst case joint fluvial and tidal flooding, the timing of the fluvial input hydrographs was adjusted to coincide with the timing of the peak coastal total water level.

The Clady River model ends in a tidal estuary (refer to Figure 4.4.1) and a Head Time Boundary (HTBDY) was used to represent the tidal and surge profile, with a 50% AEP peak water level, timed to coincide with the peak flow, for the 0.1%, 1% and 10% fluvial events and the 0.1%, 0.5% and 10% peak water levels for the coastal events. Similarly the Catheen / Derrybeg model ends in the lower, tidal part of the Catheen River for which a HTBDY was used.

The downstream HTBDY boundary is reflective of a Total Water Level (TWL) and was applied to reflect the influence of coastal water levels upon fluvial flooding scenarios. The TWL was calculated using predicted tidal levels combined with the surge residual. Outputs from the Irish Coastal Protection Strategy Study (ICPSS) produced extreme tidal and storm surge water levels at nodes around the Irish Coast for a range of AEPs. ICPSS node NW28 (Irish Grid ref. 177574_427412) was used to generate extreme water levels, as shown on Figure 4.4.19. This ICPSS node is positioned approximately 4 km WNW from the downstream extent of the Catheen River (0116M) and 4.5 km NW from the downstream extent of the River Clady (0115M). The associated AEP water levels for NW28 are listed in Table 4.4.2.

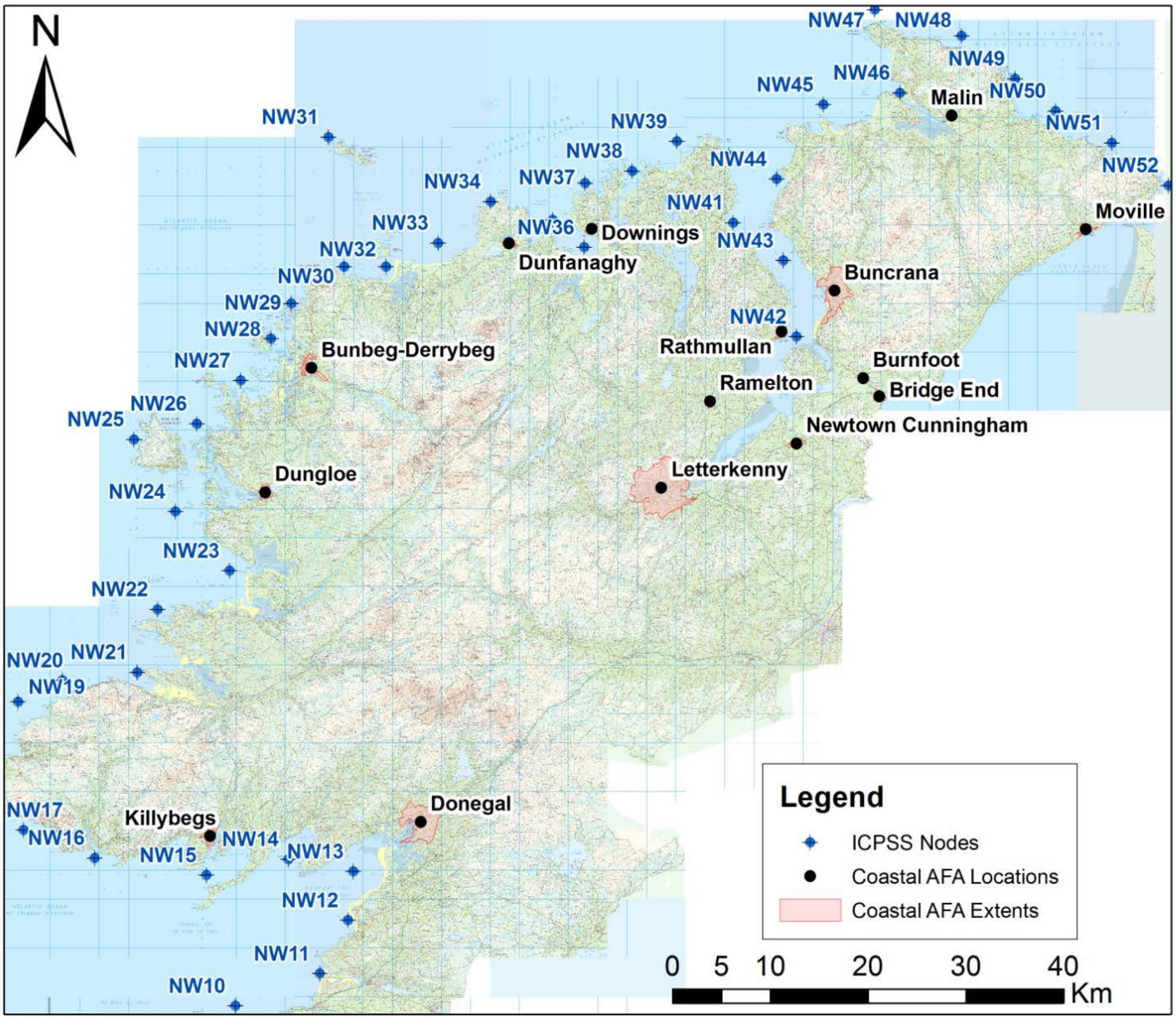


Figure 4.4.19: ICPSS Node Locations (IBE0700Rp0006_UoM01 Hydrology Report_F01)

Table 4.4.2: ICPSS extreme water levels – Node NW28

AEP (%)	50	20	10	5	2	1	0.5	0.1
NW28 (m AOD Malin)	2.53	2.663	2.758	2.851	2.972	3.063	3.154	3.364

To create a full tidal profile of the tidal part of the Catheen River, a dummy cross section and interpolates were added at the downstream end of the model to lower the bed level below the minimum tidal water level and the aforementioned HTBDY added, including the tidal and surge profiles. The dummy cross section is based on the downstream surveyed cross section (0116M0004) with the bed levels reduced and the x values increased by a factor of 10 (to ensure frictional effects in the dummy reach are insignificant).

The ICPSS TWLs comprise tidal and surge components which together yield a joint probability event of a particular AEP.

Using information from the Admiralty Tide Tables, a tidal water level was established. A tidal curve was generated by fitting this tide level to a sinusoidal curve. A normalised surge profile of 48 hour duration was scaled based on the difference between the peak water level of the generated tidal profile and the target TWL from Table 4.4.2. The scaled residual surge profile was then appended to the tidal profile to obtain the total combined water level time series as required for the relevant AEPs.

Figure 4.4.20 illustrates the tidal profile, storm surge profile and resultant combined TWL profile for a 50% AEP design event. The total water level profile was applied as a level boundary to the Northern edge of the 2D domain, representing tidal conditions at Moville.

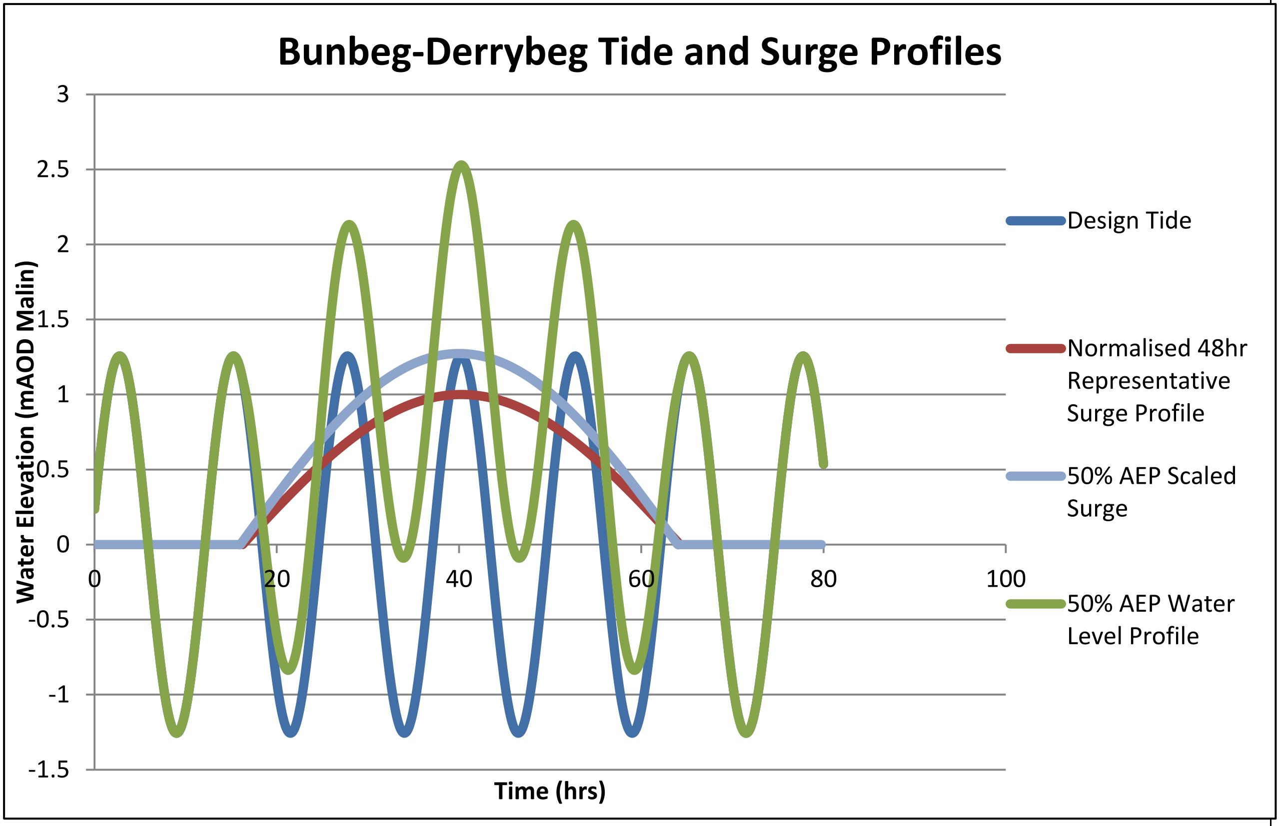


Figure 4.4.20: Tide and Surge Profiles

(6) Model Boundaries – Downstream Conditions:

A water level boundary was applied at the downstream extent of the Clady and Catheen watercourses where they discharge (chainage 5062m and 4253m respectively). This enables the transfer of flow between the 1D and 2D domain. It should be noted that these boundaries are given an initial 'dummy' water level value to match that of the water elevation of the tidal boundary at the start of the simulation, however these values are ignored once the simulation commences and the level of these boundaries varies in time based on dynamic calculations driven by the water levels in the 1D and 2D domains either side of the boundary location.

(7) Model Roughness: (see Chapter 3.6.1 'Roughness Coefficients')

(a) In-Bank (1D Domain)	Minimum 'n' value: 0.035	Maximum 'n' value: 0.050
(b) MPW Out-of-Bank (1D)	N/A	N/A
(c) MPW/HPW Out-of-Bank (2D)	Minimum 'n' value: 0.034 (Inverse of Manning's 'M')	Maximum 'n' value: 0.071 (Inverse of Manning's 'M')

Map of 2D Roughness (Manning's n)

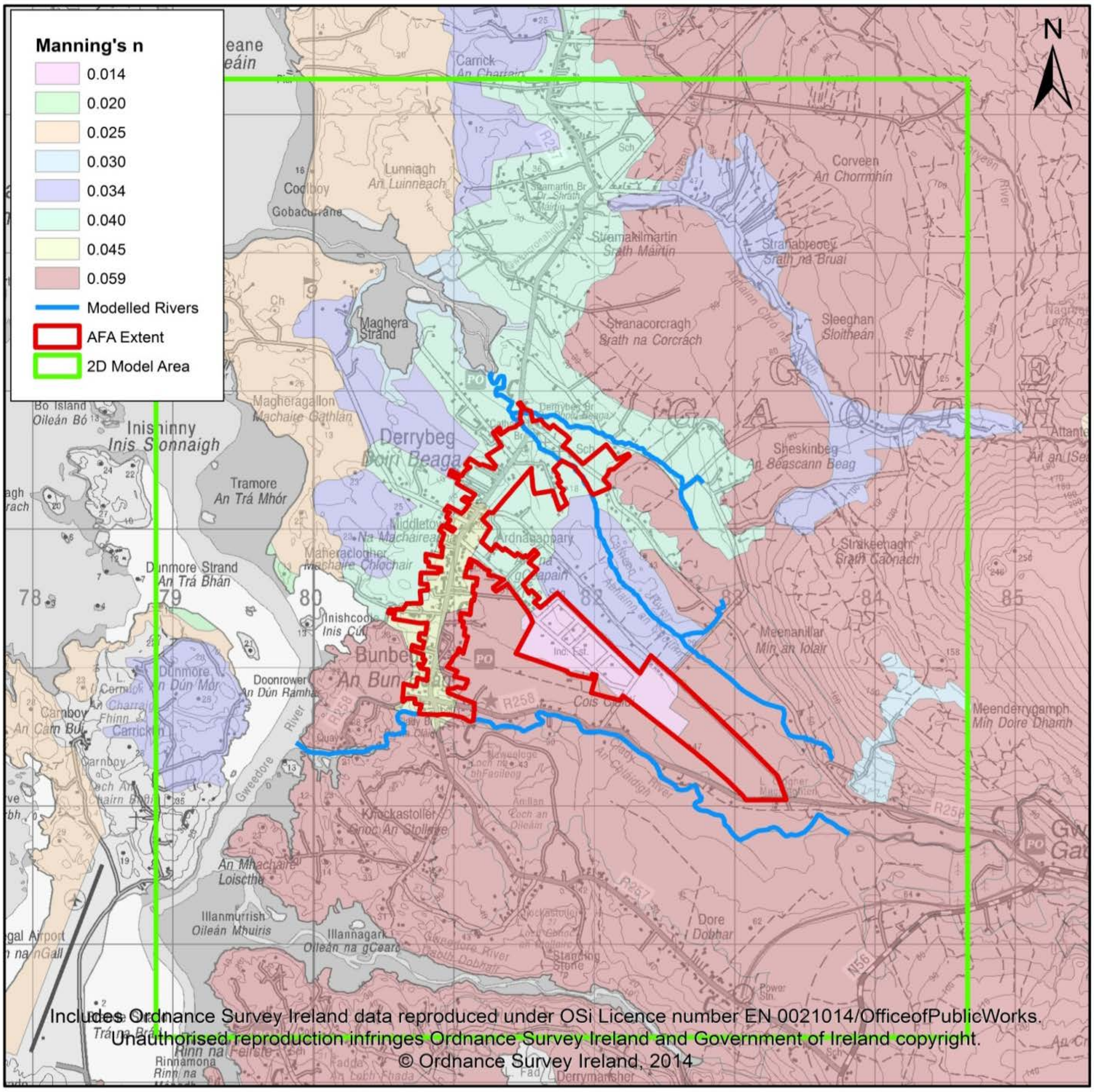


Figure 4.4.21: Map of 2D Roughness (Manning's n)

Figure 4.4.21 illustrates the roughness values applied within the 2D domain of the model. Roughness in the 2D domain was applied based on land type areas defined in the Corine Land Cover Map with representative roughness values associated with each of the land cover classes in the dataset. Any values seaward of the high water were also taken as 0.03 unless otherwise specified.

(d) Examples of In-Bank Roughness Coefficients

Figure 4.4.22: 0115M00375_DN

(Clady River, Ch 1411m)

Manning's n = 0.045

Straight stream with stones and weeds

Figure 4.4.24: 0115M00036_UP

(Clady River, Ch 4811m)

Manning's n= 0.030

Clean, straight stream

Figure 4.4.23: 0116M00167_DN

(Catheen River, Ch 2625m)

Manning's n= 0.050

Natural stream - winding, pools, shoals, stoney with some weeds.

Figure 4.4.25: 0116M00015DN

(Catheen River, Ch 4141m)

Manning's n= 0.035

Clean winding stream with some weeds and stones

 **Figure 4.4.26: 0116A00001_DN** **(Catheen Tributary, Ch 498m)** Manning's n= 0.050 Natural stream - winding, pools, shoals, stoney with some weeds.	 **Figure 4.4.27: 0117M00180_UP** **(Derrybeg Watercourse, Ch 3m)** Manning's n= 0.050 Natural stream - winding, pools, shoals, stoney with some weeds.

4.4.4 Sensitivity Analysis

To be completed for final version of report.

4.4.5 Hydraulic Model Calibration and Verification

(1) Key Historical Floods (From IBE0700Rp0002_UoM 01 Inception Report_F02 unless otherwise specified):	
(a) JUN 2009.	Information was found on various websites (www.rte.ie, www.independent.ie, www.donegaldemocrat.ie & www.belfasttelegraph.co.uk) providing details of a flood event which occurred on 23rd June 2009. According to these websites torrential rain caused flash flooding, which caused two rivers in the area to burst their banks one of which was the Catheen River (0116M). The rainfall was localised, with no rain reported only a couple of miles away in either direction from Bunbeg and Derrybeg. RTÉ reported that more than 20 houses, around a dozen business premises, and many roads and bridges were damaged in the Derrybeg and Bunbeg areas. The Belfast Telegraph reported that up to 20 houses remained cut off after three access bridges were carried away with the storm. There were two landslides and many bridges in the area became unsafe. The Irish Independent reported water depths of

	up to 6m in Derrybeg (near the public library/old chapel), resulting in a woman and her child having to be rescued from the top storey of their home. Rainfall records at the closest gauge (Bunbeg G.S. 180400_423800) located approximately 200 metres south west of the AFA extent do not cover this date. Upstream of the AFA along the Clady River a daily rain gauge at the Gweedore Weir recorded rainfall of 19.5mm. This gauge is around 2km from the AFA boundary and 5km to the south east of the Old Chapel referred to in flood reports. This rainfall depth was taken over an assumed 24 hour duration (given lack of available temporal resolution) and was used to estimate rainfall frequency using the FSU DDF model. This indicates that it was less than 1 year return period (i.e. very high frequency). Due to the lack of hourly data, more accurate rainfall duration is not available. Therefore the DDF model frequency estimation does not reflect the high intensity rainfall event that was reported. To get an impression of the rainfall intensity the hourly rain gauge at Malin Head, 70km east-north-east of the AFA, was reviewed. There was no rainfall recorded at this gauge on this date, meaning a representative duration could not be approximated. The mention of flooding near the Old Chapel (Gweedore Parish) in Derrybeg is a useful spatial reference. This building is situated approximately at Irish Grid Reference 181629.441_425601.44, approximately 80m upstream of culvert 0116A00050D on the Catheen River. The model results illustrate that the area near the Chapel is flooded following a 10% AEP fluvial event with more extensive flooding during a 1% and 0.1% AEP event. Due to the lack of detail on specific properties that flooded in this event, it was not possible to accurately calibrate the model. However the description of flooding near Gweedore Parish Chapel is reflected in modelled flood extents and therefore provides qualitative support for the model. Figure 4.4.28 presents the modelled flood extents for 10%, 1% and 0.1% AEP fluvial design event scenarios within the vicinity of the Chapel.

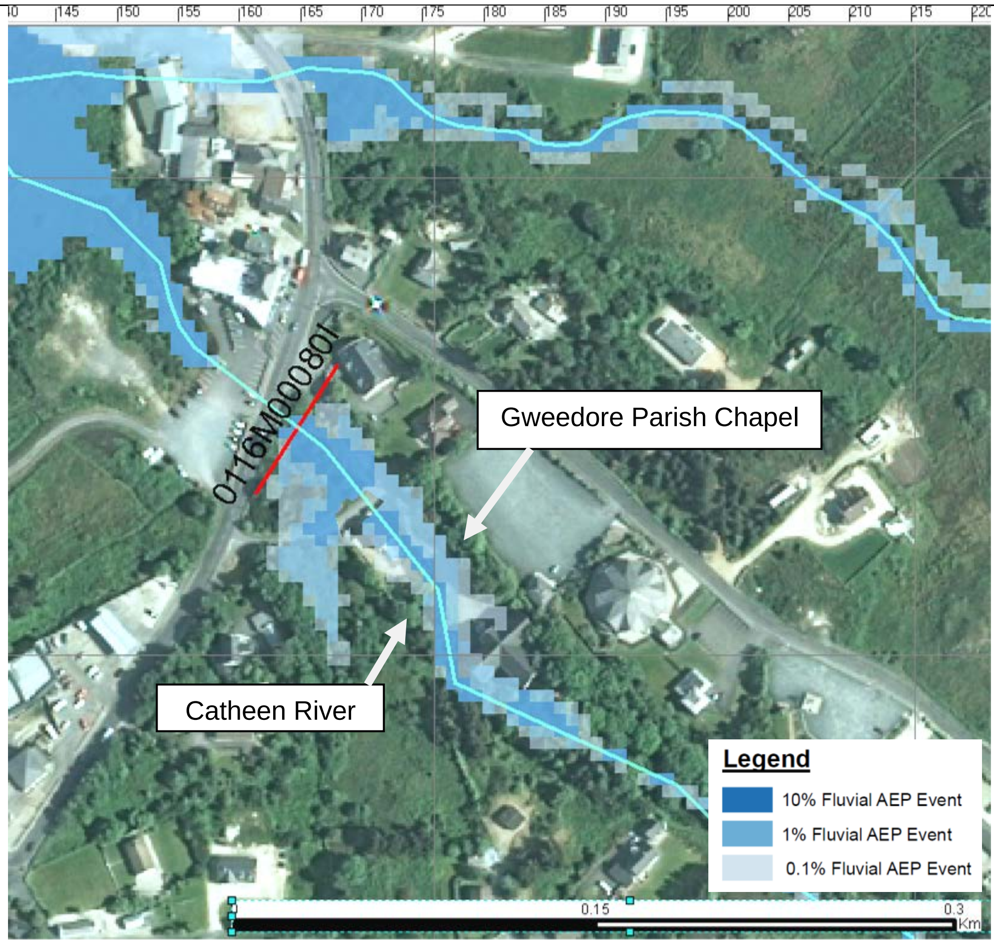
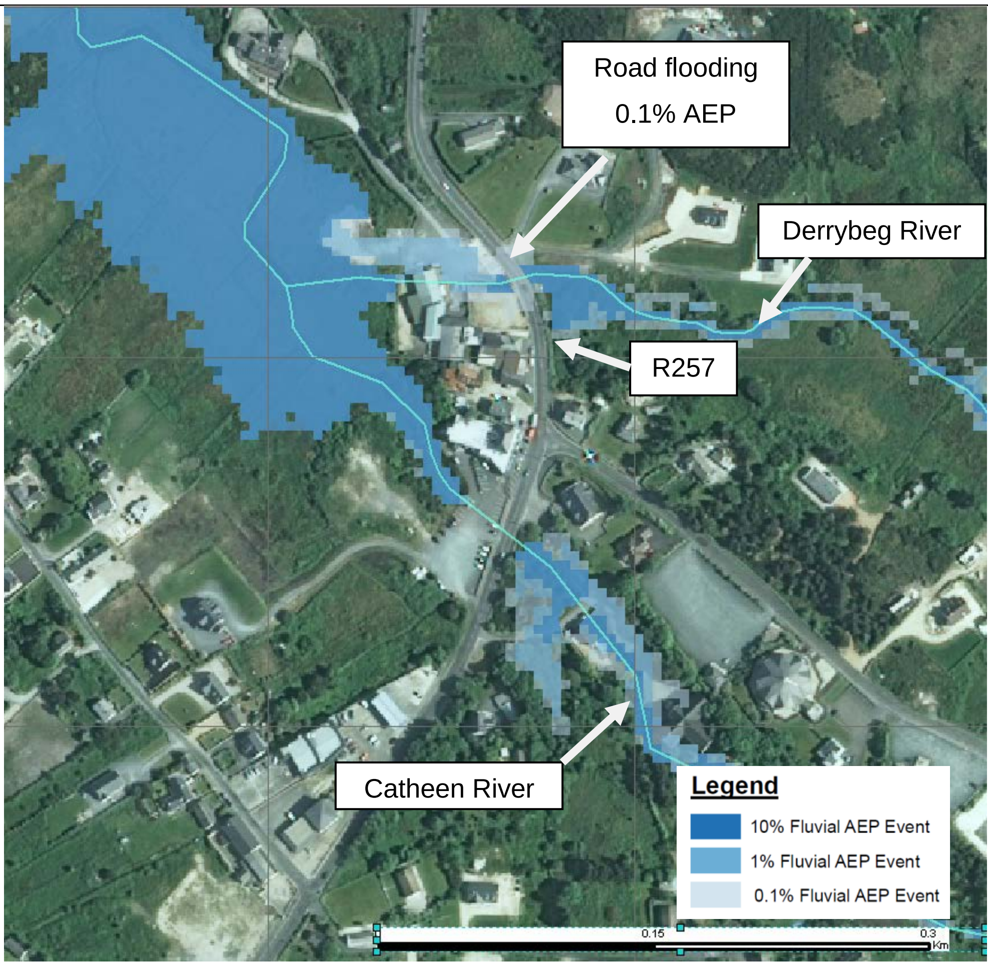


Figure 4.4.28: Modelled Flood Extents on Catheen River in Proximity to Gweedore Parish Chapel (Old Church) at Irish Grid Reference 181629_425601

(b) **OCT 1989.**

Information was found on www.floodmaps.ie during the historical review process that indicated flooding occurred in Ballybofey/Stranorlar, Bunbeg - Derrybeg, Buncrana, Castlefinn, Dungloe, Glenties, Killygordon, Letterkenny and Lifford on 29th October 1989. At Malin Head weather station, approximately 64mm of rain fell in the 24 hour period beginning at 6.00am on 28th Oct. Using this rainfall duration and depth a design rainfall frequency was estimated using the FSU DDF model. This indicated a rainfall frequency of 5% AEP for this event.

The Donegal People's Press reported that the Gortahork-Derrybeg road "was flooded for almost quarter of a mile to a depth of several feet"; however the precise location of the flooding was not stated. The R257 road is the Gortahork-Derrybeg Road, which crosses the River Clady in Bunbeg towards the south of the AFA and crosses the Catheen and Derrybeg rivers towards the north. The Catheen/Derrybeg model indicates flooding of this road when the Derrybeg River (reach 0117M) flows out of bank at the Derrybeg Bridge (0117M00013D) during the 0.1% fluvial AEP event, but not 1% or 10% AEP events. The Clady Model does not indicate flooding of the R257 from the River Clady, which passes under a bridge at cross-section 0115M00134D.

	 **Figure 4.4.29: Indicated Flooding on R257 (Derrybeg River, 0.1% AEP)**
(c) **AUG 1880.**	Information was found on a website during the internet search which indicated that flooding occurred in Bunbeg - Derrybeg on 15th August 1880. The website (www.wlrfm.com) reported that a violent thunderstorm broke out, followed by a torrential downpour. People attending mass became trapped in the church in Derrybeg when the rain caused water to pour into the area surrounding the chapel, resulting in the church also flooding. The congregation were trapped, and five members were drowned. Figure 4.4.29 highlights the Gweedore Parish church. This is the most likely location described in this historical report which would support the modelled flood extents. This report supports the model flooding extent results reasonably well. Due to the lack of meteorological data for this event it is not possible to derive a design rainfall frequency.

Summary of Calibration

Due to the lack of quantitative data on previous fluvial and coastal flood events it has not been possible to calibrate the model with historical events. With the limited information available it was possible to compare certain areas that were identified to have flooded in the past and ascertain that the model is producing similar results. As such, there has not been any information presented in previous flood events

that warrant any adjustment of the model parameters.

Generally, these reports have indicated that the main flooding mechanism associated with the Bunbeg and Derrybeg model is mainly fluvial, usually following periods of intense rainfall and flash flooding. Considering the coastal location of this area, it is surprising that no direct reference to coastal flooding has been made. There has been no mention of high tide or storm surge events. Regardless of this lack of information, it is deduced that the 28th October 1989 flooding event may have been exacerbated by the combined influence of high tide and storm surge conditions. Meteorological pressure maps relating to this date support this contention (http://www.wetterzentrale.de/topkarten/fsreaeur.html).

The high topography of the Derryveagh Mountains (to the NE, E and SE of the modelled area) may have contributed to the occurrence of intense rainfall and subsequent flash flooding of the lower coastal levels of which Derrybeg and Bunbeg form part. The flash flooding episodes that were described previously occurred during summer months of June and August. It is possible that orographic rainfall, may have significantly contributed to flash flooding in this area.

There is very limited daily and hourly rainfall data available for this location. The one event that was mentioned in the 'Inception Report' refers to Malinhead (October 1989). In this case the fluvial component was found to equate to an event with a frequency of 5% AEP.

Checks have been carried out on the ISIS mass balance model outputs for the 1% AEP events on the Bunbeg-Derrybeg models which may give an indication as to the robustness and stability of the model. These methods are discussed in Chapter 3.12.

Comparing 1D-2D link flow with flow in and out of the 2D domain indicated a difference of 6.95% for the combined Catheen / Derrybeg watercourses and their tributary and a difference of 6.6% for the Clady River. For the Catheen / Derrybeg model, the average Qe (mass balance error) was 1.53%; while the Clady model indicated an average Qe of 0.11%. These percentage differences are within tolerances relating to mass balance stated by ISIS.

Minor instabilities that exist are discussed later in Section 4.4.6(2) which also includes changes made to parameters to prevent instabilities.

Model flows were checked against the estimated flows at HEP check points, where possible to ensure they were within an acceptable range. For example at HEP 38_2587_1, the estimated flow during the 0.1% AEP event was 0.99 m^3/s and the modelled flow was 1.03 m^3/s. Full flow tables can be found in Appendix A.3. Overall the results imply both models are robust. To illustrate this, screenshots of a 'maximum stage long-section plot' relating to each watercourse at peak flow are presented in Appendix A.2. No significant model instabilities have been identified.

(2) Post Public Consultation Updates:
Following informal public consultation and formal S.I. public consultation periods in 2015, general model updates were applied to refine model resolution and improve model stability, mapping issued as Final reflects these changes.
(3) Standard of Protection of Existing Formal Defences: None
(4) Gauging Stations:
There are no gauging stations available within the modelled extents of the Clady or Catheen Rivers however there is some flow information available at the ESB dam control upstream of the modelled extents on the Clady River (38002 – ESB). This information is presented in the form of monthly and yearly maximum, minimum and average outflows from Lough Nacung. It was confirmed that the daily flow series information provided consists of average values rather than maximum values, resulting in the data not being suitable for estimation of design peak flow values.
(5) Other Information:
None

4.4.6 Hydraulic Model Assumptions, Limitations and Handover Notes

(1) Hydraulic Model Assumptions:
a) Survey of the culvert at cross section 0116A00040I shows a 0.9m diameter pipe at the upstream end and a rectangular profile culvert 1.42m wide and 0.4m high at the downstream end. It was assumed that a transition occurs midway along the culvert with an initial expansion into a chamber 1.42m x 0.9m, followed by a contraction to 1.42m x 0.4m. b) Survey of the culvert at cross section 0117M00009I shows twin 1.5m diameter pipes at the upstream end and a 2.47m wide, 1.41m high rectangular culvert at the downstream end. A transition is assumed to occur at the midway along the culvert. c) Post-processing of draft final maps was carried out regarding bridge inundation, where flood extents were removed from the appropriate AEP event where inundation does not occur. This is discussed further in Chapter 3.10.
(2) Hydraulic Model Limitations and Parameters:
a) The ADI (Alternating Direction Implicit) Solver was used in ISIS 2D, as is to be used for most coastal, fluvial and surface water models. Small isolated pockets with Froude number greater than one were identified from the model outputs, although a map showing maximum Froude for the full duration of the model suggests there are not any areas deemed as significant in proximity to receptors. The ADI solver is considered to 'produce acceptable solutions as it includes methods to reduce the effects of instabilities around supercritical flows', and therefore is considered to be appropriate for this AFA.

This information was taken from Section 1.2 of the ISIS 2D User Manual.

b) A model grid size of 5m was used in the 2D domain, refer to Chapter 3.3.2 for further information on selection of grid size.

c) Minor instability was identified at the downstream of the Clady River (0115M) where the tidal boundary is applied. This causes minor oscillation in stage between cross-section 0115M00076 and 0115M00010. This area is downstream of the AFA without any receptors in proximity that would be sensitive to minor differences in stage therefore this instability has not been deemed as significant.

d) A minimum flow of $0.1m^3/s$ was applied at the upstream end of the Catheen River (reach 0116M). Although this is higher than the peak flow for both the 10% and 1% AEP events at this point flows are within bank and modelled flood extents are therefore not affected.

e) Minimum flows of $0.1m^3/s$ were applied to the Catheen tributary (0116A) and Derrybeg tributary (0117A) to prevent model instability. A minimum flow of $0.35m^3/s$ was applied to the Derrybeg watercourse to prevent instability.

f) The dflood and maxitr parameters were increased to 5 and 17 respectively for the Catheen / Derrybeg model runs.

(3) Design Event Runs & Hydraulic Model Handover Notes:

a) Culvert at cross-section 0116A00040I on the Catheen River Tributary a transition between a 0.9m pipe to a 1.42m x 0.4m rectangular culvert is assumed midway between the culvert ends. This is conceptualised as a transition into a chamber 1.42m wide and 0.9m high followed by a contraction to the 0.4m high rectangular culvert.

b) At cross-section 0115M00302 a footbridge consisting of a few wooden planks over some natural boulders has been deemed as hydraulically insignificant and has therefore not been represented in the model.

(4) Deliverables

Please see Appendix A.4 for a list of all model files provided with this report.

(5) Quality Assurance:

Model Constructed by:	Ian Bentley
Model Reviewed by:	Stephen Patterson
Model Approved by:	Malcolm Brian

APPENDIX A.1

Structure Details – Bridges & Culverts

RIVER BRANCH	CHAINAGE	ID**	LENGTH (m)	OPENING SHAPE	HEIGHT (m)	WIDTH (m)	SPRING HEIGHT FROM INVERT (m)	MANNING'S n
Bridges								
CLADY RIVER	2020	0115M00314D	6.527	ARCH	3.96	10.12	3.96	0.045
CLADY RIVER	2759	0115M00276D	0.972	ARCH	4.07/4.294	4.06/4.72	4.07/4.72	0.045/0.045
CLADY RIVER	2841	0115M00232D	3.662	RECTANGULAR	2.138	7.08	2.138	0.045
CLADY RIVER	3812	0115M00134D	6.754	ARCH	6.1	9.78	2.82	0.045
CATHEEN RIVER	3439	0115M00085D	9.65	ARCH	1.29	4.12	1.29	0.035
CATHEEN RIVER TRIB	266	0116A00024D	3.98	ARCH	1.03	1.5	1.03	0.04
CATHEEN RIVER TRIB	287	0116A00022D	1	ARCH	0.94	2.33	0.94	0.04
CATHEEN RIVER TRIB	363	0116A00014D	2.3	ARCH	0.93	1.6	0.93	0.05
DERRYBEG	572	0117M00123D	3.562	ARCH	1.22	2.16	1.22	0.04

Structure Details – Bridges & Culverts								
RIVER BRANCH	**CHAINAGE**	**ID****	**LENGTH (m)**	**OPENING SHAPE**	**HEIGHT (m)**	**WIDTH (m)**	**SPRING HEIGHT FROM INVERT (m)**	**MANNING'S n**
DERRYBEG	632	0117M00117I	7.025	ARCH	1.58	1.95	1.58	0.045
DERRYBEG	739	0117M00107I	5.369	ARCH	1.63/1.45	1.79/1.82	1.63/1.45	0.045
DERRYBEG	836	0117M00097I	5.387	ARCH	1.79/1.83	1.76/1.77	1.79/1.83	0.045
DERRYBEG	876	0117M00091I	6.016	ARCH	1.4	2.74	1.4	0.045
DERRYBEG	969	0117M00085D	6.567	ARCH	1.61	3.18	1.61	0.04
DERRYBEG	1012	0117M00079I	5.695	ARCH	1.89/1.8	1.8/1.79	1.89/1.8	0.04
DERRYBEG	1102	0117M00070I	12.4	ARCH	1.61	2.97	1.61	0.04
DERRYBEG	1673	0117M00013D	11.63	ARCH	1.95/1.76	3.49/3.32	0.53/0.74	0.035
Culverts								
CLADY RIVER	2841	0115M00232D	3.662	CIRCULAR (TRIPLE BARREL)	2.0/2.0/0.45	2.0/2.0/0.45	N/A	0.045
CATHEEN RIVER	288	0116M00400I	8.85	CIRCULAR	0.5	0.5	N/A	0.03
CATHEEN RIVER	1395	0116M00289I	5.3	RECTANGULAR	0.97/0.98	0.6/0.54	N/A	0.02

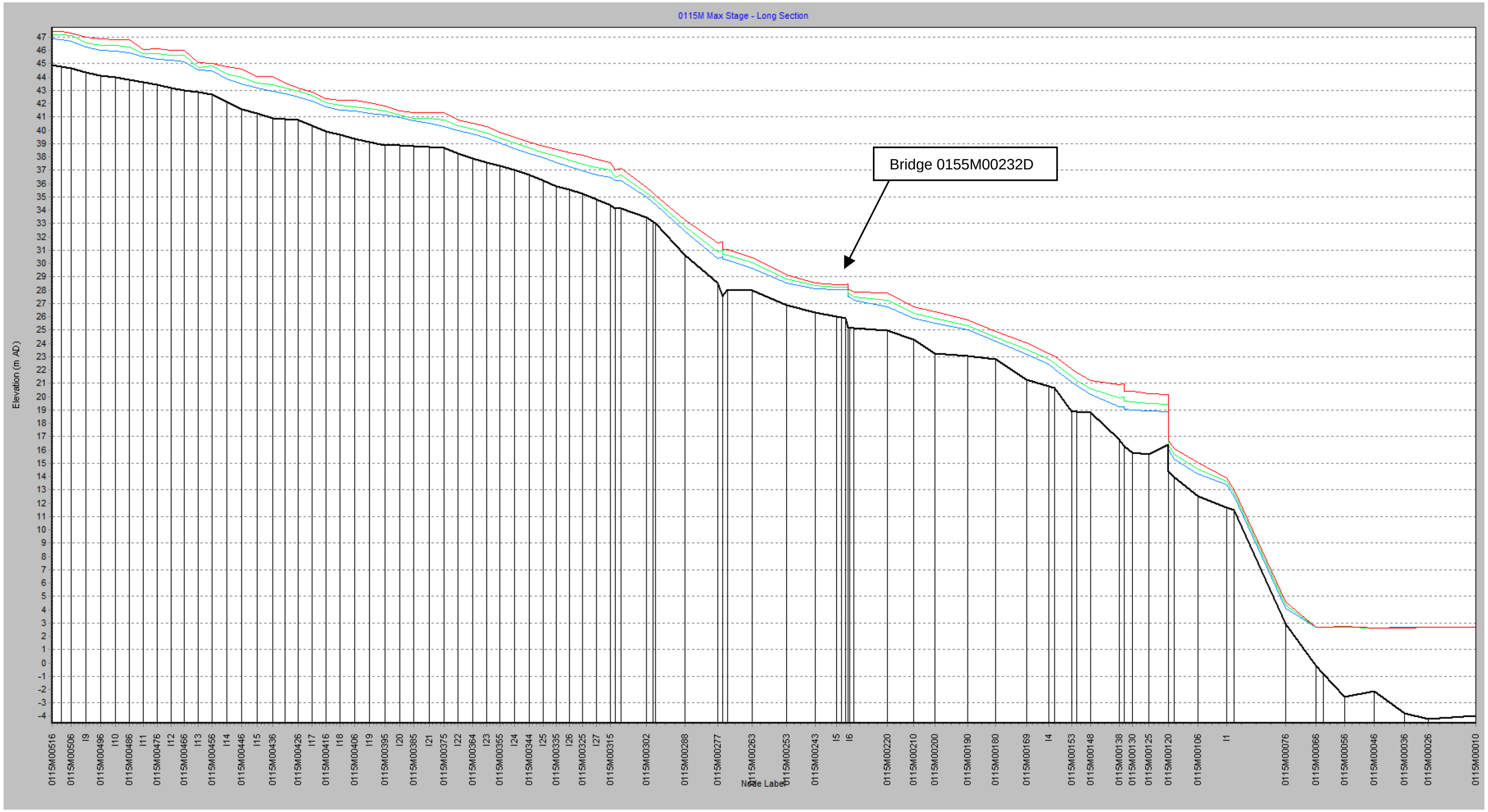
Structure Details – Bridges & Culverts								
RIVER BRANCH	**CHAINAGE**	**ID****	**LENGTH (m)**	**OPENING SHAPE**	**HEIGHT (m)**	**WIDTH (m)**	**SPRING HEIGHT FROM INVERT (m)**	**MANNING'S n**
				(DOUBLE)				
CATHEEN RIVER	2941	0116M00135I	13.5	CIRCULAR (DOUBLE)	0.9/0.9	0.9/0.9	N/A	0.015
CATHEEN RIVER	3487	0116M00080I	49.3	CIRCULAR	2.5	2.5	N/A	0.03
CATHEEN RIVER TRIB	15	0116A00050D	3.05	RECTANGULAR	0.8	0.58	N/A	0.04
CATHEEN RIVER TRIB	91	0116A00040I	69.31	CIRCULAR	0.9	0.9	N/A	0.025
DERRYBEG	319	0117M00149I	6.136	RECTANGULAR	1.44	3.04	N/A	0.035
DERRYBEG	1707	0117M00009I	35.739	CIRCULAR (DOUBLE)	1.5/1.5	1.5/1.5	NN	0.02
DERRYBEG TRIB	23	0117A00020I	5.925	RECTANGULAR	0.76	0.35	N/A	0.035
DERRYBEG TRIB	45	0117A00018I	27	CIRCULAR	0.45	0.45	N/A	0.02

Structure Details - Weirs			
RIVER BRANCH	**CHAINAGE**	**ID**	**Type**
Derrybeg	639	0117M00117J	General Weir (Spill)
Derrybeg	882	0117M00091J	General Weir (Spill)
Clady	3970	0115M00119W	General Weir (Spill)

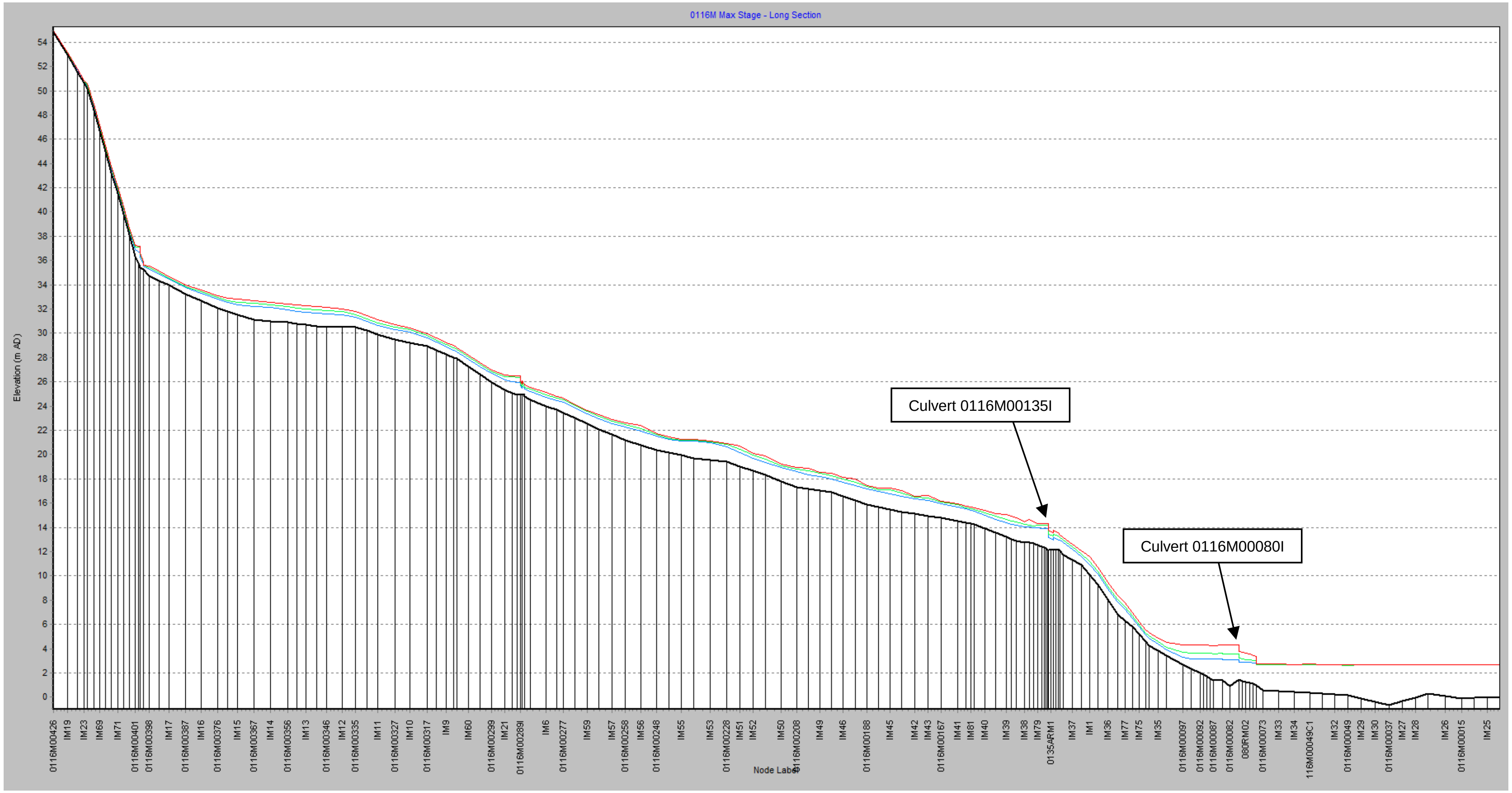
** Structure ID Key:

D – Bridge Upstream Face; **E** – Bridge Downstream Face; **I** – Culvert Upstream Face; **J** – Culvert Downstream Face

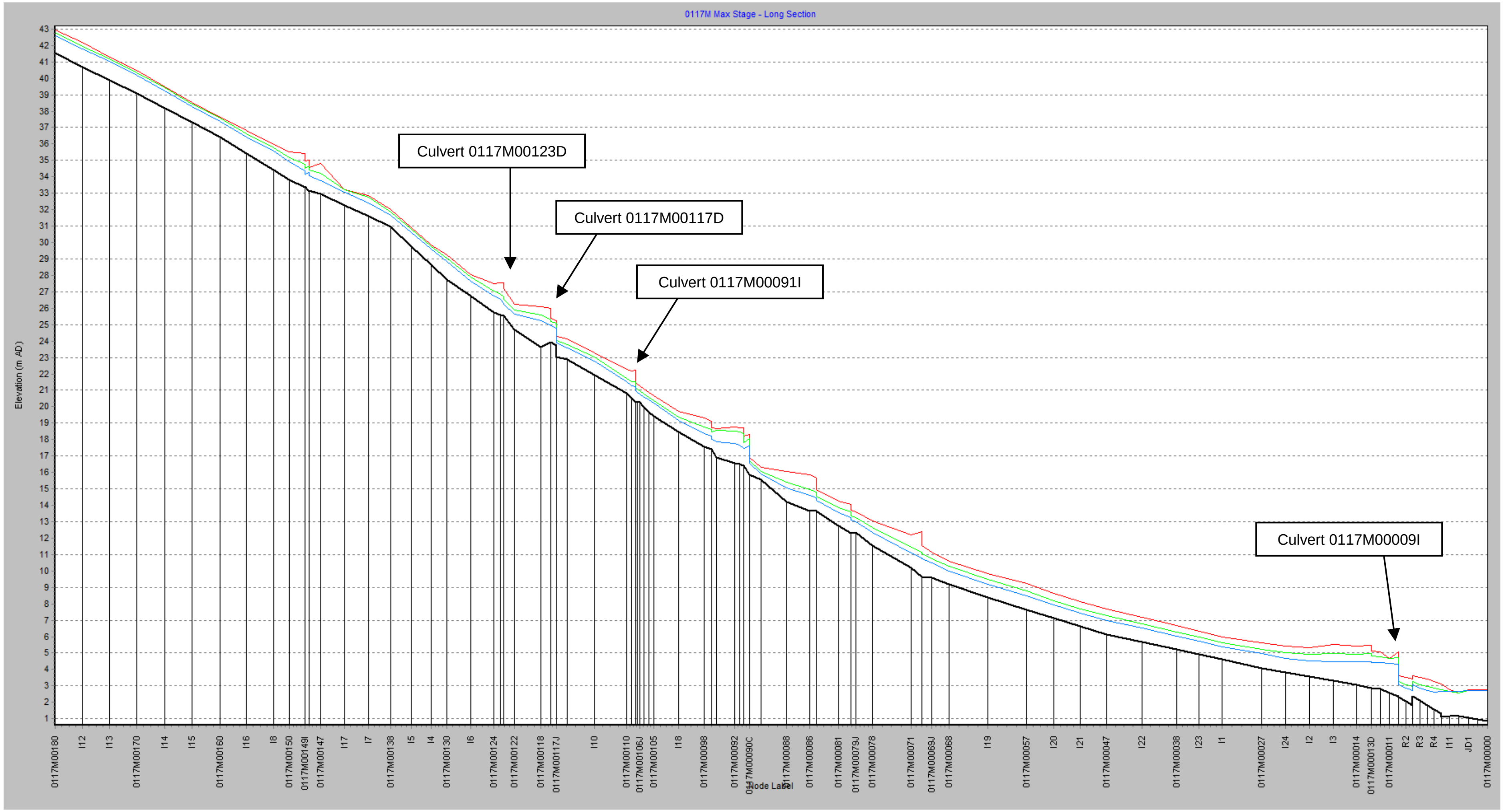
APPENDIX A.2



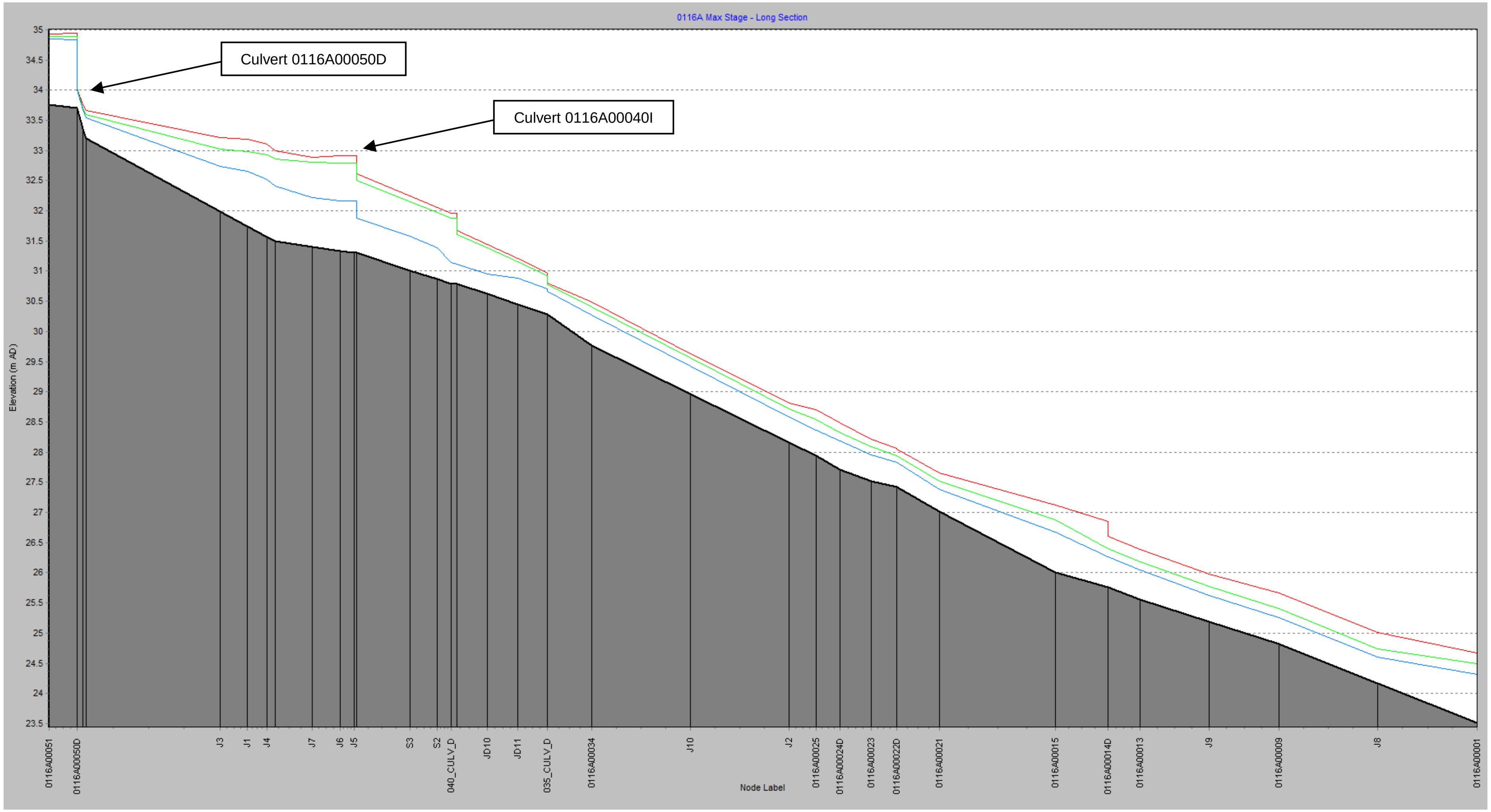
Reach 0115M: Clady River. Peak water levels for the 10% (blue), 1% (green) and 0.1% (red) AEP fluvial events.



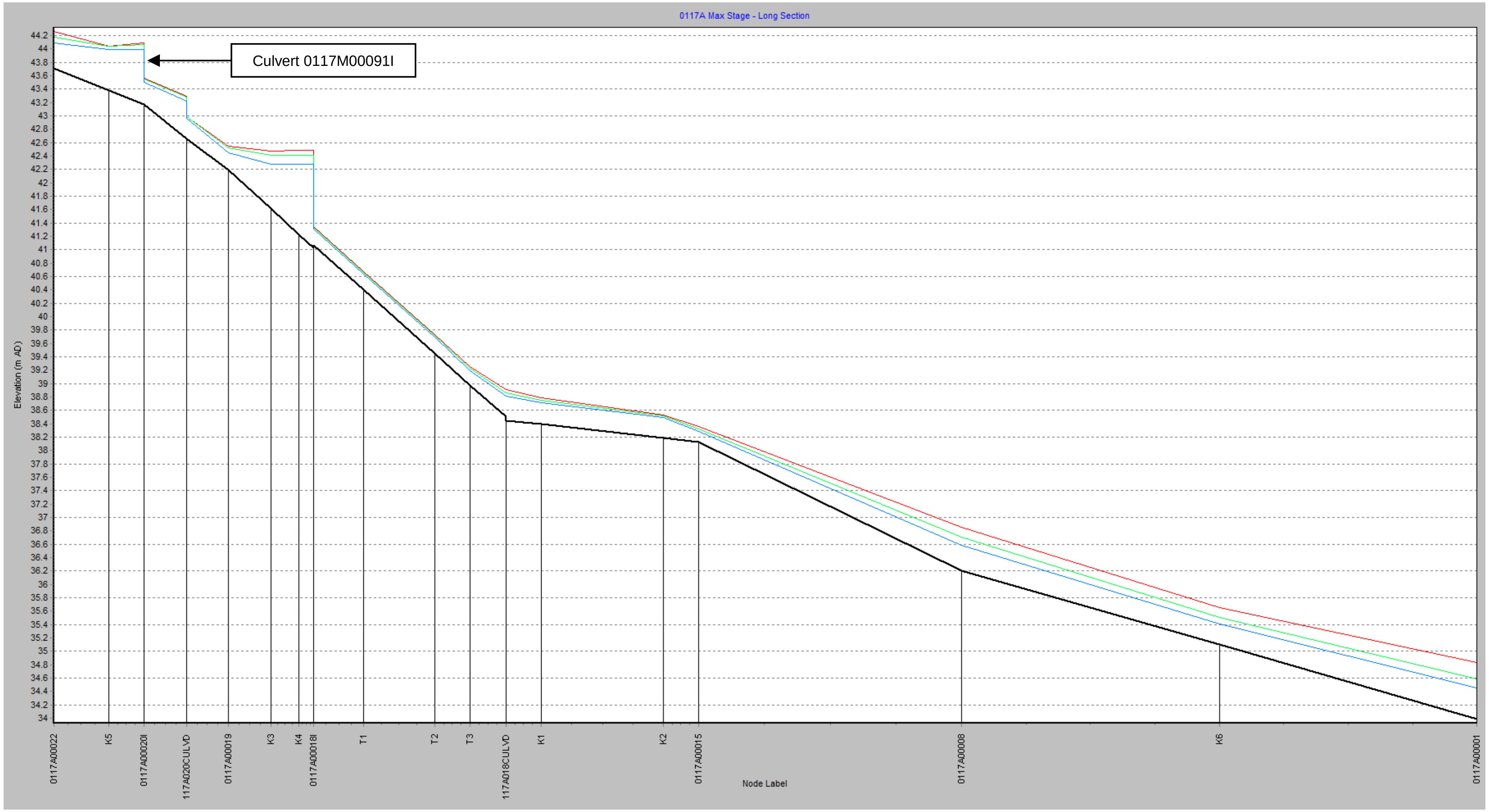
Reach 0116M: Catheen River. Peak water levels for the 10% (blue), 1% (green) and 0.1% (red) AEP fluvial events



Reach 0117M: Derrybeg River. Peak water levels for the 10% (blue), 1% (green) and 0.1% (red) AEP fluvial events.



Reach 0116A: Catheen River Tributary. Peak water levels for the 10% (blue), 1% (green) and 0.1% (red) AEP fluvial events.



Reach 0117A: Derrybeg River Tributary. Peak water levels for the 10% (blue), 1% (green) and 0.1% (red) AEP fluvial events.

APPENDIX A.3

Flow Comparison at HEP Check Points

Watercourse	HEP Point	AEP	Check Flow (m^3/s)	Model Flow (m3/s)	Difference (%)
		10%	1.50	0.97	-35.42
		1%	2.44	1.57	-35.94
Catheen Trib	**38_2911_1**	0.10%	3.98	2.57	-35.54
		10%	0.37	0.32	-14.53
		1%	0.60	0.52	-14.87
Derrybeg Trib	**38_2587_1**	0.10%	0.99	0.87	-11.75
		10%	6.55	6.52	-0.56
		1%	10.65	10.75	+0.89
Derrybeg*	**38_4132_3**	0.10%	17.36	18.43	+6.14
		10%	8.98	12.02	+33.87
		1%	14.59	14.67	+0.55
Catheen*	**38_4130_D**	0.10%	23.78	17.90	-24.73
		10%	48.04	48.04	0
		1%	74.43	74.46	+2.26
Clady	**38_3999_1**	0.10%	113.84	113.86	-2.24
		10%	48.04	49.20	+3.29
		1%	74.43	76.41	+3.53
Clady	**38_4124_2**	0.10%	113.84	117.14	+3.77

*Subject to tidal influence

The table above provides details of the flow in the model at every HEP intermediate check point, modelled tributary and gauging station. These flows have been compared with the hydrology flow estimation and a percentage difference provided.

The downstream checkpoints 38_4132_3 on the Derrybeg watercourse and 38_4130_D on the Catheen watercourse are subject to tidal influence. The discharge at these HEP points in the model is a combination of fluvial and tidal components. As a result it is not possible to reliably check the model flow at these points.

The model and check flows at two HEPs on the Clady River, 38_3999_1 and 38_4124_2, were found to correlate well during all modelled events with differences less than 5%. This suggests the model is well anchored to the hydrologically derived estimates as presented in Chapter 4.15 of the Hydrology Report (IBE0700Rp0006_UoM 01 Hydrology Report).

Storage-attenuation effects on the Catheen tributary (0116A) are strongly influenced by a small culvert which restricts flow in all events. This explains why model flows are around 35% lower than check flows at HEP 38_2911_1. Similar conditions exist due to a small culvert on the Derrybeg tributary (0117) at HEP 38_2587_1.

APPENDIX A.4

List of model files supplied with report

ISIS 2D .xml Files	ISIS 1D .ief Files	Sub Folders
UOM01_BUN15A_2D_DES_Q10C.xml UOM01_BUN15A_2D_DES_Q10F.xml UOM01_BUN15A_2D_DES_Q100F.xml UOM01_BUN15A_2D_DES_Q200C.xml UOM01_BUN15A_2D_DES_Q1000C.xml UOM01_BUN15A_2D_DES_Q1000F.xml UOM01_BUN15B_2D_DES_Q10C.xml UOM01_BUN15B_2D_DES_Q10C_EXT.xml UOM01_BUN15B_2D_DES_Q10F.xml UOM01_BUN15B_2D_DES_Q100F.xml UOM01_BUN15B_2D_DES_Q200C.xml UOM01_BUN15B_2D_DES_Q200C_EXT.xml UOM01_BUN15B_2D_DES_Q1000C.xml UOM01_BUN15B_2D_DES_Q1000C_EXT.xml UOM01_BUN15B_2D_DES_Q1000F.xml	UOM01_BUN15A_1D_DES_Q10C.ief UOM01_BUN15A_1D_DES_Q10F.ief UOM01_BUN15A_1D_DES_Q100F.ief UOM01_BUN15A_1D_DES_Q200C.ief UOM01_BUN15A_1D_DES_Q1000C.ief UOM01_BUN15A_1D_DES_Q1000F.ief UOM01_BUN15B_1D_DES_Q10C.ief UOM01_BUN15B_1D_DES_Q10F.ief UOM01_BUN15B_1D_DES_Q100F.ief UOM01_BUN15B_1D_DES_Q200C.ief UOM01_BUN15B_1D_DES_Q1000C.ief UOM01_BUN15B_1D_DES_Q1000F.ief	ISIS 1D ISIS 2D Results

1st Level Sub Folder	2nd Level Sub Folder	3rd Level Sub Folder	Files
ISIS 1D	Clady_0115M		UOM01_BUN15A_ID_DES_Q1000F.IED UOM01_BUN15A_ID_DES_Q1000C.IED UOM01_BUN15A_ID_DES_Q200C.IED UOM01_BUN15A_ID_DES_Q100F.IED UOM01_BUN15A_ID_DES_Q10C.IED UOM01_BUN15A_ID_DES_Q10F.IED UOM01_BUN15A_ID_DES.zzs UOM01_BUN15A_ID_DES.DAT
	Catheen_0116M		UOM01_BUN15B_ID_DES_Q1000F.IED UOM01_BUN15B_ID_DES_Q1000C.IED UOM01_BUN15B_ID_DES_Q200C.IED UOM01_BUN15B_ID_DES_Q100F.IED UOM01_BUN15B_ID_DES_Q10C.IED UOM01_BUN15B_ID_DES_Q10F.IED UOM01_BUN15B_ID_DES_FLVL.DAT UOM01_BUN15B_ID_DES_CSTL.zzs UOM01_BUN15B_ID_DES_CSTL.DAT

1st Level Sub Folder	2nd Level Sub Folder	3rd Level Sub Folder	Files
ISIS 2D	Clady_0115M	Active Area	UOM01_BUN15A_2D_DES.dbf UOM01_BUN15A_2D_DES.shp UOM01_BUN15A_2D_DES.shx
		Links	UOM01_BUN15A_2D_DES_DSBDY.dbf UOM01_BUN15A_2D_DES_DSBDY.shp UOM01_BUN15A_2D_DES_DSBDY.shx UOM01_BUN15A_2D_DES_LB1.dbf UOM01_BUN15A_2D_DES_ LB1.shp UOM01_BUN15A_2D_DES_ LB1.shx UOM01_BUN15A_2D_DES_ LB2.dbf UOM01_BUN15A_2D_DES_ LB2.shp UOM01_BUN15A_2D_DES_ LB2.shx UOM01_BUN15A_2D_DES_ RB1.dbf UOM01_BUN15A_2D_DES_ RB1.shp UOM01_BUN15A_2D_DES_ RB1.shx UOM01_BUN15A_2D_DES_ RB2.dbf UOM01_BUN15A_2D_DES_ RB2.shp UOM01_BUN15A_2D_DES_ RB2.shx
	Catheen_0116M	Active Area	UOM01_BUN15B_2D_DES_ACTVA_CSTL.dbf UOM01_BUN15B_2D_DES_ACTVA_EXT.dbf UOM01_BUN15B_2D_DES_ACTVA_FLVL.dbf UOM01_BUN15B_2D_DES_ACTVA_CSTL.shp UOM01_BUN15B_2D_DES_ACTVA_EXT.shp UOM01_BUN15B_2D_DES_ACTVA_FLVL.shp UOM01_BUN15B_2D_DES_ACTVA_CSTL.shx UOM01_BUN15B_2D_DES_ACTVA_EXT.shx UOM01_BUN15B_2D_DES_ACTVA_FLVL.shx

ISIS 2D	**Catheen_0116M**	**Links**	UOM01_BUN15B_2D_DES_0116A_LB.dbf UOM01_BUN15B_2D_DES_0116A_RB.dbf UOM01_BUN15B_2D_DES_0116M_LB.dbf UOM01_BUN15B_2D_DES_0116M_LB_A.dbf UOM01_BUN15B_2D_DES_0116M_RB1.dbf UOM01_BUN15B_2D_DES_0116M_RB2.dbf UOM01_BUN15B_2D_DES_0116M_RB2_A.dbf UOM01_BUN15B_2D_DES_0116M_RB3.dbf UOM01_BUN15B_2D_DES_0116M_RB3_A.dbf UOM01_BUN15B_2D_DES_0117A_LB.dbf UOM01_BUN15B_2D_DES_0117A_RB.dbf UOM01_BUN15B_2D_DES_0117M_LB.dbf UOM01_BUN15B_2D_DES_0117M_LB_A.dbf UOM01_BUN15B_2D_DES_0117M_RB1.dbf UOM01_BUN15B_2D_DES_0117M_RB2.dbf UOM01_BUN15B_2D_DES_0117M_RB2_A.dbf UOM01_BUN15B_2D_DES_DSBDY.dbf UOM01_BUN15B_2D_DES_DSBDY_A.dbf UOM01_BUN15B_2D_DES_DSBDY_EXT.dbf UOM01_BUN15B_2D_DES_0116A_LB.shx UOM01_BUN15B_2D_DES_0116A_RB.shx UOM01_BUN15B_2D_DES_0116M_LB.shx UOM01_BUN15B_2D_DES_0116M_LB_A.shx UOM01_BUN15B_2D_DES_0116M_RB1.shx UOM01_BUN15B_2D_DES_0116M_RB2.shx UOM01_BUN15B_2D_DES_0116M_RB2_A.shx UOM01_BUN15B_2D_DES_0116M_RB3.shx UOM01_BUN15B_2D_DES_0116M_RB3_A.shx UOM01_BUN15B_2D_DES_0117A_LB.shx UOM01_BUN15B_2D_DES_0117A_RB.shx UOM01_BUN15B_2D_DES_0117M_LB.shx UOM01_BUN15B_2D_DES_0117M_LB_A.shx UOM01_BUN15B_2D_DES_0117M_RB1.shx UOM01_BUN15B_2D_DES_0117M_RB2.shx UOM01_BUN15B_2D_DES_0117M_RB2_A.shx UOM01_BUN15B_2D_DES_DSBDY.shx UOM01_BUN15B_2D_DES_DSBDY_A.shx UOM01_BUN15B_2D_DES_DSBDY_EXT.shx UOM01_BUN15B_2D_DES_0116A_LB.shp UOM01_BUN15B_2D_DES_0116A_RB.shp UOM01_BUN15B_2D_DES_0116M_LB.shp UOM01_BUN15B_2D_DES_0116M_LB_A.shp UOM01_BUN15B_2D_DES_0116M_RB1.shp UOM01_BUN15B_2D_DES_0116M_RB2.shp UOM01_BUN15B_2D_DES_0116M_RB2_A.shp UOM01_BUN15B_2D_DES_0116M_RB3.shp UOM01_BUN15B_2D_DES_0116M_RB3_A.shp UOM01_BUN15B_2D_DES_0117A_LB.shp UOM01_BUN15B_2D_DES_0117A_RB.shp UOM01_BUN15B_2D_DES_0117M_LB.shp UOM01_BUN15B_2D_DES_0117M_LB_A.shp UOM01_BUN15B_2D_DES_0117M_RB1.shp UOM01_BUN15B_2D_DES_0117M_RB2.shp UOM01_BUN15B_2D_DES_0117M_RB2_A.shp UOM01_BUN15B_2D_DES_DSBDY.shp UOM01_BUN15B_2D_DES_DSBDY_A.shp UOM01_BUN15B_2D_DES_DSBDY_EXT.shp

1st Level Sub Folder	2nd Level Sub Folder	Files
ISIS 2D	2D Roughness	UOM01_BUN15_1D_DES_MANN.asc
	DTM	UOM01_BUN15_2D_DES_BLD.shx UOM01_BUN15_2D_DES_BLD.shp UOM01_BUN15_2D_DES_BLD.dbf UOM01_BUN15_2D_DES_5M_NDTM.asc UOM01_BUN15_2D_DES_2M_LID.asc
Results	Check Files	UOM01_BUN15A_1D_DES_Q10C_1DMB.csv. UOM01_BUN15A_1D_DES_Q10F_1DMB.csv UOM01_BUN15A_1D_DES_Q100F_1DMB.csv UOM01_BUN15A_1D_DES_Q200C_1DMB.csv UOM01_BUN15A_1D_DES_Q1000C_1DMB.csv UOM01_BUN15A_1D_DES_Q1000F_1DMB.csv UOM01_BUN15A_2D_DES_Q10C_2DMB.csv UOM01_BUN15A_2D_DES_Q10F_2DMB.csv UOM01_BUN15A_2D_DES_Q100F_2DMB.csv UOM01_BUN15A_2D_DES_Q200C_2DMB.csv UOM01_BUN15A_2D_DES_Q1000C_2DMB.csv UOM01_BUN15A_2D_DES_Q1000F_2DMB.csv UOM01_BUN15B_1D_DES_Q10C_1DMB.csv UOM01_BUN15B_1D_DES_Q10F_1DMB.csv UOM01_BUN15B_1D_DES_Q100F_1DMB.csv UOM01_BUN15B_1D_DES_Q200C_1DMB.csv UOM01_BUN15B_1D_DES_Q1000C_1DMB.csv UOM01_BUN15B_1D_DES_Q1000F_1DMB.csv UOM01_BUN15B_2D_DES_Q10C_2DMB.csv UOM01_BUN15B_2D_DES_Q10C_EXT_2DMB.csv UOM01_BUN15B_2D_DES_Q10F_2DMB.csv UOM01_BUN15B_2D_DES_Q100F_2DMB.csv UOM01_BUN15B_2D_DES_Q200C_2DMB.csv UOM01_BUN15B_2D_DES_Q200C_EXT_2DMB.csv UOM01_BUN15B_2D_DES_Q1000C_2DMB.csv UOM01_BUN15B_2D_DES_Q1000C_EXT_2DMB.csv UOM01_BUN15B_2D_DES_Q1000F_2DMB.csv
	ISIS 1D MIN-MAX	UOM01_BUN15A_1D_DES_Q10C.csv UOM01_BUN15A_1D_DES_Q10F.csv UOM01_BUN15A_1D_DES_Q100F.csv UOM01_BUN15A_1D_DES_Q200C.csv UOM01_BUN15A_1D_DES_Q1000C.csv UOM01_BUN15A_1D_DES_Q1000F.csv UOM01_BUN15B_1D_DES_Q10C.csv UOM01_BUN15B_1D_DES_Q10F.csv UOM01_BUN15B_1D_DES_Q100F.csv UOM01_BUN15B_1D_DES_Q200C.csv UOM01_BUN15B_1D_DES_Q1000C.csv UOM01_BUN15B_1D_DES_Q1000F.csv

1st Level Sub Folder	2nd Level Sub Folder	Files
Results	ISIS 1D UNSTEADY RESULTS	UOM01_BUN15A_1D_DES_Q10F.zzn UOM01_BUN15A_1D_DES_Q10C.zzn UOM01_BUN15A_1D_DES_Q100F.zzn UOM01_BUN15A_1D_DES_Q200C.zzn UOM01_BUN15A_1D_DES_Q1000F.zzn UOM01_BUN15A_1D_DES_Q1000C.zzn UOM01_BUN15B_1D_DES_Q10F.zzn UOM01_BUN15B_1D_DES_Q10C.zzn UOM01_BUN15B_1D_DES_Q100F.zzn UOM01_BUN15B_1D_DES_Q200C.zzn UOM01_BUN15B_1D_DES_Q1000F.zzn UOM01_BUN15B_1D_DES_Q1000C.zzn UOM01_BUN15A_1D_DES_Q10F.zzl UOM01_BUN15A_1D_DES_Q10C.zzl UOM01_BUN15A_1D_DES_Q100F.zzl UOM01_BUN15A_1D_DES_Q200C.zzl UOM01_BUN15A_1D_DES_Q1000F.zzl UOM01_BUN15A_1D_DES_Q1000C.zzl UOM01_BUN15B_1D_DES_Q10F.zzl UOM01_BUN15B_1D_DES_Q10C.zzl UOM01_BUN15B_1D_DES_Q100F.zzl UOM01_BUN15B_1D_DES_Q200C.zzl UOM01_BUN15B_1D_DES_Q1000F.zzl UOM01_BUN15B_1D_DES_Q1000C.zzl
	ISIS 2D MAX DEPTH	UOM01_BUN15A_2D_DES_Q10C.asc UOM01_BUN15A_2D_DES_Q10F.asc UOM01_BUN15A_2D_DES_Q100F.asc UOM01_BUN15A_2D_DES_Q200C.asc UOM01_BUN15A_2D_DES_Q1000C.asc UOM01_BUN15A_2D_DES_Q1000F.asc UOM01_BUN15B_2D_DES_Q10C.asc UOM01_BUN15B_2D_DES_Q10C_EXT.asc UOM01_BUN15B_2D_DES_Q10F.asc UOM01_BUN15B_2D_DES_Q100F.asc UOM01_BUN15B_2D_DES_Q200C.asc UOM01_BUN15B_2D_DES_Q200C_EXT.asc UOM01_BUN15B_2D_DES_Q1000C.asc UOM01_BUN15B_2D_DES_Q1000C_EXT.asc UOM01_BUN15B_2D_DES_Q1000F.asc

*Note - Suffix 'F' denotes fluvial design run, 'C' denotes 'mechanism 1 tidal' (surge) coastal design run.

GIS Deliverables - Hazard

Flood Extent Files (Shapefiles)	Flood Depth Files (Raster)	Water Level and Flows (Shapefiles)
Fluvial N09EXFCD001F0 N09EXFCD010F0 N09EXFCD100F0 Coastal N09EXCCD001F0 N09EXCCD005F0 N09EXCCD100F0 Wave Overtopping N/A	Fluvial N09DPFCD001F0 N09DPFCD010F0 N09DPFCD100F0 Coastal N09DPCCD001F0 N09DPCCD005F0 N09DPCCD100F0 Wave Overtopping N/A	N09NFCDF0
Flood Zone Files (Shapefiles)	**Flood Velocity Files (Raster)**	**Flood Defence Files (Shapefiles)**
N09ZNA_MCDF0 N09ZNB_MCDF0	Fluvial N09VLFCD001F0 N09VLFCD010F0 N09VLFCD100F0 Coastal N09VLCCD001F0 N09VLCCD005F0 N09VLCCD100F0	

GIS Deliverables - Risk

Specific Risk - Inhabitants (Raster)	General Risk - Economic (Shapefiles)	General Risk-Environmental (Shapefiles)
Fluvial n09rifcd100F0 n09rifcd010F0 n09rifcd001F0 Coastal n09riccd100F0 n09riccd005F0 n09riccd001F0		