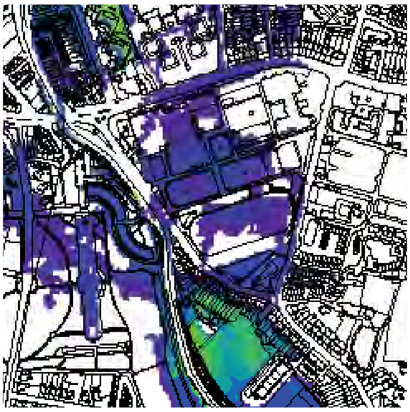
NORTH WESTERN
NEAGH BANN
CFRAM
STUDY
CATCHMENT FLOOD RISK
ASSESSMENT AND MANAGEMENT

North Western - Neagh Bann CFRAM Study

UoM 01 Hydraulics Report
4.12 Downings

IBE0700Rp0011



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Photographs of flooding on cover provided by Rivers Agency

NWNB CFRAM Study

HA01 Hydraulics Report

Downings Model

DOCUMENT CONTROL SHEET

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

Rev.	Status	Author(s)	Modeller	Reviewed by	Approved By	Office of Origin	Issue Date
D01	Draft	Various	J Canavan	S Patterson	G. Glasgow	Belfast/Limerick	10/06/2014
F01	Draft Final	Various	J Canavan	L Arbuckle	G. Glasgow	Belfast	30/01/2015
F02	Draft Final	Various	J Canavan	L Arbuckle	G. Glasgow	Belfast	13/08/2015
F03	Draft Final	Various	J Canavan	S Patterson	G. Glasgow	Belfast	21/07/2016

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_Final_v2.0	**1.3**
North Western Neagh Bann CFRAM Study UoM01 Inception Report	**February 2013**	IBE0700Rp0002_UoM 01 Inception Report_F02	**4.3.2**
North Western Neagh Bann CFRAM Study Hydrology Report UoM01	**July 2013**	IBE0700Rp0006_UoM 01 Hydrology Report_F01	**4.5**
North Western Neagh Bann CFRAM HA01_06_36 Survey Contract Report	**October 2013**	IBE0700Rp0007_HA01_06_36 NWNB_CFRAM_Survey Contract Report F01	**1.6.2**

4 HYDRAULIC MODEL DETAILS

4.12 DOWNINGS MODEL

4.12.1 General Hydraulic Model Information

(1) Introduction:

The NWNB CFRAM Flood Risk Review (2011s5232 NW&NB CFRAM FRR Report_Final_v2.0) highlighted Downings in the Magherabeg catchment as an AFA for fluvial flooding; 'mechanism 1 tidal' and 'mechanism 2 wave overtopping' flooding based on a review of historic flooding and the extents of flood risk determined during the PFRA.

The Downings AFA is located on the western side of the Rosguill Peninsula in Donegal. The main source of fluvial flood risk comes from a small watercourse which flows from the north through the village before discharging to the bay. This small watercourse is locally known as the Rosapenna Stream. The catchment is very small at 1.5km^2. For modelling purposes, this stream has been referred to as 'Magherabeg'.

The catchment is ungauged and there are no FSU pivotal sites which could be considered hydrologically similar given the very small size of the catchment. Furthermore the catchment was not delineated and the catchment descriptors not developed under FSU. Therefore these have been derived based on neighbouring catchment data, aerial photography and the national DHM. The FSU ungauged catchment estimates have not been adjusted based on a pivotal site.

Magherabeg Stream is a HPW and was modelled in 1D-2D using the MIKE suite of software. No MPWs are in the Downings model. The model includes a section of the Downings beach that extends approximately 800m seawards into Downings Bay. The 1D-2D extent of the Downings model is outlined in Section 4.12.2, Figure 4.12.2. Channel markers have been located at the right and left banks of all cross sections. Flow within these markers is calculated by the 1D model component; however when the water level rises sufficiently to meet the bank markers flow can enter the 2D domain which represents the floodplain.

Flood risk due to 'mechanism 2 wave overtopping' has also been analysed for the Downings AFA using survey data of the shoreline and wave climate data generated from the ICWWS. (See Section 4.12.3 (5)).

(2) Model Reference:	HA01_DOWN5
(3) AFAs included in the model:	Downings

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

Reach ID	**Name**	**Local Name**
0118M	Magherabeg	Rosapenna Stream

(5) Software Type (and version):		
(a) 1D Domain: MIKE 11 (2011)	**(b) 2D Domain:** MIKE 21 - Rectangular Mesh (2011)	**(c) Other model elements:** MIKE FLOOD (2011)

4.12.2 Hydraulic Model Schematisation

(1) Map of Model Extents:

Figure 4.12.1 illustrates the extent of the modelled catchment, river centre line, HEP locations and AFA extent. The model contains an Upstream Limit HEP and a Downstream Limit HEP. Refer to Appendix A.3 for details on anchoring of the model to the downstream limit HEP.

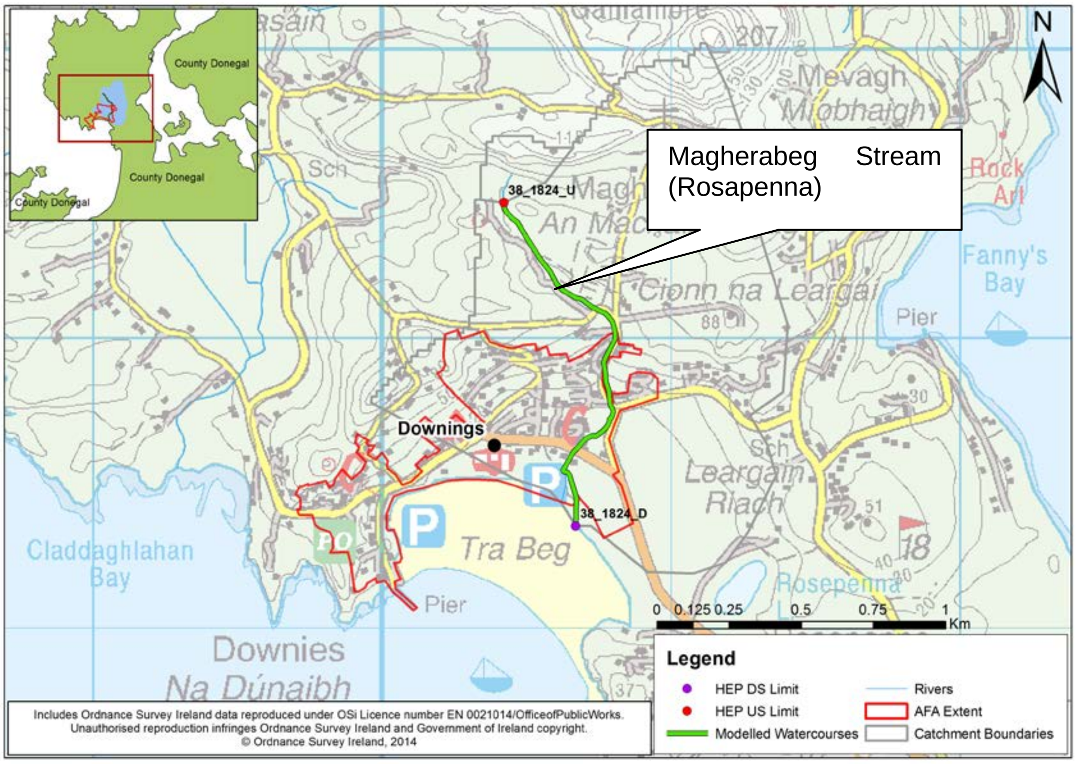


Figure 4.12.1: Downings Model Overview

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

River Name		**x**	**y**
0118M	Magherabeg	210731.87	439106.93

(3) Total Modelled Watercourse Length:		0.85km	
(4) 1D Domain only Watercourse Length:	N/A	**(5) 1D-2D Domain Watercourse Length:**	0.85km

(6) 2D Domain Mesh Type / Resolution / Area:	Rectangular/5 metres (1500x2500) 3.75 km^2

(7) 2D Domain Model Extent:

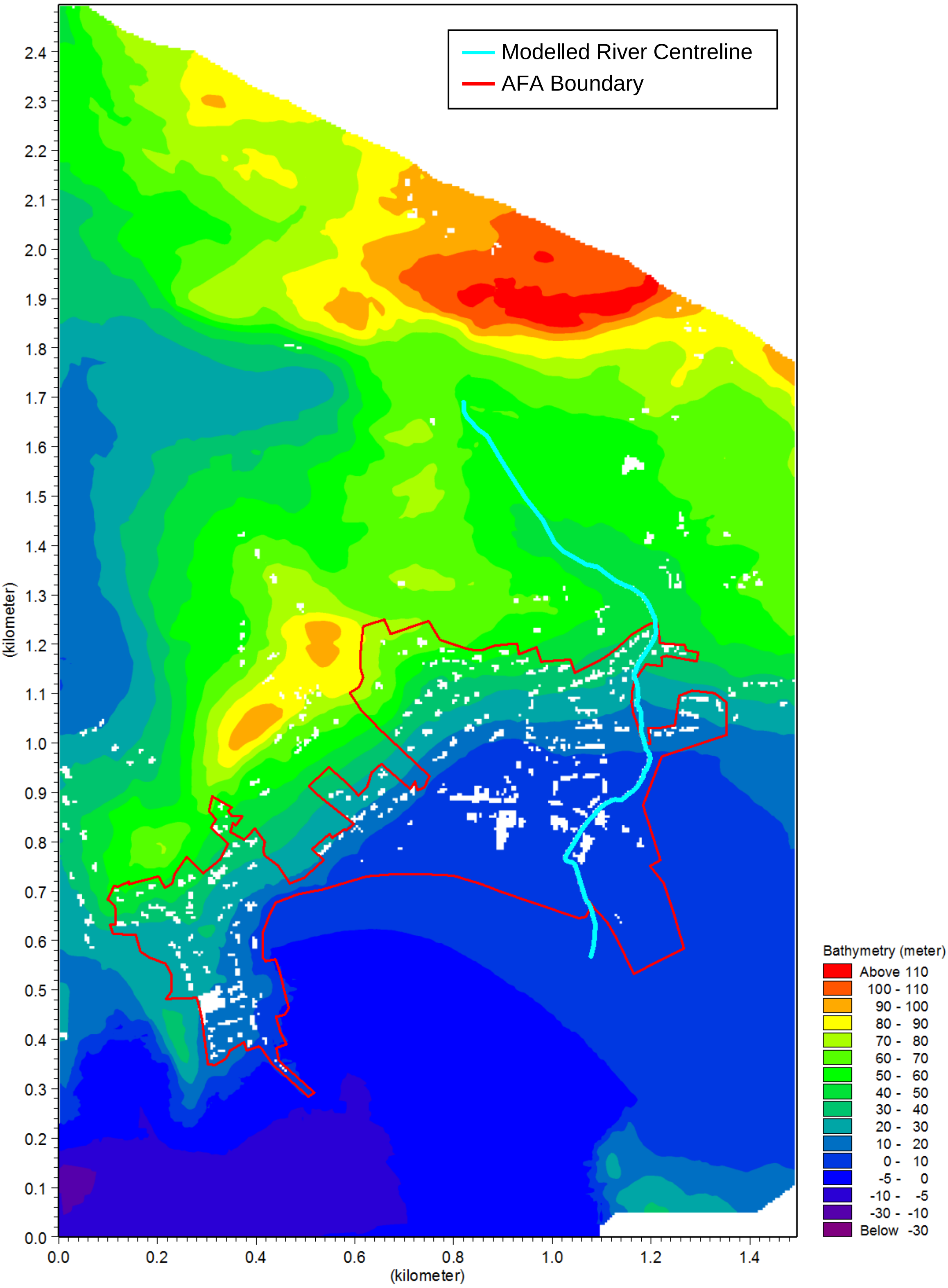


Figure 4.12.2: 2D Model Domain AFA Extent – Change Bathymetry to Elevation mOD Malin

Figure 4.12.2 illustrates the modelled extents and general topography. The spatial extent of the AFA boundary is outlined in red. The Magherabeg watercourse is 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 for details on representation of buildings in the model.

Figure 4.12.3 shows a drawing of the model schematisation. The diagram includes the surveyed cross-section locations, AFA boundary and river centre line. It also shows the location of the critical structures as discussed in Section 4.12.3(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 (i.e. within the channel).

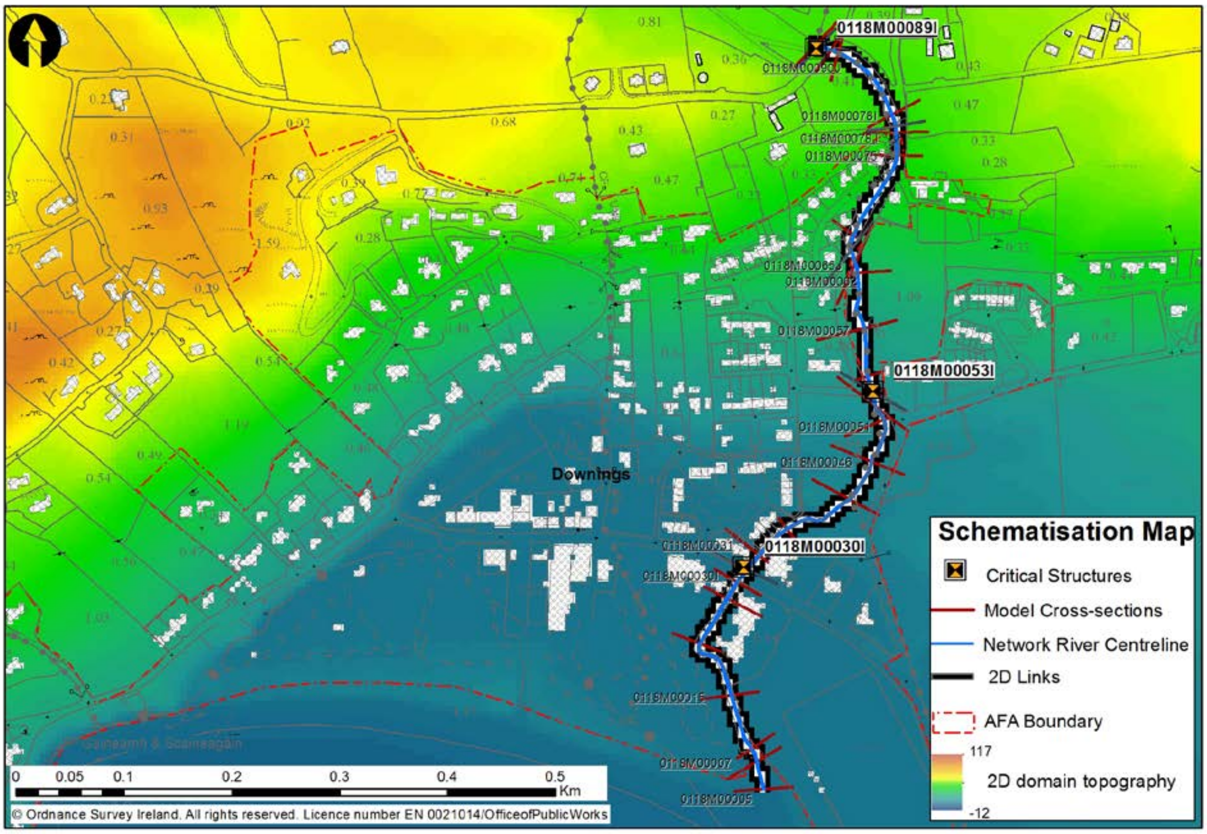


Figure 4.12.3: Detailed Area of Model Schematisation showing Critical Structures*

**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_M05_WP2_0118M_V1_130204 Downings Murphy: Surveyor Name	V0_20130201_GIS	Flood_Plain_Photos_and_Shapefile
		Structure_Register
		Surveyed_Cross_Section_Lines

NW1: North Western CFRAM Study Area, Hydrometric Area 1 M05: Model Number 5 0118M: River Reference WP2 : Work Package 2 V1: Version *130204*– Date Issued (04th Feb 2013)		Watercourse_Register
	V0_20130201_Other	FP
	V0_20130201_Photos	0118M00000_DN
	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 Ref.**
0118M	Magherabeg	*Murphy_NW1_M05_WP2_0118M_V1_130204*

(9) Survey Issues:

LiDAR elevation data at the point of the last surveyed cross-section on the Magherabeg Stream (0118M00005) was edited to equal the lowest bed level of this cross-section. This is where the watercourses from the 1D domain discharge to the 2D domain. Therefore aligning the bed levels of these two model elements improves stability and continuity of flow. LiDAR data consists of the elevation of the water in the channel at the time it was flown, so correcting data at this location based on bed levels in the channel and structure survey is appropriate.

4.12.3 Hydraulic Model Construction

(1) 1D Structures (in-channel along modelled watercourses):	5 culverts. See 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 is included in Chapter 3.3.4.

The location of critical structures included in the model is presented in Figure 4.12.3. Details of these structures are also presented in Appendix A.1.

Magherabeg Stream floods during all modelled fluvial events of 10%, 1% and 0.1% AEP. The culvert 0118M00089I (Figure 4.12.14, chainage 503m) is unable to convey sufficient quantities of flood water downstream efficiently. As a consequence, flood waters tend to back-up at this location, causing some out-of-bank flooding of the surrounding area.

Figure 4.12.4: Culvert 0118M00089I

The culvert 0118M00053I at chainage 880m (Figure 4.12.5) restricts flow causing flooding upstream during 10% AEP events or greater. During the 0.1% AEP fluvial event properties in Beech Park are affected by flooding.

Figure 4.12.5: Culvert 0118M00053I

Culverts 0118M00030I (Figure 4.12.6) is located at chainage 1113m. It causes extensive fluvial flooding during the 0.1% AEP design event due to insufficient capacity. This flooding impacts the R248 and adjacent Caravan Park.

Figure 4.12.6: Culvert 0118M00030I

(2) 1D Structures in the 2D domain (beyond the modelled watercourses):	N/A
(3) 2D Model structures:	N/A

(4) Defences:

Type	**Watercourse**	**Bank**	**Model Start Chainage (approx.)**	**Model End Chainage (approx.)**
None				

(5) Model Boundaries - Inflows:

Full details of the flow estimates are provided in the Hydrology Report (IBE0700Rp0006_UoM 01 Hydrology Report_F01_Chapter 4.4 and Appendix D). The boundary conditions implemented in the model are shown in Table 4.12.1.

Table 4.12.1: Model Boundary Conditions

Boundary Description	Boundary Type	Branch Name	Chainage	Chainage	Gate ID	Boundary ID
Open	Inflow	Magherabeg	496	0		38_1824_U
Open	Water Level	Magherabeg	1341.506	0		
Distributed Source	Inflow	Magherabeg	502.768	1315.16		Top-up between 38_1824_U & 38_1824_D

Figure 4.12.7 provides an example of the upstream hydrograph input to the Model. This hydrograph represents the Magherabeg Stream at HEP 39_1824_U for the 1% AEP fluvial design event.

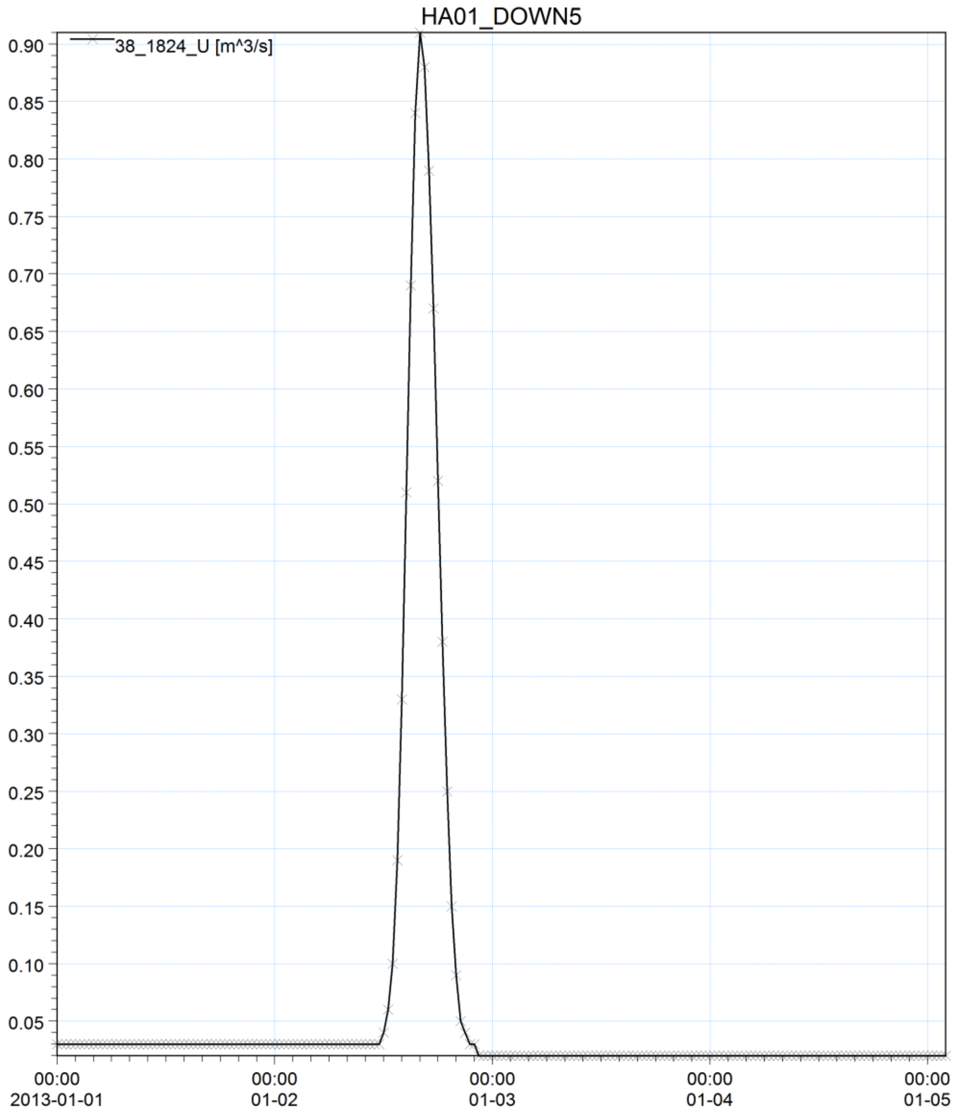


Figure 4.12.7: Upstream Hydrograph During 1% AEP Fluvial Design Run

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

An initial assessment of the Downings AFA suggested that there may be some dependency between the fluvial and coastal flood components, as detailed in section 6.3.2 of IBE0700Rp0006_UoM01 Hydrology Report_F01. A more detailed assessment of fluvial-coastal dependency was therefore carried out to establish whether the standard methodology of simulating fluvial and coastal dominated scenarios (as discussed in section 3.9.3) is valid for the Downings AFA.

There is no tidal gauge or hydrometric gauge within Downings AFA extents, the tidal gauge approximately 40km to the North-East at Malin Head and the New Mills (39001) hydrometric station, approximately 30km South of Downings in Letterkenny AFA were used for analysis.

An Extreme Value Analysis was carried out on the water level data at Malin Head in order to analyse extreme coastal events within the 52 years of available recorded data from 1958 to 2012 (note data for 2002 and 2003 is missing). This enabled a range of AEPs to be assigned to the historical level data at this

station.

A Single Site Analysis of New Mills (39001) hydrometric gauging station was carried out using the AMAX series from this station at Inception Stage in order to derive a range of AEPs for historical flows. This station has 36 years of data available between 1973 and 2009 (note data for 1981 is missing).

The AEPs derived for water level and flow data at Malin Head tidal gauging station and New Mills (39001) hydrometric station are shown in Table 4.12.2 below.

Table 4.12.2: AEPs derived from EVA and Single Site Analysis

AEP (%)	Malin Head tidal gauging station water level (mOD Malin)	New Mills (39001) hydrometric station discharge (m^3/s)
50	2.368	41.77
20	2.453	51.12
10	2.520	57.31
5	2.588	63.25
2	2.678	70.94
1	2.747	76.70
0.5	2.817	82.44
0.1	2.980	95.74

To facilitate the analysis of extreme coastal water levels, a threshold value of 50% AEP was selected, leaving 32 discreet records where this threshold was exceeded in terms of magnitude. From these 32 records, 20 occur between 1973 and 2009 when flow data is available at New Mills hydrometric station. The continuous flow record at New Mills was therefore analysed to find the maximum recorded flow ±12hours of when the peak coastal water level was recorded.

The results of this analysis showed that the maximum recorded flow at New Mills was less than $43m^3/s$ (defined as a 50% AEP event) in all 20 significant coastal events except one. The one event where both fluvial and coastal components exceeded a 50% AEP event occurred on 2nd January 1991. The recorded water level at Malin Head tide gauge during this event was 2.44mOD Malin (equating to an AEP of 24%) and the recorded flow at New Mills was $45.91m^3/s$ (equating to an AEP of 34%). No reports of flooding for this event were found during the historical review.

It is therefore concluded that there is no apparent fluvial-coastal dependence at the Downings AFA as there is only one event in 36 years of record which presented both a significant fluvial and coastal component, and there is no historical record of flooding from this event. As a result, separate fluvial and coastal dominated design scenarios as per the standard methodology (section 3.9.3) are considered appropriate.

This also provides validation for the design run scenario methodology i.e. fluvial dominated scenarios

consist of 0.1% AEP, 1% AEP or 10% AEP fluvial flows combined with a 50% AEP coastal TWL. It can be seen from the analysis of historical data that this approach is both realistic and conservative for design flood estimation.

A downstream Head Time Boundary (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 ICPSS have resulted in extreme tidal and storm surge water levels being made available around the Irish Coast for a range of AEPs. The locations of the ICPSS nodes along with the relevant AFA locations are shown in Figure 4.12.8. The coastal boundary for this model is set across the entrance to Downings Bay. Therefore the values for node NW36 were used. The associated AEP water levels for each of the nodes are contained in

Table 4.12.3. It should be noted that the water levels listed below are 'still' water levels which exclude wave conditions, and have been used to model inundation from 'mechanism 1 tidal' flooding. 'Mechanism 2 wave overtopping' flooding at Downings is considered separately and uses data including extreme coastal water levels extracted from the ICWWS as discussed later in this Section.

Figure 4.12.8:Node Locations (IBE0700Rp0006_UoM01 Hydrology Report_F01)

Table 4.12.3: ICPSS Node Elevations

AEP (%)	50	20	10	5	2	1	0.5	0.1
NW36 (m AOD Malin)	2.65	2.79	2.88	2.97	3.09	3.18	3.27	3.48

The ICPSS water levels are TWLs, comprising tidal and surge components which together yield a joint probability event of a particular AEP.

A representative tidal profile for Downings was generated based on Admiralty Tide Table data. A normalised 48 hour surge profile was scaled based on the difference between the peak water level of the generated tidal profile and the target TWL from

Table 4.12.3. 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 4.12.9 illustrates the tidal profile, storm surge profile and resultant combined TWL profile for a 0.5% AEP design event. The TWL profile was applied as a level boundary to the Western edge of the 2D domain, representing the entrance to Downings Bay.

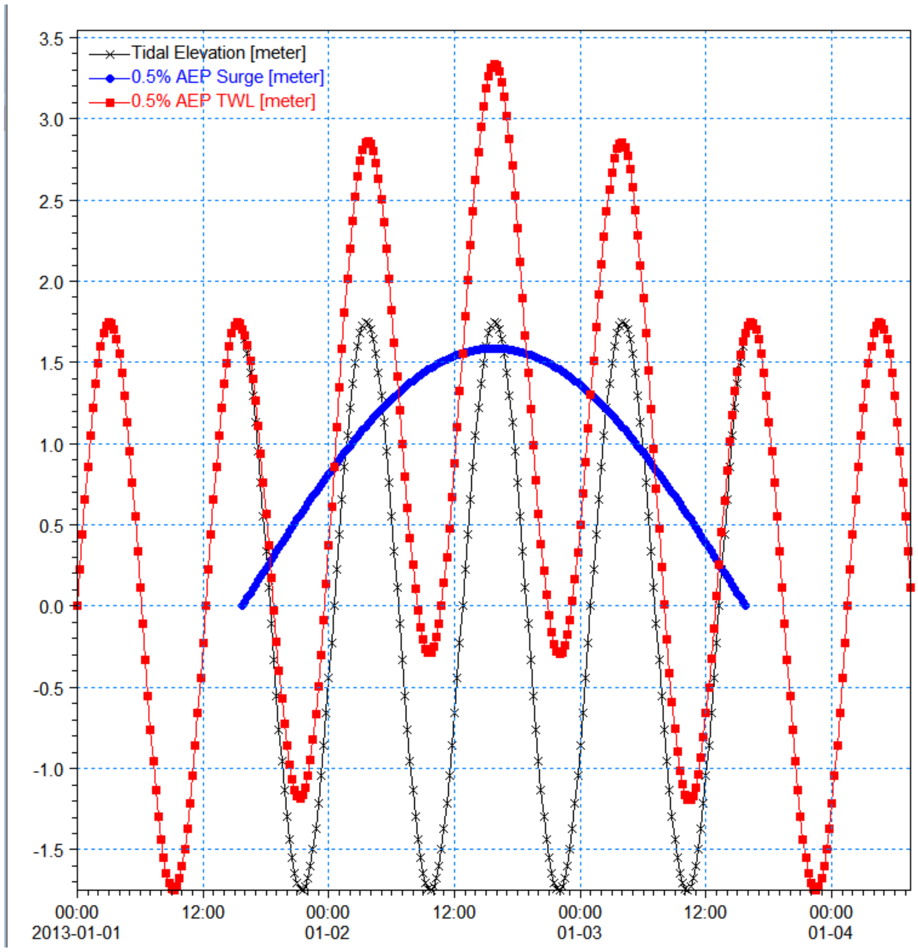


Figure 4.12.9: Downings Bay Tide and Surge Profiles

Wave Overtopping

In order to simulate 'mechanism 2 wave overtopping' flooding at Downings, data from the ICWWS was used including peak shoreline water levels and wave heights, periods and directions for each AEP event. The ICWWS CAPO location at Downings for which wave climate data was calculated is shown in Figure 4.12.10. An example of this data for the ICWWS CAPO location at Downings is shown below in Table 4.12.4.

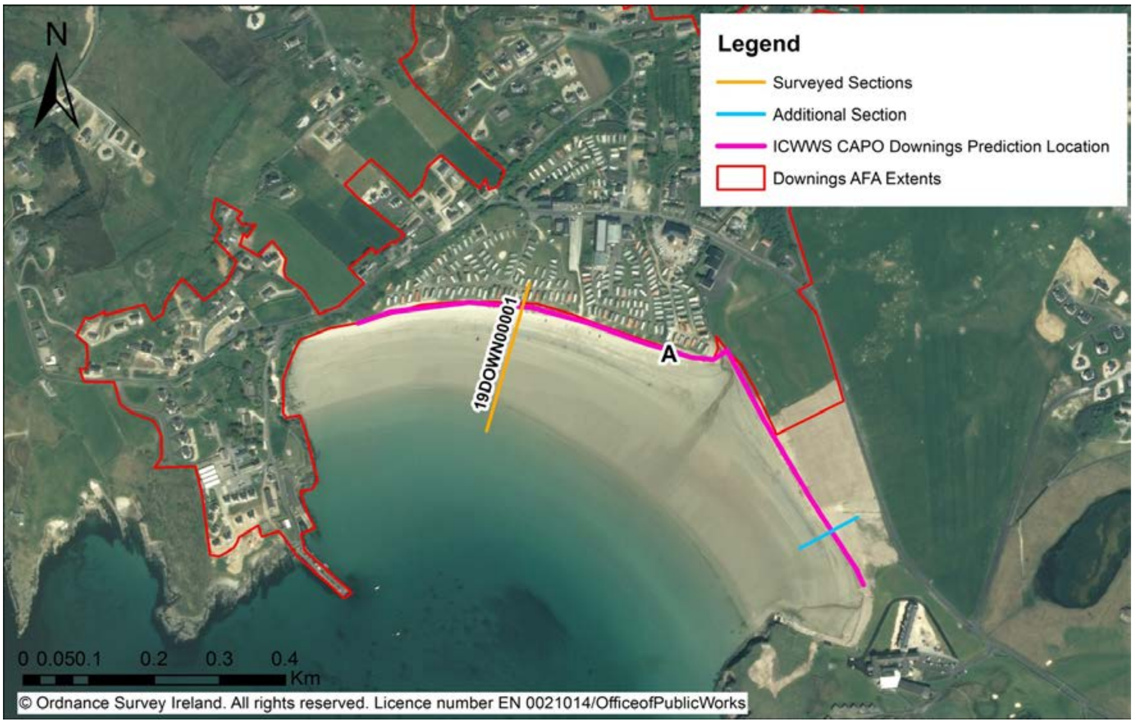


Figure 4.12.10: ICWWS CAPO Downings Prediction Location and Survey Section Location –

Table 4.12.4: ICWWS CAPO Downings Wave Climate and Water Level Data

Prediction Location Reference: Downings_Location A				
Bed Level 1.41m OD Malin				
		Wind Wave Component		
AEP	WL (OD Malin)	Hm0 (m)	Tp (s)	MWD (°)
0.1%	2.40	0.63	3.38	232
0.1%	2.53	0.69	3.42	231
0.1%	2.62	0.74	3.45	231
0.1%	2.85	0.84	3.43	230
0.1%	3.04	0.91	3.36	230
0.1%	3.25	0.94	3.26	230

In order to calculate the overtopping discharge rate for each scenario at various locations along the

shoreline, the Neural Network calculator tool outlined by the EurOtop manual was used. One surveyed cross-section of the shoreline at Downings was taken in order to enable this analysis to be undertaken, as shown in Figure 4.12.10. An additional section of the shoreline was created using data from 2m resolution LiDAR data, as shown in blue in Figure 4.12.10. An additional section was created at this location because this was found to be the lowest point of the coastline. The largest calculated discharge rate out of the six possible combinations of water levels and wave heights, periods and directions was used for each design AEP event. It should be noted that when the peak discharge rate was less than 0.03l/s/m, no further analysis was required. The overtopping discharge rate computed for both locations shown in Figure 4.12.10 at Downings was found to be below the threshold for all combinations of design water level and wave conditions. No further analysis for 'mechanism 2 wave overtopping' flooding at the Downings AFA was therefore required and this analysis was not taken forward for modelling.		
(6) Model Boundaries – Downstream Conditions:	Water level boundary was applied at the downstream extent of the River Magherabeg (chainage 1342m) as it flows into Downings Bay. 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 of 1.95mOD Malin (slightly greater than the bed level at this location), however this value is ignored once the simulation commences and the level of this boundary varies in time based on dynamic calculations driven by the water levels in Magherabeg Stream, which discharges to Downings Bay.	
(7) Model Roughness:(see Chapter 3.6.1 'Roughness Coefficients')		
(a) In-Bank (1D Domain)	Minimum 'n' value: 0.040	Maximum 'n' value: 0.065
(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: 0.025 (Inverse of Manning's 'M')	Maximum 'n' value: 0.059 (Inverse of Manning's 'M')

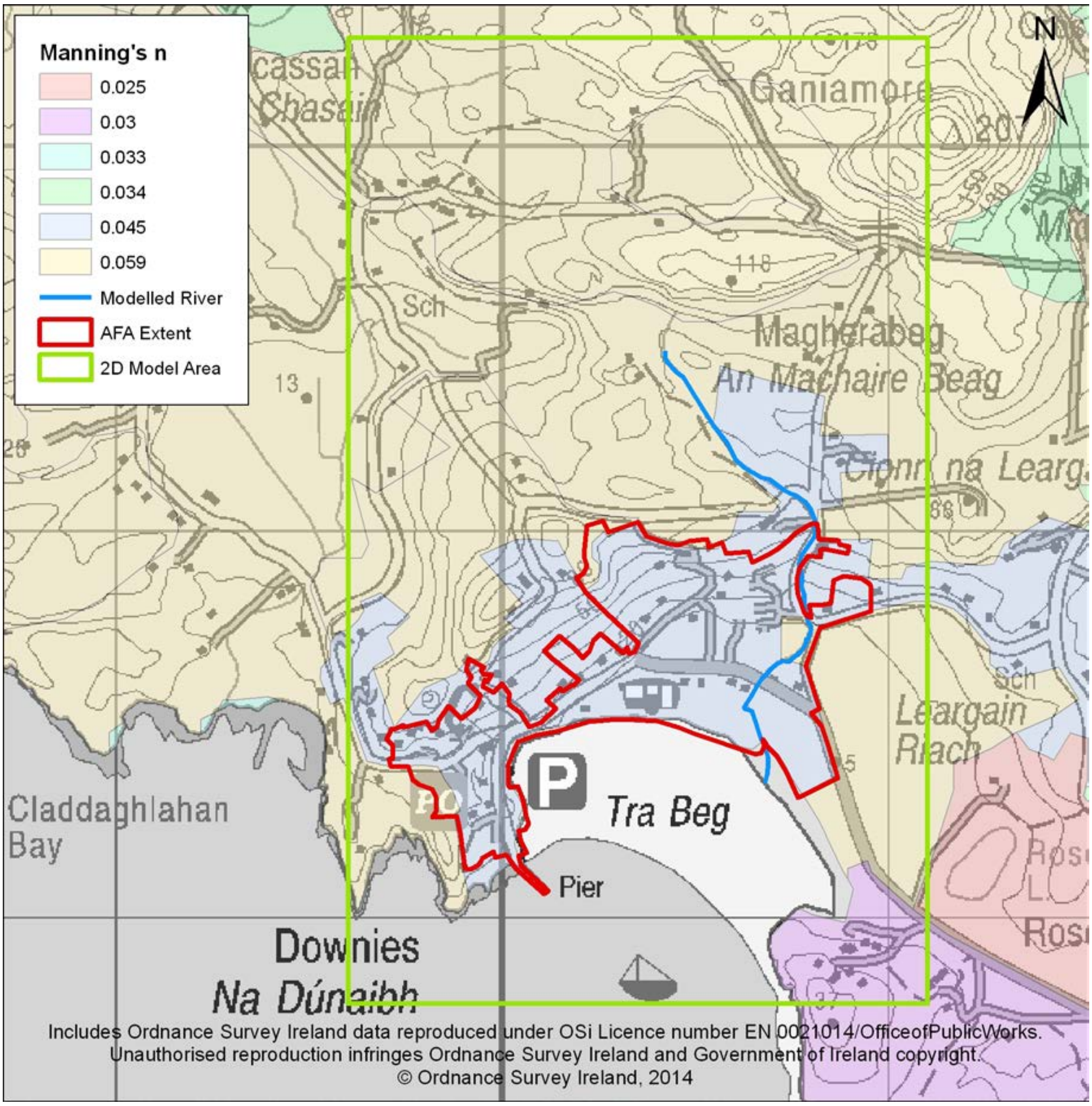


Figure 4.12.11: Map of 2D Roughness (Manning's n)

Figure 4.12.11 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 0.033 unless otherwise specified.

(d) Examples of In-Bank Roughness Coefficients

Figure 4.12.12: Magherabeg - 0118M000020-UP

Manning's n = 0.040

Natural stream - weedy, winding, some pools and shoals.

Figure 4.12.13:Magherabeg - 0118M000079-DN

Manning's n = 0.060

Natural stream - Sluggish, weedy, winding, with deep pools.

4.12.4 Sensitivity Analysis

To be completed for Final Version of report.

4.12.5 Hydraulic Model Calibration and Verification

(1) Key Historical Floods (From IBE0700Rp0002_UoM 01 Inception Report_F02 unless otherwise specified):	
(a) JAN 29th 2012	The Donegal Daily (www.donegaldaily.com) reported several flooding incidents that occurred during the 29th of January 2012, throughout Co. Donegal, including Downings. This report described how a period of continuous rainfall (24 hours) had resulted in flooding. The fire brigade was called out to deal with this downpour. This report is limited in that it does not provide specific detail regarding flooding extents or spatial information. No rain or tidal gauges have data for this event. It was therefore not possible to quantify this flood event. In addition, as there is no information on source, flows or levels available, this event is not suitable to facilitate model calibration. Regardless, this report is useful since it has provided evidence relating to fluvial flooding within Downings.
(b) NOV 28th 2011	The Donegal Daily reported that flooding occurred in Downings on 28th November 2011. This report described how heavy rain (≥50mm) caused the flooding of several rural roads but does not provide any specific spatial detail. It is not clear how reliable the reported value of 50mm of rainfall is. Met Éireann report that 30.7mm of rainfall fell at Glenties Hatchery on the 28th November 2011, and this was the highest daily rainfall total recorded in Co. Donegal in November 2011. This equates to a rainfall event AEP of approximately 90% using the FSU DDF model. This should be treated with caution however as Glenties Hatchery station is approximately 53km South West of the Downings AFA and a higher temporal resolution than the assumed 24 hour duration is not available. Tide gauge data at Malin Head indicates that there was no surge or exceptional water level during this flood event, with a peak water level of 1.85mOD Malin recorded.
(c) OCT 25th 2011	The Donegal Daily described several incidents of flooding across County Donegal, including Downings, following a period of heavy rain (≥40mm). This report described how Atlantic Drive (R248) was closed due to flooding. It also mentioned and provided a photograph of the flooding of a caravan park in Downings. Model outputs indicate that both the simulated 0.1% AEP fluvial and coastal flood depths at the caravan park range from 0.25-0.5m. This is similar to the depths shown in Figure 4.12.14 (based on visual inspection of the water level alongside the caravans in the photograph). The modelled 0.1% AEP fluvial event flood extent is shown in Figure 4.12.15.

Figure 4.12.14: Flooding at the Caravan Park - October 2011

Figure 4.12.15: 0.1% AEP Fluvial Extent

Using assumed 24 hour rainfall duration (since more detailed temporal resolution is not available), and a rainfall depth of 40mm, a design rainfall frequency was estimated using the FSU DDF model. This indicated a 30.3% AEP. The location at which the rainfall was recorded is not stated and it may be anecdotal, therefore it is not possible to estimate with any accuracy the peak flow and hence the frequency of the flood event. To gain more insight as to the actual duration of the rainfall event, records from Malin Head hourly rainfall station were checked. These records indicate that 16.4mm of rain fell within a 12 hour period on 23rd October, which equates to a rainfall event less severe than 100% AEP using the FSU DDF model.

	Tide gauge data at Malin Head indicates that the peak water level recorded on the 23rd October was 1.56 mOD Malin. This equates to a coastal event considerably less severe than 50% AEP. The rainfall and tidal data should be treated with caution however as Malin Head station is approximately 40km North-East of the Downings AFA.

Summary of Calibration

Several press reports have provided evidence that there have been some incidents of flooding at Downings. All the reports reviewed have described how flooding resulting from heavy rainfall has been the main mechanism. In addition to the press reports, a site assessment and discussion with key stakeholders described how the Beach Hotel, the caravan park and the front gardens of adjacent houses have been flooded.

(http://nwnb.cfram.com/wp-content/uploads/2011/10/2011s5232-Site-Assessment-Donegal_PT2_web.pdf).

There are no hydrometric gauges within the model extent. Data from daily and hourly rainfall stations was used where available to estimate the rainfall event frequency using the FSU DDF model. Data at Malin Head or Glenties Hatchery rainfall stations was used if possible, however as these stations are located approximately 40-50km from the Downings AFA their data should be treated with caution.

The closest tidal gauge with data available is Malin Head, and this was used where possible to give an indication of the coastal component of historic flood events. It should be noted however that the magnitude of coastal events at Downings can differ significantly from Malin Head due to the effect of Downings Bay, and this is highly dependent on wind speed and direction. It is therefore difficult to accurately estimate the coastal AEP of historic events with the data available.

Model flows were checked against the estimated flows at HEP check point 38_1824_D where possible to ensure the model is well anchored to the hydrological estimates. The maximum percentage difference of +4.89% occurs at the downstream HEP 38_1824_D on the Magherabeg watercourse during the 0.1% AEP design run. This is due to overland flooding causing flow attenuation upstream of the check point which is not as well reflected in hydrological estimates. Full flow tables and discussion are included 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. Results showed a difference of -0.79% for the 1% AEP even indicating that the model is robust and stable.

There are no significant instabilities present within the model.

There are some reports available of historical flood events in the Downings AFA. Rainfall and tide gauge data was used where possible to quantify these historic flood events, however these deductions should be treated with caution due to local coastal processes in Downings Bay and localised intense rainfall which may not be accounted for.

Model calibration was not possible due to the nature of the data available; however limited model verification has been achieved. Despite the limited calibration and verification data, data model is

considered to be performing satisfactorily for design event simulation.
(2) Public Consultation Comments and Response:

Following informal public consultation and formal S.I. public consultation periods in 2015, it was noted that flooding should be more frequent and extensive along Main Street (R248) close to the Beach Hotel is more common than is shown in the draft flood maps. The following updates to the model were carried out.

- Markers were repositioned on some cross sections of the Magherabeg River.
- Manning's n values of four structures located on the Magherabeg River were increased

These changes resulted in increased flooding on Main Street as shown in Figure 4.12.16. The model results are further supported by the Key Historical Flooding discussed in Section 4.12.5(1). The model was updated and check flows recalculated with a revised set of flood hazard and risk mapping issued as Final to reflect this change.

Figure 4.12.16: Increased flooding adjacent to the Beach Hotel, Main Street (R248)

(3) Standard of Protection of Existing Formal Defences:

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

(4) Gauging Stations:
The catchment is ungauged and there are no FSU pivotal sites which could be considered hydrologically similar given the very small size of the catchment.
(5) Other Information:
Considering the close proximity of Downings to the shoreline, there is limited information describing tidal or storm-surge (coastal) flooding. The only report indicating coastal flooding was made by the Donegal Democrat (dated 3rd January 2014). This report only supplied a general description of how storm surge conditions caused flooding around the coastal areas of Donegal, including Downings. However, this report was not used for model calibration since it lacked significant detail.

4.12.6 Hydraulic Model Assumptions, Limitations and Handover Notes

(1) Hydraulic Model Assumptions:
(a) A downstream water-level boundary, set at a value of 1.95m OD Malin (based on the lowest bed level of the final cross-section) was used. (b) The input hydrographs were delayed so that the fluvial peak corresponds with the surge peak – refer to Section 4.12.3(5). (c) The in-channel roughness coefficients were selected based on normal bounds using photos received from the survey and have been reviewed during the calibration process - it is considered that the final selected values are representative. (d) It has been assumed that all culverts and screens are free of debris and sediment. (e) Bathymetry at the model boundary in Downings Bay was edited and levels lowered to prevent adjacent cells drying and causing instabilities.
(2) Hydraulic Model Limitations and Parameters:
(a) The calibration of the model could be improved if more historical information was available. (b) A grid resolution of 5 metres has been selected. It is considered that the 5m 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 Downings AFA may have been too small of a resolution to be 'picked up' by LiDAR information e.g. fences, walls, paths and minor roads. Consequently, it is recognised that complex hydraulic processes of a finer resolution may not be represented in this model. (c) The model has not currently undergone sensitivity testing.

Hydraulic Model Parameters:	
MIKE 11	
Timestep (seconds)	1
Wave Approximation	High Order Fully Dynamic
Delta	0.8
MIKE 21	
Timestep (seconds)	2
Drying / Flooding (metres)	0.02 / 0.03
Eddy Viscosity (and type)	Constant eddy formulation varying in space based on equation $0.02\Delta x^2/\Delta t$.
MIKE FLOOD	
Link Exponential Smoothing Factor (where non-default value used)	All default (1)
Lateral Length Depth Tolerance (m) (where non-default value used)	All default (0.1)
(3) Design Event Runs & Hydraulic Model Handover Notes:	
(a) The Network and Cross Section files linked to the Mike 11 setup are identical for all event runs. (b) The model runs best when the Mike 11 initial condition is set to Steady State. (c) An initial surface elevation -0.198m in the 2D domain has been used during all design runs (d) There are no significant instabilities present within the model. (e)There is the backing up of Magherabeg Stream flood waters during all modelled flood scenarios of 10%, 1% and 0.1% AEP. During periods of fluvial flooding, just outside the AFA extent the culvert 0118M00089I (chainage 508m) is unable to convey sufficient quantities of flood water downstream efficiently resulting in a small amount of out-of-bank flooding as shown in Figure 4.12.17.	

Figure 4.12.17: Flooding during 10% , 1% and 0.1% AEP events at Culvert 0118M00089I

(f) A section of the R248 (Atlantic Drive), nearby caravan park and surrounding properties are liable to flood during a 0.1%AEP event, as shown in Figure 4.12.18.

Figure 4.12.18: 0.1% Fluvial Flood Extent

(g) The caravan park and area adjacent to the Rosapenna Hotel and Golf Resort is subject to coastal flooding during a 0.1% AEP coastal event, this is shown in Figure 4.12.19.

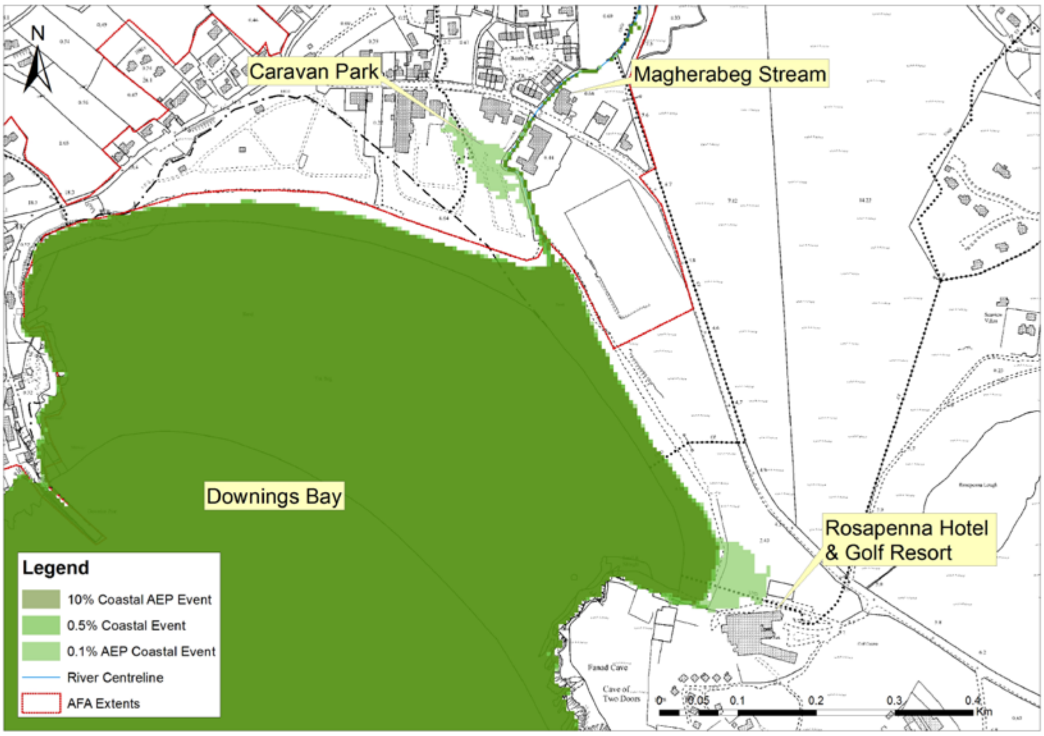


Figure 4.12.19: Coastal Flooding at the Caravan Park and Golf Resort

(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:	Jen Canavan
Model Reviewed by:	Stephen Patterson
Model Approved by:	Malcolm Brian

APPENDIX A.1

Table of Structure Details

Structure Details – Bridges and Culverts								
RIVER BRANCH	**CHAINAGE**	**ID****	**LENGTH (m)**	**OPENING SHAPE**	**HEIGHT (m)**	**WIDTH (m)**	**SPRING HEIGHT FROM INVERT (m)**	**MANNING'S n**
Magherabeg	508.374	0118M00089I	11.2	Circularx1	43.82	0.05	N/A	0.010
Magherabeg	613.882	0118M00078I	5.6	Irregularx1	40.63	1.6	N/A	0.025
Magherabeg	742.625	0118M00066I	10.6	Irregularx2	24.32, 24.36	0.87, 0.55	N/A	0.025
Magherabeg	879.276	0118M00053I	14.1	Circularx1	11.1	0.45	N/A	0.025
Magherabeg	1112.866	0118M00030I	14.9	Irregularx1	3.46	1.67	N/A	0.017

** Structure ID Key:

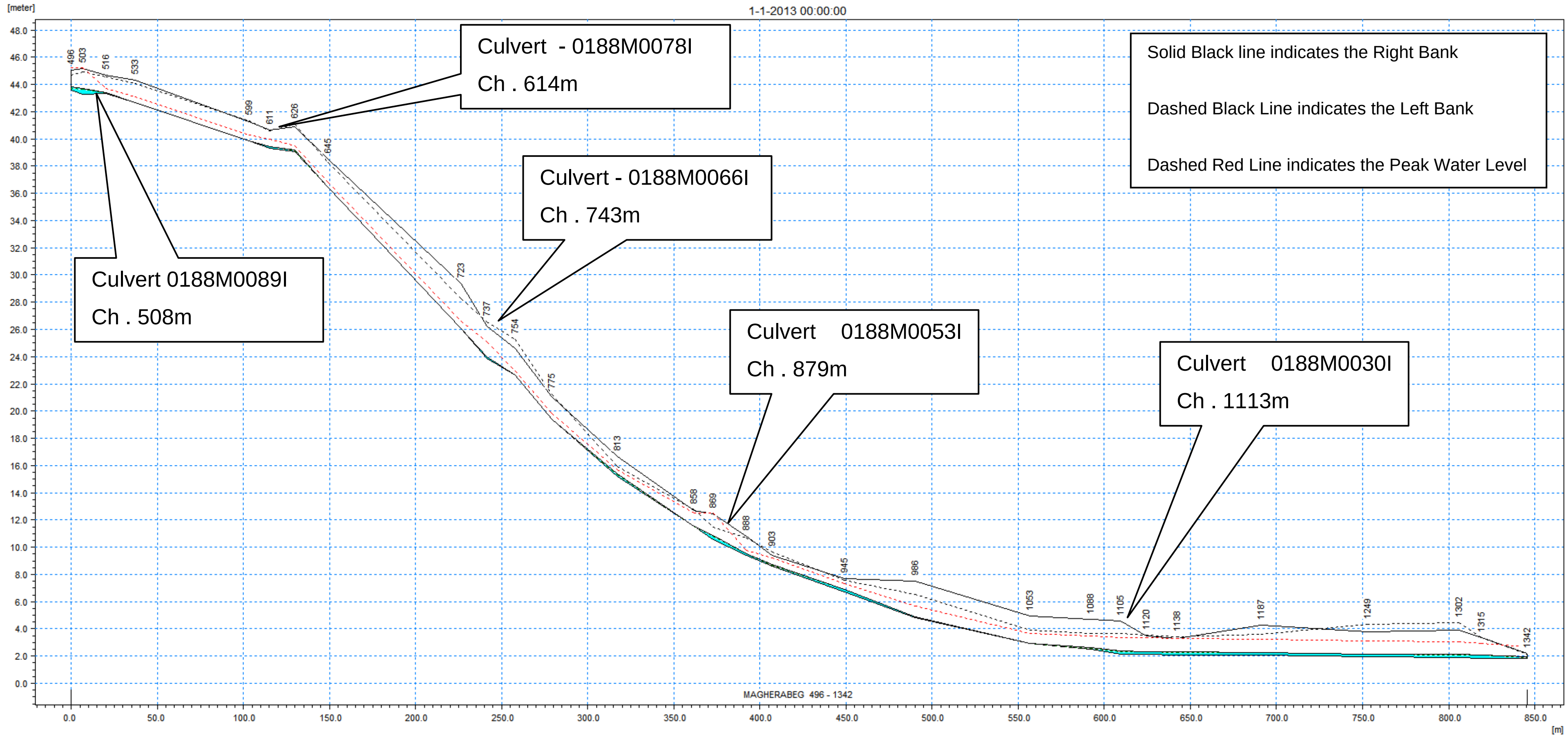
D – Bridge Upstream Face

E – Bridge Downstream Face

I – Culvert Upstream Face

J – Culvert Downstream Face

APPENDIX A.2



Magherabeg Watercourse 0.1% Fluvial Flow

APPENDIX A.3

	Peak Water Flows			
River Name & Chainage	**AEP**	**Check Flow (m^3/s)**	**Model Flow (m^3/s)**	**Diff (%)**
MAGHERABEG 1328.33	10%	1.51	1.48	-1.95
38_1824_D	1%	2.45	2.45	0
	0.1%	4.00	4.10	+2.59

The table above provides details of the peak flows at the downstream HEP 38_1824_D. The peak flows have been compared with the hydrology flow estimations and a percentage difference provided.

The percentage difference between modelled and estimated flows indicates the model is well anchored to the hydrologically derived estimates at this location.

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APPENDIX A.4

A list of all model files provided with this report.

MIKE FLOOD	MIKE 21	MIKE 21 RESULTS
HA01_DOWNS_5_MF_DES_3_F2_C10 HA01_DOWNS_5_MF_DES_3_F2_C200 HA01_DOWNS_5_MF_DES_3_F2_C1000 HA01_DOWNS_5_MF_DES_3_F10_C2 HA01_DOWNS_5_MF_DES_3_F100_C2 HA01_DOWNS_5_MF_DES_3_F1000_C2	HA01_DOWN5_M21_DES_3_F2_C10 HA01_DOWN5_M21_DES_3_F2_C200 HA01_DOWN5_M21_DES_3_F2_C1000 HA01_DOWN5_M21_DES_3_F10_C2 HA01_DOWN5_M21_DES_3_F100_C2 HA01_DOWN5_M21_DES_3_F1000_C2 HA01_DOWN5_DFS2_MESH_6 HA04_DOWN5_Roughness_2 HA01_DOWN5_EddyViscosity	HA01_DOWN5_M21_DES_3_F2_C10 HA01_DOWN5_M21_DES_3_F2_C200 HA01_DOWN5_M21_DES_3_F2_C1000 HA01_DOWN5_M21_DES_3_F10_C2 HA01_DOWN5_M21_DES_3_F100_C2 HA01_DOWN5_M21_DES_3_F1000_C2

MIKE 11 - SIM FILE & RESULTS FILE	MIKE 11 - NETWORK FILE	MIKE 11 - CROSS-SECTION FILE	MIKE 11 - BOUNDARY FILE
HA01_DOWN5_M11_DES_3_F2_C10 HA01_DOWN5_M11_DES_3_F2_C200 HA01_DOWN5_M11_DES_3_F2_C1000 HA01_DOWN5_M11_DES_3_F10_C2 HA01_DOWN5_M11_DES_3_F100_C2 HA01_DOWN5_M11_DES_3_F1000_C2	HA01_DOWN5_NWK_DES_4	HA01_DOWN5_XNS_DES_4	HA01_DOWN5_BND_DES_1_F2C10 HA01_DOWN5_BND_DES_1_F2C200 HA01_DOWN5_BND_DES_1_F2C1000 HA01_DOWN5_BND_DES_1_F10C2 HA01_DOWN5_BND_DES_1_F100C2 HA01_DOWN5_BND_DES_1_F1000C2
MIKE 11 - DFS0 FILE		**MIKE 11 - HD FILE & RESULTS FILE**	
HA01_DOWN5_DFS0_Q2_2 HA01_DOWN5_DFS0_Q10_2 HA01_DOWN5_DFS0_Q100_2 HA01_DOWN5_DFS0_Q200_2 HA01_DOWN5_DFS0_Q1000_2		HA01_DOWN5_HD_DES_3_F2_C10 HA01_DOWN5_HD_DES_3_F2_C200 HA01_DOWN5_HD_DES_3_F2_C1000 HA01_DOWN5_HD_DES_3_F10_C2 HA01_DOWN5_HD_DES_3_F100_C2 HA01_DOWN5_HD_DES_3_F1000_C2	

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

GIS DELIVERABLES

Flood Extent Files (Shapefiles)	**Flood Depth Files (Raster)**	**Water Level and Flows (Shapefiles)**
Fluvial N21EXFCD100F0 N21EXFCD010F0 N21EXFCD001F0 Coastal N21EXCCD100F0 N21EXCCD005F0 N21EXCCD001F0	Fluvial n21dpfcd100f0 n21dpfcd010f0 n21dpfcd001f0 Coastal n21dpccd100f0 n21dpccd005f0 n21dpccd001f0	Fluvial N21NFCDF0 N21NFCDF0_Join Coastal N21NCCDF0 N21NCCDF0_Join
Flood Zone Files (Shapefiles)	**Flood Velocity Files (Raster)**	**Flood Defence Files (Shapefiles)**
N21ZNA_MCDF0 N21ZNB_MCDF0	Fluvial n21vlfcd100f0 n21vlfcd010f0 n21vlfcd001f0 Coastal n21vlccd100f0 n21vlccd005f0 n21vlccd001f0	Defended Areas N/A
Specific Risk - Inhabitants (Raster)	**General Risk - Economic (Shapefiles)**	**General Risk-Environmental (Shapefiles)**
Fluvial N21RIFCD100F0 N21RIFCD005F0 N21RIFCD001F0 Coastal N21RICCD100F0 N21RICCD005F0 N21RICCD001F0		