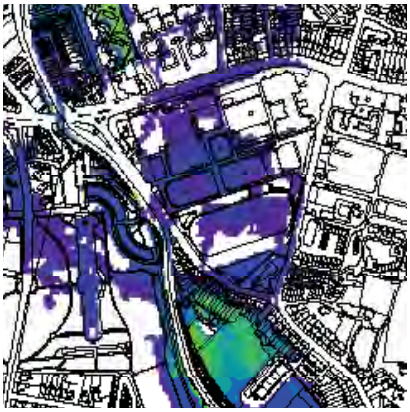
RPS

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

North Western - Neagh Bann CFRAM Study

UoM 01 Hydraulics Report
4.15 Glenties

IBE0700Rp0011



OPW
The Office of Public Works
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Photographs of flooding on cover provided by Rivers Agency

NWNB CFRAM

Study

HA01 Hydraulics Report

Glenties Model

DOCUMENT CONTROL SHEET

Client	OPW
Project Title	NWNB CFRAM Study
Document Title	IBE0700Rp0011_HA01 Hydraulics Report
Model Name	Glenties

Rev.	Version	Author(s)	Reviewed By	Approved By	Issue Date
D01	Draft	M. Houston	I. Bentley	G. Glasgow	06/02/2014
D02	Draft	Various	I. Bentley	G. Glasgow	12/06/2014
F01	Draft Final	J. Murdy	L. Arbuckle	G. Glasgow	14/01/2015
F02	Draft Final	J. Murdy	L. Arbuckle	G. Glasgow	13/08/2015
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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_Final_v2.0	
North Western Neagh Bann CFRAM HA01_06_36 Survey Contract Report	October 2013	IBE0700Rp0007_HA01_06_36 NWNB_CFRAM_Survey Contract Report	1.7, 1.18
North Western Neagh Bann CFRAM Study UoM01 Inception Report	October 2012	IBE0700Rp0002_UoM 01 Inception Report	4.3.2
North Western Neagh Bann CFRAM Study Hydrology Report UoM01	August 2014	IBE0700Rp0006_UoM 01 Hydrology Report	4.17

4 HYDRAULIC MODEL DETAILS

4.15 GLENTIES MODEL

4.15.1 General Hydraulic Model Information

(1) Introduction:

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

The Glenties model represents the lower reaches of the Owenea River and its tributaries, where they flow through Glenties Town in the west of Donegal (refer to Section 4.15.2, Figure 4.15.1). The main Owenea River passes Glenties Town to the south but the Stracashel River and the Gortnamucklagh watercourse flow through the AFA extents, joining the Owenea to the south-west of the town. The Owenea flows into an estuary upstream of Loughros More Bay (Atlantic) approximately 10km to the west of Glenties. The Owenea catchment is a medium sized catchment (126km^2) with a fair mix of forest (23%), pasture (15%) and peat (37%) coverage. The Stracashel catchment (49km^2) has a similar land coverage mix whereas the smaller Gortnamucklagh watercourse is a mixture of pasture (46%) and peat (44%) coverage. The main river channels are fairly flat (S1085 less than 10m/km) whereas the Gortnamucklagh watercourse is steeper (S1085 of 23.98m/km).

The Glenties model is gauged approximately 6km downstream of the AFA extents on the Owenea River. The OPW Clonconwal Ford gauging station (Stn no. 38001) was given a B rating classification under FSU meaning there is confidence in the flows up to around Q_{med}. The adjustment factor at the gauging station, the ratio of the gauged Q_{med} to the Q_{med} from catchment descriptors, is 0.80 suggesting the catchment descriptor equation overestimates the value of Q_{med} in the Owenea catchment. In light of this, ungauged catchment descriptor based estimates have been reduced by 20% on the Owenea and Stracashel Rivers. Ungauged catchment descriptor based estimates on the smaller Gortnamucklagh watercourse have not been adjusted.

All watercourses were modelled using the MIKE suite of software. The HPWs include the Gortnamucklagh River (Modelling Reach ID 0113M), the Stracashel River as it flows through the AFA (ID 0112M, chainage 0 - 5228.89m) and the Stracashel Tributary (ID 0112A). These HPWs were modelled as 1D-2D. The Stracashel River (0112M) is a MPW running from the south western AFA boundary until its confluence with the Owenea at grid reference 181520, 393716. It was therefore modelled in 1D only (chainage 5228.89m - 12925.2m). From this confluence point, the Owenea progresses to the estuary through rural landscape and is also MPW. For surveying and modelling purposes, both the HPW and MPW reaches of the Stracashel River, and the Owenea River are called reach ID 0112M.

The inflow of the Owenea River upstream of its confluence with the Stracashel is represented as a point

source in the model (HEP 38_3822_4_RPS) (*refer to* Figure 4.15.1 and 4.15.2).

(2) Model Reference:	HA01_GLEN17
(3) AFAs included in the model:	Glenties

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

Reach ID	Name
0112M	OWENEA (Stracashel) - The Stracashel joins the Owenea south west of Glenties AFA (Grid ref 181520, 393716)
0112A	STRACASHEL Trib – This tributary joins the Owenea south west of Glenties AFA (Grid ref 181445, 393720)
0113M	GORTNAMUCKLAGH

(5) Software Type (and version):

(a) 1D Domain:	(b) 2D Domain:	(c) Other model elements:
MIKE 11(2011)	MIKE 21 - Rectangular Mesh (2011)	MIKE FLOOD (2011)

4.15.2 Hydraulic Model Schematisation

(1) Map of Model Extents:

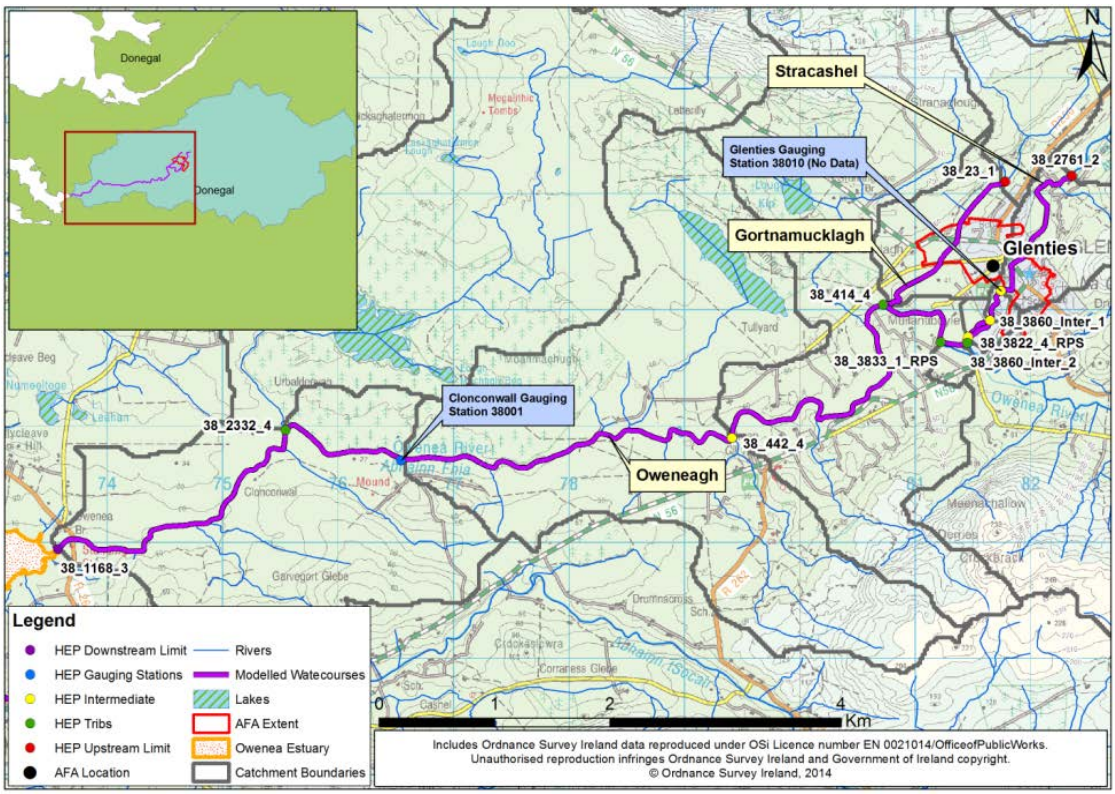


Figure 4.15.1: Map of Model Extents (including the Stracashel and Owenea

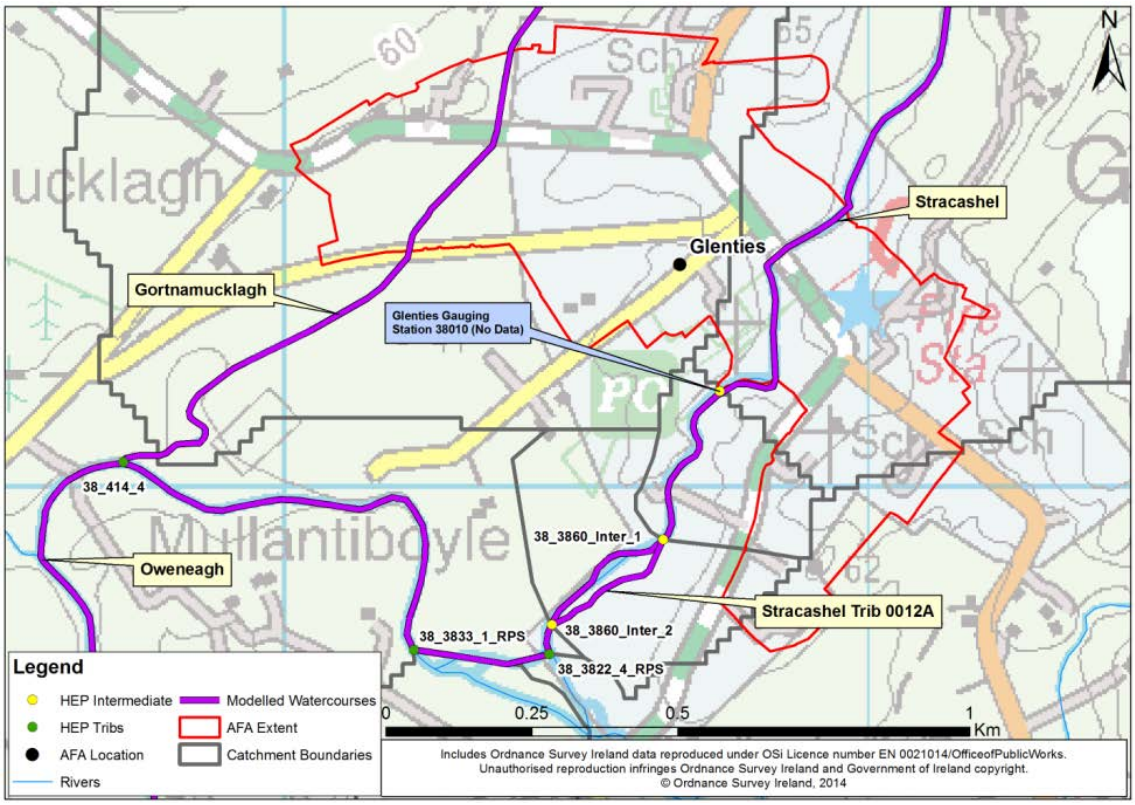


Figure 4.15.2: Map of Model Extents

Figure Figure 4.15.1**: Map of Model Extents (including the Stracashel and Owenea** and Figure 4.15.3**: 2D Domain Model Extents** illustrate the extent of the modelled catchment, river centreline, HEP locations and AFA extents. Figure 4.15.3: **2D Domain Model Extents**provides a closer view of the AFA. There are 2no. Upstream Limit HEPs (38_23_1) and (38_2761_2), relating to the Gortnamucklagh and Stracashel Rivers, respectively. There is 1no. Gauging Station HEP (Stn no. 38001). There are 3no. Tributary HEPs. Points 38_3822_4_RPS, 38_3833_1_RPS represent the inflow of the Owenea River and HEP 38_2332_4 represents inflow from Lough Machugh and Lough Free located to the north of the modelled catchment. There are 5no. Intermediate HEPs including Gauging station 38010 which has no data available and was therefore redefined as an Intermediate HEP.

A rating review was conducted to extend the existing rating curve using hydraulic modelling for Station 38001 (Clonconwal Ford) *refer to* Section 4.15.5(4).

The model flows were checked against the estimated flows at all gauging station and intermediate HEPs. Full flow tables can be found in Appendix A.3.

Full details of hydrology analysis are included in Chapter 4.17 of the Hydrology Report (IBE0700Rp0006_UoM 01_Hydrology Report_F02).

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

River ID	River Name	x	y
0112M	STRACASHEL (HPW/MPW and OWENEA MPW)	181452	393713
0112A	STRACASHEL TRIB.	182353	395152
0113M	GORTNAMUCKLAGH	181778	395104

(3) Total Modelled Watercourse Length:			
(4) 1D Domain only Watercourse Length:	9.5 km (approx)	**(5) 1D-2D Domain Watercourse Length:**	5.6 km (approx)
(6) 2D Domain Mesh Type / Resolution / Area:		Rectangular / 5 metres / 11.2km²	

(7) 2D Domain Model Extent:

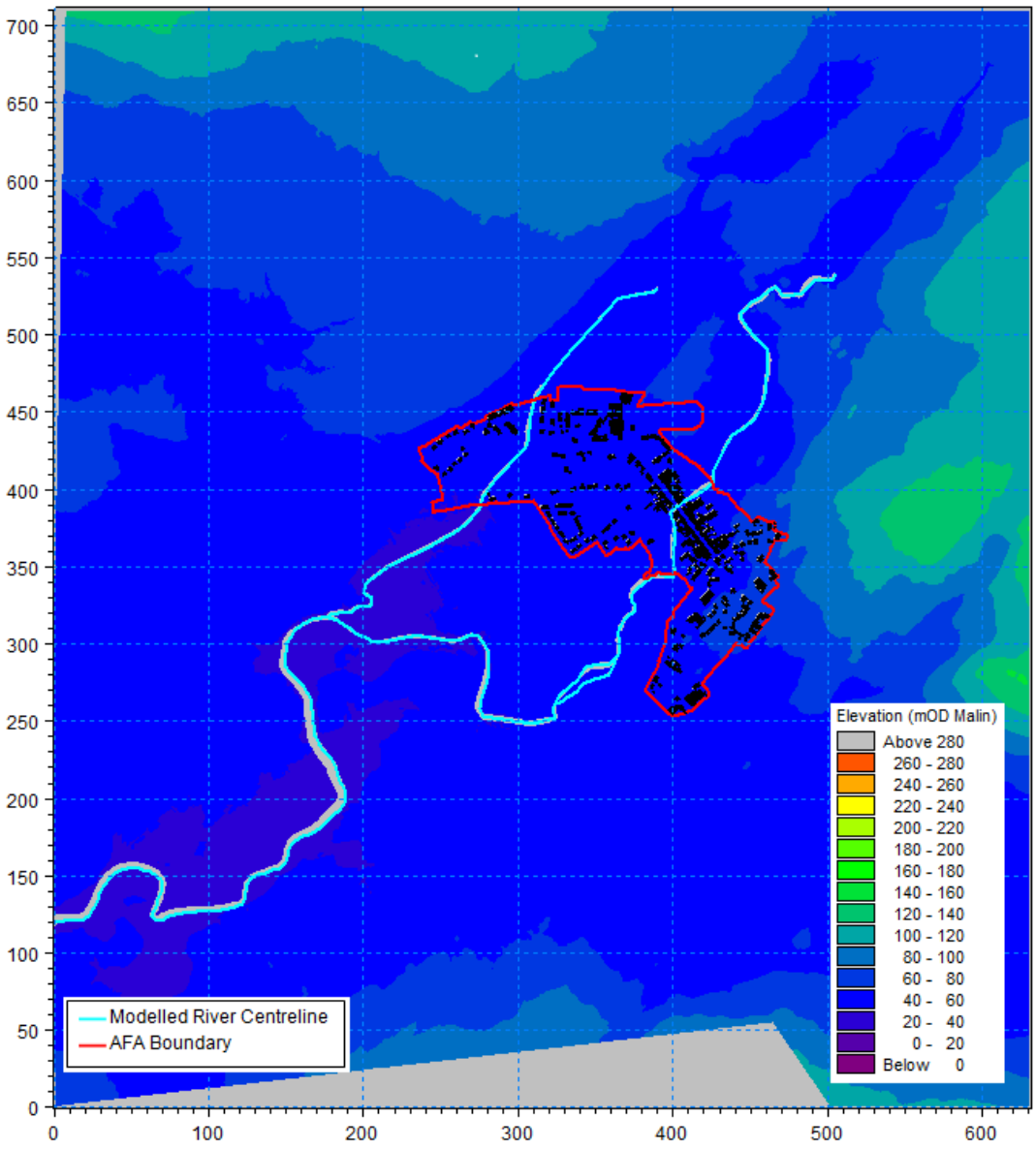
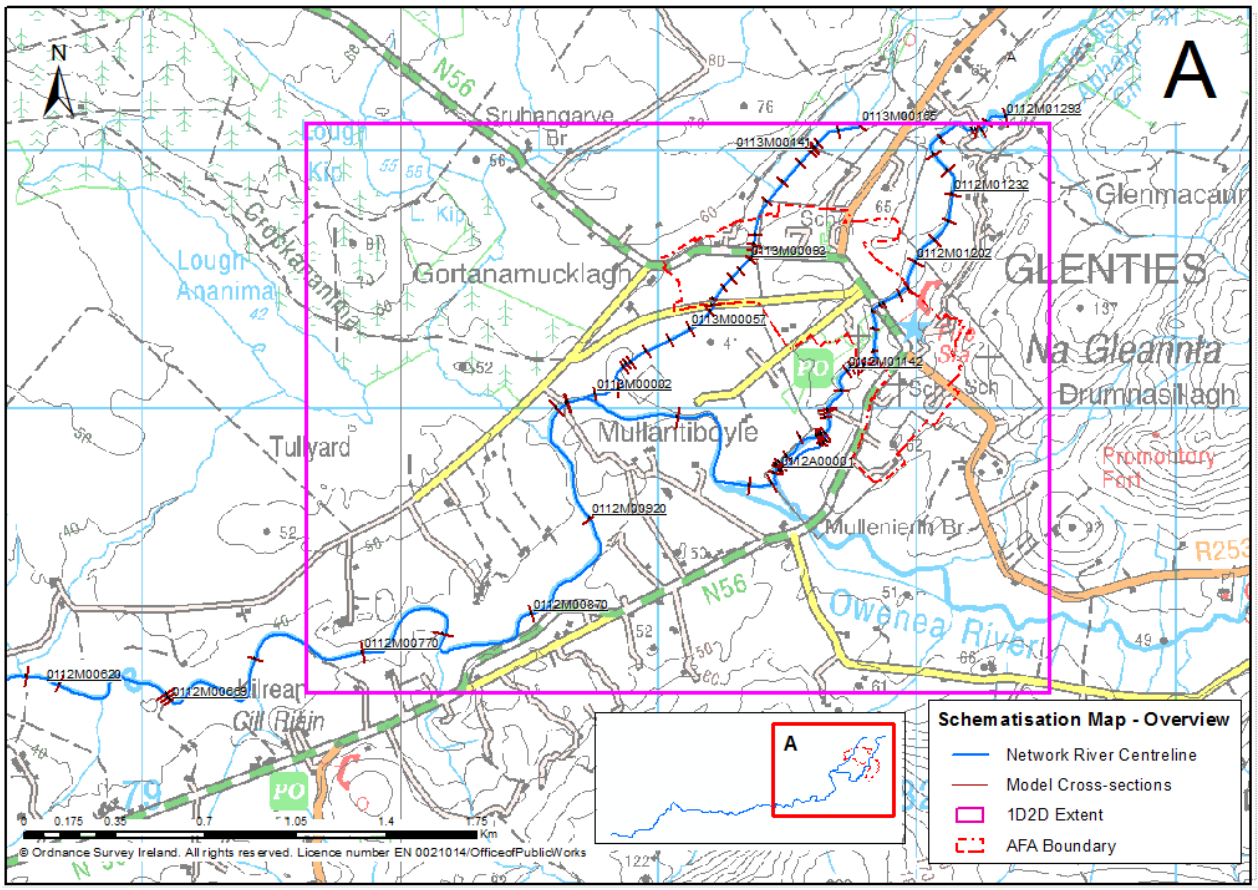


Figure 4.15.3: 2D Domain Model Extents

Figure 4.15.3**: 2D Domain Model Extents** provides an illustration of the modelled extents and the general topography. The spatial extent of the AFA boundary is outlined in red. The reach centrelines are illustrated in light blue which also represents the 1D modelled extent that is within the 2D area. Buildings within the Glenties AFA are illustrated in black. Refer to Chapter 3 for details on representation of buildings in the model.

Figure 4.15.4 shows an overview drawing of the model schematisation. Figure 4.15.5**: Detailed Area of Model Schematisation showing Critical Structures** shows a detailed view. The overview diagram illustrates 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 view (Figure 4.15.5) is provided where there is the most significant risk of flooding. This includes the surveyed cross-section locations, AFA boundary and river centreline. It also shows the location of the critical structures as

discussed in Section 4.15.3(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.



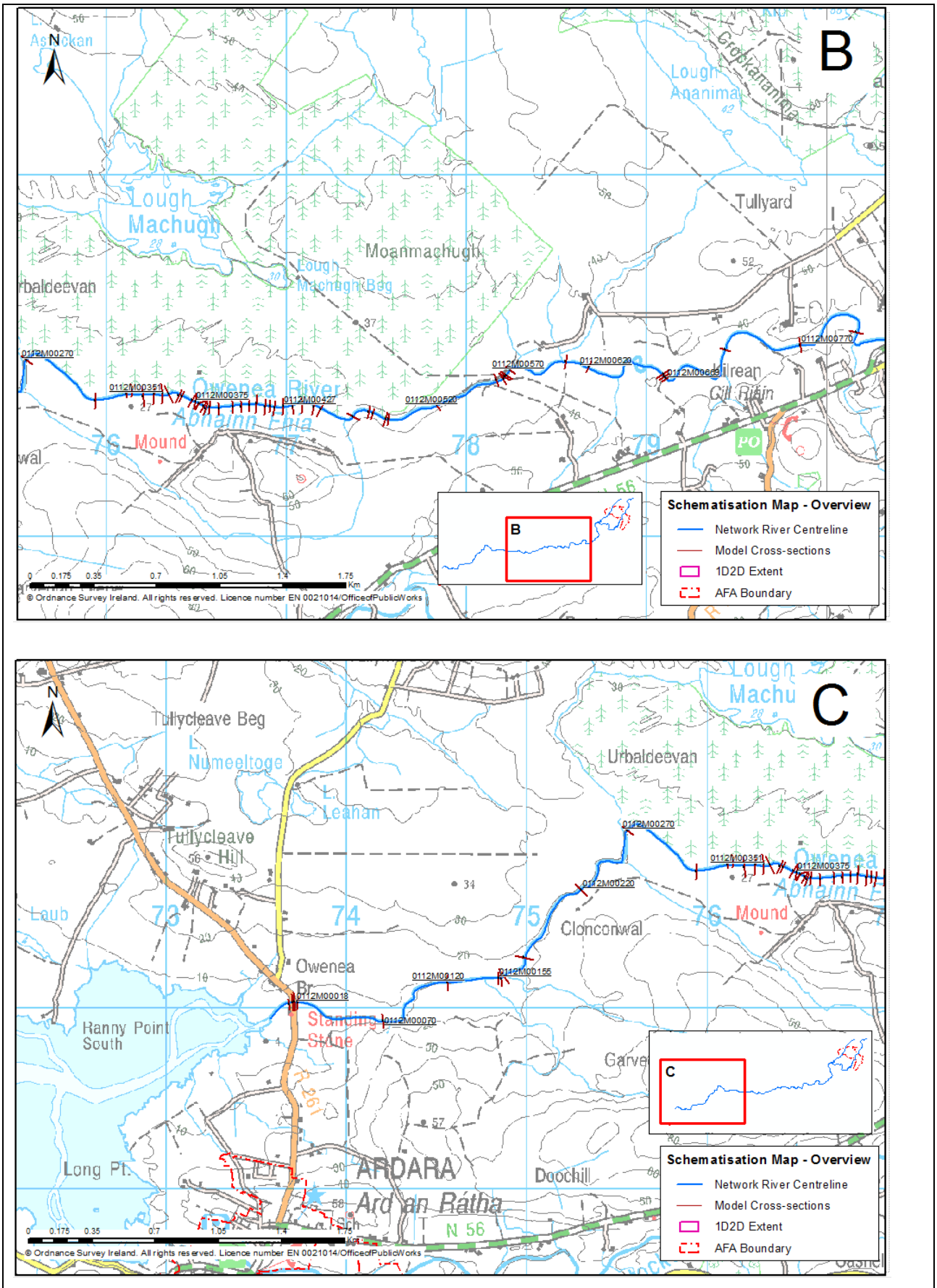


Figure 4.15.4: Model Schematisation Overview (A) Showing Rivers Gorthnamucklagh and Stracashel. (B) River Owenea (c) River Owenea to Ranny Point South

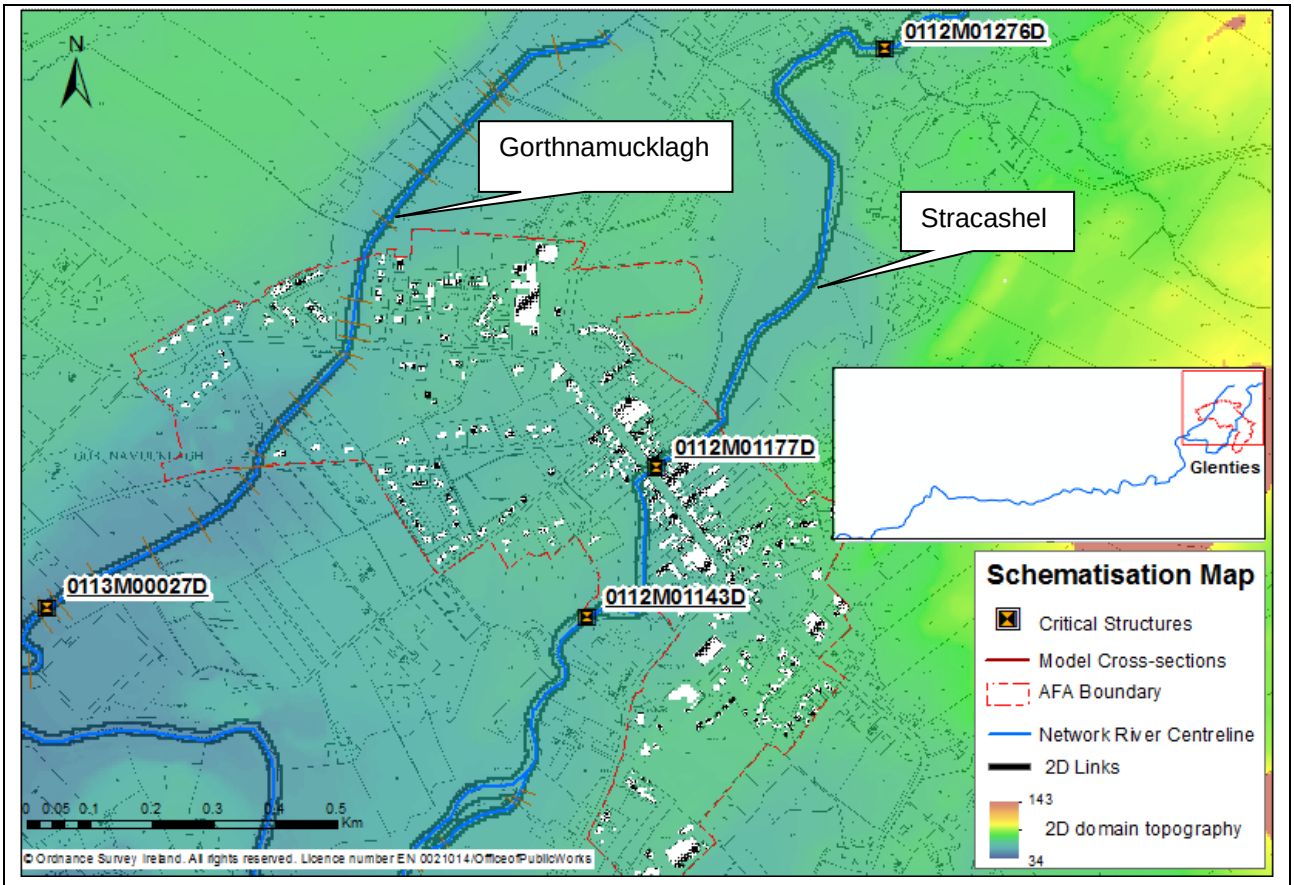


Figure 4.15.5: Detailed Area of Model Schematisation showing Critical Structures *

** 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.*

(8) Survey Information

(a) Survey Folder Structure:

First Level Folder	Second Level Folder	Third Level Folder
Murphy_NW1_M17_WP1_0112M_V1_130315 Where: Murphy – Surveyor Name NW1 – North Western –Neagh Bann CFRAM Study Area, Hydrometric Area 1 M17 – Model Number 17 WP1 – Work Package 1 0112M– River Reference V1 - Version 130315 – Date Issued (15th Mar 2013)	Ascii	
	GIS	Flood Plane Photos and Shapefiles
		Structure Register
		Surveyed Cross Section Lines
		Watercourse Register
	Other	FP Photos
	Photos *(Naming convention is in the format of Cross-Section*	Surveyed Cross Section Lines

	ID and orientation - upstream, downstream, left bank or right bank)	

(b) Survey Folder References:

Reach ID	**Name**	**File Ref.**
0112M	OWNENEA / STRACASHEL	Murphy_NW1_M17_WP1_0112M_V1_130315 Murphy_NW1_M17_WP5A4_0112M_V1_130410 Murphy_NW1_M17_WP5A5_0112M_V1_130410 Murphy_NW1_M17_WP5A6_0112M_V1_130410
0112A	STRACASHEL TRIB.	Murphy_NW1_M17_WP5A6_0112A_V1_130719
0113M	GORTNAMUCKLAGH	Murphy_NW1_M17_WP5_0113M_V1_130410

(9) Survey Issues:

No survey issues.

4.15.3 Hydraulic Model Construction

(1) 1D Structures (in-channel along modelled watercourses):	*See* Appendix A.1 Number of Bridges and Culverts: 18 Number of Weirs: 2 Number of Abandoned Structures (Other): 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 is included in Chapter 3.3.4.

The location of critical structures included in the model is presented in **Figure 4.15.5**. Details of these structures are also presented in Appendix A.1 and discussed as follows.

Bridge structure 0112M01276D (Figure 4.15.6, chainage 155.16m) is located upstream of the River Stracashel (0112M)Figure **4.15.6: Structure 0112M01276D (chainage 155.16)** contributes to flooding upstream during ≥1%AEP fluvial events. This is an old railway bridge that restricts flow during 1% AEP fluvial event scenarios and greater. Flooding mainly occurs on the right bank of this structure, flooding agricultural fields

Figure 4.15.6: Structure 0112M01276D (chainage 155.16)

Figure 4.15.7 is an image of 0113M00027D (chainage 1371.525) which is located on the River Gortnamucklagh. This structure located close to the confluence between the Gorthnamacuklagh River (0113M) and the Owenea River (0112M). This structure becomes submerged during ≥1%AEP fluvial events. The river initially flows out of bank upstream of this structure with flooding located mainly on the left bank. As the River Stracashel (0112M) floods, the lower section of this reach experiences a second episode of flooding.

Figure 4.15.7: Structure 0113M00027D (chainage 1371.525)

Figure 4.15.8: **Structure 0112M01177D (chainage 1154.81)**shows structure 0112M1177D (chainage 1154.81); this single arched structure is a road bridge, which allows the N56 to cross over the Stracashel River (0112M). During ≥1%AEP fluvial events flood water backs up behind this structure contributing to flooding upstream (between chainages 703m and 1059m). Flooding mainly occurs on the left bank (SE side of the River) and the rears of several properties are affected by the occurrence of ≥1%AEP fluvial events.

Figure 4.15.8: Structure 0112M01177D (chainage 1154.81)

Figure 4.15.9: **Footbridge 0112M01143D (chainage 1491.93m)** shows a pedestrian foot bridge (0112M001143D) over the River Stracashel (0112M). This footbridge contributes to flooding upstream by restricting flow due to lack of capacity and debris accumulation. This causes flooding of several properties upstream during all modelled % AEP fluvial events.

Figure 4.15.9: Footbridge 0112M01143D (chainage 1491.93m)

(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:

Type	Watercourse	Bank	Model Start Chainage (approx.)	Model End Chainage (approx.)
No formal or informal defences.				

(5) Model Boundaries - Inflows:

Full details of the flow estimates are provided in the Hydrology Report (IBE0700Rp0006_UoM01 Hydrology Report_F01 - Section 4.17 and Appendix D). The boundary conditions implemented in the model are shown below in Table 4.15.10: **Model Boundary Conditions**

Table 4.15.10: Model Boundary Conditions

	Boundary Description	Boundary Type	Branch Name	Chainage	Chainage	Gate ID	Boundary ID
1	Open	Inflow	RIVER_GORTNAMUCKLA	0	0		38_23_1
2	Distributed Source	Inflow	RIVER_GORTNAMUCKLA	0	1610.69		Top-up flow between 38_23_1 & 38_414_4
3	Open	Inflow	Stracashel River	0	0		38_2761_2
4	Distributed Source	Inflow	Stracashel River	0	1491.335		Top up 38_2761_2 & 38010
5	Distributed Source	Inflow	Stracashel River	1491.335	1795.053		Top-up flow between 38010 & 38_3860_Inter_1
6	Distributed Source	Inflow	Stracashel River	1795.053	2045.4		Top-up flow between 38_3860_Inter_1 & 38_3860_Inter_2
7	Point Source	Inflow	Stracashel River	2088.424	0		38_3822_4_RPS Owenea River point inflow_0112M
8	Point Source	Inflow	Stracashel River	2322.69	0		38_3833_1_RPS Owenea River point inflow_0112M
9	Distributed Source	Inflow	Stracashel River	2045.4	5858		Top-up flow between 38_3860_Inter_2 & 38_442_4
10	Distributed Source	Inflow	Stracashel River	5858	9085.867		Top-up flow between 38_442_4 & 38001
11	Point Source	Inflow	Stracashel River	10220.049	0		38_2332_4 Trib3_0112M
12	Distributed Source	Inflow	Stracashel River	9085.867	12783.169		Top-up flow between 38001 & 38_1168_3
13	Open	Q-h	Stracashel River	12925.195	0		38_1168_3

Details on inflow hydrograph generation are also outlined in IBE0700Rp0006_UoM01 Hydrology Report_F01. The Upstream HEP inflow hydrographs for the Gorthnamucklagh (HEP 38_23_1) and the Stracashel River (HEP 38_2671_2) are shown in Figure 4.15.10 (0.1% AEP fluvial event).

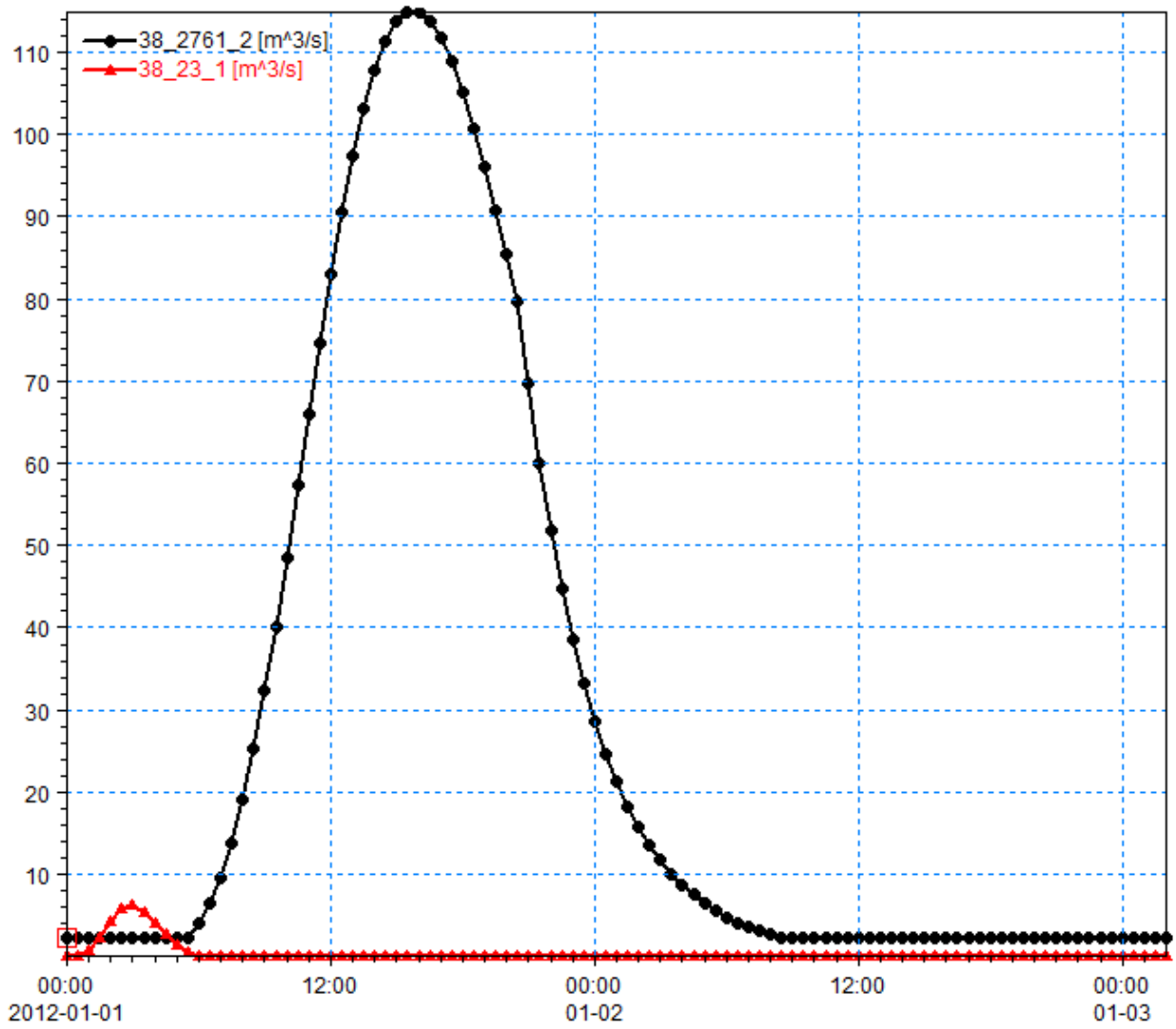


Figure 4.15.10: Upstream HEP Hydrographs - 0.1% AEP Fluvial Design Event

(6) Model Boundaries – Downstream Conditions:	Q/h relationship boundary was applied at the downstream model extent of the Stracashel/ Owenea (chainage 12925m). This was automatically generated by MIKE11 software and is presented in Figure 4.15.11: **Q-h Relation of the d/s boundary (chainage 12925m) generated by MIKE11**

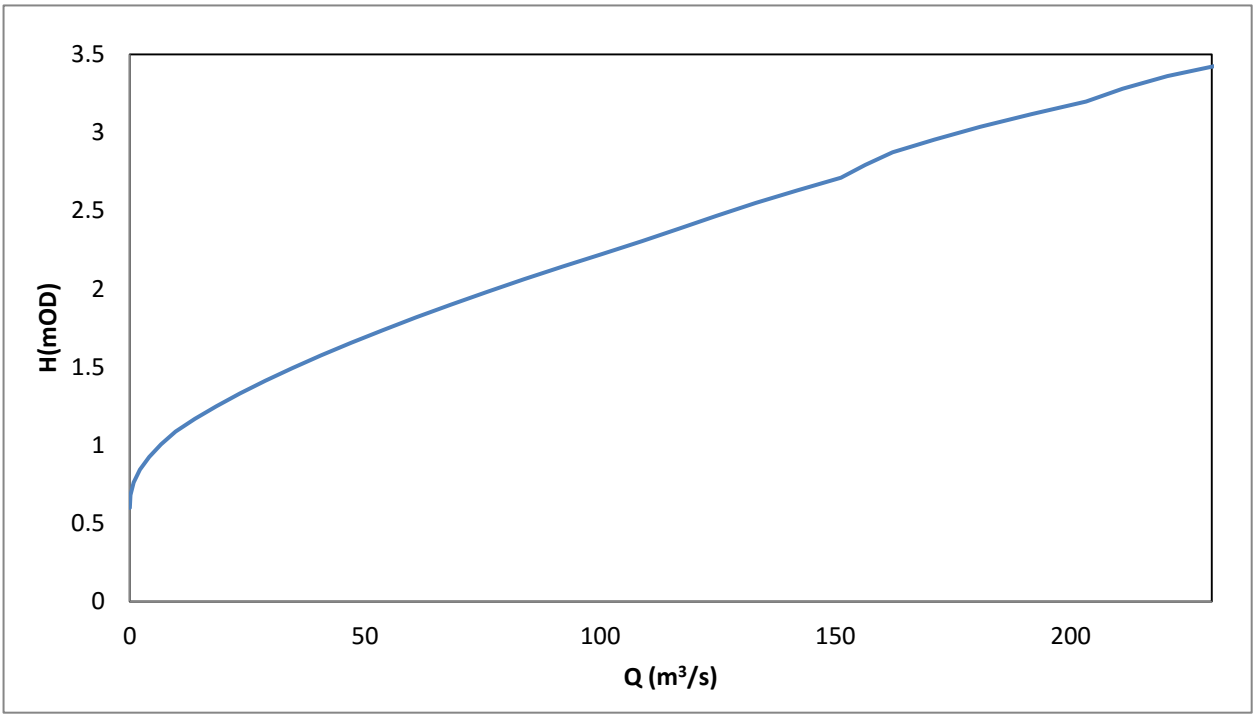


Figure 4.15.11: Q-h Relation of the d/s boundary (chainage 12925m) generated by MIKE11

(7) Model Roughness: (see Chapter 3.6.1 'Roughness Coefficients')		
(a) In-Bank (1D Domain)	Minimum 'n' value: 0.035	Maximum 'n' value: 0.060
(b) MPW Out-of-Bank (1D)	Minimum 'n' value: N/A	Maximum 'n' value: N/A
(c) MPW/HPW Out-of-Bank (2D)	Minimum 'n' value: 0.034 (Inverse of Manning's 'M')	Maximum 'n' value: 0.058 (Inverse of Manning's 'M')

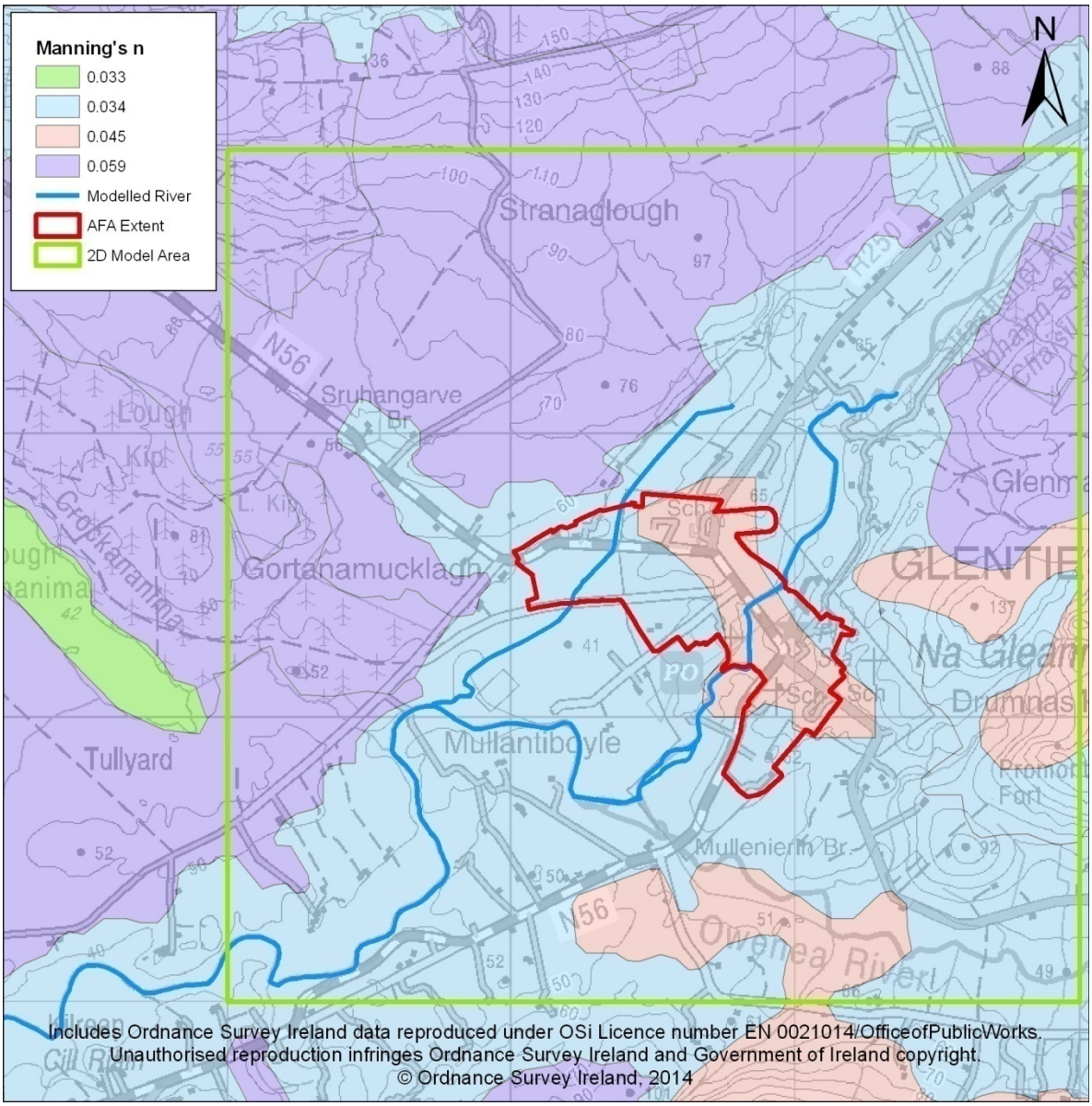


Figure 4.15.12: Map of 2D Roughness (Manning's n)

Figure 4.15.12 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.

(d) Examples of In-Bank Roughness Coefficients

Figure 4.15.13: *Gorthnamucklagh - 0113M00165-UP*

Manning's n = 0.050

Clean, winding stream with some pools and shoals, and some weeds and stones.

Figure 4.15.14: *Stracashel River 0112M00449_UP*

Manning's n =0.045

Clean, winding stream with some pools and shoals, and some weeds and stones.

Figure 4.15.15: *Stracashel River - 0112M00432_UP*

Manning's n = 0.035

Clean, winding stream with stones and weeds

Figure 4.15.16: *Stracashel River 0112M00338_DN*

Manning's n=0.035

Clean, winding stream with stones and weeds

4.15.4 Sensitivity Analysis

To be completed for final version of report (F02).

4.15.5 Hydraulic Model Calibration and Verification

(1) Key Historical Floods (From IBE0700Rp0002_UoM01 Inception Report_F02 unless otherwise specified):	
(a) **Jan 2012**	The review process indicated that flooding occurred in Glenties on 4th January 2012 because of heavy rainfall. A website (www.donegaldaily.com) reported that many roads were flooded around County Donegal with Gardaí issuing warnings about several areas including Glenties. Further details regarding flood extents or flows are unavailable. No information was recorded by the Clonconwal gauging station on the Owenea River for this event. Met Eireann's Monthly Weather Bulletin for January 2012 states that 86.1mm of rainfall was recorded at climatological station 'Glenties Hatchery' between 1st and 10th January 2012 http://www.met.ie/climate/monthly-weather-reports.asp. This source of evidence provides insufficient temporal detail to estimate a rainfall frequency for the 4th January event using the FSU DDF model. Modelled flood extents relating to all the % AEP scenarios illustrate that several roads to the south-west of the Glenties AFA are prone to flooding. Figure 4.15.17 shows that a section of the N56 that runs adjacent to the Owenea River floods during a 0.1% AEP fluvial event. The model also indicates that several minor roads in and around Mullantiboyle flood during the 10% AEP event. OPW Flood Hazard Mapping - Phase 1 report (2007) states that the River Owenea will overflow its banks every year after heavy rain and the road is liable to flooding. Although this report cannot be used to calibrate the model it is useful in that it has provided useful spatial references, particularly the mention of the roads that are prone to frequent flooding.

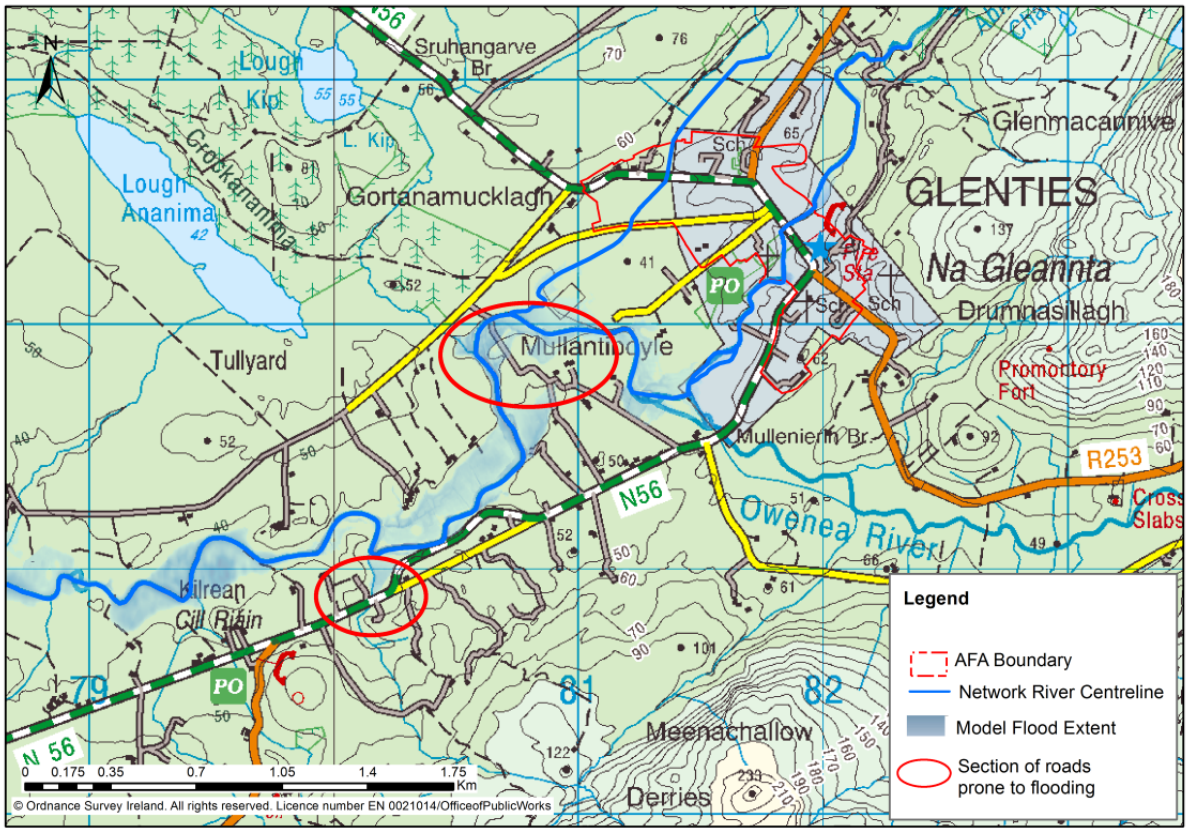


Figure 4.15.17: Model Results Showing Road Flooding including the N56 and Mullantiboyle

(b) **Dec 2011**	An internet search indicated that flooding occurred in Glenties, on 30th December 2011 following heavy rain. It was found that flooded roads were reported www.donegaldaily.com. However, no further details of the source of flooding or the extents have been reported. Information was found detailing how flooding occurred in Glenties on 13th December 2011 following heavy rain, which subsequently led to many roads becoming impassable. Although no exact spatial reference has been given in the above mentioned reports, it has been deduced that the areas where the roads that are most likely to be affected by a flooding event are those that have already been highlighted in Figure 4.15.17. Records at the Clonconwall Ford Hydrometric Station (38001) only extend to 27/10/2011. Other sources of information were also examined, including the Glenties Hatchery Climatological station. During the month of December 2011 (11th-20th), this recorded a total rainfall of 121.2mm. During the end of the month (11th-31st), 108.6mm of rain was recorded (http://www.met.ie/climate/MonthlyWeather/clim-2011-Dec.pdf) which is less than the previous record period. More detailed temporal resolution is required to understand the nature of the rainfall that caused flooding in this case, which is likely to have been of a short duration and high intensity. It is not

	enough detail to estimate a rainfall frequency using the FSU DDF model.
(c) **Oct 1989**	Information was found on www.floodmaps.ie during the historical review process that has indicated that flooding occurred in Glenties on 28th October 1989. It was reported that the flooding of roads and farms was extensive in the Glenties area. Furthermore, roads from Letterkenny to Dungloe and Glenties were closed for a period. During this event the Clonconwal Ford Gauge (38001) recorded a peak water level of 29.09m (OD Poolbeg). Due to gauge failure, the actual peak level has been estimated – no further information has been given as to how this peak was estimated or why the gauge failed on this occasion (*see* http://opw.hydronet.com/default.aspx?page=6&appid=169&lang=2). The estimated peak relating to this event was 80.11.m^3/s. It is estimated that this fluvial event equates to a 15% AEP Glenties Hatchery daily rainfall station recorded 82mm of rain over a 24 hour period (27th October 1989). Using this rainfall duration (assumed 24 hours since higher temporal resolution is not available) – and depth information a rainfall frequency of 4.3% AEP was estimated using the FSU DDF model.

Summary of Calibration and Verification

Several historical flooding events have been presented, these occurred during the autumn/winter of 2012, 2011 and 1989. In summary, these events have generally described how roads (located outside the Glenties AFA); were flooded following episodes of heavy rainfall. The October 1989 event mentioned 'farms flooded' with no further detail. Generalised flooding references are mentioned relating to the high frequency of road flooding. Using evidence provided by OPW Flood Hazard Mapping (*see* Section 4.15.5(5)) it is deduced that the main area of road flooding is likely to be Mullantiboyle. The model results show that the roads in and around the Mullantiboyle area flood during events of 10%AEP or greater in magnitude (*see* Figure 4.15.17). Another road that is frequently flooded is the R232 (Glenties Road); situated to the east of Glenties town. This road has a long historical record of flooding. Interestingly, a traditional dance reel exists simply known as the 'Flooded Road to the Glenties'. However, it should be noted that the section of the Owenea River near the R232 flows through a predominately agricultural area and has been incorporated into the model as a HEP point source / tributary (HEP 38_3822_4_RPS). This section of the Owenea River was not modelled as a MPW, since a MPW is defined as a watercourse between an AFA and the sea.

The 2012, 2011 and 1989 flooding events at Glenties are not well documented. Information has been pieced together using several sources to provide some qualitative support for the model. The rating curve and spot gaugings at the Clonconwal Gauging station (38001) were used to calibrate the model at this location. There is a good correlation between the existing OPW rating curve and the rating curve produced by the model, this is described in Section 4.15.4(4)(b).

Daily and hourly rainfall information (where available) was also used to estimate a rainfall frequency using the FSU DDF model. The October 1989 flooding event had a rainfall frequency of 4.3% AEP based on daily data from Glenties hatchery and the FSU DDF model. No recent localised or high frequency rainfall is available. The earlier events lack detailed geographical descriptions of flooding extent.

The largest peak flow recorded by the Clonconwal Ford Gauge (38001) was 113.38 m^3/s (11/09/1992). This equates to a 1% AEP. There are no records of flooding relating to this event to enable model calibration.

Model flows were checked against the estimated flows at HEP check points where possible to ensure the model is well anchored to the hydrological estimates. Full flow tables and a detailed explanation of differences identified are in Appendix A.3.

A mass balance check has been carried out on the model to make sure that the total volume of water entering and leaving the model at the upstream and downstream boundaries balances the quantity of water remaining in the model domain at the end of a simulation. Refer to Chapter 3.11 for details of acceptable limits. Throughout the model construction and development stage results were frequently reviewed to identify the occurrence of high velocities and the Courant number did not exceed 1. Results produced a mass balance difference of -1.63% which is within acceptable limits. This mass balance assessment was only applied to the 1% AEP fluvial model which is reasonable since the identification of a mass balance issue for the 1% AEP event would also apply for all % AEP design runs. Since the mass balance is well within acceptable limits for the 1% AEP event this is not a consideration.

No significant model instabilities have been identified. To illustrate this, a screen shot of a 'discharge long-section plot' relating to all the modelled rivers at their peak flow is presented in Appendix A.2.

(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:

Defence Reference	Type	Watercourse	Bank	Modelled Standard of Protection (AEP)
N/A				

(4) Gauging Stations:

There are two gauging stations within the Glenties model. These are 38001 (Clonconwal Ford) and 38010 (Glenties).

(a) 38010 (Glenties) (located at Irish Grid G816939) is located within the Glenties AFA. Donegal County Council has maintained this staff gauge. No records are available.

(b) 38001 (Clonconwal Ford) is an OPW gauge (located at Irish Grid G763927). (Ref. IBE0700Rp0006_UoM 01 Hydrology Report_F01). This gauge is situated on the Owenea River

downstream 6.5km (approx) from the Glenties AFA. This active gauge has water level and flow measurements covering 39 years (October 1972 to October 2011). This gauge has FSU 'B' rating meaning that there is a confidence in flows up to Q_{med}. It was rebuilt around 1992 - the spot gaugings have been separated into pre and post 1992 recording..

Figure 4.15.18**: A Comparison between RPS Model and Exiting Rating Curve** below shows the result of a rating review at the Clonconwal Ford Gauge.

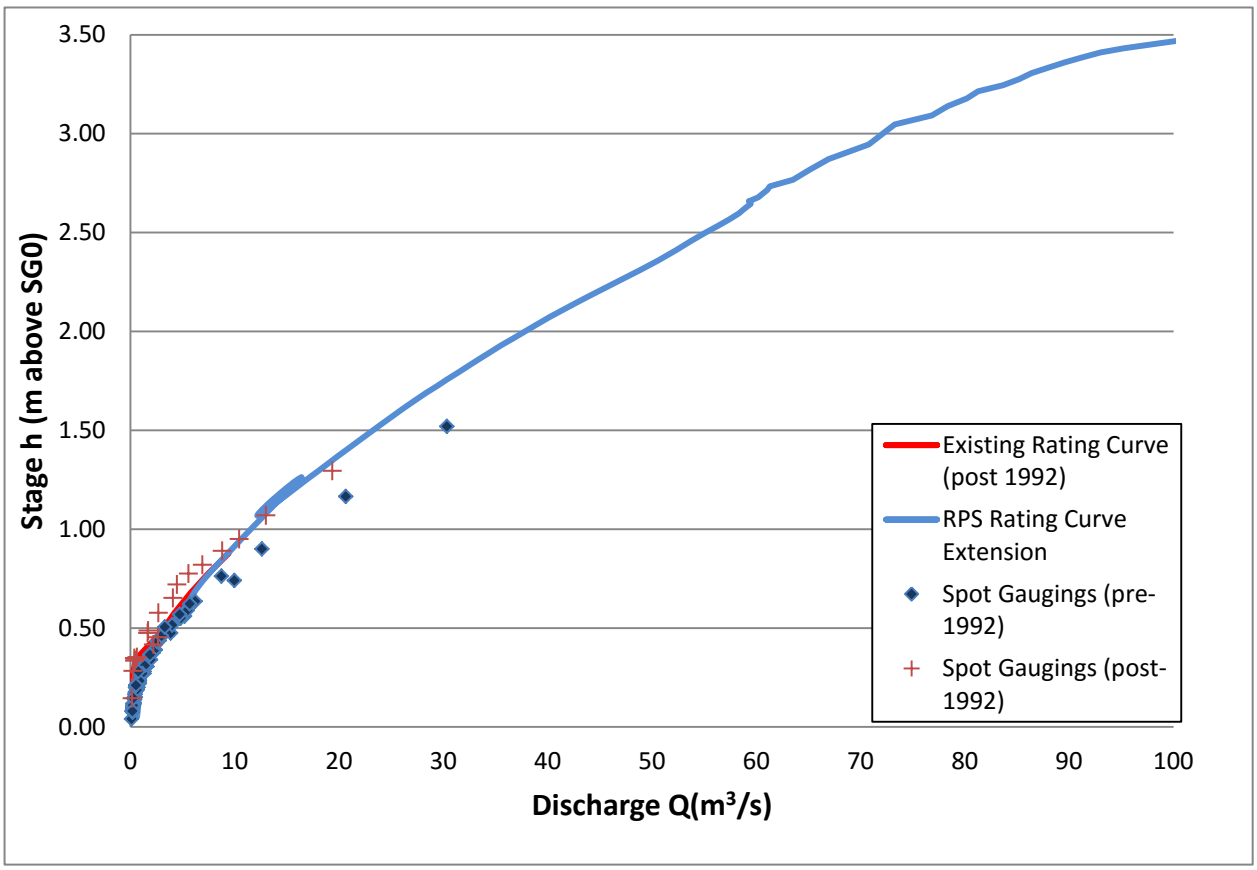


Figure 4.15.18: A Comparison between RPS Model and Exiting Rating Curve

Attempts at calibration to the low flow spot gaugings and the existing rating curve resulted in a reasonable agreement below a stage height of 0.5m OD Malin. Calibration at flows greater than 0.5m could not be achieved with the available survey data within the bounds of realistic roughness parameters. Calibration above low flows is much improved with the modelled curve providing a reasonable fit to the post 1992 spot gaugings (within 200mm to all spot gaugings). Given that the gauging station is significantly downstream of the AFA and that calibration above low flows is reasonable it is not thought that the low flow performance will have a significant impact on the flood flow performance of the model. Good calibration to the highest spot gaugings has been achieved (post-1992).

It has been shown that the best fit rating curve was achieved with a Manning's n value of 0.055. The head loss factor relating to the weir located at cross-section 0112M00377W was adjusted; where the positive flow, 'Inflow' was increased from its default value of 0.5 to 0.6 and the 'Free Overflow' was increased from its default value of 1 to 1.2.

(5) Other Information:

Flooding in Glenties Town has been briefly mentioned in an 'OPW West Region Report' relating to January 1995. It stated that the river flowing through Glenties Town has flooded in the past causing damage to houses. The exact location and extent has not been provided. Some evidence of the spatial extent of flooding in the town was briefly mentioned in site assessment report (http://nwnb.cfram.com/wp-content/uploads/2011/10/2011s5232-Site-Assessment-Donegal_PT3_web.pdf). It describes how a back-garden of a private residence adjacent to the Court House floods once every few years. Figure 4.15.19: is a comparison of the modelled flood extents (10% AEP Fluvial) and the position of the 'court house'.

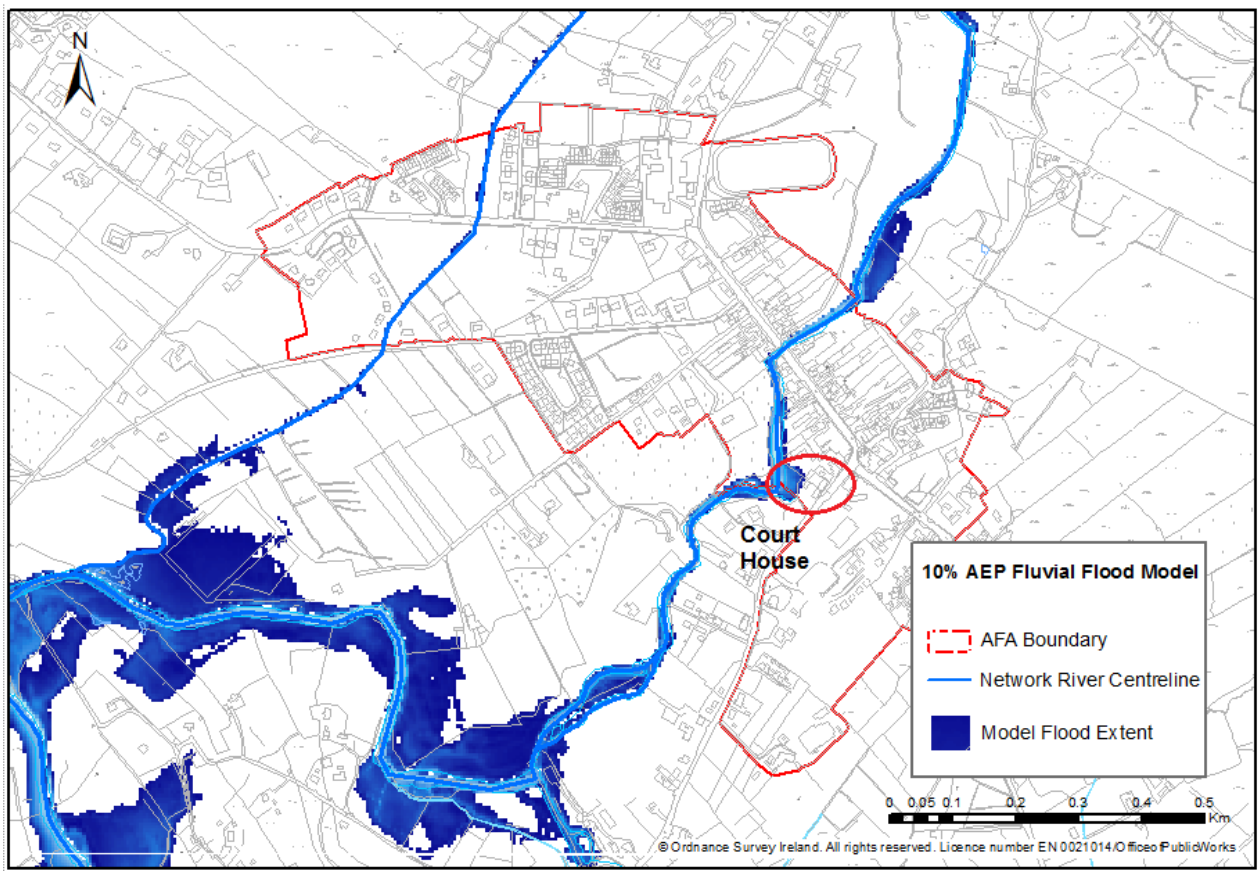


Figure 4.15.19: 10% AEP Modelled Flood Extent

This evidence provides a reasonable although limited verification of the modelled flood extent.

4.15.6 Hydraulic Model Assumptions, Limitations and Handover Notes

(1) Hydraulic Model Assumptions:

(a.) In order to improve model stability at cross-section 011200972D, the soffit levels of this bridge have been straightened and levelled, this adjustment was conducted so that no significant alterations to the existing model parameters are required.

(b.) A relict and abandoned sluice gate located at cross-section 0112A00022 was not included in the

model, since it is no longer operational. This section of the river was treated as 'Open' rather than 'Closed Irregular'. The presence of this structure owes its existence to the former salmon hatchery located within a close proximity. The construction of this structure has been mentioned in http://www.jstor.org/discover/10.2307/25525403?uid=3738232&uid=2129&uid=2&uid=70&uid=4&sid=21103275890327 this document was produced in 1924. As evident from its current poor condition (see photograph 0112A00022_DN), it can be concluded that this sluice gate is no longer operational.

(c.) At cross-section 0112M01158 *(see photo* 0112M01158_DN) there is a concrete structure that crosses over the river. It is likely that this structure may contain or support a utility pipe. For modelling purposes this undefined structure was treated in a similar manner to a bridge or irregular culvert.

(d.) The invert levels at structure 0112M01143D were not collected by the surveyors due to health and safety concerns. However, this structure was included in the model as it was surveyed, no estimated depths were included.

(2) Hydraulic Model Limitations and Parameters:

Hydraulic Model Parameters:

MIKE 11	
Timestep (seconds)	2
Wave Approximation	High Order Fully Dynamic
Delta	0.80
MIKE 21	
Timestep (seconds)	2
Drying / Flooding / Wetting depths (metres)	0.02/0.03
Eddy Viscosity (and type)	0.025 Constant eddy formulation varying in space based on equation $k*x^2/t$, where k=0.02
MIKE FLOOD	
Link Exponential Smoothing Factor (where non-default value used)	
Lateral Length Depth Tolerance (m) (where non-default value used)	All default (0.1)

Sensitivity testing to be completed for final version.

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

(a) Historical reports have provided an indication of the possible flooding mechanism, whereby following periods of heavy rainfall this area is susceptible to flooding.

(b) Upstream on the Strachashel River, the presence of a old railway bridge 0112M01276D (chainage 155.16) may hold back flood waters during ≥1% AEP fluvial events, flooding surrounding agricultural fields. Downstream of this bridge the waters are restricted to the river channel due to the presence of high embankments. Further downstream, before entering the Glenties AFA boundary the river floods in an area of parkland. The extent of flooding expands into the AFA following a 0.1%AEP fluvial event, flooding the grounds of commercial and residential buildings, within a close proximity to the Stracashel River. At the back of the Courthouse in Glenties, the River Stracashel meanders, at this point the river floods for all model AEP% fluvial events.

(c) When the Stracashel River merges with the Owenea River a considerable amount of flooding occurred at all modelled %AEP events. The river meanders along this stretch and is adjoined with the Gorthnamucklagh River. During flooding events, the presence of the structure 0113M00027D (chainage 1366.53) restricts flow back up this river during a 10% AEP event. During larger events (≥10%) the presences of the road close to structure 0113M00070D (chainage 959.06) acts as a boundary to this flooding extent.

(d) After the Owenea River is adjoined with the Gorthnamucklagh River, the river meanders, during all modelled %AEP scenarios, the river floods out into an area known as Mullantiboyle. Historical OS maps have labelled the Mullantiboyle as an area 'liable to floods'. The main usage of this area is clearly for pasture. The presence of an old railway bridge (0112M01276D chainage 155.16) may restrict flow at this point delaying the rate at which the area upstream of this location is drained.

(e) A 5 x 5 m mesh was used in 2D modelling, even though 2 m and 10 m resolution LiDAR data was available. It is considered that the 5 m resolution is best suited for modelling purposes, e.g. reducing run times while still maintaining sufficient detail of the modelled area and floodplain. It is recognised that some detail relating to Glenties may have been of too small resolution to be 'picked up' by LiDAR information e.g. fences, walls, paths and minor roads. Therefore, it is recognised that complex hydraulic processes of a finer resolution may not be represented in this model.

(f) Sensitivity testing to be completed for final version.

(4) Hydraulic Model Deliverables:

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

(5) Quality Assurance:

Model Constructed by:	Joanne Murdy
Model Reviewed by:	Lorraine Ardbuckle
Model Approved by:	Malcolm Brian

APPENDIX A.1 – MODELLED STRUCTURES

Structure Details – Bridges *(D) and Culverts #(I)								
RIVER BRANCH	**CHAINAGE (m)**	**ID****	**LENGTH (m)**	**OPENING SHAPE**	**HEIGHT (m)**	**WIDTH (m)**	**SPRING HEIGHT FROM INVERT (m)**	**MANNING'S n**
STRACASHEL RIVER	155.16	0112M01276D	3.83	2xirregular	56.97, 56.86	1.65, 4.19	N/A	0.015
STRACASHEL RIVER	1154.81	0112M01177D	18.97	1xarch	49.95	7.23	4.995	0.015
STRACASHEL RIVER	1491.93	0112M01143D	1.2	2xirregular	46.14, 46.07	5.31, 5.46	N/A	0.017
STRACASHEL RIVER	1705.52	0112M01122D	2.92	3xirregular	44.64, 44.64, 44.53	4.93, 5.57, 2.93	N/A	0.017
STRACASHEL RIVER	2025.83	0112M1088D	1.3	1xIrregular	42.17	11.4	N/A	0.017
STRACASHEL RIVER	3209.29	0112M00972D	3.26	2xIrregular	40.05, 39.52	5.63, 8.26	N/A	0.013
STRACASHEL RIVER	6249.75	0112M00667D	1.17	3xIrregular	35.33, 35.29, 35.25	2.77, 8.27, 8.32	N/A	0.02
STRACASHEL RIVER	7321.01	0112M00561D	8.14	1xIrregular	32.15	21.93	N/A	0.02
STRACASHEL RIVER	8027.69	0112M00488D	2.18	2xIrregular	29.55, 29.57	7.01, 7.04	N/A	0.013
STRACASHEL RIVER	8127.27	0112M00478D	1.37	1xIrregular	28.98	21.55	N/A	0.017
STRACASHEL RIVER	9101.32	0112M00380D	1	2xIrregular	12.42, 12.32	3.61, 10.14	N/A	0.017
STRACASHEL RIVER	11434.84	0112M00157D	1.2	2xArch	12.32, 12.32	6.61, 10.14	N/A	0.017
STRACASHEL RIVER	12758.71	0112M00016E	7.25	5xArch	4.78, 5.66,	2.47, 4.97,	3.104, 4.232,	0.02

Structure Details – Bridges *(D) and Culverts #(I)								
RIVER BRANCH	**CHAINAGE (m)**	**ID****	**LENGTH (m)**	**OPENING SHAPE**	**HEIGHT (m)**	**WIDTH (m)**	**SPRING HEIGHT FROM INVERT (m)**	**MANNING'S n**
					5.74, 5.6, 4.84	5.54, 4.34, 3.19	4.88, 4.166, 3.38	
RIVER_GORTNAMUCKLAGH	216.205	0113M00143I	5.487	2xCircular	41.92, 42.71	5.49	N/A	0.011
RIVER_GORTNAMUCKLAGH	705	0113M00095I	25.869	1xCircular	41.52	1.5	N/A	0.013
RIVER_GORTNAMUCKLAGH	959.06	0113M00070D	7.081	1xArch	39.86	1.47	1.142	0.017
RIVER_GORTNAMUCKLAGH	1372.99	0113M00027D	2.92	1xIrregular	38.47	1.63	N/A	0.013
STRACASHEL RIVER	242.241	0112M00003I	2.43	3xCircular	41.14, 41.17, 41.23, 41.33	2.43	N/A	

Structure Details - Weirs				
RIVER BRANCH	**CHAINAGE**	**ID****	**MANNING'S n**	**TYPE**
Stracashel River	1812.213	0112M01111W	0.013	Broad Crested Weir
Stracashel River	9129.67	0112M00377W	0.013	Broad Crested Weir
Stracashel River	1812.213	0112M01111W	0.013	Broad Crested Weir

** Structure Key:

D - Bridge Upstream Face

E - Bridge Downstream Face

I - Culvert Upstream Face

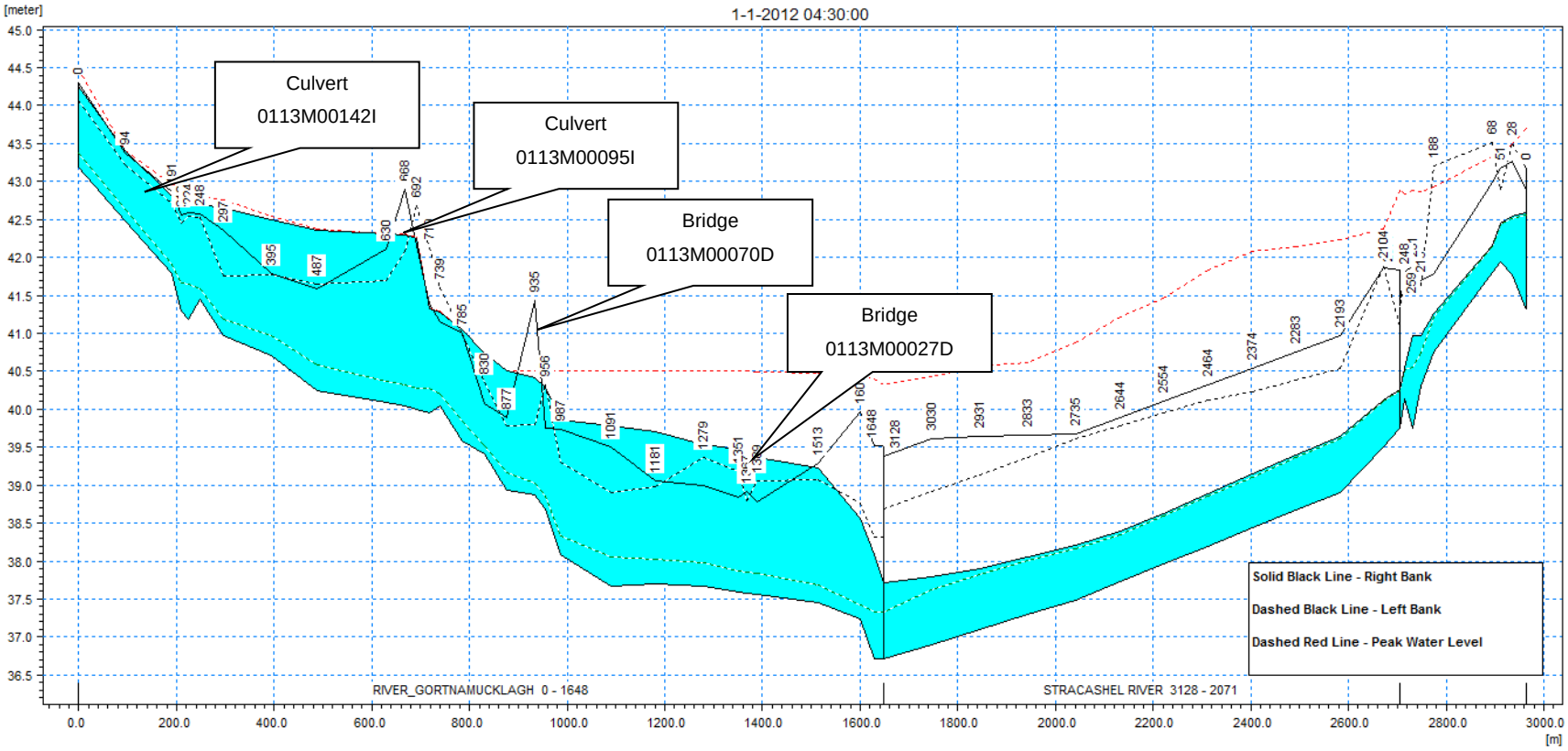
J - Culvert Downstream Face

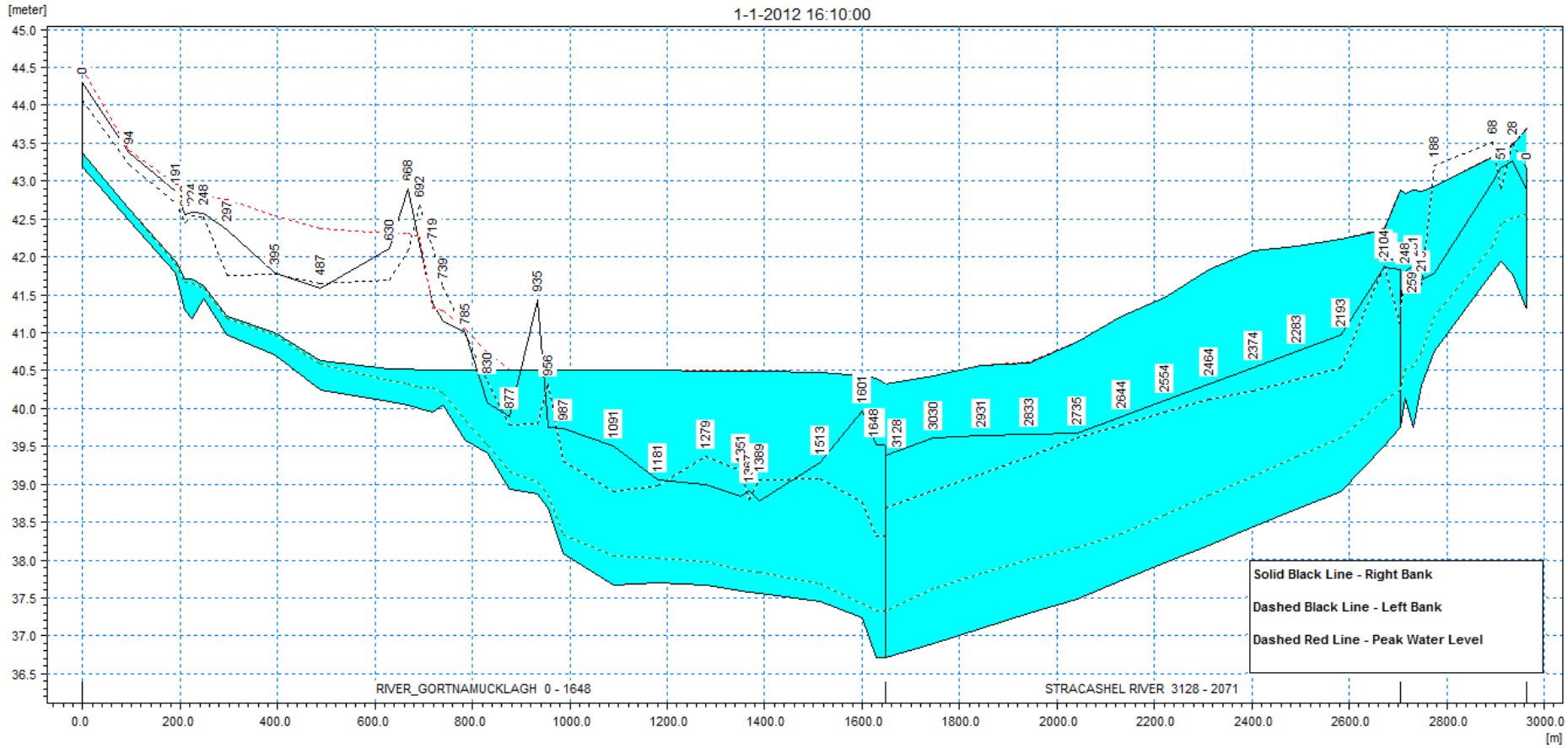
W - Weir Crest

NB: All other weirs in the Network file are overtopping weirs which form part of a composite structure with the culvert/bridge at the corresponding chainage.

APPENDIX A.2

Long-section plots


[meter]
1-1-2012 04:30:00
Culvert
0113M00142I
Culvert
0113M00095I
Bridge
0113M00070D
Bridge
0113M00027D
Solid Black Line - Right Bank
Dashed Black Line - Left Bank
Dashed Red Line - Peak Water Level
RIVER_GORTNAMUCKLAGH 0 - 1648
STRACASHEL RIVER 3128 - 2071
[m]



Illustrated are long-sections of the Gorthnamucklagh River and the Stracashal River (chainages 2071-3128) at a 0.1% AEP fluvial event. The first image shows the full stage of flooding (04:03 approx) in the Gortnamucklagh, when peak flow, that has originated upstream of the Gortnamucklagh catchment area flows downstream and into the Stracashel River. Flow is delayed at the culvert 0113M00095I (chainage 692.00) and bridge 0113M00070D (chainage 959.06). The second image illustrates how peak flow associated with the Stracashel River occurring at a later time (16:20); there is flooding out of bank and flooding backing up into the Gorthnamucklagh River.

APPENDIX A.3

Model Flow tables

	Peak Water Flows			
River Name & Chainage	**AEP**	**Check Flow (m^3/s)**	**Model Flow (m^3/s)**	**Diff (%)**
STRACASHEL RIVER 1491.93 38010_RPS	10%	49.45	49.53	+0.17
	1%	75.25	76.99	+2.31
	0.1%	114.93	119.60	+4.06
STRACASHEL RIVER 1785.66 38_3860_Inter_1	10%	49.19	33.35	-32.21
	1%	74.85	76.55	+2.27
	0.1%	114.33	93.19	-18.49
STRACASHEL RIVER (Owenea) 2058.55 38_3860_Inter_2	10%	49.32	36.64	-25.71
	1%	75.05	57.97	-17.25
	0.1%	114.62	96.29	-15.99
STRACASHEL RIVER (Owenea) 5863.51 38_442_4	10%	100.64	110.79	+10.09
	1%	152.55	169.90	+11.37
	0.1%	228.79	273.76	+19.66
STRACASHEL RIVER (Owenea) 9101.32 38001	10%	101.7	118.32	+16.34
	1%	153.82	189.70	+23.33
	0.1%	230.41	288.57	+25.24
RIVER_GORTNAMUCKLAGH 1451.04 38_414_4	10%	4.68	2.87	-38.76
	1%	7.61	5.05	-33.64
	0.1%	12.4	7.45	-39.95

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 area surrounding the Intermediate HEP 38010_RPS on the Stracashel River floods during all % AEP design runs. There is a difference of 0.17%, 2.31% and 4.06% between the modelled and check flows for 10%, 1% and 0.1%AEP fluvial scenarios respectively. The model is well anchored to the estimated flows in this location as the differences are within 5%.

Clonconwal Gauging Station (HEP 38001_RPS) located on Owenea River (MPW, Reach ID 0112M). At this node, modelled flows are less than the check flow at 16.34%, 23.33% and 25.24% for the design runs of 10%, 1% and 0.1% AEP respectively. Along these reaches there is significant out of bank flooding in all return periods however the lower extents of the Stracashel River are simulated as 1D only. This modelling approach, while capable of representing floodplain extents and water levels is unlikely to accurately capture the flood flow attenuation which is likely given the large flood extents within the floodplain. Given that it is unlikely floodplain flows are being accurately represented it is not considered that the differences are cause for review of the model inflows.

Intermediate HEPs 38_3860_Inter_1 and 38_3860_Inter_2 are located at a point along the Stracashel River where it splits into the Stracashel Tributary (0112A) (38_3860_Inter_2), and rejoins the main river after approximately 250m (38_3860_Inter_2). The comparison between model and check flow indicates that model flow is mostly lower during the event scenarios. This is due to the out of bank flooding that occurs at this location attenuating the flow.

HEP 38_442_4 is located along the MPW section of the River Stracashel downstream of the AFA, in an area referred to as Kilrean. The comparison between model and check flow indicates that model flow is higher at all % AEP fluvial scenarios. Differences of 10.09%, 11.37% and 19.66% have been determined for the 10%, 1% and 0.1% AEP fluvial scenarios, respectively.

HEP 38_414_4 is located at the downstream extent of the River Gorthnamucklagh where it joins the River Stracashel. Model flows are lower than check flows with a maximum difference of 40% during design events. The attenuation in the model is greater than that assumed to be the case in the hydrological analysis. Given the uncertainty in the estimates for this ungauged tributary catchment it is not considered that the discrepancy is cause for a review of the model inputs.

APPENDIX A.4 DELIVERABLE MODEL AND GIS FILES

MIKE FLOOD	**MIKE 21**	**MIKE 21 RESULTS**
HA01_ GLEN17_MF_DES8_Q10 HA01_ GLEN17_MF_DES8_Q100 HA01_ GLEN17_MF_DES8_Q1000	HA01_ GLEN17_M21_DES3_Q10 HA01_ GLEN17_M21_DES3_Q100 HA01_ GLEN17_M21_DES3_Q1000 HA01_GLEN17_extended_181214_v1_0 roughnessv2	HA01_GLEN17_HD_DES8_Q10_MAX HA01_GLEN17_HD_DES8_Q100_MAX HA01_GLEN17_HD_DES8_Q1000_MAX

MIKE 11 - SIM FILE & RESULTS FILE	**MIKE 11 - NETWORK FILE**	**MIKE 11 - CROSS-SECTION FILE**	**MIKE 11 - BOUNDARY FILE**
HA01_ GLEN17_M11_DES7_Q10 HA01_ GLEN17_M11_ DES7_Q100 HA01_ GLEN17_M11 _DES7_Q1000	HA01_ GLEN17_NWK_DES5	HA01_ GLEN17_XNS_DES4	HA01_ GLEN17_BND_DES2_Q10 HA01_ GLEN17_BND_ DES2_Q100 HA01_ GLEN17_BND_ DES2_Q1000
MIKE 11 - DFS0 FILE		**MIKE 11 - HD FILE & RESULTS FILE**	
HA01_ GLEN17_DFS0_Q10 HA01_ GLEN17_DFS0_Q100 HA01_ GLEN17_DFS0_Q1000		HA01_ GLEN17_HD_DES8_Q10 HA01_ GLEN17_HD_DES8_Q100 HA01_ GLEN17_HD_DES8_Q1000	glen_grid_2 Glen_Help_grid_v1

GIS Deliverables - Hazard

Flood Extent Files (Shapefiles)	Flood Depth Files (Raster)	Water Level and Flows (Shapefiles)
N25EXFCD001F0 N25EXFCD010F0 N25EXFCD100F0	O25DPFCD001F0 O25DPFCD010F0 O25DPFCD100F0	N25NFCD_F0
Flood Zone Files (Shapefiles)	**Flood Velocity Files (Raster)**	**Flood Defence Files (Shapefiles)**
N25ZNA_EXFCDF0 N25ZNB_EXFCDF0	O25vlFCD001F0 O25vlFCD010F0 O25vlFCD100F0	

GIS Deliverables - Risk

Specific Risk - Inhabitants (Raster)	General Risk - Economic (Shapefiles)	General Risk-Environmental (Shapefiles)
O25RIFCD100F0 O25RIFCD005F0 O25RIFCD001F0		