Fintona Feasibility Study

Fintona Feasibility Report

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

EXECUTIVE SUMMARY

DfI Rivers commissioned RPS Consulting Engineers to identify the flood risk associated with the complex watercourse system in and around Fintona, County Tyrone, and assess options (including economic viability) for the alleviation of future flooding.

RPS liaised with DfI Rivers to request hydraulic models, flood reports, information on DfI Rivers assets, historical flood information and any other available information relevant to the study area. A walkover survey of the study reaches was conducted by RPS in order to gain an appreciation of the topography of the catchment, the flooding mechanisms which prevailed during the May 2014 event and the identification of any structures along each of the watercourses within the study area. RPS updated the hydraulic model, with details provided in the Fintona Modelling Report.

RPS then undertook a comprehensive option development and assessment process to ensure that all potential flood alleviation measures were considered. The works involved with each proposal were incorporated into revised models. This was to ensure that the preferred options would deliver the required reduction in flood risk to the relevant properties (to at least a 1% AEP event) and would not increase the risk of flooding elsewhere in the catchment. Three potential options were considered, option 1 being the existing regime and therefore the baseline condition. The option appraisal showed that options 2 and 3 would achieve the primary objective of providing the design Standard of Protection and that both would have similar impacts when considering the other objectives and constraints identified.

A detailed economic appraisal to evaluate the viability of each option was completed as part of the overall study. Option 3 was considered to be better value for money and to have less of a residual risk associated with it. Option 3 is therefore the recommended preferred option and consists of flood walls, upgrading culverts and culvert diversions.

The vision of DfI Rivers is to manage the flood risk to facilitate the social, economic and environmental development of Northern Ireland. To support this vision, the Agency aims to reduce the risk to life and the damage to property from flooding from rivers and the sea and to undertake watercourse and coastal flood management in a sustainable manner. RPS believes that the preferred option successfully achieve these aims of the DfI Rivers.

1 INTRODUCTION

1.1 BACKGROUND

The Preliminary Flood Risk Assessment (Rivers Agency, December 2011) report identified Fintona as an Area for Further Study. The Quiggery River is the principle river in Fintona which generally flows in a northerly direction through Fintona. This watercourse sits within the upper catchment of the River Foyle. The Fintona Stream (U1401) and the stream that drains the Castletown area (U1401*) are heavily culverted through Fintona town and flow from north west of Fintona joining to become one culverted stream (U1401) at a site formerly occupied by Lidl. A third stream, known as the Brookwood Stream (U1402*), flows from west to east from the Tonnaghbane/Lisky area and is culverted along the Tattymoyle Road. It joins the other culverted stream (U1401) at the SuperValu site, Main Street, before discharging into the Quiggery River downstream of New Bridge.

Historical flooding in Fintona includes significant flood events known to have occurred in October 1987, August 2008, October 2011, May 2014 and Winter 2015/2016 affecting both residential and commercial properties, as well as local infrastructure including several roads. During the event on 17th of October 2011 several homes suffered flood damage in Meadowbrook, King Street and Patterson Park due to the Quiggery River bursting its banks during unprecedented heavy rainfall. The Tattymoyle area was largely affected during the 22nd of May 2014 event. This is said to have been due to torrential rainfall in the Seskinore area which led to flooding from overland flow, runoff from roads and inadequate drainage systems. During winter 2015/2016, extreme flooding was caused by three consecutive storms; Desmond, Eva and Frank, resulting in out of bank flooding and urban damage.

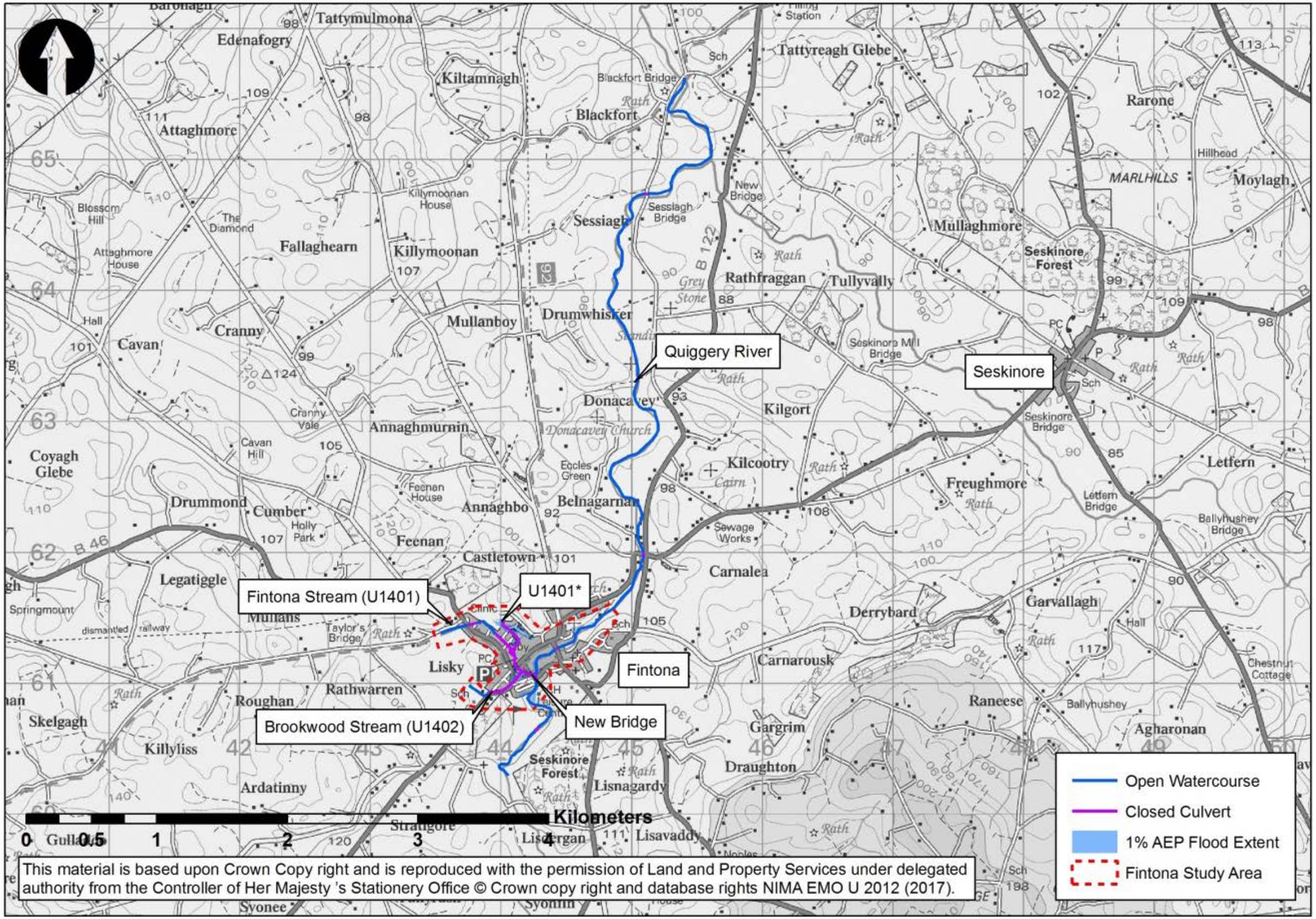

Figure 1.1 - General Location of Watercourses

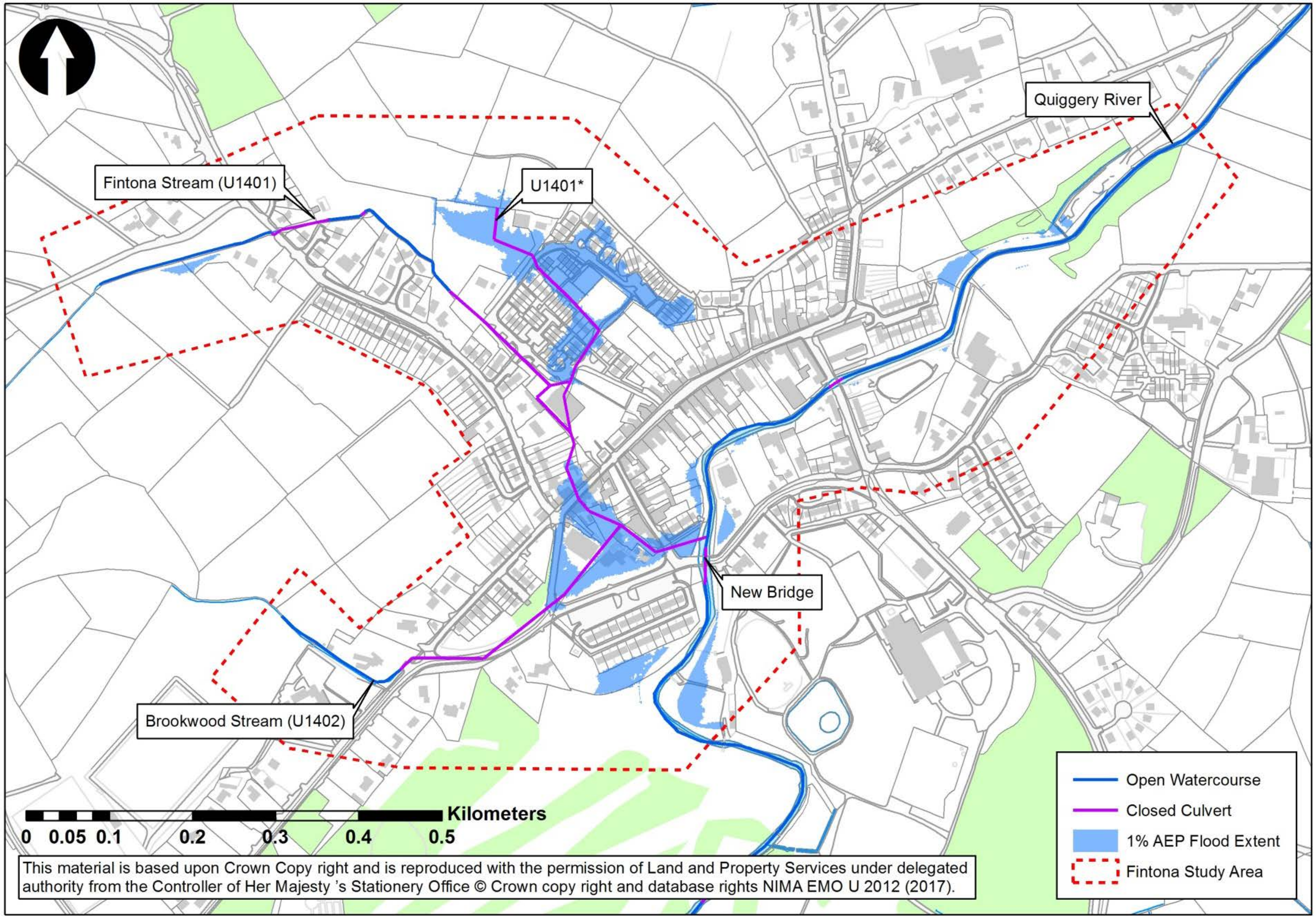

Figure 1.2 - Fintona Study Area

1.2 AIMS AND SCOPE

DfI Rivers has appointed RPS to carry out a feasibility study for the complex watercourse system in and around Fintona, Tyrone. The main aim of the study is to appraise flood risk and investigate options (including economic viability) which will alleviate flood risk in Fintona.

The project brief included the following requirements:

- Investigate the effect any watercourse, located within the study area, may have on flood risk to the study area;
- Assess the flood risk to infrastructure and properties from flooding during a range of flood events;
- Identify the flood risk and quantify the flood damage avoidance benefit;
- Consider a wide range of flood alleviation options (including short term (0-5 years) interim measures and medium to long term measures (5+ years)) to alleviate potential future flooding and provide protection to properties currently at risk of flooding during events up to and including the 1 in 100 year return period flood (Q100) i.e. 1% Annual Exceedance Probability;
- Consider all aspects of suitable and sustainable options proposed, including but not limited to environmental, health and safety, technical, constructability, economic, sustainability etc.;
- Undertake an Economic Appraisal in accordance with ‘The NI Guide to Expenditure Appraisal and Evaluation’ (NIGEAE) and the ‘Flood and Coastal Erosion Risk Management - Appraisal Guidance’ (published by the Environment Agency);
- Outline recommendations and present the optimum solution.

2 FLOOD RISK ASSESSMENT

2.1 INTRODUCTION

DfI Rivers commissioned RPS to carry out a feasibility study for the complex watercourse system in and around Fintona, Tyrone. The main aim of the study is to appraise flood risk and investigate options (including economic viability) which will alleviate flood risk in Fintona.

A flood risk assessment was carried out for the Fintona study in order to establish the risk to the various receptors located within the study area. The assessment considered the relevant economic, social and environmental receptors and their vulnerability to flooding. The overarching objective of the study is to provide protection within the study area to the 1% AEP standard of protection. However the FRA provided the information to define the specifics of this objective along with the constraints to be considered during the optioneering process.

This chapter details an overview of the flood hazard, identifying the flooding mechanisms along each of the watercourses. Details of the monetised and non-monetised risk are provided including the methods used and receptors considered. A summary of these findings are provided in this chapter and further details can be found in appendix A and B

2.2 OVERVIEW OF FLOOD HAZARD

Flooding is caused by the interaction of several flood mechanisms within the Fintona urban area which includes the coming together of three streams with flashy and steep catchments. The Quiggery River has insufficient channel capacity downstream of New Bridge, Tattymoyle Road resulting in overtopping of both banks during a Q10 flood event. The drainage infrastructure of the U1401* stream is inadequately sized causing flooding in the Ashfield Gardens area and overland flooding through the back of the properties on Main Street. The final section of the culvert that drains the U1402* stream has an upward sloping gradient before connecting with the main U1401 culvert resulting in a reduced culvert capacity.

Ultimately the joining of three streams in Fintona’s small urban area along with a steep catchment and an undersized culvert along U1401* causes a significant back water effect along U1401. U1402* is also affected by a culvert capacity issue which is exacerbated by the section of the culvert which slopes upwards. Overtopping of both banks of the Quiggery River downstream of New Bridge causes significant overland flow and flooding to properties on the Tattymoyle Road and Main Street. These issues are highlighted in Figure 2.1 below.

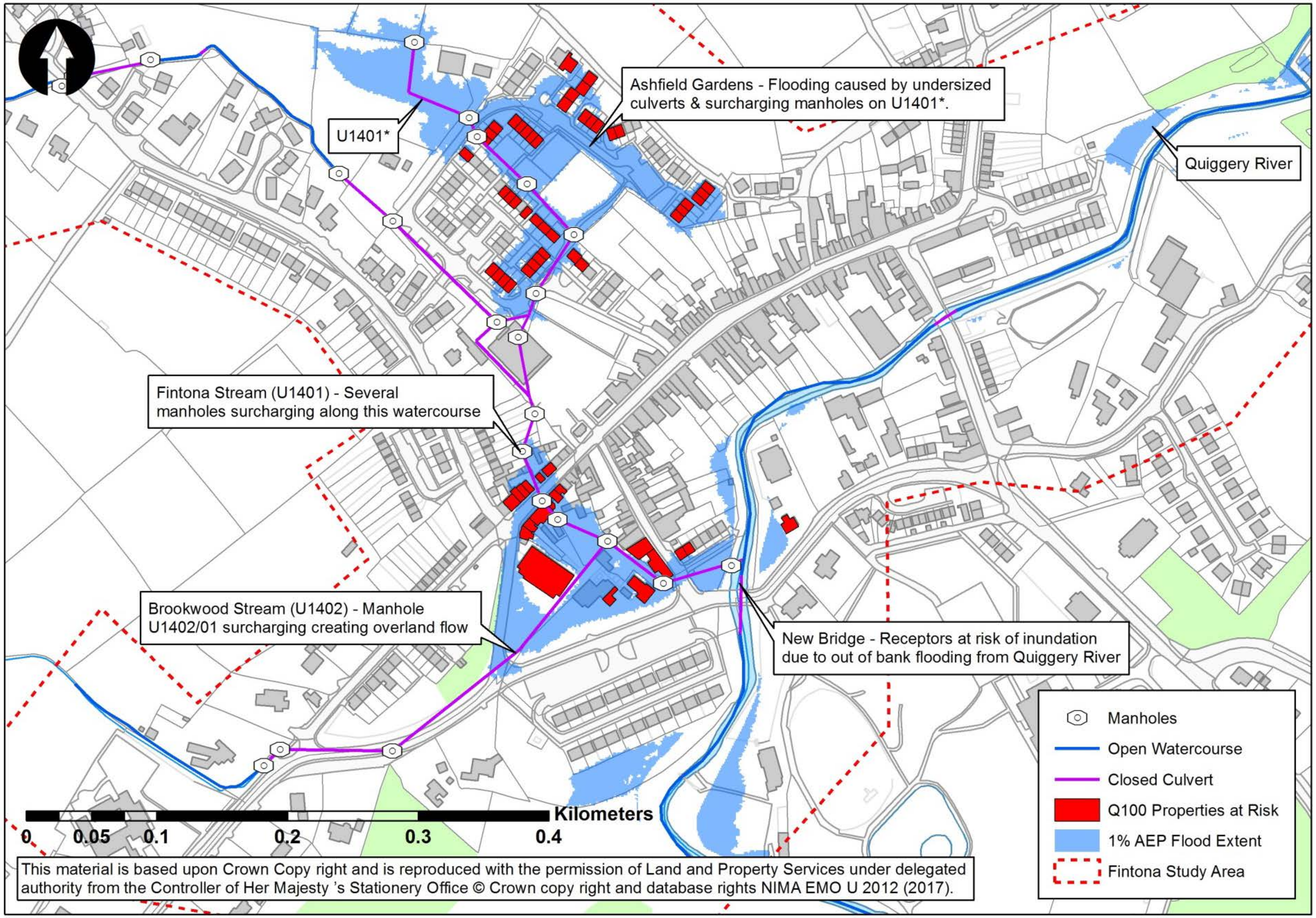

Figure 2.1 - Flooding Mechanisms in Fintona

2.3 FLOOD RISK RECEPTOR GROUPS

The aim of the Flood Risk Assessment is to assess and map the potential adverse consequences (risk) associated with flooding in the study area to the three receptor groups as described in Table 2.1 below. The level of flood risk to a receptor can be affected by its location within the flood extent, the depth with which it is flooded, the frequency which it is likely to be flooded and the receptors' vulnerability to flooding.

Table 2.1 - Flood Risk Receptor Groups

Flood Risk Receptor Group	**Receptor**	**Indicator**
Social and Cultural Heritage	NI Buildings	Location, type and number
	Areas of Special Archaeological Interest, Areas of Archaeological Potential, Historic Parks and Gardens, Listed Buildings, Industrial Heritage Buildings	Location, extent and nature
Environment	Special Area of Conservation (SAC), Special Protected Area (SPA), Area of Natural Beauty (AONB), Area of Special Scientific Interest (ASSI)	Location, type and number
Economic	Residential and Commercial Properties	Location, type, number, depth-damage data
	Electricity Substations, Gas Lines, Wastewater Treatment Works, Water Treatment Works	Location, type and number
	Road networks, Rail networks	Location, type and number

2.4 FLOOD RISK IN FINTONA

Table 2.2 below summarises the flood risk to the study area.

Table 2.2 - Flood Risk within Fintona

Flood Risk Receptor Group	Receptor	Risk
Social and Cultural Heritage	NI Buildings, Areas of Special Archaeological Interest, Areas of Archaeological Potential, Historic Parks and Gardens, Listed Buildings, Industrial Heritage Buildings	No Cultural Heritage assets at risk within the 1% AEP flood event.
Environment	Special Area of Conservation (SAC), Special Protected Area (SPA), Area of Natural Beauty (AONB), Area of Special Scientific Interest (ASSI)	None at risk within the 1% AEP flood event.
Economic	Residential and Commercial Properties	55 residential properties are at risk from the 1% AEP flood event. 8 commercial properties are at risk from the 1% AEP flood event. 1 veterinary centre at risk from the 1% AEP flood event. The total AAD from residential and commercial properties is £38,517.
	Electricity Substations, Gas Lines, Wastewater Treatment Works, Water Treatment Works	None at risk within the 1% AEP flood event.
	Road networks, Rail networks & Stations	Roads at risk include Main Street (B46), Tattymoyle Road (B122), King Street and local roads in the Ashfield Gardens area.

2.5 MONESTISED RISK - DAMAGE ASSESSMENT

As part of the economic risk assessment a monetary damage is assigned to certain receptors at risk. This damage represents the costs to the nation if the flood events being considered were to occur. The following receptors are assigned a monetary damage value:

- Residential properties
- Commercial properties

The total damage to a study area is used to quantify the economic risk and provide the amount of potential benefit that would occur if a FRM measure is put in place which would prevent the damage from occurring.

2.5.1 Damage Assessment Guidelines

The damage assessment methodology follows the guidance in “Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal" (Penning-Rowsell, *et al*., 2013). This book is a successor to and replacement of the highly respected manual and handbook “The Benefits of Flood and Coastal Defence: A Manual of Assessment Techniques" (Flood Hazard Research Centre, Middlesex University, UK, 2005). This document was often referred to as the ‘Multi-Coloured Manual’ (MCM).

The new manual draws on collaboration between the Flood Hazard Research Centre, the Environment Agency, Defra and other stakeholders. Its use, accompanied by the MCM-Online, has been recommended for benefit assessment as part of a flood and coastal erosion risk management appraisal.

The MCM is a result of research carried out by Middlesex University Flood Hazard Research Centre and provides data and techniques for assessing the benefits of flood risk management in the form of flood alleviation. The MCM has focused on the benefits that arise from protecting residential property, commercial property, and road disruption amongst other areas as experience has shown that these sectors constitute the vast majority of the potential benefits of capital investment.

Based on this research the MCM provides depth damage data for both residential and commercial properties. For certain depths of flood water, a monetary damage has been assigned to a property. This damage is a combination of the likely items within the building and the building structure itself. The damage to each property is dependent on the property type, as such the MCM has categorised both the residential and commercial properties.

The updated version of the manual provides a completely new set of data on the potential flood damage to non-residential properties, methods for assessing benefits in sectors not previously covered by MCM and, access to the rational and background on appraisal techniques, with links to the practical methods presented on a new web-based MCM.

For residential properties the new manual also incorporates the consideration of social grade and building periods. An example of the depth damage data for residential properties is shown in Figure 2.2 below.

3	Property-Type	MCM code	Property Type - Age	-0.3	0	0.05	0.1	0.2	0.3	0.6	0.9	1.2	1.5	1.8
4		111	pre-1919 Detached	1,606	1,606	15,018	26,224	43,860	54,476	64,439	71,559	78,045	85,808	94,353
5		112	1919-1944 Detached	1,009	1,009	7,046	11,355	19,934	24,468	29,727	32,245	36,222	40,039	44,545
6		113	1945-1964 Detached	884	884	8,637	13,957	23,791	28,777	34,509	37,624	41,590	45,092	49,433
7	Detached	114	1965-1974 Detached	754	754	7,117	11,402	19,934	24,427	29,758	32,315	36,033	39,049	42,763
8		115	1975-1985 Detached	792	792	7,879	12,541	21,976	27,465	33,745	37,601	41,446	44,805	48,761
9		117	utility Detached	641	641	2,485	3,606	5,154	6,410	7,305	8,599	10,442	12,473	14,903
10		118	post-1985 Detached	792	792	7,775	12,551	22,109	28,208	35,244	39,444	43,942	47,428	51,389
11		121	pre-1919 Semi-Detached	1,481	1,481	6,028	9,251	15,891	19,548	24,299	26,388	29,460	32,176	35,335
12		122	1919-1944 Semi-Detached	1,507	1,507	6,735	10,613	17,474	21,123	25,875	27,950	30,873	33,292	36,273
13		123	1945-1964 Semi-Detached	1,507	1,507	6,679	10,552	17,409	21,055	25,802	27,875	30,797	33,211	36,189
14	Semi-detached	124	1965-1974 Semi-Detached	661	661	5,381	8,745	15,229	18,690	23,313	25,222	28,329	30,994	34,375
15		125	1975-1985 Semi-Detached	629	629	5,110	8,393	14,985	18,734	23,642	25,973	28,750	30,916	33,610
16		127	utility Semi-Detached	643	643	2,434	3,583	5,092	6,385	7,330	8,530	10,030	11,727	13,648
17		128	post-1985 Semi-Detached	629	629	5,056	8,453	15,154	19,373	24,965	27,580	30,933	33,105	35,718
18		131	pre-1919 Terrace	1,419	1,419	6,280	9,419	16,030	19,806	24,776	26,812	29,332	31,660	34,348
19		132	1919-1944 Terrace	1,468	1,468	7,043	11,261	19,328	22,966	27,797	29,843	32,646	34,805	37,541
20		133	1945-1964 Terrace	934	934	4,118	6,068	9,030	10,101	12,482	13,653	15,851	17,094	18,808
21	Terrace	134	1965-1974 Terrace	723	723	5,925	9,636	16,504	20,089	24,778	26,833	29,843	32,149	35,060
22		135	1975-1985 Terrace	543	543	4,767	7,735	13,845	17,108	21,550	23,217	25,495	27,136	29,178
23		137	Utility Terrace	629	629	2,263	3,305	4,570	5,784	6,821	8,087	9,432	11,072	12,945
24		138	post-1985 Terrace	543	543	4,717	7,817	14,051	17,828	23,041	25,021	27,941	29,566	31,497
25		141	pre-1919 Bungalow	1,294	1,294	7,059	10,683	18,700	23,084	28,821	31,712	34,644	37,050	39,763
26		142	1919-1944 Bungalow	940	940	9,637	15,373	24,676	29,520	35,874	39,336	43,425	47,360	52,069
27		143	1945-1964 Bungalow	978	978	9,192	14,374	23,131	27,600	33,595	36,960	41,520	45,822	50,864
28	Bungalow	144	1965-1974 Bungalow	717	717	10,593	17,068	26,749	31,790	38,366	42,240	46,914	51,732	57,416
29		145	1975-1985 Bungalow	898	898	8,959	14,346	23,483	28,725	35,694	39,987	44,044	48,020	52,672
30		148	post 1985 Bungalow	898	898	8,844	14,538	24,117	30,630	39,452	44,548	50,161	54,181	58,656
31		151	pre-1919 Flat	1,294	1,294	5,517	8,512	14,203	17,084	21,490	22,940	24,871	26,231	27,914
32		152	1919-1944 Flat	765	765	8,362	13,632	22,101	26,319	31,905	34,431	37,142	39,560	42,437
33		153	1945-1964 Flat	765	765	4,935	7,668	13,807	16,816	21,006	22,633	24,783	26,140	27,873
34	Flat	154	1965-1974 Flat	543	543	7,232	11,859	19,519	23,411	28,735	30,987	33,642	35,849	38,565
35		155	1975-1985 Flat	543	543	5,468	8,891	15,674	19,303	24,514	26,769	28,973	30,534	32,481
36		157	utility Flat	616	616	2,058	2,987	3,967	5,038	6,096	7,369	8,553	10,145	11,971
37		158	post 1985 Flat	543	543	5,377	8,895	15,752	19,938	26,035	28,647	31,592	33,130	34,943

Figure 2.2 - MCM's Depth Damage Data for Residential Properties

2.5.2 Recording Damage Assessment Data

The damage assessment is carried out in order to quantify the economic risk to the study area. This requires many details to be recorded such as background data, interim calculations and final damage results. As such, RPS created several geo-referenced shapefiles with relevant data recorded in their attribute tables, an example of which is shown in Figure 2.3.

Two shapefiles created by RPS in order to complete the damage assessment are the buildings polygon shapefile and the Finished Floor Level (FFL) point shapefile.

The buildings polygon shapefile was created to contain background data for building polygons including building use and area.

The FFL shapefile includes data regarding the elevation aOD of doors/entries to properties within the study area. This FFL data was obtained from a threshold survey carried out.

An additional point shapefile was created to contain all information needed to complete the damage assessment. Information such as building area, FFL and water elevations from the modelled flood events (Q2, Q5, Q10, Q25, Q50, Q75 and Q100) were combined into this shapefile to give depths referenced to finished floor level for each flood event. For buildings with multiple entries, the maximum level of water above FFL was taken. This shapefile could then be used to show economic risk of properties relating to a range of flood events.

The following sections detail how the damage assessment is carried out and the data that is recorded during various processes within the shapefile attribute tables.

FID	Shape	GEODB_ID	Use	MCM_CODE	SA2011	HRPs	Per_AB	Per_C1	Per_C2	Per_DE	Prop_Type
42	Point ZM	0	C	2	N00004395	72	4	13	17	38	Commerial Property
46	Point ZM	0	C	6	N00004395	72	4	13	17	38	Veterinary Centre
47	Point ZM	0	C	2	N00004395	72	4	13	17	38	Petrol Station
48	Point ZM	0	C	2	N00004395	72	4	13	17	38	Pub/Social club/Wine bar
51	Point ZM	0	C	2	N00004395	72	4	13	17	38	Butchers
53	Point ZM	0	C	2	N00004395	72	4	13	17	38	Car Wash
54	Point ZM	0	C	2	N00004395	72	4	13	17	38	Superstore/Hypermarket (Supervalue)
57	Point ZM	0	C	2	N00004395	72	4	13	17	38	(High Street) Shop
0	Point ZM	0	R	115	N00004392	107	6	17	33	51	1975 - 1985 Detached
1	Point ZM	0	R	135	N00004393	97	4	31	19	43	1975 - 1985 Terrace
2	Point ZM	0	R	135	N00004393	97	4	31	19	43	1975 - 1985 Terrace
3	Point ZM	0	R	135	N00004393	97	4	31	19	43	1975 - 1985 Terrace
4	Point ZM	0	R	135	N00004393	97	4	31	19	43	1975 - 1985 Terrace
5	Point ZM	0	R	125	N00004393	97	4	31	19	43	1975 - 1985 Semi-Detached Bungalow
6	Point ZM	0	R	135	N00004393	97	4	31	19	43	1975 - 1985 Terrace
7	Point ZM	0	R	135	N00004393	97	4	31	19	43	1975 - 1985 Terrace

Record: 5 Show: All Selected Records (0 out of 63 Selected) Options

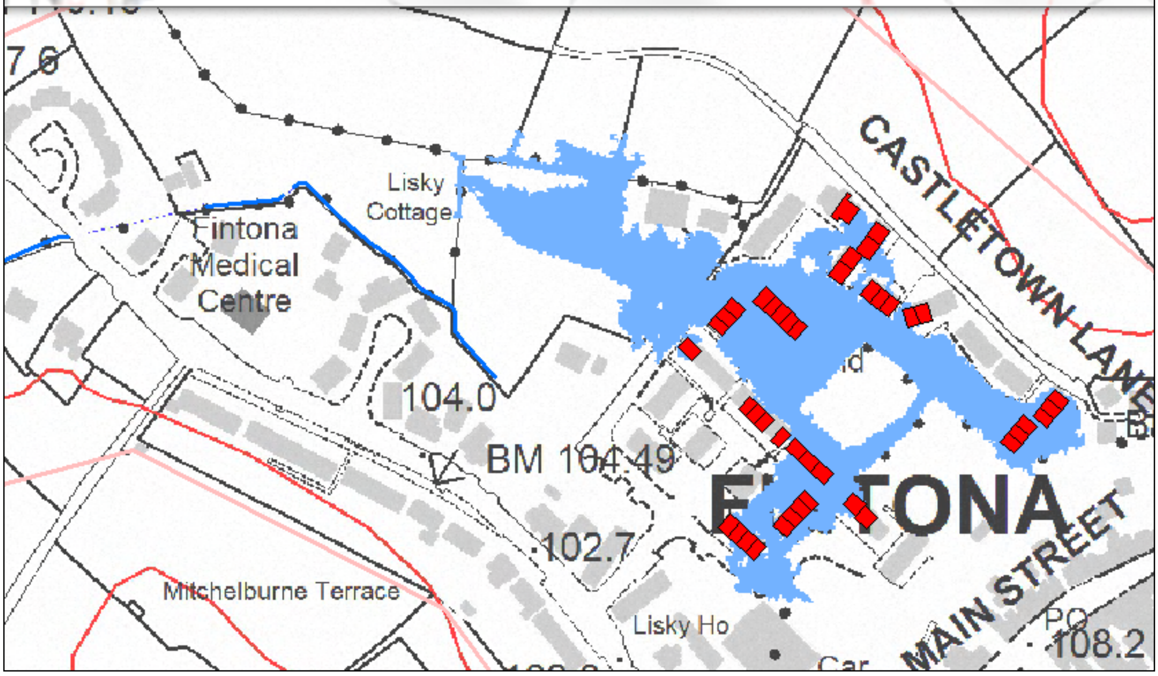

Figure 2.3 - Example shapefile with attributes showing damage assessment data

2.5.3 Categorisation of Properties

All properties within the 1 in 100 year floodplain were surveyed and classified according to MCM guidelines were included in the damage assessment. The type and age along with the social category of the occupants was noted. The MCM assigns a code to each property type to aid the damage calculations. Table 2.3 and Table 2.4 detail the various residential and non-residential property types.

Table 2.3 - Residential Properties MCM Codes

Property Type	MCM code	Property Type - Age
Detached	111	Pre-1919 Detached
	112	1919-1944 Detached
	113	1945-1964 Detached
	114	1965-1974 Detached
	115	1975-1985 Detached
	117	Utility Detached
	118	Post-1985 Detached
Semi-Detached	121	Pre-1919 Semi-Detached
	122	1919-1944 Semi-Detached
	123	1945-1964 Semi-Detached
	124	1965-1974 Semi-Detached
	125	1975-1985 Semi-Detached
	127	Utility Semi-Detached
	128	Post-1985 Semi-Detached
Terrace	131	Pre-1919 Terrace
	132	1919-1944 Terrace
	133	1945-1964 Terrace
	134	1965-1974 Terrace
	135	1975-1985 Terrace
	137	Utility Terrace
	138	Post-1985 Terrace
Bungalow	141	Pre-1919 Bungalow
	142	1919-1944 Bungalow
	143	1945-1964 Bungalow
	144	1965-1974 Bungalow
	145	1975-1985 Bungalow
	148	Post 1985 Bungalow
Flat	151	Pre-1919 Flat
	152	1919-1944 Flat
	153	1945-1964 Flat
	154	1965-1974 Flat
	155	1975-1985 Flat
	157	Utility Flat
	158	Post 1985 Flat

Table 2.4 - Non-Residential Property MCM Codes

New MCM Code	Property type	New MCM Code	Property type
2	**Retail**	**N/A**	**Sport**
	Shop/Store	521	Sports Grounds and Playing Fields
	(High Street) Shop	521	Golf Courses
	Superstore/Hypermarket	523	Sports and Leisure centres
	Retail Warehouse	523	Amusement Arcade/Park
	Showroom	525	Football Ground and Stadia
	Kiosk	526	Mooring/Wharf/Marina
	Outdoor market	523	Swimming Pool
	Indoor Market	**6**	**Public Buildings**
	Vehicle Services		School/College/University/Nursery
	Vehicle Repair Garage		Surgery/Health Centre
	Petrol Filling Station		Residential Home
	Car Showroom		Community Centres/Halls
	Plant Hire		Library
	Retail Services		Fire/Ambulance station
	Hairdressing Salon		Police Station
	Betting Shop		Hospital
	Laundrette		Museum
	Pub/Social club/wine bar		Law court
	Restaurant		Church
	Café/Food Court	**8**	**Industry**
	Post Office		Workshop
	Garden Centre		Factory/Works/Mill
3	**Offices**		Extractive/heavy Industry
	Offices (non-specific)		Sewage treatment works
	Computer Centres (Hi-Tech)		Laboratory
	Bank	**N/A**	**Miscellaneous**
4	**Warehouses**	910	Car Park
	Warehouse	Not currently available	Public Convenience
	Electrical w/h		Cemetery/Crematorium
	Ambient goods w/h		Bus Station
	Frozen goods w/h	526	Dock Hereditament
	Land Used for Storage	960	Electricity Hereditament
	Road Haulage		
51	**Leisure**		
	Hotel		
	Boarding House		
	Self-catering Unit		
	Hostel (including prisons)		
	Bingo hall		
	Theatre/Cinema		
	Beach Hut		

For Fintona, all properties found within the 1 in100 year CC flood extent were categorised. This was carried out using data gained from site visits, surveys, OSi mapping and online mapping. The NI Buildings polygon layer was initially used to locate all the properties and provide their floor area. Sheds and garages, which have no depth damage data in the MCM guidelines, were removed and the remaining buildings categorised. Within the Fintona 1 in100 year flood extent there was a total of 63 properties (8 commercial and 55 residential), however only 57 properties incur monetary damage (5 commercial and 52 residential).

Using the FCERM 2013 Manual, residential properties in the UK can be classified by house type, age and the social grade of the occupants. Taking into account these variables allows a more accurate estimation of inventory damages based on the presence or absence of household possessions. Table 2.5 below shows the social grade categories used in the FCERM 2013 Manual.

Table 2.5 - Approximated social grade categorisation by occupation

Social Grade	**Description**
AB	Upper middle and middle class: higher and intermediate managerial, administrative or professional.
C1	Lower middle class: supervisory or clerical and junior managerial administrative or professional.
C2	Skilled working class: skilled manual workers
DE	Working class and those at the lowest level of subsistence: semi-skilled and unskilled manual workers, unemployed and those with no other earnings (e.g. state pensioners).

Using Small Area Census data, the flood depth damage values for each property can be adjusted based on approximate proportions of households in each social group.
The following details were recorded within the buildings point shapefile attribute table:

Table 2.6 - Categorisation of Properties Data

Data Type	**Attribute Name**	**Data Details**
Property Use	Use	"R" for residential and "C" for commercial
MCM Code	MCM_CODE	As per MCM guidelines
Property Type	Prop_Type	As per MCM guidelines
Small Area Code	SA2011	Code of Census data Small Area in which property is located
Floor Area	AREA	Floor area of the property

2.5.4 Property Threshold Level

The damage assigned to a property relates to the depth of water above floor level. As such the threshold level of all properties is required as part of the damage assessment. As a general rule most properties are constructed with the floor level raised 300mm above the adjacent ground level. This would be particularly characteristic of fluvial or coastal floodplains which are generally low lying and flat in nature. Steep topography also has an influence on finished floor levels whereby some properties have split level front doors and back doors and some properties enter at ground level but have basements below. The standard approach of adding 300mm to the average of the surrounding ground level could potentially produce some erroneous results.

To achieve an accurate finished floor level for properties within the study area a threshold survey was conducted. However, as surveyors could not enter a property's grounds, some of the data may not be representative and so it was necessary to check LiDAR defined ground levels and property entrance types in some regions.

To improve the accuracy in the assessment of threshold levels RPS have undertaken a number of exercises in this regard. These are detailed below:

A review of each property initially using Google Street view and Bing maps and a walkover check survey to establish front and back door locations.

Classification on the entrance type to each property:

- Raised = +150mm for every step above LiDAR defined ground level (where 2 more steps exist).
- Normal = +300mm above LiDAR defined ground level.
- Flat = LiDAR defined ground level taken as threshold level.
- Lowered = -150mm for every step down below LiDAR defined ground level.

A final chosen threshold level was assigned to each property by taking the worst case of the predicted flood level at both the front and back door locations.

2.5.5 Flood Depth of Properties

To estimate the damage to a property an estimation of the predicted flood depths is required for a wide range of flood events. The Project Brief requires the depths to which the properties flood during the 1 in 2, 1 in 5, 1 in 10, 1 in 25, 1 in 50, 1 in 75 and 1 in 100 year events to be calculated. The depth of flooding is calculated by finding the difference between the flood water elevation and the estimated threshold level (as described in Section 2.5.4). The flood elevation was extracted by using the triangulated model output to find the maximum depth of water touching each building polygon. This process was achieved by carrying out a statistical analysis in ArcGIS and was carried out for each property and for each flood event. Table 2.7 below shows details which were recorded within the economic risk shapefile attribute tables:

Table 2.7 - Flood Depth of Properties Data

Data type	Attribute name	Data details
Flood level for all flood events	Q100Elv, Q75Elv, Q50Elv, Q25Elv, Q10Elv, Q5Elv, Q2Elv	The maximum flood level adjacent to the building (mOD)
Flood depth for all flood events	Q100Dp, Q75Dp, Q50Dp, Q25Dp, Q10Dp, Q5Dp, Q2Dp	Difference between the flood level and FFL

2.5.6 Flood Damage to Properties

Once the depths of flooding are known the damage can be calculated using the MCM depth damage data. This is known as direct damage in that the flooding directly damages assets, it does not account for indirect damages such as heating costs to dry out the house. For each property type, a typical damage based on historical data has been assigned to a depth of flooding. These direct damage figures have been updated to 2016 pound sterling prices and are based on the square metre of the floor area of the building. An example of this data is presented in

Figure 2.2. A GIS tool has been developed which provides the direct damage in each flood event for each building in pound sterling 2016 prices per square metre by interpolating between the depth damage figures provided in the MCM guidance. This damage figure is then multiplied by the floor area of the property to give the total damage.

Table 2.8 - Flood Damage to Properties Data

Data type	Attribute name	Data details
Direct damage per meter square	Q100_M2Dm, Q75_M2Dm, Q50_M2Dm, Q25_M2Dm, Q10_M2Dm, Q5_M2Dm, Q2_M2Dm	Damage per meter square to each property according to the depth of flooding from each flood event as per MCM data. Values in pound sterling updated to 2016 costs.
Damage to property over full floor area	Q100_Dm£16, Q75_Dm£16, Q50_Dm£16, Q25_Dm£16, Q10_Dm£16, Q5_Dm£16, Q2_Dm£16	Damage per meter square multiplied by floor area of building.

2.5.7 Emergency Costs

A cost will be associated with emergency services dealing with the flood events. Following the Environment Agency's Flood or Coastal Erosion Risk Management (FCERM) appraisal guidance, which the MCM guidance has been adapted to comply with, a value of 10.7% of the residential damages has been assigned to the emergency services costs. This figure is based on data collected from previous flood events in the UK and has also been used in this damage assessment. The details in Table 2.9 were recorded within the economic risk shapefile attribute tables:

Table 2.9 - Emergency Cost Data

Data type	**Attribute name**	**Data details**
Emergency costs	Q100_emerg, Q75_emerg, Q50_emerg, Q25_emerg, Q10_emerg, Q5_emerg, Q2_emerg	Equal to 10.7% of the residential damages.

2.5.8 Intangible Impacts of Flooding

Apart from the material damages to the building structure and the goods inside the property, it is recognised that there are monetary damages associated with clean-up costs, temporary accommodation, stress, etc. The measure of 'intangible impact' is detailed in the FCERM-AG (Environment Agency, 2010a) however this method appears to contribute far too low an intangible effect. As such, the best estimate of these intangible effects is now linked to a value of £2,513 per household per event, based on future climate change metrics (Ramsbottom *et al.*, 2012). This value is comprised of a figure of £1,065 per person and the assumption that there are 2.36 persons per house from the 2001 Census (still applicable after the 2011 Census). This value was then weighted using social grade factors and the proportion of each social grade in an individual small area (using 2011 Small Area Census Data). The social grade factors are shown in Table 2.10 below.

Table 2.10 - Total weighted factors by approximated social grade

AB	**C1**	**C2**	**DE**
0.74	1.12	1.22	1.64

No intangible damages are assigned to commercial properties as these costs do not apply at the same level.

Table 2.11 - Intangible Damage Data

Data type	Attribute name	Data details
Intangible Damage	Q100_IntD, Q75_IntD, Q50_IntD, Q25_IntD, Q10_IntD, Q5_IntD, Q2_IntD	The equation to calculate the intangible damage is as follows: (2513*0.74*([Per_AB]/[HRPs]))+(2513*1.12*([Per_C1]/[HRPs]))+(2513*1.22*([Per_C2]/[HRPs]))+(2513*1.64*([Per_DE]/[HRPs]))

2.5.9 Annual Average Damage and Present Value Damage

In order to gain an appreciation of the economic risk the overall damage needs to be calculated. This is represented by assessing the likelihood of each of these flood events occurring in any given year and applying this as a percentage to the damage; this is known as the Annual Average Damage (AAD). The AAD can then be taken over the lifetime of the study that has been set at 100 years and discounted back to present day costs; this is known as present value damage (pvD). The events that were considered for this study were the 1 in 2, 1 in 5, 1 in 10, 1 in 25, 1 in 50, 1 in 75 and 1 in 100 year flood events.

The AAD can best be described by considering the graph shown Figure 2.4. The points shown represent the various design flood events where the damage has been calculated. Their position on the graph is dictated by the damage caused and the frequency of the flood event occurring in any given year. These points are joined together to create a damage curve. The area under the curve is therefore a function of the damage and the frequency and gives the AAD. The events that were considered for this study were the 1 in 2, 1 in 5, 1 in 10, 1 in 25, 1 in 50, 1 in 75 and 1 in 100 year flood events.

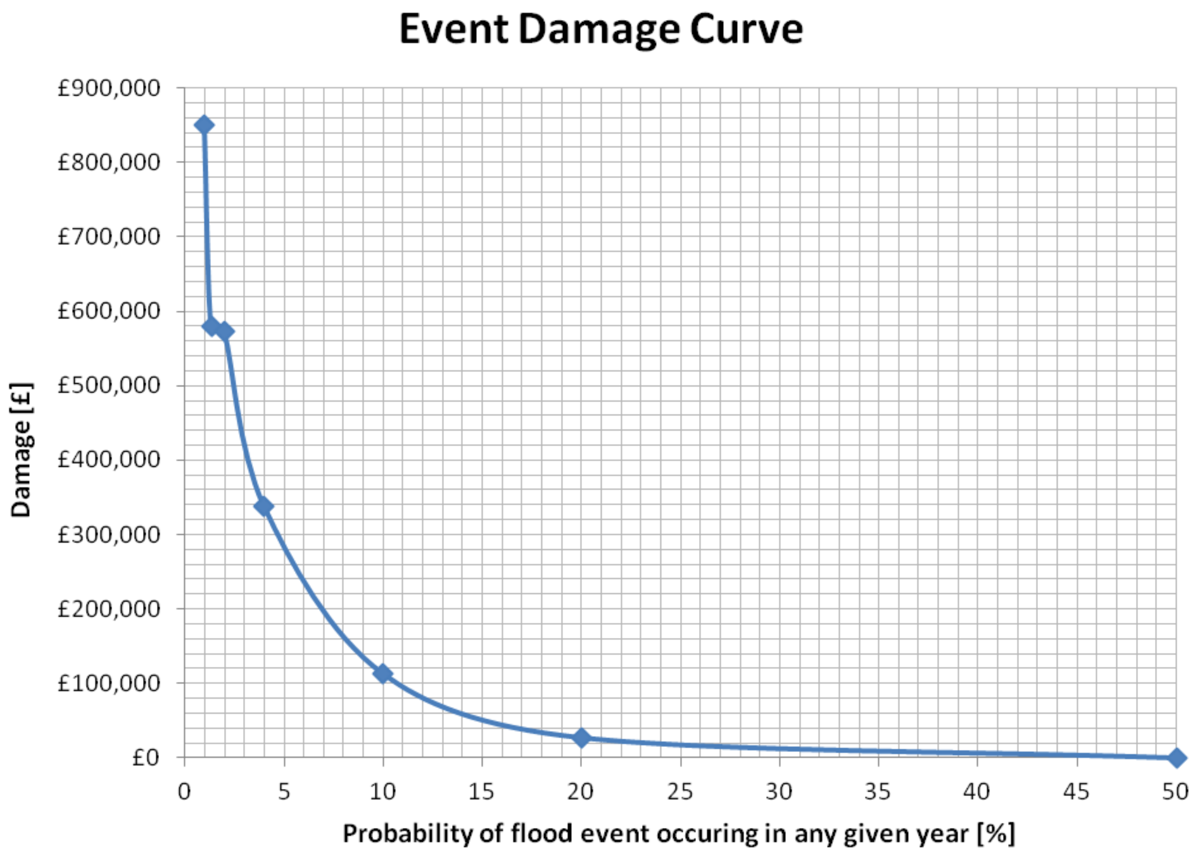

Figure 2.4 - Fintona Event Damage Curve

Once the AAD is calculated the present value damage is calculated. The present value damage calculation sums the AAD that is expected to occur for each of the 100 years being considered in this study. However in order for the damage value in each year to be comparable with each other they are discounted to represent the equivalent present damage value. Discounting damage values in the future is based on the principle that generally people prefer to receive goods or services now rather than later. This is known as time preference. The cost therefore of providing a flood management option will also be discounted to present day values. For this project the discount rates were taken from the Treasury's 'Green Book' (HM Treasury, 2003), as shown in Table 2.12 below.

Table 2.12 - The Green Book's Long Term Discount Rate

Period of Years	**0 - 30**	**31 - 75**	**76 - 125**	**126 - 200**	**201 - 300**	**301 +**
Discount Rate	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%

This amounted to factoring the AAD by 29.813. The AAD and PvD are calculated for the direct damages and intangible damages separately then totalled to give the overall damage available.

The following details were recorded within the economic risk shapefile attribute tables:

Table 2.13 - AAD and pvD Data

Data type	Attribute name	Data details
Annual Average Damage for direct damages, intangible damages	AAD, AADInt,	The equation to calculate the AAD is as follows: (((([Q2_EvDam]+[Q5_EvDam])/2*(0.5-0.2)+([Q5_EvDam]+[Q10_EvDam])/2*(0.2-0.1)+([Q10_EvDam]+[Q25_EvDam])/2*(0.1-0.04)+([Q25_EvDam]+[Q50_EvDam])/2*(0.04-0.02)+([Q50_EvDam]+[Q75_EvDam])/2*(0.02-0.01333)+([Q75_EvDam]+[Q100_EvDam])/2*(0.01333-0.01))
Present value damage	pvD, pvDInt,	The AAD factored by 29.813.

2.5.10 Capping Damages

It is recognised that for certain properties the overall damage associated with it can far exceed the market value of the property. This can be due to either the depth to which it floods or the frequency with which it floods or a combination of both factors. Where such a situation occurs it is necessary to cap the damages at the market value.

When capping damages for a property, the regional average risk free market value is used. Detailed research was carried out in order to establish an accurate and robust representation of property values. For residential properties in Fintona the 2017 Quarter 2 Standardised House Price for Fermanagh and Omagh was used. This information was produced by Land and Property Services and released under the Open Government License v3.0.

For a non-residential property its rateable value multiplied by a factor which reflects the added value of percentage rental yield from that property is used. Research was carried out to identify both the rateable value and the average rental yield for commercial properties in the region. Again detailed research was undertaken to identify robust rateable values for commercial properties in the region. Data produced by the Department of Finance detailing the prime rate per square metre for shops, offices, warehouses and factories in January 2017 was obtained. Relevant wards and therefore properties could be identified within the document. An average rate (£/m^2) for each property type across the relevant wards was calculated and used for the assessment.

For percentage rental yield, an average for Northern Ireland of around 6.9% was identified using data produced by Savills, 2017.

The methods used to acquire robust values for capping damages were recommended in the FCERM Manual 2013 and the MCM 2016.

The approach taken in this study is to cap the direct damages and the intangible damages separately before totalling up the overall damages.

The following details in Table 2.14 were incorporated within the economic risk shapefile attribute tables:

Table 2.14 - Capping Damages Data

Data type	Attribute name	Data details
Capped damages for direct and intangible	pvD_Cap, pvDInt_Cap,	Residential property damages over £118,451 are capped at this value. Commercial property damages capping value = rateable value x % rental yield

Table 2.15 - Commercial Capping Damages Data

MCM_Code	Property Type	Capping Value /m^2
2	Shops	£78.84 x 16.7 = 1316.63
3 **51** **6**	Offices Leisure Public Buildings	£50.41 x 16.7 = 837.39
4 **8** **910** **960**	Warehouses Industry Car Park Electricity Hereditament	£15.21 x 16.7 = 254.01

2.5.11 Damage Assessment Review

A review of the damage assessment was carried out to quality check the data being used. This was carried out by reviewing the properties that contribute over 1% of the capped PVd. The review consists of checking the property type and the finished floor level including split levels, the footprint areas and the depth damage being applied.

2.5.12 Summary of Damage Assessment

The field ‘PvBFinal’ in the attribute table of the economic benefit shapefile is the total potential avoided damage which sums the capped present value direct damages and the uncapped present value intangible damages. This gives the overall present value damage. The table below summarises the damages associated with Fintona.

Total AAD	Total PvB
£38,516.71	£1,148,298.69

Overall in Fintona, it was found that 63 properties were located within the 1% AEP flood extent (55 residential and 8 commercial), with 57 of these incurring monetary damage during a 1% AEP flood event (52 residential and 5 commercial).

2.6 NON-MONETISED RISK

2.6.1 Economic Receptors

Economic receptors which were considered within this study include Residential and Commercial Properties, Wastewater Treatment Works and Water Treatment Works, Electricity Substations, Gas Lines, Roads, Railways and New Developments. Figure 2.5 below highlights the receptors which were located within the Fintona Study Area.

During the design flood event 55 residential properties and 8 non-residential properties were identified as at risk. In addition to these properties other residential properties at Meadowbrook have historical evidence of flooding and should also be considered to be at risk. Parts of Main Street and Kings Street would also experience flooding during the design event.

A section of Fintona's Wastewater Treatment Works was also identified as at risk during the design flood event. Other receptors assessed such as Electricity Substations and New Development Areas are not at risk from inundation.

2.6.1 Social Receptors

Social receptors considered within this study include Industrial Heritage Buildings, Listed Buildings, Historic Parks and Gardens, Areas of Archaeological Potential, Areas of Archaeological Interest and Residential and Commercial Properties. Figure 2.6 below highlights the receptors which were located within the Fintona Study Area.

One social receptor, New Bridge which is a listed structure was identified. While the bridge is considered flood resilient and would not require protection the status of the structure should be considered during optioneering to avoid alteration or damage if possible.

The police station is not at direct risk of flooding during the design flood event however access to the police station would be affected by the flooding to Main Street. Other social receptors such as the health centre, primary school and fire station are also not at direct risk of flooding but should be considered during the optioneering phase to ensure access to them is maintained.

2.6.1 Environmental Receptors

Environmental Receptors which were considered within this study include Salmonid Rivers, Ancient Woodland, RAMSAR, Areas of Specific Scientific Interest (ASSI), Areas of Natural Beauty (AONB), Special Areas of Conservation (SAC) and Special Protection Areas (SPA). Figure 2.7 below highlights the receptors which were located within the Fintona Study Area.

The Quiggery River is designated as a salmonid river. As such the implications of any option during construction, maintenance and operation will need to be considered. Disturbance to the Quiggery River should be kept to a minimum. No other environmentally designated areas were identified within the study area.

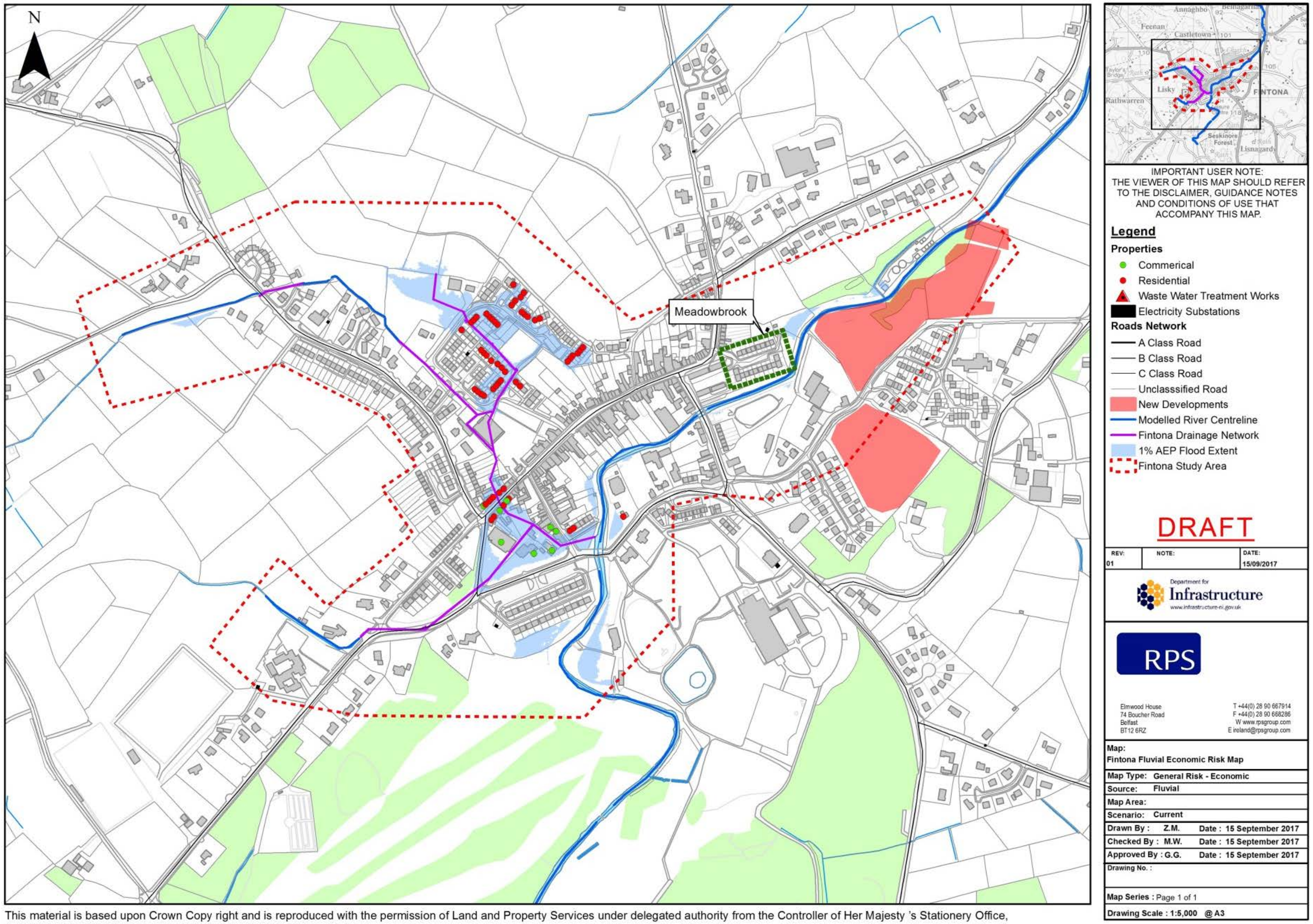

Figure 2.5 – Summary of Flood Risk to Economic Receptors in Fintona Study Area

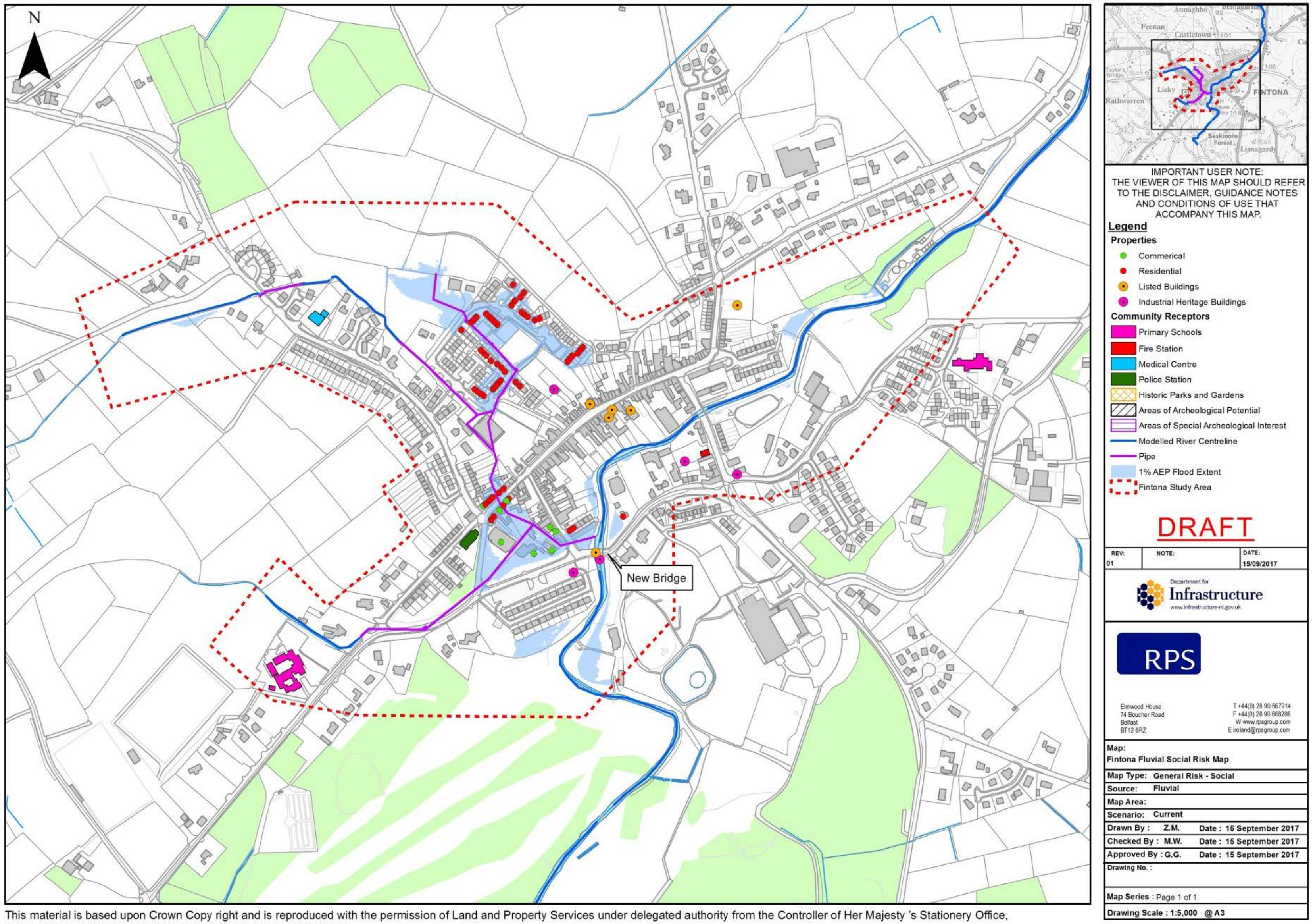

Figure 2.6 - Summary of Flood Risk to Social Receptors in Fintona Study Area

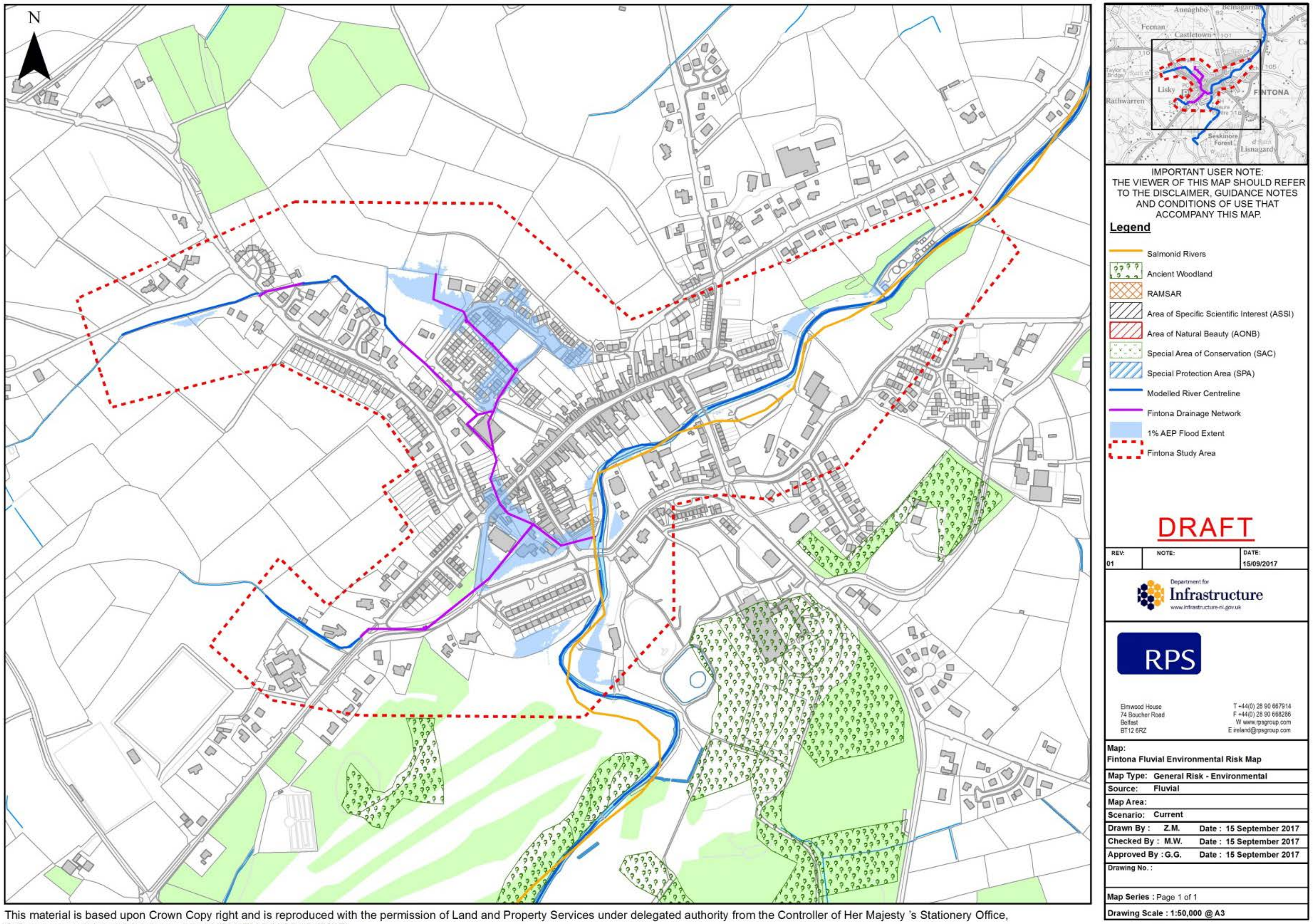

Figure 2.7 - Summary of Flood Risk to Environmental Receptors in Fintona Study Area

2.6.2 Summary of Non-Monetised Risk

The following receptors in Table 2.16 were identified as at flood risk during the design flood event or at potential risk during the construction, maintenance and operation of the preferred option.

Table 2.16 – Summary of Non-Monestised Risk in Fintona

Risk Category	**Receptor**	**Risk type**
Economic	55 residential properties	At risk from flooding
Economic	8 non-residential properties	At risk from flooding
Economic	Main Street and Kings Street	At risk from flooding
Economic	Fintona WwTW	At risk from flooding
Social	New Bridge	Listed building at risk of damage or modification during construction, maintenance and operation.
Environmental	Quiggery River	Salmonid river at risk of disturbance during construction, maintenance and operation.

3 OBJECTIVES AND CONSTRAINTS

The following objectives and constraints have been identified from the project brief, reviewing the flooding mechanisms and the Flood Risk Assessment.

3.1 OBJECTIVES

The scope of services detailed the need to consider a wide range of flood alleviation options including short-term (0-5 years) measures and long-term (5+ years) measures for the Fintona Study Area. The long term measures should alleviate potential future flooding and provide protection to properties currently at risk of flooding during events up to and including the 1 in 100 year return period flood for the life time of the scheme. The primary objectives are therefore:

- Reduce the flood risk through short-term measures
- Provide the design SoP through long-term measures.

These remain the primary objectives of this study however other objectives and constraints have been identified from the flood risk assessment and are detailed according to the categories set out below.

3.1.1 Reduce the Flood Risk to Receptors in Fintona

As discussed earlier in Section 2.5, a damage assessment was carried out which determined that during a current 1 in 100 year flood event, there are 57 properties which incur a monetary damage – 5 commercial properties and 52 residential properties. Flood risk areas in Fintona are a result of two separate flooding mechanisms; out of bank flooding from the Quiggery River and surcharging manholes on culverted watercourses U1401*, U1401 and U1402. The recommended options should seek to reduce this flood risk as much as possible.

3.1.2 Technical Objectives and Constraints

Technical objectives and constraints consider any factor that needs to be accounted for or that may cause limitations to the design, construction or maintenance of the proposed option. The following objectives or constraints have been identified:

- A section of the culverted watercourse U1401 travels underneath the Eurospar in Fintona. As the culvert travels under this building, altering it would be very difficult.
- A section of the culverted watercourse U1401 travels underneath the houses on Main Street. Altering this section of the culvert would be very difficult.
- Reviewing the flooding mechanism showed that manholes will surcharge during the design flood event. As the road drainage network connects into culverted watercourses there is also a risk of the road drainage network surcharging also.
- There should be no increase in flood risk to any other flood vulnerable receptor within Fintona.
- The flood alleviation option should provide or be readily adaptable to provide future climate change protection.

- The flood alleviation option should have few and/or managed health and safety issues regarding construction, maintenance and operation.

3.1.3 Social Constraints

Social constraints consider any social receptor or receptor used for social purposes that may be affected by the design, construction and maintenance of the proposed option. The following objectives or constraints have been identified:

- Access to the study area would be via residential areas. The impact to residents would need to be considered during constructions, maintenance and operation.
- Some areas zoned for flood alleviation measures are private land. The proposed works would be proceeding under the goodwill of the private land owner. The proposed measures should have as limited impact as possible to the landowners current use of the land and also future use.
- Continued access to socially important receptors during flood events should be maintained. These include the GP Surgery, Fire Station, Police Station and Primary Schools.

3.1.4 Environmental Constraints

Environmental constraints consider any environmental receptor or receptor with environmental significance that may be affected by the design, construction and maintenance of the proposed option. The following objectives or constraints have been identified:

- The Quiggery River which runs through Fintona is a salmonoid river and as such any in-channel works or any works which may involve modification to the river bed should be avoided.

3.1.5 Economic Constraints

Economic constraints consider current cost to operations relative to the estimated costs of any proposed option in relation to the available budget and achieving value for money. The following objectives or constraints have been identified:

- As this project has been commissioned by a public organisation, the objective is to identify the most economically viable option and at a minimum have a benefit cost ratio (BCR) greater than unity.
- It is desirable if possible to prevent flooding to Main Street and King Street.
- It is desirable if possible to provide protection to Fintona Waste Water Treatment works.

4 OPTION DEVELOPMENT AND ANALYSIS

4.1 OPTION IDENTIFICATION

There are various ways to manage the flood risk within any study area. These methods can be grouped into four areas.

- **Protect methods**: reduce the likelihood of flooding. Methods include flood walls, flow diversion and upstream storage.
- **Prepare methods**: reduce the impact of flooding. Methods include individual property protection, flood forecasting and public awareness campaigns.
- **Prevent methods**: avoids future flood risk. Methods include planning and development control.
- **Permit methods**: accepts that flooding will occur. Methods include maintaining the existing regime and doing a minimal amount of maintenance.

The main aim of the Fintona study is to assess whether an economical, environmentally and socially sensitive scheme can be produced which will alleviate the flood risk to affected properties, infrastructure and businesses in the study area. This would, in general, entail providing ‘protect’ methods over ‘prepare’ methods and avoiding ‘permit’ methods where possible. Prevent methods should always be included to prevent an increase in future flood risk.

4.1.1 Shortlist of Options

The aim of the screening process is to ensure the widest possible range of flood management options are considered in the assessment process while the rejection of any methods shall be robust and with clear and transparent reasoning. The long list of measures considered is presented in Table 4.1 below.

Table 4.1 - Long List of Potential Measures

Option	Method type	Description
Do Nothing	Permit	Implement no new flood risk management measures and abandon any existing practices.
Maintain Existing Regime	Permit	Continue any existing flood risk management practices, such as reactive maintenance.
Do Minimum (Temporary Defences)	Permit	Implement additional minimal measures to reduce the flood risk in specific problem areas without introducing a comprehensive strategy.
Planning and Development Control	Prevent	Zoning of land for flood risk appropriate development, prevention of inappropriate incremental development, review of existing planning policies.

Land Use Management	Protect	Changing how the land is used in order to store or slow surface water runoff and slow in channel and out of bank flow along the river in order to store flood water in suitable locations. This may consist of the creation of wetlands, restoring river meanders, increasing the amount of boulders and vegetation in channel, perpendicular hedges or ditches in the floodplain, tree rows and planting in floodplain to either slow flow or direct flow, planting along banks parallel to flow, fencing off livestock from riparian strip, changing agricultural practices to decrease soil compaction and increase water infiltration.
Maintenance Programme	Protect	Increased frequency of routine maintenance, targeting of problem culverts, bridges or other control structures, removal of debris and rubbish tipping, desilting of sedimentation prone areas.
Upstream Storage/Storage	Protect	Large scale dam and reservoir, offline wash lands (embanked areas of floodplain to store water during larger flood events).
Tidal Barrage	Protect	A fixed or moveable barrier across the river to prevent tidal water progressing upstream.
Improvement of Channel Conveyance	Protect	Deepening of channel bed, widening of channel, realigning long section profile, removal of constraints, lining or smoothing channel. Increasing the capacity of existing culverted watercourses.
Hard Defences	Protect	Reinforced concrete walls, earth embankments, demountable barriers.
Relocation of Properties	Protect	Abandoning flood risk area and properties within and providing alternative properties in suitable area.
Diversion of Flow	Protect	Removing flow from the watercourse via a diversion and discharging to a suitable river or coastline or reintroducing the flow further downstream. This may consist of a culvert, an open channel or using the existing topographical features of the floodplain to convey out of bank flow and discharge to other suitable rivers, the coast line, further downstream on the same river or to an open area for storage. This may consist of fields, park land, roads, etc.
Sealing Manholes	Protect	Preventing pressurised culverts from surcharging through manholes and flooding the surrounding area.
Flood Warning/Forecasting	Prepare	Installation of flood forecasting and warning system and development of emergency flood response procedures.
Public Awareness Campaign	Prepare	Informing public who live, work or use a flood risk area on risks of flooding and how to prepare for flooding.
Individual Property Protection	Prepare	Flood protection and resilience measures such as flood gates, vent covers, use of flood resilient materials, raising electrical power points, etc.

Each of these measures has been reviewed against its applicability for the Fintona area and those which are obviously unsuitable have been removed. Table 4.2 below indicates those measures which have been included and excluded.

Table 4.2 - Applicable list of measures to the Fintona Study Area

Option	Review Comment	Applicable?
Do Nothing	Required to maintain the watercourses and remove blockages etc. under the requirements of the Drainage (Northern Ireland) Order 1973. Therefore cannot carry out the Do Nothing or walk away measure.	×
Maintain Existing Regime	Baseline condition, consider further.	✓
Do Minimum (Temporary Defences)	Consider further.	✓
Planning and Development Control	Consider further.	✓
Land Use Management	Consider further.	✓
Maintenance Programme	Consider further.	✓
Upstream Storage/Storage	Consider further.	✓
Tidal Barrage	Not applicable - principle source of flooding is fluvial.	×
Improvement of Channel Conveyance	Consider further.	✓
Hard Defences	Consider further.	✓
Relocation of Properties	Consider further.	✓
Diversion of Flow	Consider further.	✓
Sealing Manholes	Consider further.	✓
Flood Warning/Forecasting	Consider further.	✓
Public Awareness Campaign	Consider further.	✓
Individual Property Protection	Consider further.	✓

4.1.2 Technical Review of Options

All measures which have been considered as applicable are reviewed on their technical merits and their ability to alleviate the specific mechanisms of flooding that exist in the Fintona area. This is based on engineering judgement, information from DfI Rivers staff, flood mapping and through review of animations output from the hydraulic model. The following sections give a technical review of all applicable measures.

4.1.2.1 Additional Maintenance

This method considers whether improvements can be made to augment the existing maintenance regime which will provide a significant beneficial impact on flood risk in the area. A review was carried out of the existing watercourse network. This included assessing the channel vegetation, the amount of debris present in the channels and the likelihood of structures becoming blocked. Although additional maintenance could be carried out, it was concluded that this would not help to reduce the risk of flooding to receptors in Fintona and so was not considered further within this study.

4.1.2.2 Temporary Defences

This option includes interim measures which could be implemented as a short-term flooding solution to offer protection to individual properties such as sand bags, small earth bunds or block work walls. A review was carried out to identify suitable areas for temporary defences. This review considered the flow path of the flood waters and the depth of water at various locations. To avoid the risk of sudden failure, depths of over 0.6m were considered unsuitable for temporary defences. The flood risk area of Ashfield Gardens was found to be a suitable location for temporary defence measures, the layout of which is shown in Figure 4.1 below. The measures consist of a small earth bund in the field adjacent to the north-westerly edge of Ashfield Gardens to reduce the likelihood of overland flow into the residential estate. Also as a manhole located on high ground adjacent to a residential property is at risk of surcharging, the replacement of the existing fence for a block work wall was considered so as to provide a stronger and more permanent defence than sandbags. Sandbags are then shown to direct flood water south-easterly down Ashfield Gardens to the footpath which runs parallel to the football pitch. This path is lower than the surrounding ground and would direct flood water to manholes U1401*/02 and U1401*/01 which would drain water away as flood waters recede. Some modifications to kerb lines may be required in this area to assist with free drainage of water.

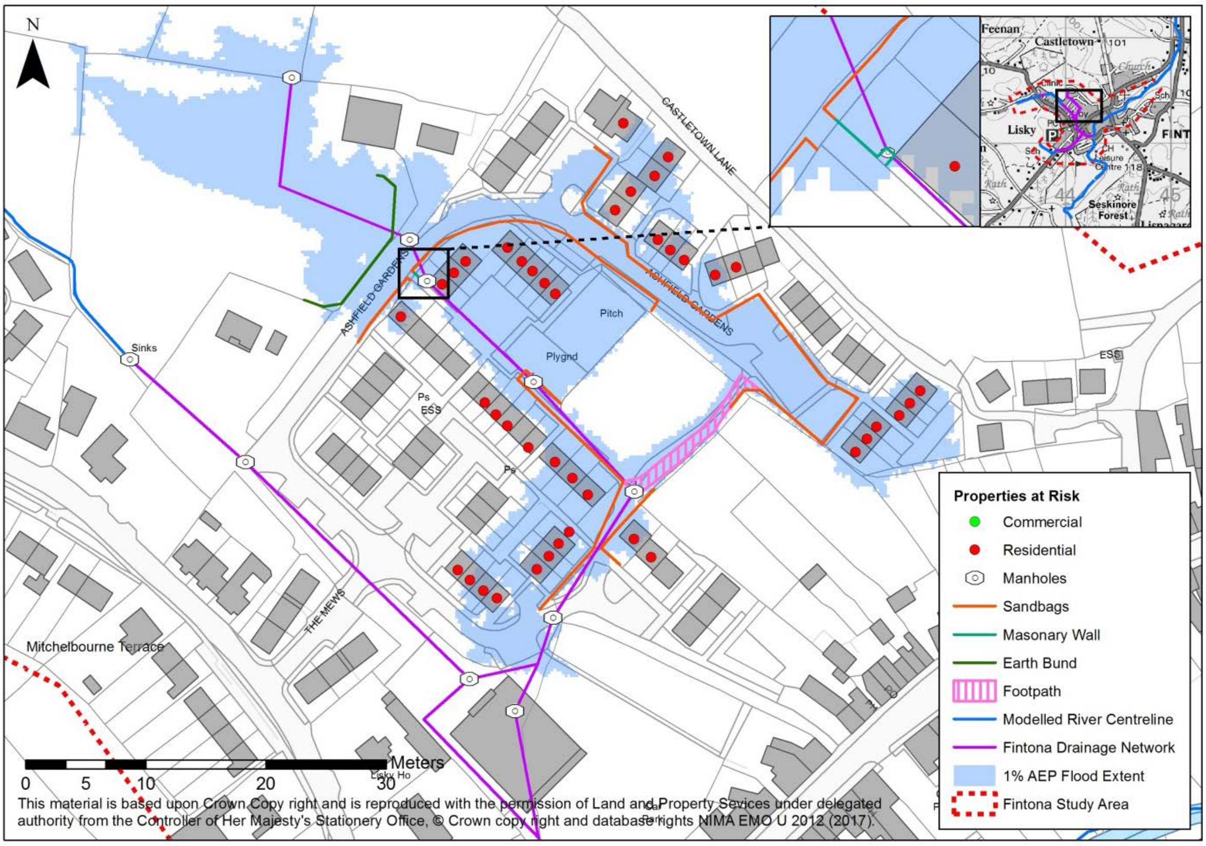

Figure 4.1 - Potential Sandbag Locations - Ashfield Gardens Area

Sandbags may also be placed along Main Road and at New Bridge in order to provide a level of protection to the properties immediately behind. Figure 4.2 below shows the proposed locations for the sandbags.

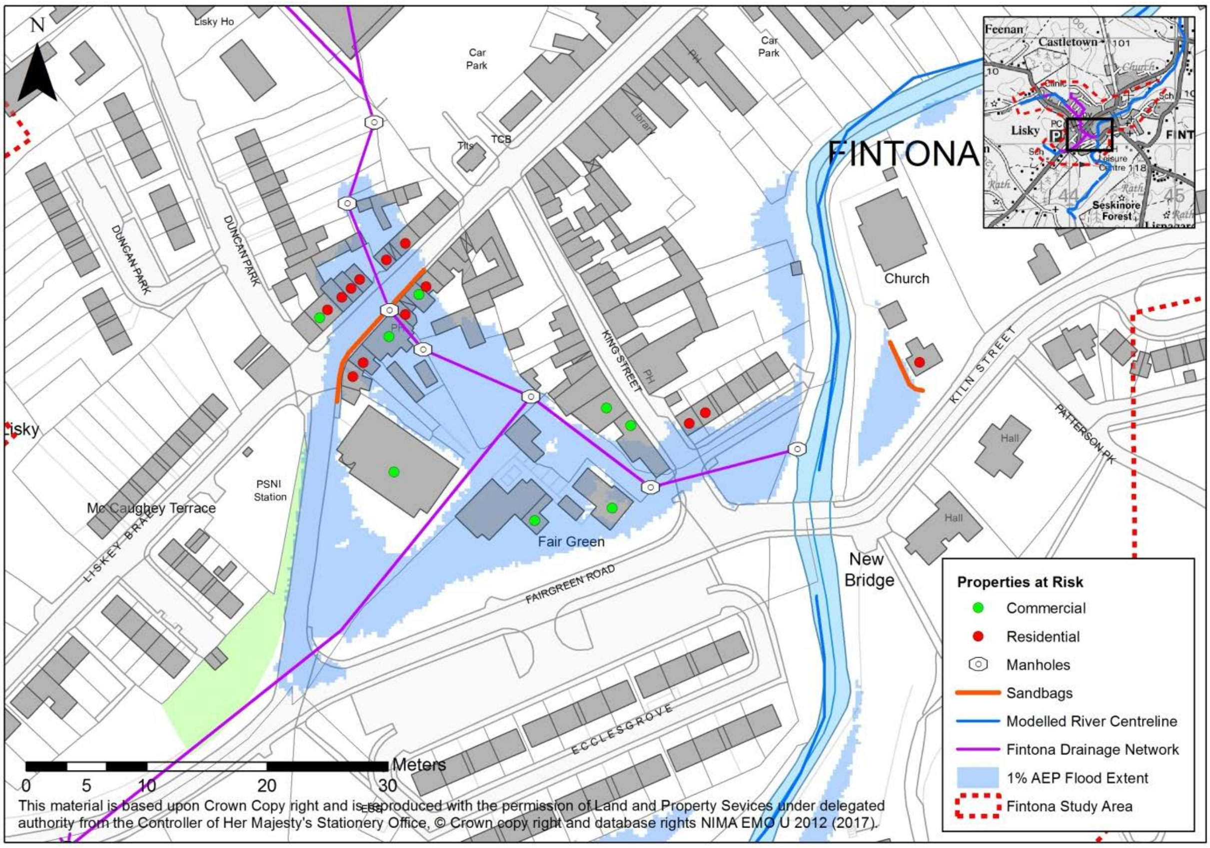

Figure 4.2 - Potential Sandbag Locations - Main Street/New Bridge Area

4.1.2.3 Planning and Development Control

Fintona's urban area is already largely developed so this method may not help resolve flooding issues. There are two areas zoned for development within Fintona as shown in Figure 4.3 below. These areas do not lie within the current 1 in 100 year flood extent and so any properties built here in the future will not be at risk of flooding up to a 1% AEP event.

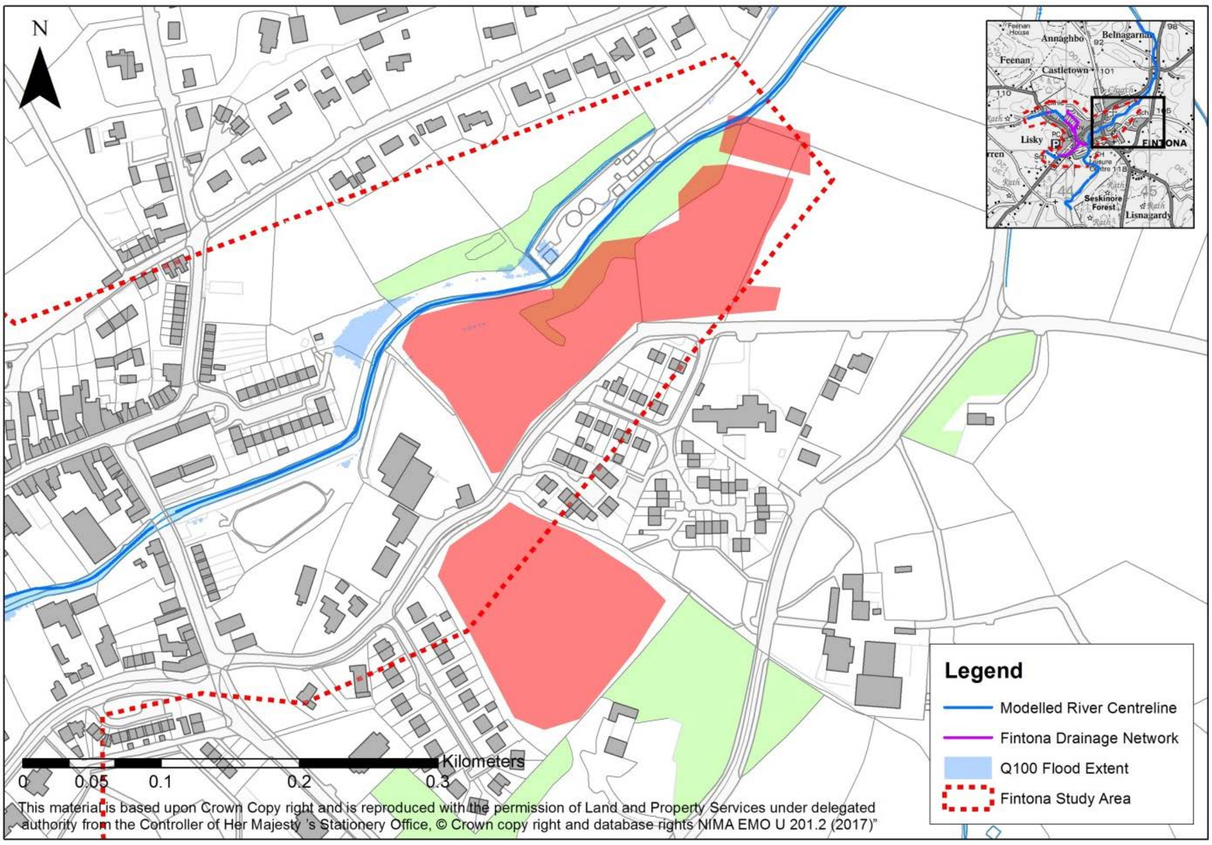

Figure 4.3 - Areas zoned for development in Fintona

4.1.2.4 Land Use Management

Land Use Management was considered for the streams U1401, U1401* and U1402. This method was not considered for the Quiggery River. The Quiggery River has a large catchment (320km^2) and for Land Use Management to be effective would require many areas within the catchment to change their land use and many Natural Flood Management (NFM) features to be implemented throughout the catchment requiring the positive contribution of many land owners. While this method could reduce flood risk to Fintona the level of risk resulting from the Quiggery River is small in comparison to the total flood risk and the method would not be proportionate to the scale of the risk. The likelihood of reducing flood risk through land use management methods is good in the urban streams mentioned above and the assessment of this method has therefore focused within these catchments.

A historical review was carried out to ascertain if the land use and watercourses have changed over time. The OSNI Historical Mapping 1846-1862 indicates that the land within the catchments of U1401, 1401* and 1402 were predominately used for agricultural purposes with the field sizes similar to present day. However, an area at the upper reaches of streams U1401 and U1402 is shown to have been marshy land. Compared with present day land use this marsh area has reduced in size and the land improved to be used for agricultural purposes. Figure 4.4 below shows the change in land use. The route of the watercourses has not significantly changed over time however the lower reaches of U1401 and 1402 and nearly all of U1401* have now been culverted. The Fintona Settlement has grown also with development in proximity to the lower reaches of streams U1401 and U1402 and along the majority of stream U1401*. The extent of Ecclesville Demesne has remained relatively unchanged and is mainly forested or grassland as it was during the 1846-1862 period.

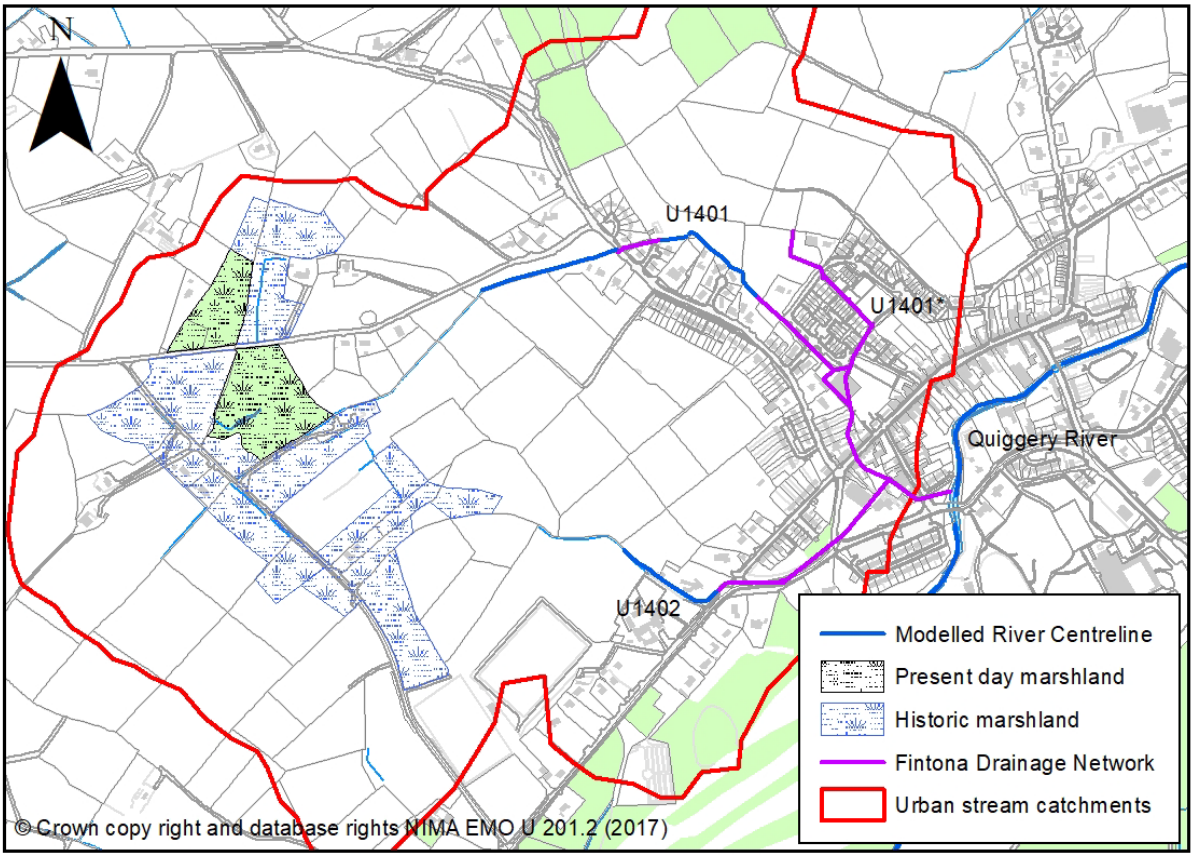

Figure 4.4 - Map showing reduction in marshy land from 1846-1862

The cumulative changes to land use and to the watercourses, namely the reduction of the marshland area, improved drainage to the fields, increased development and culverting of the watercourses, will have increased the rate at which water will travel from head to source. The result of this in terms of flood risk is to produce flashier flood events with higher peak flows.

This method seeks to find ways to revert the effects of these changes through the restoration, enhancement and alteration of the existing natural features and characteristics. This method focuses on retaining water and slowing run-off in the catchment thereby lowering water levels and reducing the associated flood risk within the watercourses. This can be achieved by a number of techniques for example planting, restoring meanders and attenuation ponds. Land use management methods can be applied to any catchment with characteristics that provide favourable conditions to make land use management an effective method in managing the flood risk.

The urban stream catchments were divided into three area types. Area Type 1 is made up of fields used for livestock grazing, including cattle, on relatively steep slopes. Area Type 2 is also made up of fields used mainly for livestock grazing however the lands are flatter. Area Type 3 is urbanised with a lot of hard standing areas, storm drainage networks and culverted watercourses. Figure 4.5 shows the location of these areas.

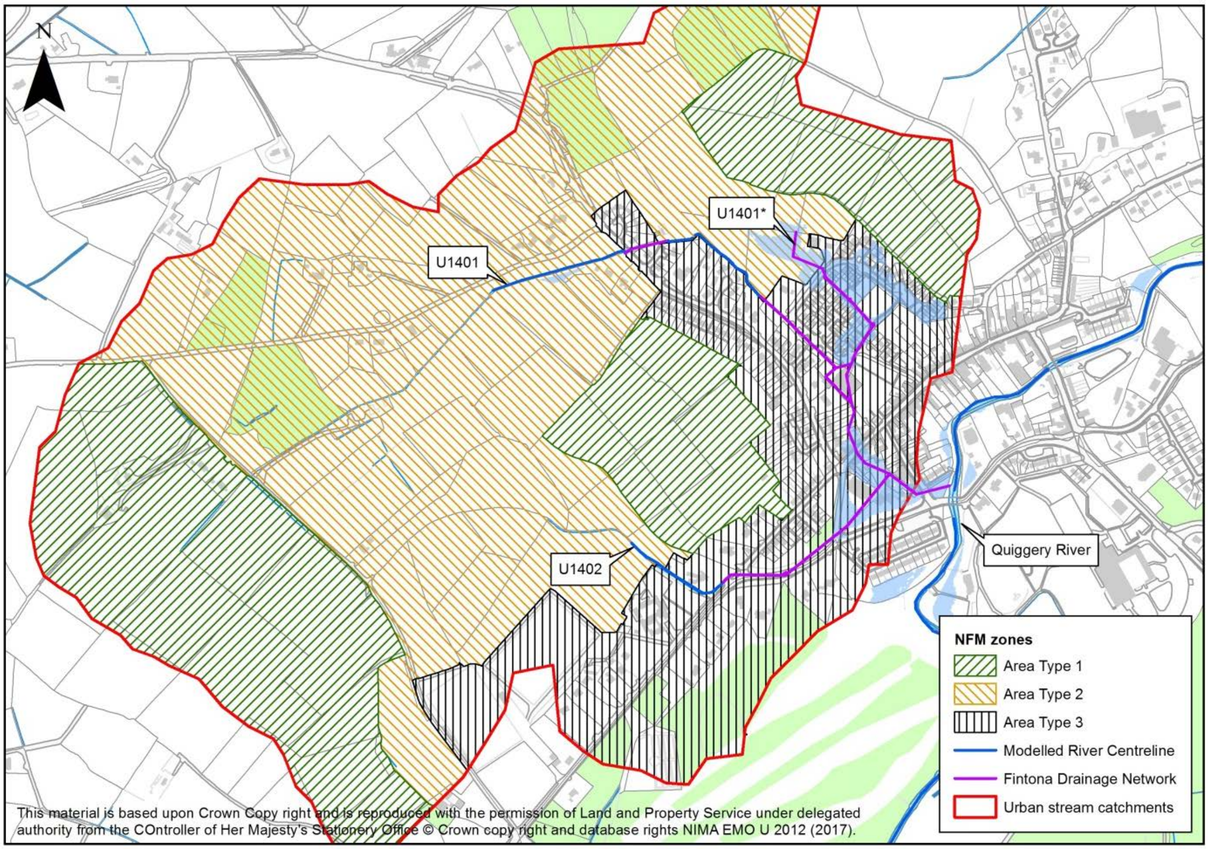

Figure 4.5 - Land use area types

Forest Research which is the Research Agency of the Forestry Commission has undertaken significant research into opportunities for woodland creation to reduce flood risk in Northern Ireland. One map which Forest Research have produced (shown as Figure 4.6 below) shows high priority areas for planting floodplain, riparian, and wider catchment woodland to reduce downstream flood risk. A total of 2,493 km^2 or 17.6% of Northern Ireland is identified as priority areas for woodland planting to reduce downstream flood risk, comprising 1,721 km^2 for wider woodland, 110 km^2 for riparian woodland and 663 km^2 for floodplain woodland. Currently, only 4.7% of Northern Ireland's floodplain is covered with woodland. Almost 44% of the floodplain is free from constraints to woodland planting, highlighting opportunities to significantly increase the floodplain woodland cover in Northern Ireland, from 71 km^2 to 663 km^2.

Defra's Sustainable Agricultural Land Management Strategy also highlighted a key feature of sustainable land management in Northern Ireland as: '*Properly located woody riparian strips in overland flow pathways to reduce nutrient and sediment loss to waterways to improve biological water quality'.* This for example could be implemented along the Quiggery River to help alleviate flood risk to Fintona. Agro forestry was also suggested in the strategy, where tress may be integrated within crop of livestock farming systems. As there are large areas of agricultural land along the Quiggery River this is an NFM measure which may reduce flood risk, as well as reducing soil erosion and providing shelter for livestock.

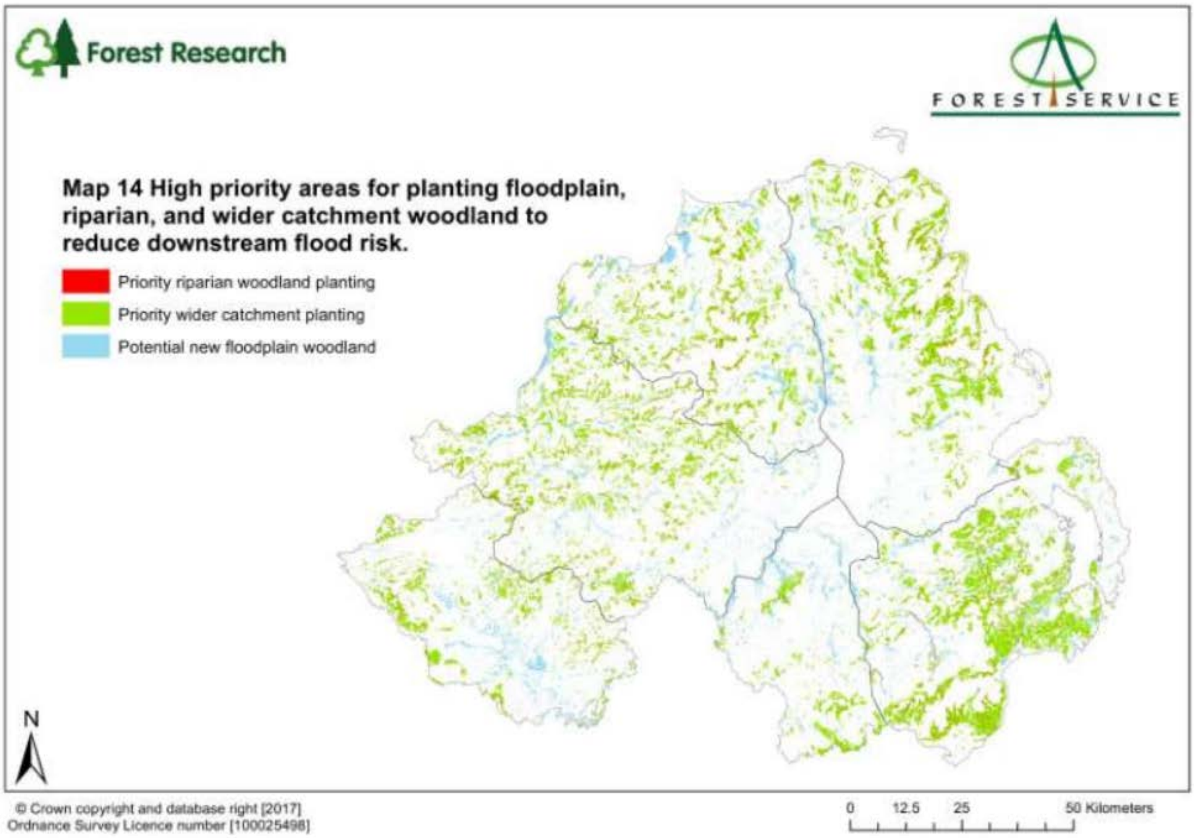

Figure 4.6 - High priority areas for planting floodplain, riparian and wider catchment woodland to reduce downstream flood risk

The Department of Agriculture, Environment and Rural Affairs (DAERA) also encourage the creation of new woodland and the management of existing woodlands by providing grant aid towards the cost of the work. Opportunity mapping for woodland expansion for the Forest Expansion Scheme 2017/18 shows areas of high priority riparian woodland planting, high priority catchment planting and medium priority woodland planting, a screenshot of which is shown in Figure 4.7 below. This mapping has highlighted large areas of medium priority woodland planting. Downstream of Fintona areas of high priority riparian woodland planting and high priority catchment planting have also been identified.

Figure 4.7 – DAERA Forest Expansion Scheme 2017/18

It would be possible to implement NFM features in Area Type 1. These features would aim to slow and store surface water runoff. It may be possible to create vegetation strips. This would consist of planting a hedgerow with trees along the contours of the fields. Incorporating a ditch system into these features would also be effective in intercepting the surface water runoff and increasing the infiltration rate of the soil profile. Figure 4.8 shows where these features could be placed within the catchment.

It would be possible to implement NFM features in Area Type 2. These features would aim to store water principally. As discussed in the upstream storage section it may be possible to construct a series of small earth bunds which would store the flood water temporarily in the fields. While the land could be used for the majority of the year, during times of high prolonged rainfall the areas behind the bunds would pond with water. Soil infiltration rate could be increased by hedgerow and woodland planting. This could take place along existing field boundary line, especially in lower lying areas. There are some fields which appear to be of low agricultural value. These areas could be designated for riparian woodland creation. Infiltration rates could be further improved by replacing cows with a lighter livestock such as sheep. Figure 4.8 shows where these feature could be placed within the catchment.

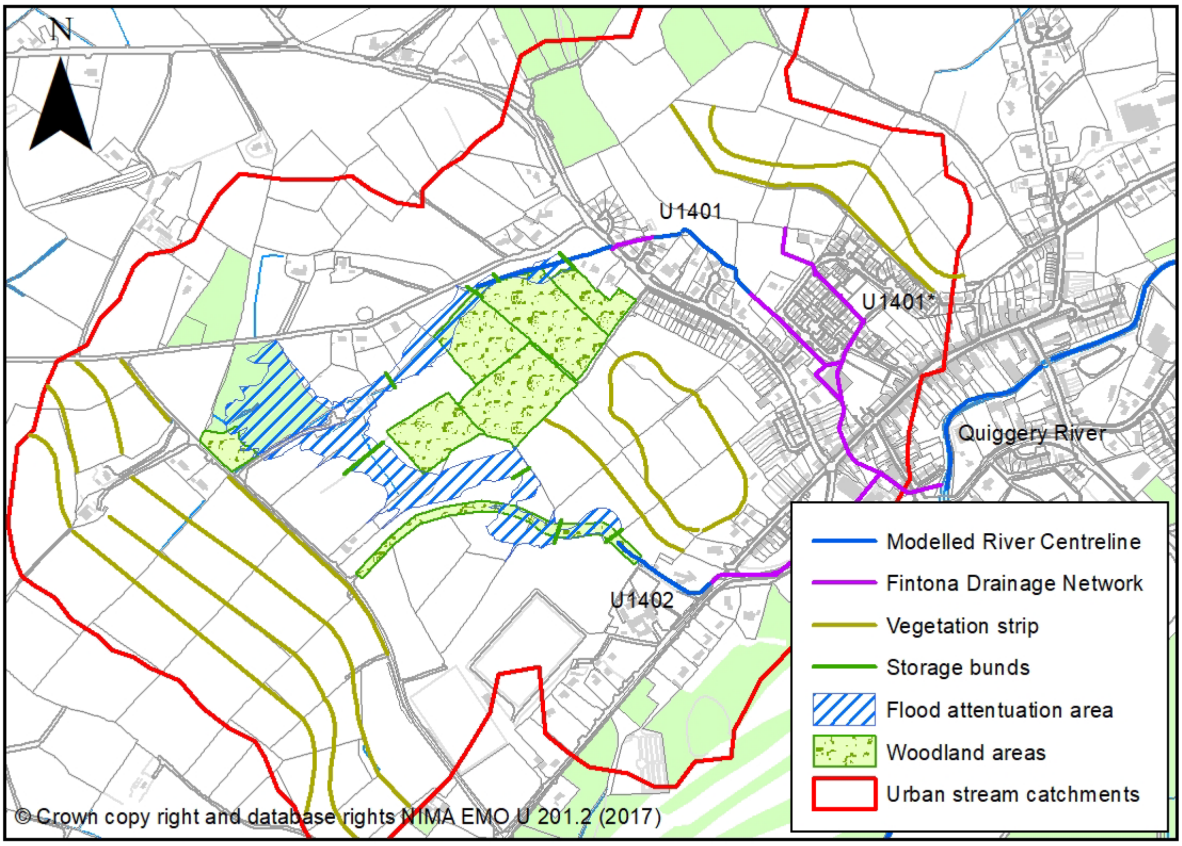

Figure 4.8 - Location of NFM measures

A review of the land use in Area Type 3 was carried out. It was found that there is little scope to change the land use. Any open space available would not be conducive with storing water. It may be possible to fit underground tanks in strategic places however this would be technically difficult to achieve and expensive to construct. It is therefore considered that Area Type 3 is not suitable for land use management methods.

Given that the majority of Area Types 1 and 2 are outside of the hydraulic model extent it is not possible to quantify the reduction in flood risk during the design event. While there are social, economic and environmental positives and negatives for land use management features it is technically feasible and should be considered further.

4.1.2.5 Upstream Storage

This method considers areas where flood water can be stored and then released at a controlled rate therefore reducing the flow rate through the study area and reducing the level of flood risk. This can be achieved by using existing depressions to create online or offline storage areas or by identifying pinch points which could be dammed such as a restricted point along a valley. Storage areas can be effective either upstream of the risk areas or within the risk area where parks or open areas are located.

For upstream storage to be effective on the Quiggery River the water level would need to be lowered by 0.9m. This would avoid out of bank flooding at New Bridge where there is one property at risk. The tail water level at the U1401 culvert outlet would also be lowered which would reduce the head loss through the culvert and the risk of manholes surcharging.

For this method to be technically feasible an equivalent flow to the 4% AEP flood event would have to be achieved. Relative to the scale of risk at Fintona and the potential benefiting areas a large area would be required to store the water and an extensive dam structure needed to regulate the flow. This measure is therefore not proportionate to the scale of the study and would be economically expensive to implement. Upstream storage on the Quiggery River is therefore considered to be unfeasible.

Storage areas were also considered on the urban streams U1401, U1401* and U1402. The topography is such that it would be possible to impound water upstream of the U1401 and U1402 culvert inlets. Various impoundment structure configurations could be used, such as large dam structures upstream of the culverts as shown in Figure 4.9, or a series of smaller bunds in the upper catchment as shown in Figure 4.10. The large impoundment area on Fintona Stream U1401 was modelled and results showed that it would be effective in preventing some of the manholes along the U1401 culvert from surcharging. Calculations carried out found that 7,401m^3 of storage would be required to reduce the 1% AEP flow equivalent to a 50% AEP flood event. It was also found that this impoundment area would provide 26,032m^3 of storage, therefore large enough to significantly reduce the volume of water travelling though the culverted watercourse U1401. Due to the limit of the model extents it is not possible to simulate the large impoundment area on Brookwood Stream U1402 or the series of smaller impoundments areas of U1401 and U1402. The reduction in flood risk cannot therefore be quantified. While there are social, economic and environmental positives and negatives for both configurations they are both technically feasible and should be considered further. Storage areas for the U1401* stream was also considered however the topography is such that it does not lend itself to storage. During the course of a flood event the field at the start of the modelled watercourse does flood and the potential to store the water in this field might be possible. This would prevent overland flow into the estate downstream. However this would have limited impact to the overall flood risk. It is recommended that this be considered as a “quick win” which is discussed further in the Temporary Defences measure.

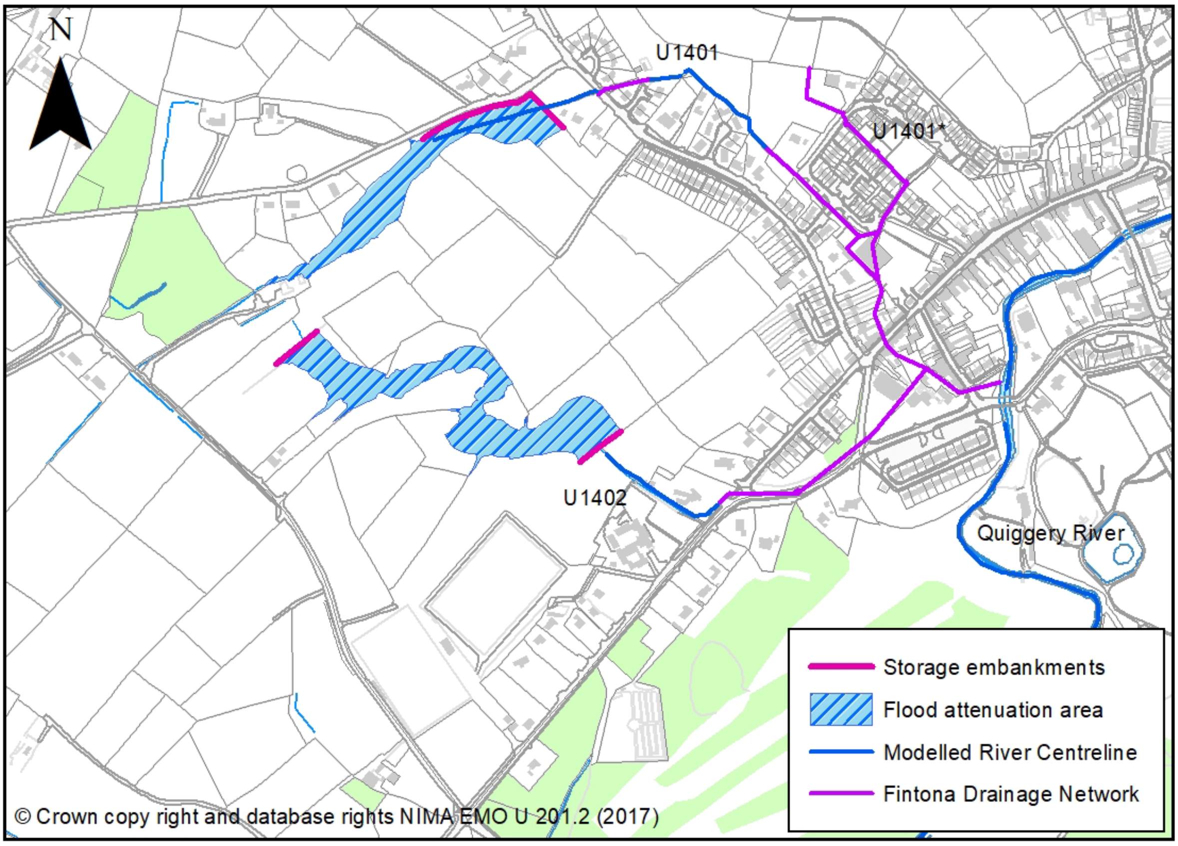

Figure 4.9 - Location of proposed large dams and resulting attenuation areas

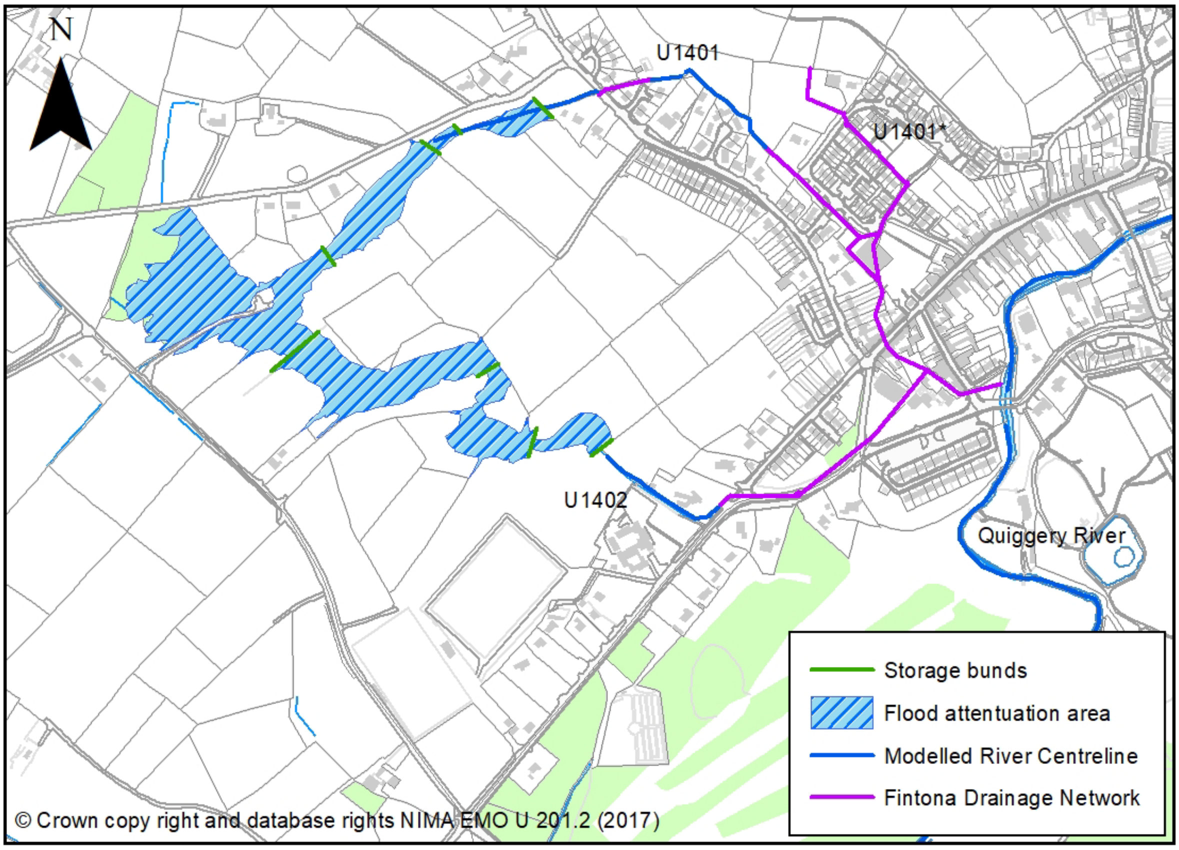

Figure 4.10 - Location of small bunds and resulting attenuation areas

4.1.2.6 Improvement of Channel Conveyance

This method focuses on increasing watercourse conveyance thereby lowering water levels and reducing the associated flood risk. This can be achieved by lowering the bed level, widening/reshaping channels, removing channel/structure constrictions, culverting reaches of watercourse or upgrading existing culverts and reducing roughness of the channel.

From analysing the channel bed of the Quiggery River an area of potential for improvement of channel conveyance was identified downstream of New Bridge. A long section of this area (highlighted in pink) is shown in Figure 4.11 below.

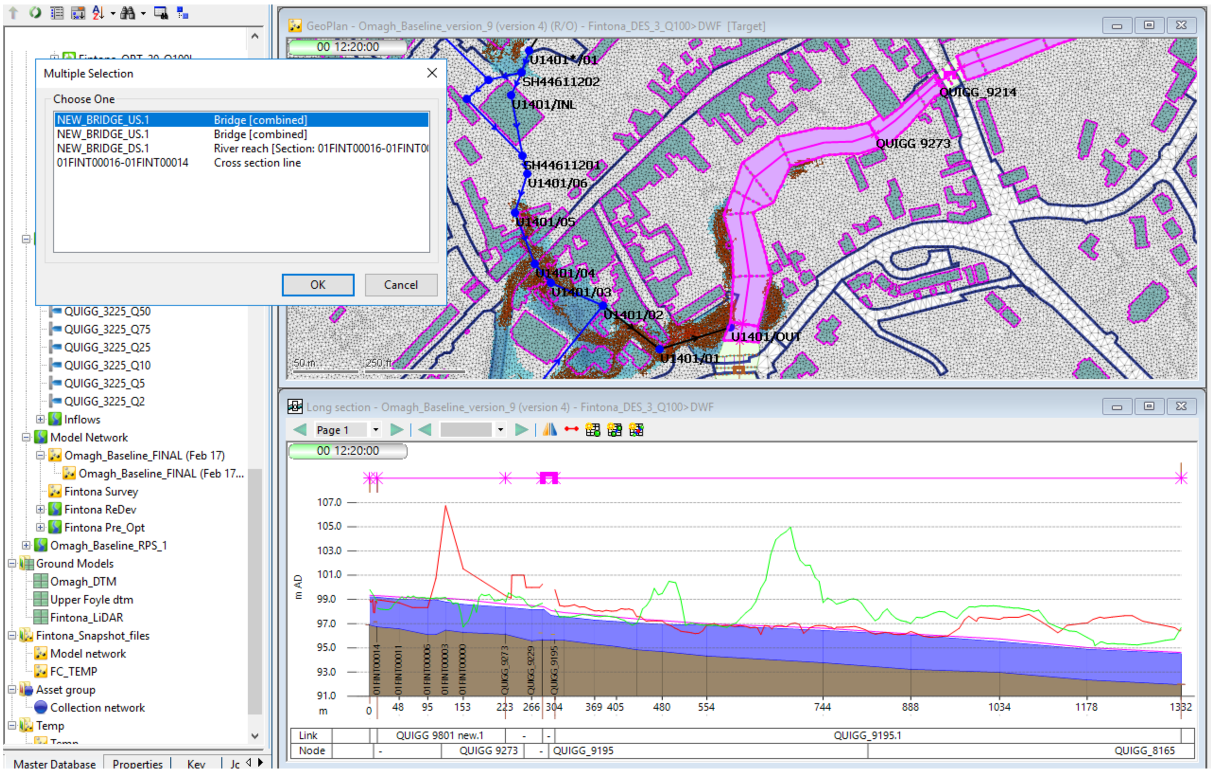

Figure 4.11 - Long section of the Quiggery River downstream of New Bridge

At New Bridge there is one detached residential property at risk of inundation from out of bank flooding due to insufficient channel capacity in the Quiggery. There is potential for dredging the river bed in this area which would lower the bed level of the river and reduce the backwater effect to the tributaries in Fintona. While it is technically feasible to lower the bed in the Quiggery River it would not be desirable. This is due to the river being a designated salmonoid river. As such disturbance to be bed and in channel works would be considered environmentally unacceptable. Work to the Quiggery channel bed should not be considered any further. However, if no other solution presents itself this method may be re-considered along with the necessary environmental mitigation measures.

There is also potential for improvement of culvert conveyance along the U1401* stream. The upstream end of this culvert which drains the Ashfield Gardens area is significantly undersized causing several manholes to surcharge and considerable overland flow in the area. Increasing the size of the culvert should increase conveyance during high return period events, preventing manholes from surcharging. A hydraulic model was run to simulate the effect of upgrading a section of this culvert. The section of culvert upgraded within the model is highlighted in Figure 4.12 below. The model simulation results showed that the upgraded culvert would provide a significant reduction in flood risk and would prevent manholes from surcharging on the U1401* watercourse.

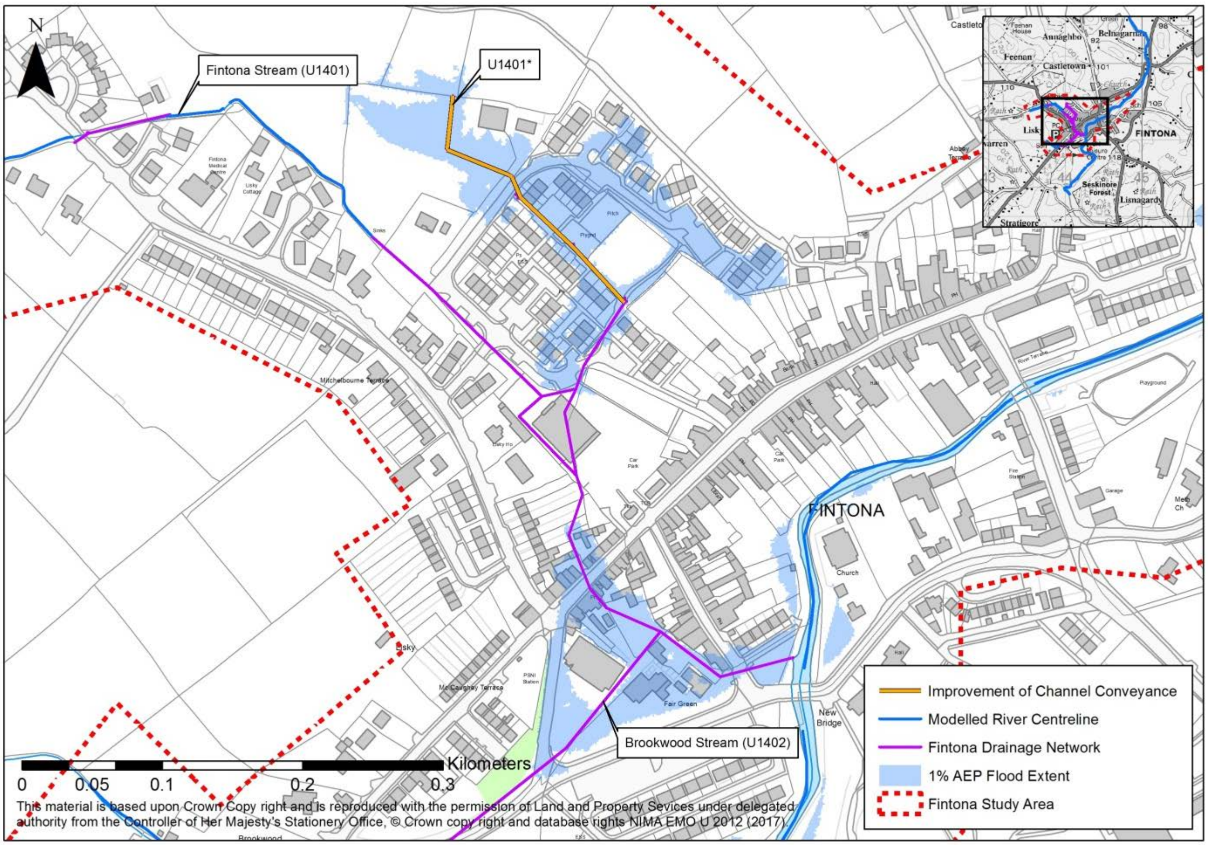

Figure 4.12 - Improvement of Channel Conveyance

4.1.2.7 Sealing Manholes

On the U1402 watercourse, the potential to seal a manhole has been identified. Currently during the 1%AEP event the manhole U1402/01 surcharges causing overland flow down Main Street. This manhole is circled in Figure 4.13 below. Given the topography of this culvert network, if this manhole was sealed, water may be held within the system therefore preventing water escaping from this network. This scenario was tested using the hydraulic model for Fintona. The results showed that no water escaped from U1402, however, no benefit was achieved as water continued to fill this area due to surcharging manholes on the U1401 watercourse, as shown in Figure 4.13 below.

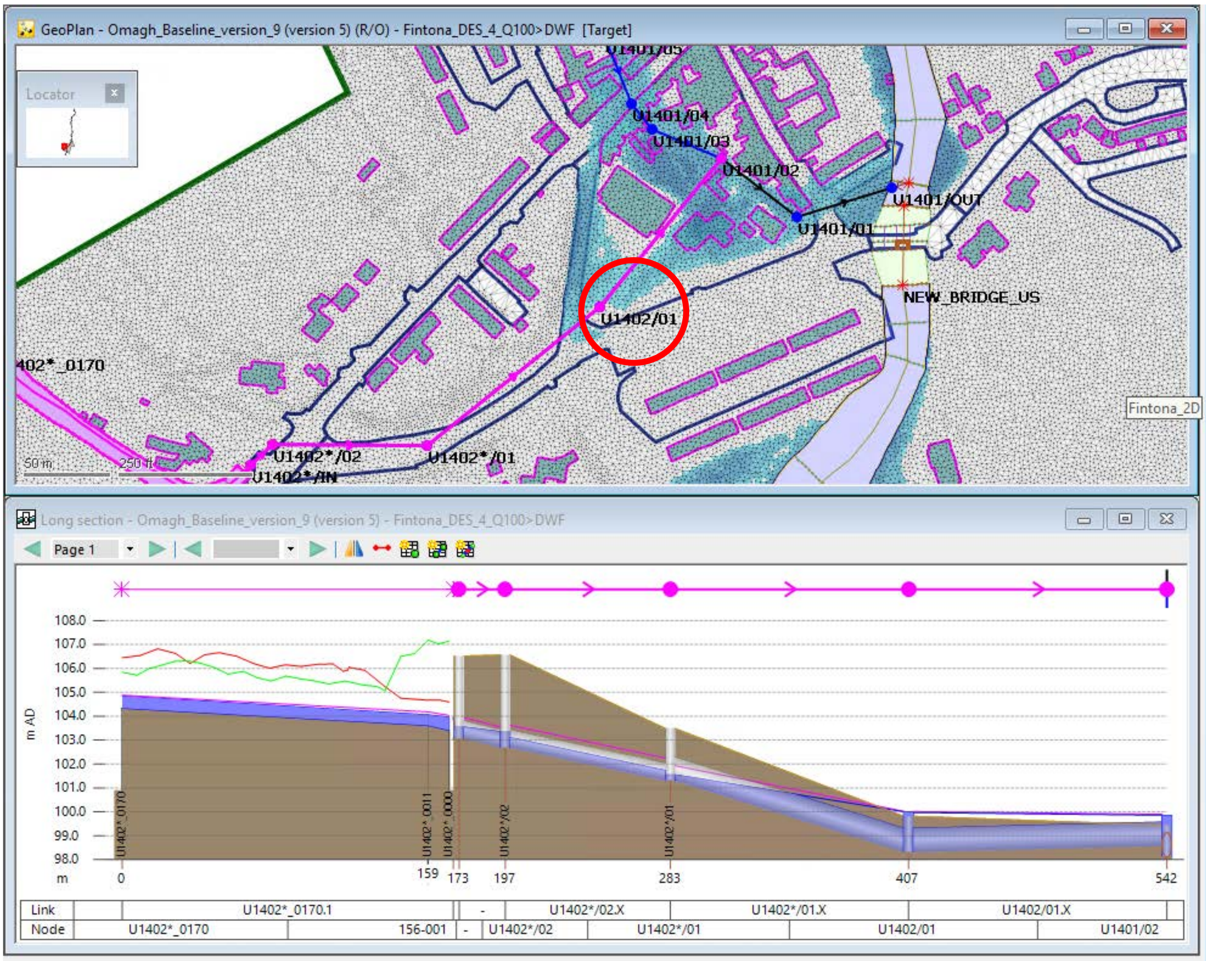

Figure 4.13 - Culverted watercourse U1402

At the downstream end of the Fintona Stream (U1401) six consecutive manholes surcharge during a 1%AEP event, as shown in Figure 4.14 below.

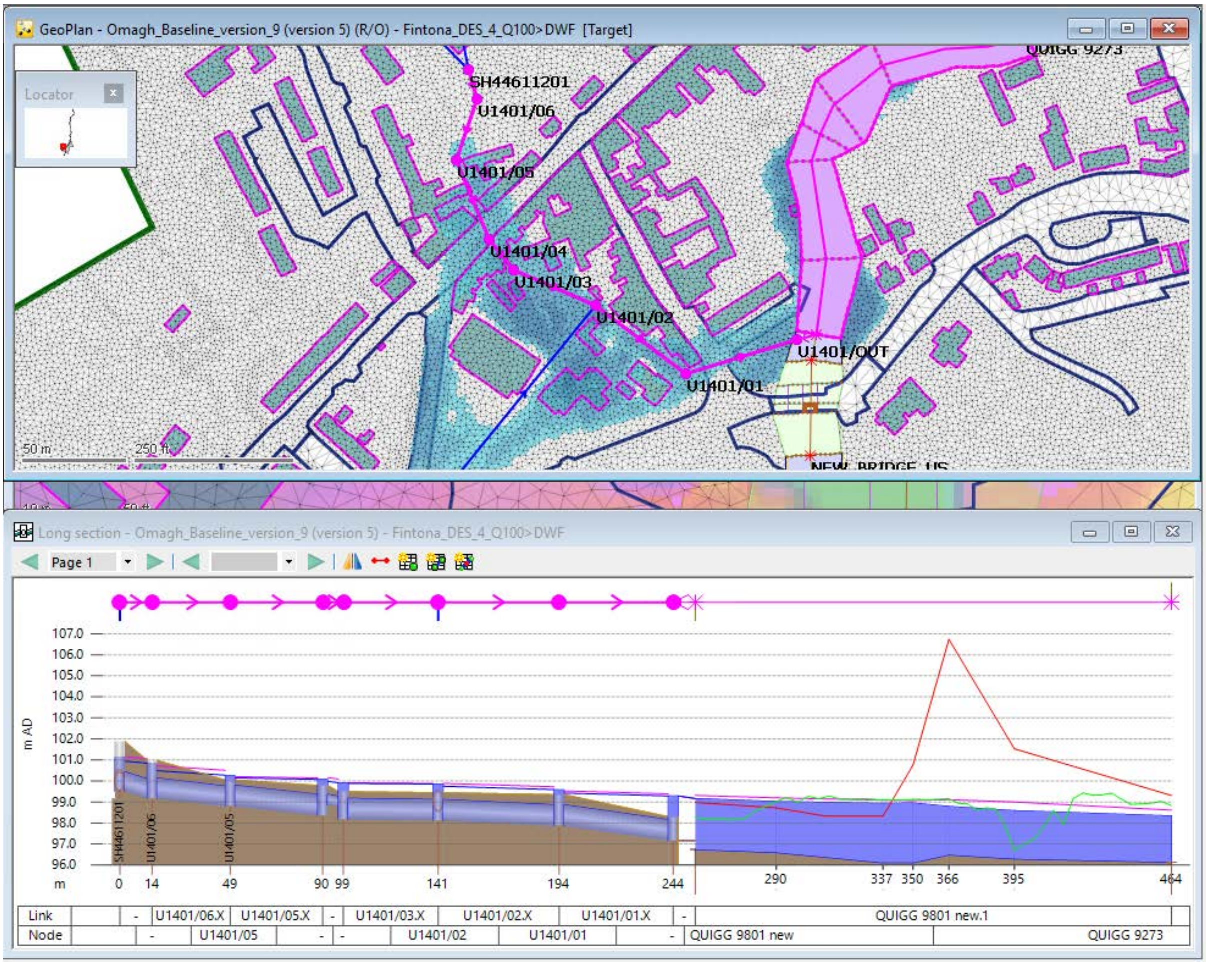

Figure 4.14 - Surcharging manholes at the downstream extent of Fintona Stream (U1401)

This is triggered by a combination of high flow in the culvert and a backwater effect due to high water levels in the Quiggery River. There is potential to seal these manholes to prevent water from escaping the system. However, there are also many road gullies which drain surface water from this area. These drains are likely to connect into the U1401 culvert system to be discharged into Quiggery River and so the backwater effect from the Quiggery would still cause water to surcharge from gullies/drains in the area. Consideration should be given to the installation of 'non-return' valves where storm water drainage systems connect with the main U1401 culvert. In order to fully quantify the benefit a full drainage model should be incorporated into the current hydraulic model for Fintona. However, this is beyond the scope of this study and will not be investigated further.

On the U1401*watercourse seven out of eleven manholes are shown to surcharge during the 1 in 100 year flood event. The first manholes to surcharge on this watercourse are at the beginning of the culvert system. This suggests that the culvert is significantly undersized at this point and therefore sealing manholes would not be an appropriate method to reduce flood risk on this watercourse.

Overall, sealing manholes may be appropriate methods for reduction of flood risk on the U1401 and U1402 culverted watercourses however these measures should be included as part of a complete option as they will not provide the required SoP as standalone measures.

4.1.2.8 Hard Defences

Hard Defences refers to physical barriers which prevent water from entering an area such as flood walls, embankments and barrages. As a general rule Hard Defences are kept as far back from the river channel or coast line as possible allowing the floodplain function to remain active. Where this is not possible, due to flood risk receptors being located within the floodplain, Hard Defences are placed around the property boundary to afford it protection. Where space allows flood embankments are used but where space is restricted flood walls are utilised.

A review was carried out to ascertain where hard defences would be required to protect properties at risk during a 1% AEP flood event within the Fintona study area. As the flooding mechanisms of the streams U1401, 1401* and 1402 involve undersized culverts and surcharged manholes it is considered that hard defences would be technically unfeasible and was not considered any further. However hard defences would be applicable in preventing the out of bank flooding from the Quiggery River reaching the properties at risk. To determine the effectiveness of hard defences, a hydraulic model was constructed to simulate the method of protection. The locations of the hard defences are shown in Figure 4.15 below. The model showed that the hard defences would protect to the 1% AEP event. The wall on the left bank of New Bridge would be approximately 70m long and 1m high whist the wall on the right bank would be approximately 40m long and 0.75m high. The wall at Meadowbrook would be approximately 190m long and 0.6m high. Although properties in the Meadowbrook area were not identified as at risk through this study, there is historical evidence of flooding in this area. For that reason a wall was included to protect properties in Meadowbrook against a 1% AEP flood event.

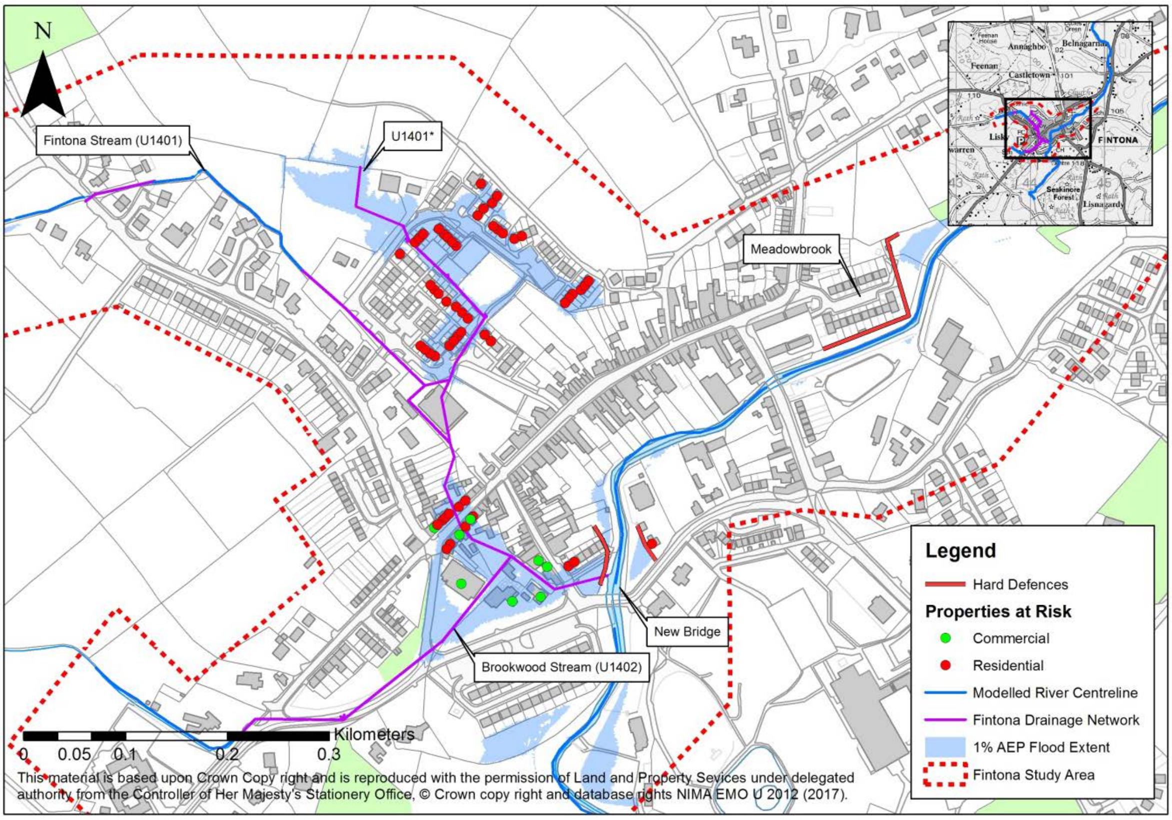

Figure 4.15 – Potential locations of Hard Defences in Fintona

4.1.2.9 Relocation of Properties

To relocate a property is to abandon the existing at risk property and provide an alternative in a location not at risk. While this method is, in theory, possible, it is not practical for a whole town of many at risk properties. Its use is more applicable for discrete areas where single properties or clusters of properties are located.

One discrete location was identified where one detached residential property is at risk of inundation from out of bank flooding from the Quiggery River during the 1% AEP event. This property may be considered for relocation. Reviewing the economic viability of such a measure it was estimated that to relocate this property would potentially cost £118,451 which considerably more than the cost of constructing a wall to protect it which was estimated at £14,620. Relocation of this property while technically feasible is considered to be economically unviable and was not considered further in the study.

The majority of properties at risk of flooding in Fintona are due to complex flooding mechanisms on the smaller culverted tributaries. The relocation of a large number of properties would be considered as socially complex and therefore would not be appropriate for Fintona.

4.1.2.10 Diversion of Flow

This method involves directing some of the floodwater via a new route thereby reducing flow and associated flood risk along the original route. The new flow route would normally consist of a constructed open channel and/or culvert system or an existing linear feature able to convey the flow to a designated discharge point.

A review was carried out to identify locations where a Flow Diversion route could be constructed. One flow diversion route was identified which would involve constructing a new culvert which would take flow away from the U1401* system, allowing it to discharge directly to the Quiggery River, as shown in Figure 4.16 below. The culvert would extend approximately 220m, continuing behind properties in Ashfield Gardens and crossing Main Street before discharging into the Quiggery.

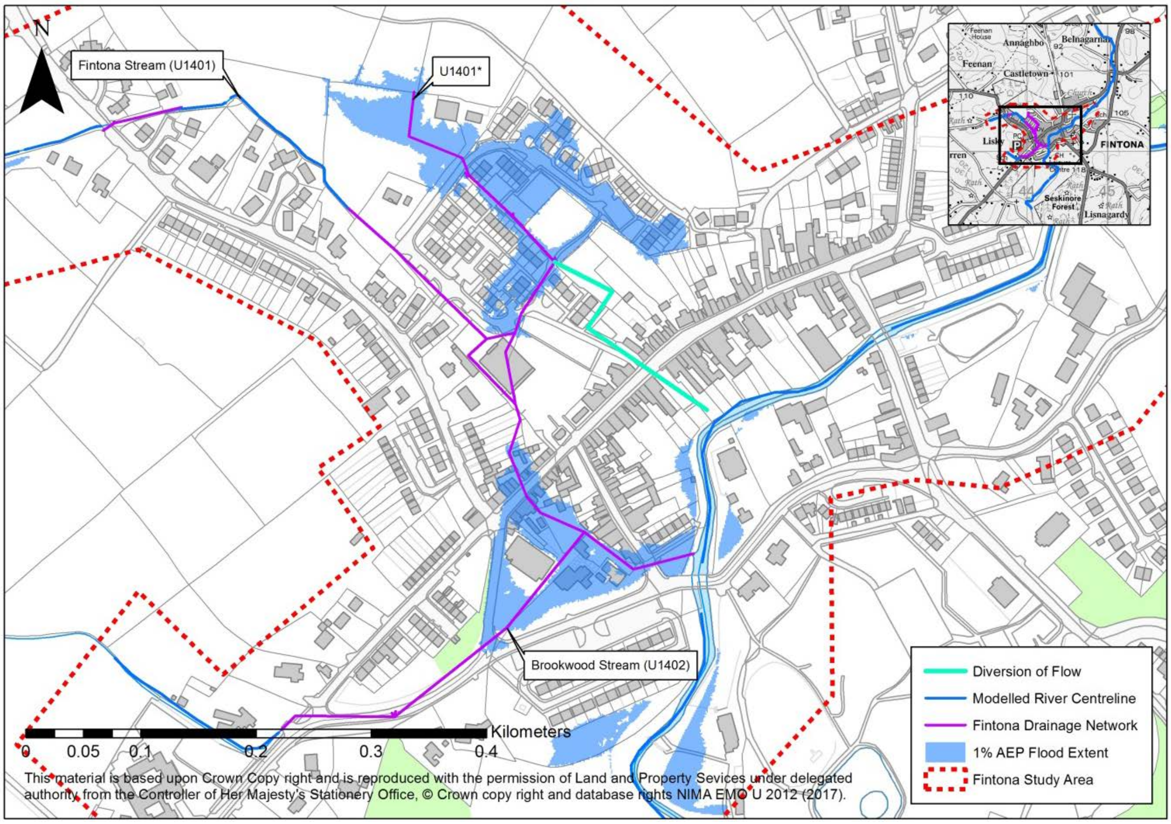

Figure 4.16 - Diversion of Flow - Ashfield Gardens

A second potential route for Diversion of Flow was identified, which would take flow away from the Brookwood Stream (U1402), as shown in Figure 4.17 below. This new culvert branch would extend approximately 190m, diverting flow around residential properties on Tattymoyle Road and through a section of Fintona Golf Course before discharging into the Quiggery River.

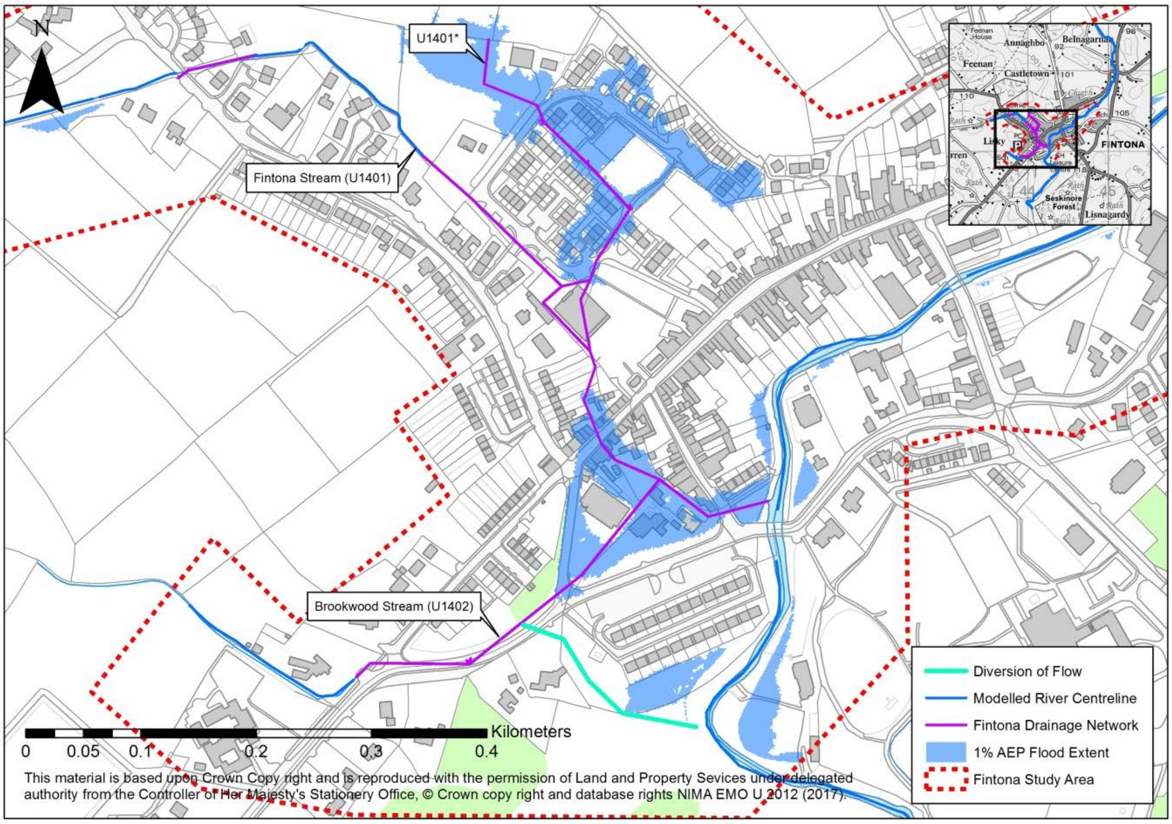

Figure 4.17 - Diversion of Flow route from Brookwood Stream (U1402)

4.1.2.11 Flood Warning/ Forecasting

For a flood warning/forecasting system to be effective there needs to be adequate warning time for appropriate action to be taken. As the flood risk in Fintona is largely associated with the small tributaries which have a flashy response time, there would not be adequate flood warning time to allow a forecasting system to be effective. This option was therefore not considered further.

4.1.2.12 Public Awareness Campaign

A public awareness campaign would be useful in Fintona to alert residents and business owners to the types and sources of flooding in their area. This would allow individuals to take informed actions to help prevent their property from flooding.

A section of Fintona's Wastewater Treatment Works has been identified as at risk of flooding during a 1% AEP flood event. It is recommended that as part of the Public Awareness Campaign NI Water is made aware of this potential risk so that they can judge if any further action is necessary.

4.1.2.13 Individual Property Protection

Individual property protection could consist of flood gates and vent seals on the building structure itself. Where flood depths are over 0.6m this method becomes unfeasible and flood resilience techniques would be recommended over flood gates. As this method is temporary and relies of human intervention there is an element of uncertainty as to whether the full SoP will be met for every flood event. As such it is assumed that 20% of the flood damage will be avoided.

Individual property protection may be suitable for the single detached residential property at New Bridge, however due to the grouped nature of the other properties in Fintona this method of protection would not be technically the best method of protection to use. For this reason this method has not been considered further within this study.

4.2 DEVELOPMENT OF OPTIONS

In Fintona, areas at risk of flooding have been identified to result from two flooding mechanisms. One area at risk results from out of bank flooding from the Quiggery River whilst the other areas at risk results from surcharged manholes along culverted streams U1401, U1401* & U1402. In order to develop options each flooding mechanism was considered separately during the screening of measures and the results are shown below. Two types of options have been considered, short-term solutions or “quick-wins” and long-term solutions. The “quick-win” options may not provide the full SoP but aim to reduce the flood risk in the interim period before a long-term solution can be implemented. Interim measures are discussed in Section 4.6. Long-term solutions should provide the design SoP.

4.2.1 Suitable measures for the Quiggery River

Method	**Screening**	**Explanation**
Do nothing	✗	Technically unfeasible
Additional Maintenance	✗	Technically unfeasible
Temporary defences	✓	Short term solution
Planning and Development Control	✓	Short term solution
Land Use Management	✗	Technically unfeasible
Upstream Storage	✗	Technically unfeasible
Improvement of Channel Conveyance	✗	Environmentally unacceptable
Sealing Manholes	✗	Technically unfeasible
Hard Defences	✓	Long term solution
Relocation of Properties	✗	Economically unviable
Diversion of Flow	✗	Technically unfeasible
Flood Warning/Forecasting	✗	Technically unfeasible
Public Awareness Campaign	✓	Short term solution
Individual Property Protection	✓	Short term solution

The following long-term measures have been carried forward to address the flood risk arising from the Quiggery River:

- Hard Defences

The following short-term measures have been carried forward to address the flood risk arising from the Quiggery River:

- Temporary defence
- Planning and development control
- Public awareness campaign
- Individual property protection

4.2.2 Suitable measures for the Fintona Stream (U1401), U1401* and Brookwood Stream (U1402)

Method	**Screening**	**Explanation**
Do nothing	✗	Technically unfeasible
Additional Maintenance	✗	Technically unfeasible
Temporary Defences	✓	Short term solution
Planning and Development Control	✓	Short term solution
Land Use Management	✓	Long term solution
Upstream Storage	✓	Long term solution
Improvement of Channel Conveyance	✓	Long term solution
Sealing Manholes	✓	Long term solution
Hard Defences	✗	Technically unfeasible
Relocation of Properties	✗	Technically unfeasible
Diversion of Flow	✓	Long term solution
Flood Warning/Forecasting	✗	Technically unfeasible
Public Awareness Campaign	✓	Short term solution
Individual Property Protection	✗	Technically unfeasible

The following long-term measures have been carried forward to address the flood risk arising from the U1401*, U1401 and U1402 watercourses:

- Land Use Management
- Upstream Storage
- Improvement of Channel Conveyance
- Sealing Manholes
- Diversion of Flow

The following short-term measures have been carried forward to address the flood risk arising from the U1401*, U1401 and U1402 watercourses:

- Temporary defence
- Planning and development control
- Public awareness campaign

4.2.3 Potential Options

The suitably screened measures will not provide the full SoP required for Fintona and are therefore required to be combined with each other in order to achieve the design SoP.

Hard defences along the Quiggery River are the only measures available at these locations and therefore any option will have to include this measure.

The measures for watercourses U1401, U1401* and U1402 all work by reducing the flow through the culverts or increasing the capacity of the culverts. As such only certain combinations are appropriate. Considering watercourse U1401, the two main measures involved are upstream storage or flow diversion. As both options achieve the same thing, a reduced flow through the existing culvert network, there is little merit in combining them. Two potential options are therefore required to consider these two measures.

Watercourse U1401* joins U1401 and the measure used in U1401 will therefore effect the suitable measures in U1401*. The culverted upper reaches of U1401* have been identified as being undersized which results in manhole surcharging. The only suitable measure to mitigate this is improved conveyance and should therefore form part of all potential options. Two solutions are provided for the lower reaches, flow diversion or further improved conveyance. If upstream storage is considered for watercourse U1401 the flow would be reduced but not enough to prevent flooding and the flow diversion measure for U1401* would the preferred combination. If however the flow diversion for watercourse U1401 is considered then all the flow would be redirected leaving the lower reach of the U1401 culvert free to take the flow of the U1401* watercourse following improved conveyance of the culvert. However due to the backwater effect from the Quiggery River three manholes would need to be sealed.

A culverted flow diversion was the only measure identified for watercourse U1402. Depending on the measures considered for watercourse U1401 this diversion would either discharge into a channel which connects to the Quiggery River or would connect to the 1401 culvert flow diversion.

Three potential options have therefore been identified and summarised below.

Option 1:

- Maintain Existing Regime

Option 2:

- Hard Defences (Quiggery River)
- Upstream Storage (U1401)
- Improved Conveyance and Flow Diversion (U1401*)
- Flow Diversion (U1402)

Option 3:

- Hard Defences (Quiggery River)
- Flow Diversion and Sealing Manholes (U1401)
- Improved Conveyance and Flow Diversion (U1401*)
- Flow Diversion (U1402)

4.3 APPRAISAL OF OPTIONS

Table 4.3 below provides a qualitative assessment of the anticipated performance of each option considering the relevant objectives and constraints. [✓ to ✓✓✓] represents a moderately good to very good performance. [-] represent a neutral outcome. [× to ×××] represents a moderately negative to very negative performance.

Table 4.3 - Qualitative assessment of options for Fintona

Objectives/Constraints	Option 1	Option 2	Option 3
Provide design SoP to all properties	×××	✓✓✓	✓✓✓
Complexity of option	-	××	×
Impact to road drainage	-	✓	✓
No increase in flood risk to other receptors	-	×	-
Adaptability to climate change	-	×	××
Health and Safety issues	-	××	×
Impact to residential areas	-	××	××
Impact to private land owners	-	××	×
Impact to socially important receptors	-	✓	✓
Impact to the Quiggery River	-	×	×
Reduced risk to Main Street and King Street	-	✓	✓
Reduced risk to Fintona WwTW	-	-	-
Value for money	-	✓	✓✓

The qualitative assessment shows that both Option 2 and 3 would produce a significant improvement to the flood risk in Fintona compared to the baseline Option 1. Both Option 2 and 3 would provide the design SoP to a 1% AEP flood event.

The remainder of the qualitative assessment compares Option 2 and 3 in order to identify the preferred option. Option 2 has been marked down on complexity, health & safety issues and impact to private land owners. Both options would reduce the flow through culvert U1401 and therefore relieve the backwater effect to the road drainage network.

Neither option could be readily adapted to increase the SoP in order to account for climate change. The proposed culverts would be difficult to modify, however, the proposed hard defences on the Quiggery River could be added to for both options. The storage measure in Option 2 could also be added to. Option 3 would be particularly difficult to adapt for climate change as this option is more reliant on culverts to provide protection. This option is restricted by the sections of culvert in U1401 that travel underneath properties and cannot be easily accessed. Option 3 is therefore less readily modified for climate change.

Both options will have their inherent health and safety issues. Option 2 consists of a large earth dam over 200m long and 3m high immediately upstream of Fintona town. If a breach were to occur there would be significant risk to the receptors downstream including the health centre. This storage option may also be unsightly to local residents. Option 3 relies on sealed manholes and a pressurised pipe during times of flooding. If the chamber of the manholes were to fail the water would escape under pressure and flood the surrounding receptors. For Option 2, the diversion of flow route identified from U1401* travels between properties on Main Street and across services on Main Street, as such careful consideration should be given to this measure. For example, directional drilling may be required which is complex and may be costly. If a traditional trench was used to lay the culvert this would pose a hazard to the general public using Main Street during construction. Given the severity of the residual risk, Option 2 would be considered to have a greater concern.

There would be significant disruption to the Ashfield Gardens residential area for both options as they both specify upgrading culvert U1401*. However, Option 2 would cause more disruption, as the storage area has been proposed on private land. Land upstream of the structure would also experience significant ponding during times of flood. As such, the storage area would be subject to approval from private land owners.

There are socially important receptors in Fintona that flooding may prevent access to. Both options would improve this situation by protecting the road network in Fintona.

The Quiggery River is designated as a Salmonoid River. Both Option 2 and 3 included hard defences in the form of walls along the banks of the Quiggery River. Although the measure may cause some disruption to the salmonoid Quiggery River during construction, this would be kept to a minimum.

Both Option 2 and 3 reduce the risk to Main Street, King Street.

Neither option currently reduce the flood risk to Fintona's Wastewater Treatment Works, however it has been recommended that as part of the Public Awareness Campaign, NI Water are made aware of the potential risk to a section of the WwTW during a 1% AEP flood event. NI Water can then judge whether it is necessary to provide protection to the complex.

The cost was estimated for both Option 2 and 3. Option 2 was estimated to cost £1.3million whilst Option 3 was estimated to cost £1.0million. Therefore Option 3 offers better value for money.

4.4 CONSIDERATION OF LAND USE MANAGEMENT

Land Use Management measures were considered for the urban streams U1401, U1401* and U1402 in Fintona. It was discovered that an area at the upper reaches of streams U1401 and U1402 was previously marshy land. Compared with present day land use this marsh area has reduced in size and the land improved to be used for agricultural purposes.

The proposed land use management measure consists of various NFM features such as vegetation strips, storage bunds, and woodland creation. The implementation of some or all of these features would have a cumulative effect of reducing flood risk to Fintona. It is however difficult to quantify this reduction in flood risk through a hydraulic model and is outside the model extent of this model. Given the uncertainty then associated with this measure it is not appropriate to recommend it as part of the preferred option.

However, when considering climate change and the predicted increase in flood risk in the future, it has been commented, in the appraisal of options section, that both of the proposed options have poor adaptability. It is therefore anticipated that the preferred option will not be able to provide the design SoP in the future (1% AEP plus climate change). As such the proposed NFM features would be an appropriate measure to implement. In order to ascertain the effectiveness of these features monitoring would be required using data before and after the features have been placed. River gauges should therefore form part of the preferred option. The location of these gauges should be assessed in order to measure the effectiveness of the NFM features. It is also recommended that a long-term strategy be carried out working with the land owners to “buy in” to using their land for NFM. Other interested parties such as NIEA and available schemes such as the Environmental Farming Scheme should form part of this long-term strategy.

4.5 ECONOMIC ANALYSIS

RPS undertook a preliminary benefit-cost analysis to demonstrate the economic case for the identified options. This involved an assessment of the benefits (i.e. reducing flood impact) and the costs of the options over a 100 year design life span. This approach ensures that DfI Rivers has a robust economic argument which shows that the preferred option provides best value for money.

Full details of the Economic Appraisal can be found in the Fintona Economic Appraisal Report. Details of the option costing and damage assessment assumption are presented in appendix C and D. Table 4.4 below summarises the results of the Economic Appraisal.

Table 4.4 - Summary of Economic Appraisal

	Costs (£)		
	Option 1	**Option 2**	**Option 3**
Construction costs from estimates	0	815,514	634,206
Optimism Bias Adjustment	0	415,912 (51%)	296,808 (46.8%)
Maintenance Costs (NPV over 100 years)	29,813	71,251	71,251
Total Present Value Costs	29,813	1,302,677	1,002,265
	Benefits (£)		
	Option 1	**Option 2**	**Option 3**
Present Value Damage	818,397	0	0
Present Value Damage Avoided	0	818,397	818,397
Intangible Damage	329,902	329,902	329,902
Total Present Value Damage Avoided	0	1,148,299	1,148,299
	Benefit Cost Ratio		
	Option 1	**Option 2**	**Option 3**
Average benefit/cost ratio	-	0.88	1.15

The results from the economic appraisal indicate that Option 2 is not economically viable as it does not have a Benefit/Cost Ratio greater than unity. Therefore Option 3 is the only economically viable option with a benefit cost ratio of 1.15.

4.6 SHORT TERM OPTIONS

RPS also considered the potential of interim or short-term measures that could be employed to reduce the flood risk to properties, without significantly increasing the risk of flooding elsewhere in the catchment.

4.6.1 Quiggery River

The following short-term measures have been carried forward to address the flood risk arising from the Quiggery River:

- Temporary Defences
- Public Awareness Campaign
- Planning and Development Control
- Individual Property Protection

4.6.1.1 Assessment of Short-Term Measures for Quiggery River

In the short-term, Temporary Defences using sandbags would provide immediate protection to the discrete area of flooding downstream of New Bridge. Within 2m of the property water depths during the 1% AEP event do not exceed 0.5m meaning Individual Property Protection measures may also be viable. These measures however depend on residents to implement this protection and so may not be reliable. A Public Awareness Campaign would not provide any formal protection to the areas at risk from out of bank flooding from the Quiggery River; however it would help residents take informed actions to protect their own property. Planning and Development Control is a measure which should be considered to ensure no further properties are constructed within the floodplain in Fintona. As such this measure will not alleviate flood risk to those receptors already identified as at risk within the 1% AEP event. These measures would be relatively inexpensive to complete and would not have any adverse impacts.

4.6.2 U1401*, U1401 and U1402

The following short-term measures have been carried forward to address the flood risk arising from the U1401*, U1401 and U1402 watercourses:

- Temporary Defences
- Upstream Storage
- Public Awareness Campaign
- Planning and Development Control

4.6.2.1 Assessment of Short-Term Measures for watercourses U1401, U1401* and U1402

In the short-term, the Temporary Defences measure would provide a ‘quick-win’ through the use of sandbags, a small blockwork wall and an earth bund to create a small area of storage in an area of agricultural land adjacent to Ashfield Gardens. These measures may be implemented quickly to provide immediate protection to properties at risk of flooding in the Ashfield Gardens area however may not provide protection to the required SoP. Temporary Defence measures such as sandbags would also provide interim protection to properties in the Main Street area of Fintona. Implementation of these measures may create a small negative impact to residents and private land owners, but only throughout the duration of flooding. A Public Awareness Campaign would help to inform residents so that they may take informed actions to protect their own properties. Planning and Development Control is a measure which should be considered to ensure no further properties are constructed within the floodplain in Fintona. As such this measure will not alleviate flood risk to those receptors already identified as at risk within the 1% AEP event.

4.6.3 Short-Term Options

From review of the measures appropriate for each flood mechanism, a preferred option was developed for short-term alleviation of flood risk.

Option 1:

- Temporary Defences
- Upstream Storage (U1401*)
- Public Awareness Campaign
- Planning and Development Control

One preferred option was identified for the short-term alleviation of flood risk in Fintona. A combination of Temporary Defences and Upstream Storage on U1401* was considered the best method to protect properties at risk in the Ashfield Gardens area and at New Bridge and Main Street. Public Awareness Campaigns and Planning & Development Control were also deemed to be suitable measures for reducing flood risk in the short-term in Fintona.

5 RECOMMENDATIONS AND CONCLUSIONS

The option appraisal showed that both options would achieve the primary objective of providing the design Standard of Protection. Both options would have similar impacts when considering the other objectives and constraints identified however Option 3 has less of a residual risk associated with it and is the only economically viable option. Therefore Option 3 is the recommended preferred option.

Option 3 would provide the best cost beneficial solution. The total cost of the option was estimated to be £1.0million compared to the £1.3million estimated for Option 2. The total potential benefit was estimated at £1.15million therefore giving a cost benefit ratio of 1.15 for Option 3.

Option 2 considered upstream storage. It was recognised that there are other storage solutions, such as smaller storage bunds and additional storage areas in watercourse U1402’s upper catchment. While these measures could not be modelled and therefore their benefit could not be quantified there may be potential to reduce the cost of Option 2 and the residual risk. Further study would be required to answer these questions.

It has been pointed out that the preferred option has poor adaptability to climate change. It is recommended that Land Use Management and NFM features be considered to provide further protection in the future. As the effectiveness of these measures will likely rely on monitoring, river gauges would be required to be installed along with the short-term or long-term options.

Sealing manholes are required for the preferred option in the lower reaches of the U1401 culvert. This is due to the pipes surcharging the manholes. As mentioned in this report, the road drainage network is likely to discharge into this culvert also. Although the preferred option would reduce the risk of surcharge to the road gullies there would still be a potential risk. In order to confirm this and find a suitable mitigation measure a further study would be required of the road drainage network.

Subject to approval from the Department for Infrastructure Economics Branch, Option 3 could progress to detailed design, subject to competing priorities and resources.

6 REFERENCES

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The Northern Ireland Guide to Expenditure Appraisal and Evaluation (NIGEAE). Department of Finance (2009)

Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG). Environment Agency (2010)

Preliminary Flood Risk Assessment & Methodology for the Identification of Significant Flood Risk Area. Rivers Agency (2011)

Flood and Coastal Erosion Risk Management- A Manual for Economic Appraisal. Flood Hazard Research Centre, Middlesex University (2013). Often referred to as the Multi Coloured Manual (MCM)

Flood and Coastal Defence Project Appraisal Guidance, FCGPAG3 Economic Appraisal, Supplementary Note to Operating Authorities. Defra (2004)

Supplementary Green Book Guidance on the treatment of optimism bias, HM Treasury (2002)

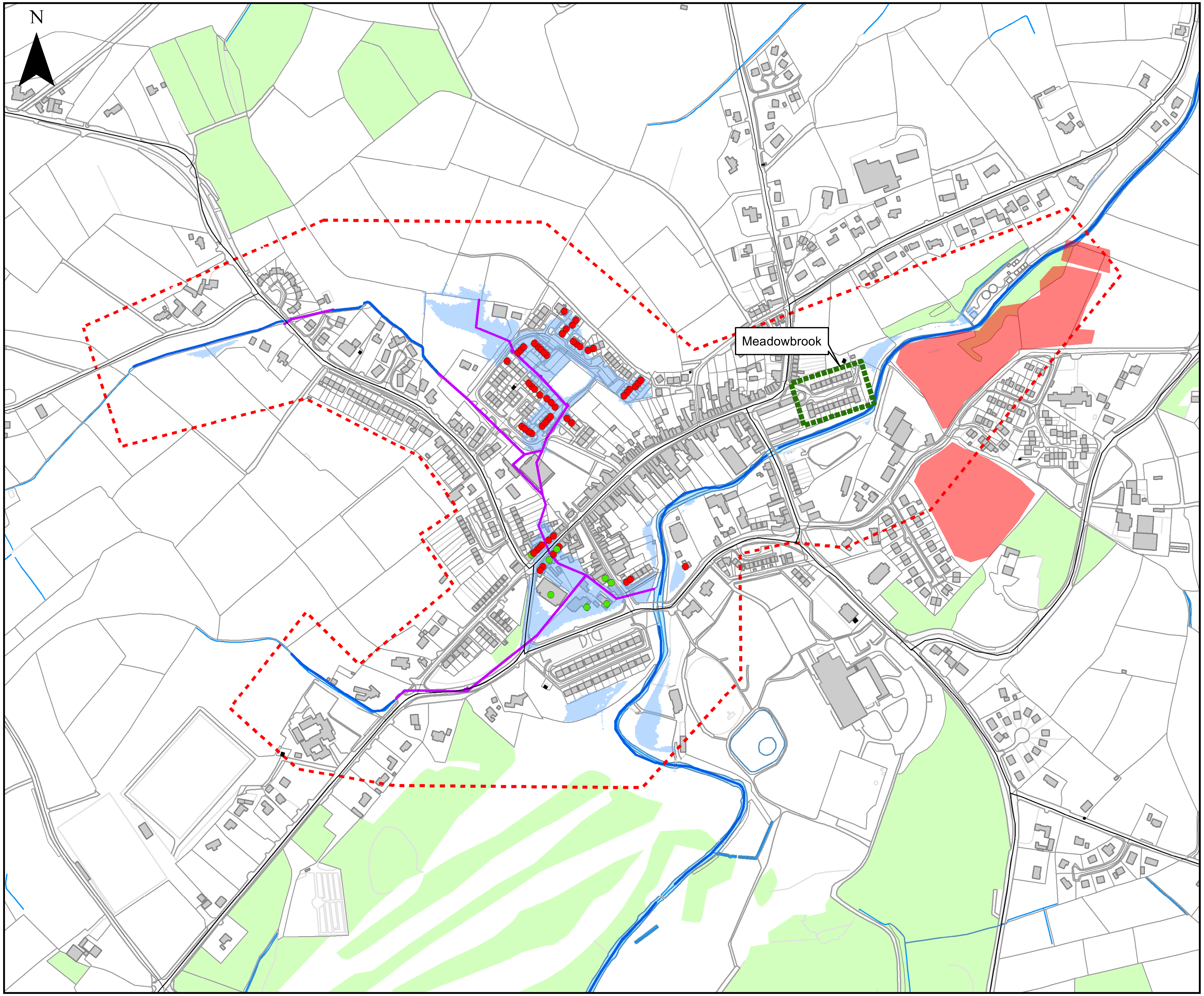
APPENDIX A

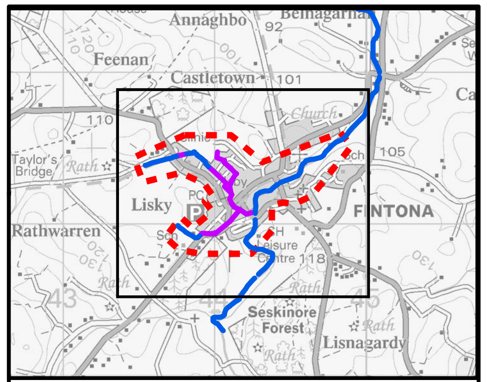
CLASSIFICATION OF PROPERTIES AND DEPTHS OF FLOODING

FID	Use	MCM CODE	Property Type	GL	Steps	Raised	FFL	AREA	Q100_Dp	Q75_Dp	Q50_Dp	Q25_Dp	Q10_Dp	Q5_Dp	Q2_Dp
0	R	115	1975 - 1985 Detached	99.13	1	0.15	99.28	110.8	-0.17	-0.23	-0.3	-999	-999	-999	-999
1	R	135	1975 - 1985 Terrace	0	0	0.3	102.05	57.03	-0.13	-0.18	-0.18	-999	-999	-999	-999
2	R	135	1975 - 1985 Terrace	0	0	0.3	102.24	54.59	-0.32	-0.36	-0.36	-0.4	-999	-999	-999
3	R	135	1975 - 1985 Terrace	0	0	0.3	101.94	52.18	-0.02	-0.05	-0.05	-0.1	-0.18	-0.56	-999
4	R	135	1975 - 1985 Terrace	0	0	0.3	101.79	50.77	0.13	0.1	0.1	0.05	-0.03	-0.16	-999
5	R	125	1975 - 1985 Semi-Detached Bungalow	0	0	0.3	102.08	78.65	-0.16	-0.2	-0.2	-0.24	-999	-999	-999
6	R	135	1975 - 1985 Terrace	0	0	0.3	102.03	53.47	-0.06	-0.1	-0.1	-0.14	-0.22	-999	-999
7	R	135	1975 - 1985 Terrace	0	0	0.3	101.75	54.57	0.22	0.18	0.18	0.14	0.06	-999	-999
8	R	135	1975 - 1985 Terrace	0	0	0.3	101.97	53.61	-0.05	-0.09	-0.09	-0.13	-0.24	-999	-999
9	R	135	1975 - 1985 Terrace	0	0	0.3	102.16	60.87	-0.24	-0.28	-0.28	-999	-999	-999	-999
10	R	125	1975 - 1985 Semi-Detached Bungalow	0	0	0.3	102.21	77.76	-0.29	-999	-999	-999	-999	-999	-999
11	R	135	1975 - 1985 Terrace	0	0	0.3	102.01	52.46	-0.09	-0.13	-0.13	-0.17	-0.28	-999	-999
12	R	135	1975 - 1985 Terrace	0	0	0.3	101.77	60.23	0.2	0.16	0.16	0.12	0.03	-0.11	-999
13	R	135	1975 - 1985 Terrace	0	0	0.3	101.79	57.38	0.13	0.1	0.1	0.05	-0.03	-999	-999
14	R	125	1975 - 1985 Semi-Detached Bungalow	0	0	0.3	102.18	109.3	-0.26	-999	-999	-999	-999	-999	-999
15	R	125	1975 - 1985 Semi-Detached Bungalow	0	0	0.3	102.1	73.76	-0.18	-999	-999	-999	-999	-999	-999
16	R	135	1975 - 1985 Terrace	0	0	0.3	101.96	53.98	-0.04	-0.08	-0.08	-0.12	-999	-999	-999
17	R	135	1975 - 1985 Terrace	0	0	0.3	101.88	49.47	0.04	0	0	-0.04	-0.15	-999	-999
18	R	135	1975 - 1985 Terrace	0	0	0.3	102.07	63.21	-0.15	-0.19	-0.19	-0.23	-999	-999	-999
19	R	135	1975 - 1985 Terrace	101.79	2	0.3	102.09	55.71	-0.17	-0.21	-0.21	-0.25	-999	-999	-999
20	R	135	1975 - 1985 Terrace	0	0	0.3	101.86	55.11	0.06	0.02	0.02	-0.02	-0.13	-999	-999
21	R	135	1975 - 1985 Terrace	0	0	0.3	101.82	50.34	0.1	0.07	0.07	0.02	-0.06	-999	-999
22	R	135	1975 - 1985 Terrace	0	0	0.3	102.14	60.25	-0.22	-0.27	-0.27	-999	-999	-999	-999
23	R	135	1975 - 1985 Terrace	0	0	0.3	101.73	63.58	0.2	0.16	0.16	0.11	0.03	0.02	-999
24	R	125	1975 - 1985 Semi-Detached Bungalow	0	0	0.3	102.25	73.91	-0.33	-999	-999	-999	-999	-999	-999
25	R	135	1975 - 1985 Terrace	0	0	0.3	102.66	65.66	-0.79	-999	-999	-999	-999	-999	-999
26	R	135	1975 - 1985 Terrace	0	0	0.3	102.03	58.18	-0.17	-999	-999	-999	-999	-999	-999
27	R	135	1975 - 1985 Terrace	0	0	0.3	102.09	60.03	-0.22	-999	-999	-999	-999	-999	-999
28	R	135	1975 - 1985 Terrace	0	0	0.3	102.05	67.65	-0.18	-0.3	-0.3	-999	-999	-999	-999
29	R	135	1975 - 1985 Terrace	0	0	0.3	102.03	58.27	-0.15	-0.27	-0.27	-999	-999	-999	-999
30	R	135	1975 - 1985 Terrace	0	0	0.3	101.91	64.01	-0.03	-0.15	-0.15	-999	-999	-999	-999
31	R	135	1975 - 1985 Terrace	0	0	0.3	101.97	58.36	-0.1	-0.22	-0.22	-999	-999	-999	-999
32	R	135	1975 - 1985 Terrace	0	0	0.3	102.15	50.09	-0.24	-999	-999	-999	-999	-999	-999
33	R	135	1975 - 1985 Terrace	0	0	0.3	102.12	59.24	-0.24	-0.34	-0.34	-999	-999	-999	-999
34	R	135	1975 - 1985 Terrace	0	0	0.3	102.14	48.71	-0.22	-999	-999	-999	-999	-999	-999
35	R	135	1975 - 1985 Terrace	0	0	0.3	101.9	58.36	-0.03	-999	-999	-999	-999	-999	-999
36	R	135	1975 - 1985 Terrace	0	0	0.3	102.13	51.98	-0.22	-999	-999	-999	-999	-999	-999
37	R	135	1975 - 1985 Terrace	0	0	0.3	101.92	61.17	-0.05	-999	-999	-999	-999	-999	-999
38	R	135	1975 - 1985 Terrace	0	0	0.3	102.1	48.22	-0.22	-999	-999	-999	-999	-999	-999
39	R	135	1975 - 1985 Terrace	0	0	0.3	101.82	57.19	0.05	-999	-999	-999	-999	-999	-999
40	R	135	1975 - 1985 Terrace	0	0	0.3	102.17	64.13	-0.1	-999	-999	-999	-999	-999	-999
41	R	135	1975 - 1985 Terrace	0	0	0.3	102	56.53	-0.13	-0.25	-0.25	-999	-999	-999	-999
42	C	2	Commerial Property	0	0	0	101.01	208.8	-1.35	-1.42	-1.43	-1.6	-999	-999	-999
43	R	133	1945 - 1964 Terrace	0	0	0.3	99.9	58.41	0.04	-0.01	-0.01	-0.11	-999	-999	-999
44	R	133	1945 - 1964 Terrace	0	0	0.3	99.88	31.42	0.07	0.01	0.01	-0.09	-999	-999	-999
45	R	134	1965 - 1974 Terrace	0	0	0.3	99.89	42.43	0.05	0	-0.01	-999	-999	-999	-999
46	C	6	Veterinary Centre	99.68	0	0	99.68	203.8	0.02	-0.06	-0.07	-999	-999	-999	-999
47	C	2	Petrol Station	0	0	0	100.12	179.3	-0.45	-999	-999	-999	-999	-999	-999
48	C	2	Pub/Social club/Wine bar	0	0	0	99.76	182.9	0.19	0.14	0.13	0.03	-999	-999	-999
49	R	134	1965 - 1974 Terrace	0	0	0.3	99.75	43.24	0.19	0.14	0.14	0.04	-999	-999	-999
50	R	133	1945 - 1964 Terrace	0	0	0.3	99.97	64.58	-0.02	-0.08	-0.08	-0.18	-999	-999	-999
51	C	2	Butchers	0	0	0	99.88	47.54	0.06	-999	-999	-999	-999	-999	-999
52	R	133	1945 - 1964 Terrace	0	0	0.3	99.96	47.54	-0.02	-999	-999	-999	-999	-999	-999
53	C	2	Car Wash	99.3	0	0	99.3	74.73	0.4	0.32	0.31	0.19	-999	-999	-999
54	C	2	Superstore/Hypermarket (Supervalue)	0	0	0	100.23	890.8	-0.48	-0.57	-0.62	-999	-999	-999	-999
55	R	133	1945 - 1964 Terrace	0	0	0.3	99.82	50.55	0.12	0.07	0.07	-0.03	-999	-999	-999
56	R	133	1945 - 1964 Terrace	0	0	0.3	99.8	47.11	0.14	0.09	0.09	-0.01	-999	-999	-999
57	C	2	(High Street) Shop	0	0	0	99.85	55.04	0.09	0.04	0.03	-0.25	-999	-999	-999
58	R	135	1975 - 1985 Terrace	0	0	0.3	99.53	55.37	-0.14	-0.18	-0.19	-0.31	-999	-999	-999
59	R	135	1975 - 1985 Terrace	0	0	0.3	100	63.52	-0.07	-0.11	-0.12	-0.21	-999	-999	-999
60	R	135	1975 - 1985 Terrace	0	0	0.3	99.83	77.46	0.09	0.05	0.04	-999	-999	-999	-999
61	R	135	1975 - 1985 Terrace	0	0	0.3	99.51	54.71	-0.19	-999	-999	-999	-999	-999	-999
62	R	138	Post-1985 Terrace	0	0	0.3	102.02	45.57	-0.15	-0.27	-0.27	-0.37	-999	-999	-999

APPENDIX B

RISK MAPS





IMPORTANT USER NOTE:
THE VIEWER OF THIS MAP SHOULD REFER TO THE DISCLAIMER, GUIDANCE NOTES AND CONDITIONS OF USE THAT ACCOMPANY THIS MAP.

Legend

Properties

- Commerical
- Residential
- Waste Water Treatment Works
- Electricity Substations

Roads Network

- A Class Road
- B Class Road
- C Class Road
- Unclasssified Road
- New Developments
- Modelled River Centreline
- Fintona Drainage Network
- 1% AEP Flood Extent
- Fintona Study Area

DRAFT

REV:	NOTE:	DATE:
01		15/09/2017

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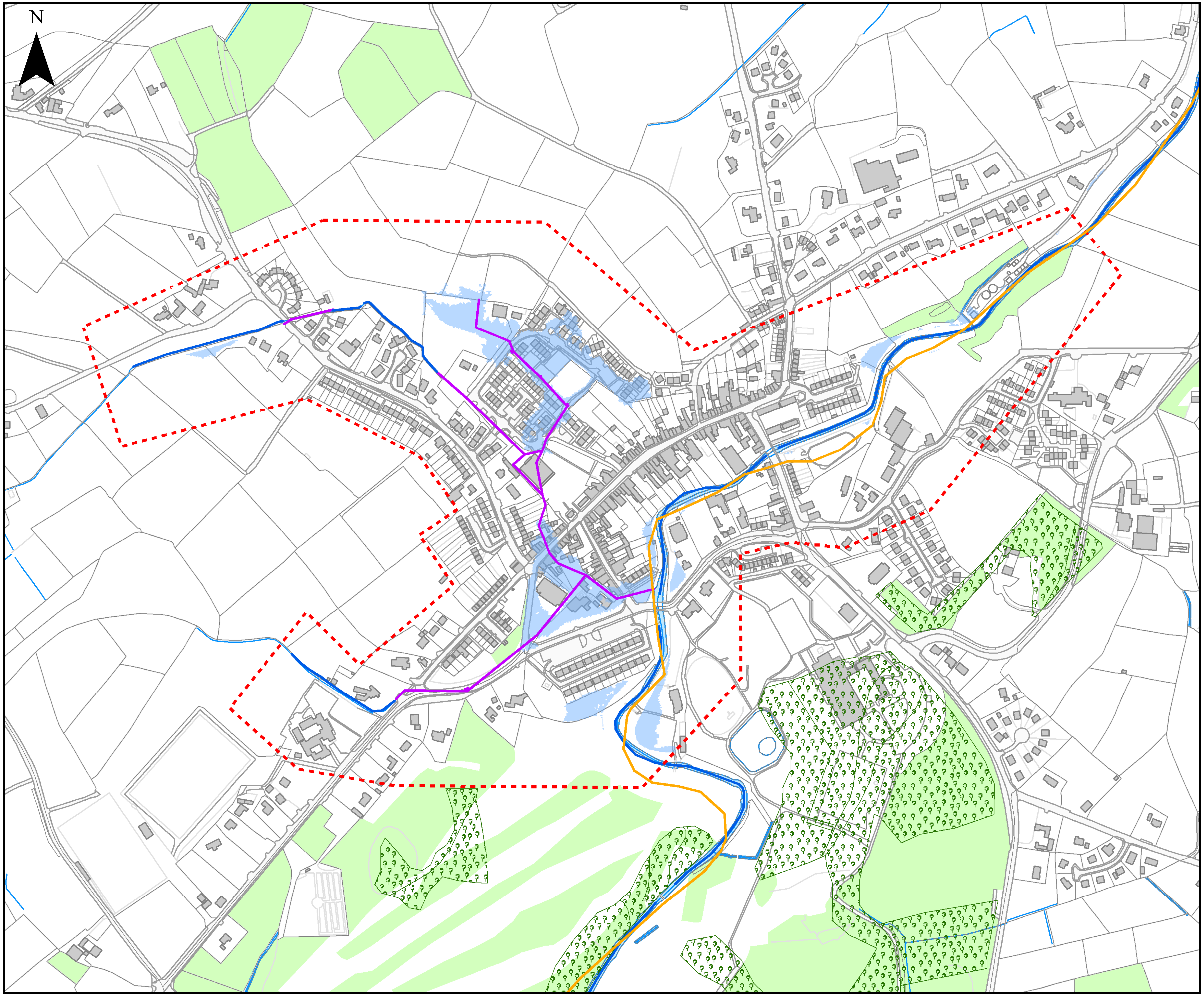
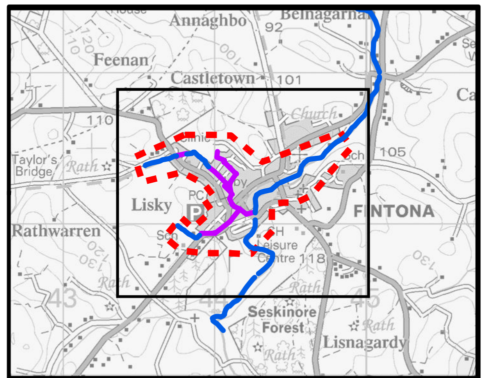
Map:
Fintona Fluvial Economic Risk Map

Map Type: General Risk - Economic
Source: Fluvial
Map Area:
Scenario: Current
Drawn By : Z.M. **Date :** 15 September 2017
Checked By : M.W. **Date :** 15 September 2017
Approved By : G.G. **Date :** 15 September 2017
Drawing No. :

Map Series : Page 1 of 1
Drawing Scale : 1:5,000 @ A3





IMPORTANT USER NOTE:
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Legend

- Salmonid Rivers
- Ancient Woodland
- RAMSAR
- Area of Specific Scientific Interest (ASSI)
- Area of Natural Beauty (AONB)
- Special Area of Conservation (SAC)
- Special Protection Area (SPA)
- Modelled River Centreline
- Fintona Drainage Network
- 1% AEP Flood Extent
- Fintona Study Area

DRAFT

REV:	NOTE:	DATE:
01		15/09/2017

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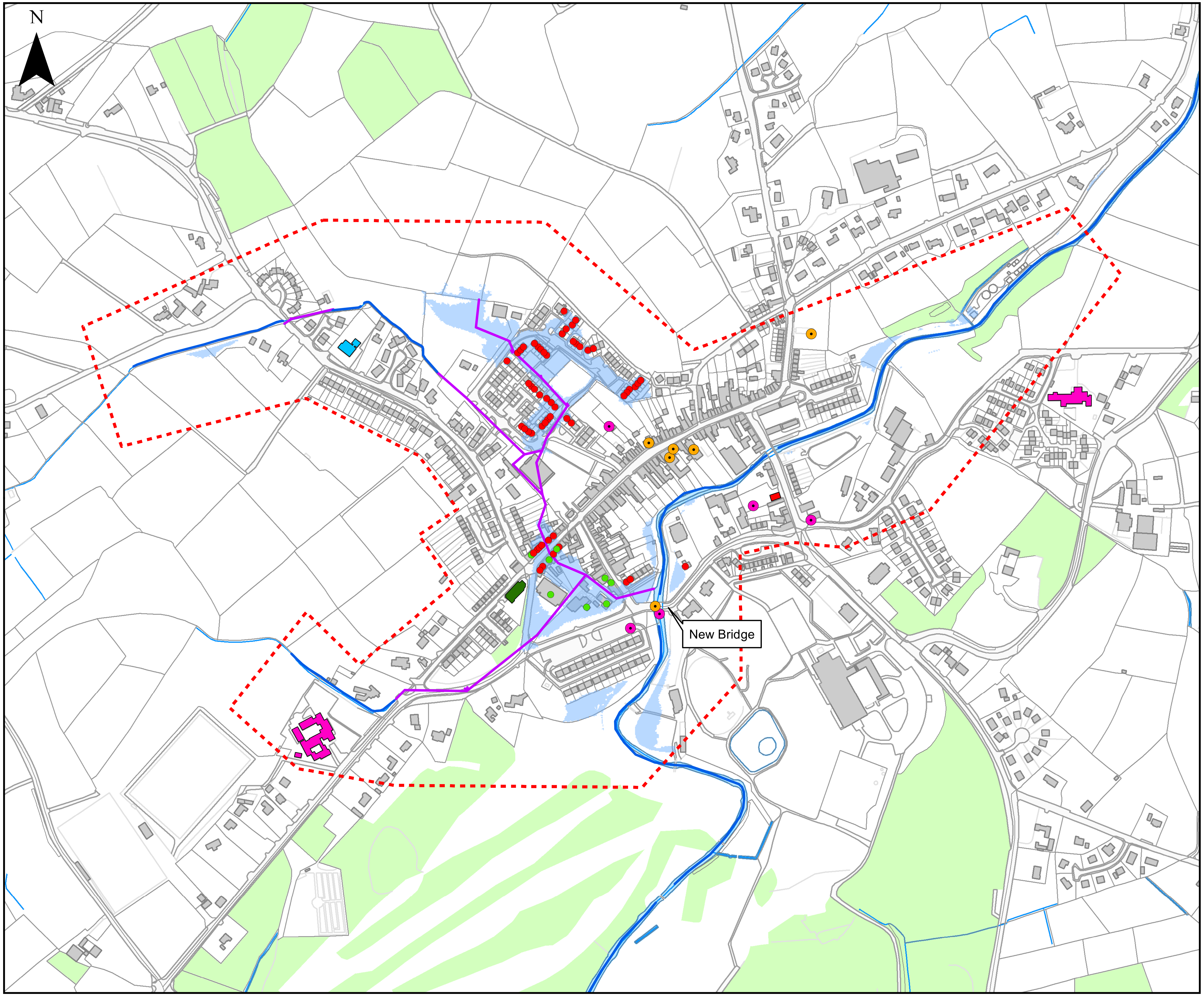
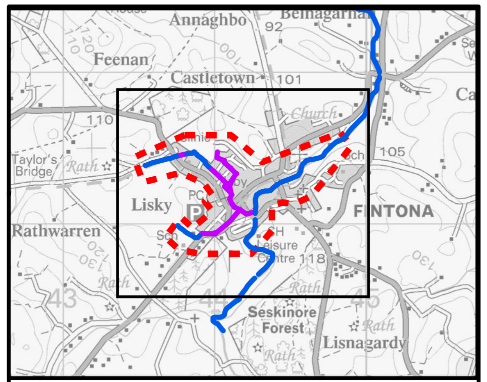
Map:
Fintona Fluvial Environmental Risk Map

Map Type: General Risk - Environmental
Source: Fluvial
Map Area:
Scenario: Current
Drawn By : Z.M. Date : 15 September 2017
Checked By : M.W. Date : 15 September 2017
Approved By : G.G. Date : 15 September 2017
Drawing No. :

Map Series : Page 1 of 1
Drawing Scale : 1:50,000 @ A3





IMPORTANT USER NOTE:
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Legend

Properties

- Commerical
- Residential
- Listed Buildings
- Industrial Heritage Buildings

Community Receptors

- Primary Schools
- Fire Station
- Medical Centre
- Police Station
- Historic Parks and Gardens
- Areas of Archeological Potential
- Areas of Special Archeological Interest
- Modelled River Centreline
- Pipe
- 1% AEP Flood Extent
- Fintona Study Area

DRAFT

REV:	NOTE:	DATE:
01		15/09/2017

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Map:
Fintona Fluvial Social Risk Map

Map Type: General Risk - Social
Source: Fluvial
Map Area:
Scenario: Current
Drawn By : Z.M. Date : 15 September 2017
Checked By : M.W. Date : 15 September 2017
Approved By : G.G. Date : 15 September 2017
Drawing No. :

Map Series : Page 1 of 1

Drawing Scale : 1:5,000 @ A3

APPENDIX C

DAMAGE AND DEFENCE COSTS ASSUMPTIONS

COST & DAMAGE ASSUMPTIONS

Assumptions made on maintenance/inspection costs

The maintenance and operational costs have been supplied by DfI Rivers. The annual maintenance costs have been calculated as follows:

Inspections at £405 per day x 0.15 day	£61
Maintenance at £405 per day x 2.5 day	£1,012

The total estimated annual inspection/maintenance cost is therefore £1,073 (approximated to £1,000)

Assumptions made on defence costs

The following assumptions were made in the calculation of the defence costs.

Reinforced concrete walls only:

- Flood wall thickness assumed to be 300mm;
- Base thickness of floodwall assumed to be the same as the stem (300mm);
- Height of the proposed floodwall calculated on the assumption that the top of the base is 1m below GL;
- Base width of floodwall assumed to be base thickness + wall height.

Earth embankment:

- Slope of embankment assumed to be 1:3;
- Assume constructed using impermeable clay material;
- Assume depth below ground level of 4m;
- Width and depth of capping beam assumed to be 800mm.

All:

- An additional 15% has been added to the costs to cover the preliminaries. This include items associated with: Establishment of the site; Insurance, permits, paperwork, etc.; Site running costs; Handover of site; Supervision, labourers, etc.; and Overheads or others costs;
- An additional 10% has been added for fees and contingencies. This cost is included to cover consultancy and design fees and an allowance for the unknown risk associated with a project.
- The lifespan of the scheme is assumed to be 100 years;
- Maintenance costs have been included at £2,000 per year and £5,000 every 5 years for flood defences.

The following rates have been used (2016):

Item	Assumption	Rate	Unit
Clearance - vegetation killing		£230	ha
Clearance - site clearance & disposal	Allowance for tree, plant & scrub removal	£5	m^2
Excavation - topsoil strip &stockpile	Assumed 300mm depth	£3	m^2
Provision & placing of concrete	Assumed Grade 40	£110	m^3
Reinforcement (provision & fix)	Assumed 1t per 9m^3 of reinforced concrete	£900	t
Trenchfill (Grade C20)	Allowance made for 1m depth (throughout length & width)	£75	m^3
Formwork (plain)		£50	m^2
Formwork (moulded feature)		£75	m^2
Granite finish to wall		£80	m^2
Filling - provision of topsoil		£16	m^3
Filling - topsoil	Assumed 300mm depth	£8.50	m^3
Finishing- grassing out		£1.05	m^2
Filling - provision of clay fill		£25	m^3
Filling - clay fill		£8.50	m^3
Geotextile mat		£3	m^2
Drainage		£35	m
Concrete pipes with rebated flexible joints to BS 5911 Class 120	900mm in trenches depth: up to 1.50m 1.50-2.00m 2.50-3.00m 3.50-4.00m 1200mm in trenches depth: up to 1.50-2.00m 2.00-2.50m 2.50-3.00m 3.00-3.50m	£182.42 £195.71 £220.33 £294.22 £311.95 £325.18 £344.16 £372.56	m m m m m m m m
Concrete pipes – extra for bends	750mm 900mm 1200mm	£984.03 £1338.63 £2255.23	- - -
Manhole – precast concrete construction	Circular shafts; 1200 dia. x 1500 depth to invert 1200 dia. x 2000 depth to invert 1200 dia. x 3000 depth to invert 1800 dia. x 4000 depth to invert	£1444.28 £1532.10 £2202.36 £5110.14	- - - -
Sealed Manholes	Replace depth: 1.00-1.50m up to 3m	£6755.40 £12780.50	- -
Inlet/Outlet Headwall and Screen		£10,820.00	
Flap Valve	900mm 1200mm	£1,799.31 £3,082.84	- -
Weir	2m high, 20m long	£74,681.08	-
Excavation for cuttings	Max depth 3.5m	£11.03	m^3

Road reinstatement		**£229.07**	**m**
	Cold milling	£1.50	m^2
	Resurfacing surface course	£11.00	m^2
	Binder course cold milling	£2.00	m^2
	Binder course	£8.00	m^2
	Base course	£10.00	m^2
	Concrete surround/backfill	£100.00	m^3
	Misc. (road markings)	£8.60	m

Assumptions made on Damage Assessment

The following assumptions and methods were used in the damage assessment:

- The damage assessment follows the MCM guidance;
- Finished floor levels of properties were taken to be 300mm above ground level;
- The average flood depth for any given event was taken at the centre of the property;
- Damage values were based on the MCM 2016 data;
- Intangible benefits were assumed and were calculated according to DEFRA Flood and Coastal Defence Project Appraisal Guidance (FCDPAG3), Economic Appraisal Supplementary Note to Operating Authorities, Revisions to Economic Appraisal on: Reflecting socio-economic equity in appraisal and Appraisal of human related intangible impacts of flooding;
- Damage values to houses and commercial properties were capped at their market value according to data supplied from Land & Property Services.

APPENDIX D

CONSTRUCTION COSTS

U1401* Improvement of Conveyance

	Length	Original Pipe Dia.	Upgraded Pipe Dia.	Trench Depth	Price/m	Pipe Cost
	38.9	450	900	1.3	182.42	7096.138
	48.2	450	900	1.45	182.42	8792.644
	2	450	900	1.5	195.71	391.42
	19.6	450	900	1.8	195.71	3835.916
	52.3	450	900	1.8	195.71	10235.633
up to manhole U1401*/02	53.1	450	900	1.7	195.71	10392.201
Total	214.1					£40,743.95

Manhole size	Manhole Price	No. of Manholes	Manhole Cost	No. of Bends	Extra for Bends	Inlet/Outlet Headwall + Screen
1200 dia x 1500 depth to invert	1444.28	3	4332.84	3	£1,338.63	£10,820.00
1200 dia x 2000 depth to invert	1532.1	4	6128.4			
			10461.24		£4,015.89	£10,820.00

Road Reinstatement	Unit	Quantity	Price/unit	Cost	
Cold milling 1.50m2 (3mx 350m)	m2	1050	£1.50	£1,575.00	
Resurfacing Surface course (Full road)	m2	2100	£11.00	£23,100.00	
Binder course cold milling (0.6x 350)	m2	210	£2.00	£420.00	
Binder course (3.6m x 350m)	m2	1260	£8.00	£10,080.00	
Base course (3m x 350)	m2	1050	£10.00	£10,500.00	
* May be required by Dfl Concrete surround/back fill (3m x 0.3x 350)	m3	315	£100.00	£31,500.00	
Misc for road makings				£3,000.00	
				£80,175.00	per 350m
				£229.07	per m

Length of works on road	Cost of road reinstatement
40	£9,162.86

Sub-Total	£75,203.94
Pelimainaries	£11,280.59
Total Cost	£86,484.53

U1401* Diversion of Flow

	Length	Upgraded Pipe Dia.	Trench Depth	Price/m	Pipe Cost
	56.1	900	2.7	220.33	12360.513
	38.1	900	3.9	294.22	11209.782
	126	900	3.75	294.22	37071.72
Total	220.2				£60,642.02

Manhole size	Manhole Price	No. of Manholes	Manhole Cost	No. of Bends	Extra for Bends	Inlet/Outlet Headwall + Screen
1800 dia x 4000 depth to invert	5110.14	3	15330.42	2	£1,338.63	£10,820.00
			£15,330.42		£2,677.26	£10,820.00

Flap Valve Cost
£1,799.31

Road Reinstatement	Unit	Quantity	Price/unit	Cost	
Cold milling 1.50m2 (3mx 350m)	m2	1050	£1.50	£1,575.00	
Resurfacing Surface course (Full road)	m2	2100	£11.00	£23,100.00	
Binder course cold milling (0.6x 350)	m2	210	£2.00	£420.00	
Binder course (3.6m x 350m)	m2	1260	£8.00	£10,080.00	
Base course (3m x 350)	m2	1050	£10.00	£10,500.00	
* May be required by Dfi Concrete surround/back fill (3m x 0.3x 350)	m3	315	£100.00	£31,500.00	
Misc for road makings				£3,000.00	
				£80,175.00	per 350m
				£229.07	per m

Length of works on road	Cost of road reinstatement
115	£26,343.21

Sub-Total	£117,612.22
Pelimainaries	£17,641.83
Total Cost	£135,254.05

U1402 Diversion of Flow

Open Watercrouse Section

a	b	h	L	Area	Volume	
1	2.5	2.5	21.18	4.375	92.6625	
1	2.5	3.5	48.84	6.125	299.145	
1	2.5	1.5	66.22	2.625	173.8275	
					565.635	Total Volume

Excavation for Cuttings

Max depth	Cost/m3	Volume	Total Excavation Cost
3.5	11.03	565.635	£6,238.95

Allowance for interaction with water

Factor	Total Cost of New Channel
2	£12,477.91

Culverted Section

Length	Original Pipe Size	Upgraded Pipe Dia.	Trench Depth	Price/m	Pipe Cost
99.3	1200x1000	750	2.3	167.03	16586.079
42	1200x1000	750	2.8	178.38	7491.96
141.3					£24,078.04

Manhole size	Price	No. of Manholes	Manhole Cost	No. of Bends	Extra for Bends	Inlet/Outlet Headwall + Screen
1200 dia x 2000 depth to invert	1532.1	1	1532.1	2	£984.03	£10,820.00
1200 dia x 3000 depth to invert	2202.36	1	2202.36			
			3734.46		£1,968.06	£10,820.00

Flap Valve Cost
£1,799.31

Road Reinstatement	Unit	Quantity	Price/unit	Cost	
Cold milling 1.50m2 (3mx 350m)	m2	1050	£1.50	£1,575.00	
Resurfacing Surface course (Full road)	m2	2100	£11.00	£23,100.00	
Binder course cold milling (0.6x 350)	m2	210	£2.00	£420.00	
Binder course (3.6m x 350m)	m2	1260	£8.00	£10,080.00	
Base course (3m x 350)	m2	1050	£10.00	£10,500.00	
* May be required by Dfi Concrete surround/back fill (3m x 0.3x 350)	m3	315	£100.00	£31,500.00	
Misc for road makings				£3,000.00	
				£80,175.00	per 350m
				£229.07	per m

Length of works on road	Cost of road reinstatement
100	£22,907.14

Total Cost of New Culvert
£65,307.01

Sub-Total	£77,784.92
Pelimainaries	£11,667.74
Total Cost	£89,452.66

Hard Defences: Walls

Reinforced concrete retaining wall	Rate	Units	Quantity (Wall 1 - RHS New Bridge)	Cost	Quantity (Wall 2 - LHS New Bridge)	Cost	Quantity (Wall 3 - Meadowbrook)	Cost
Wall thickness		m	0.30		0.30		0.30	
Base thickness		m	0.30		0.30		0.30	
Wall height		m	0.76		0.97		0.60	
Base width		m	1.06		1.27		0.90	
Length of section		m	40.00		70.00		190.00	
Main Elements								
Clearance - Vegetation killing	£230.00	ha	0.004	£0.98	0.009	£2.04	0.017	£7.87
Clearance - Site clearance & disposal	£5.00	m^2	42.400	£212.00	88.900	£444.50	171.000	£1,710.00
Excavation - Topsoil strip & stockpile	£3.00	m^2	42.400	£127.20	88.900	£266.70	171.000	£513.00
Base Slab - Provision & placing of concrete	£110.00	m^3	12.720	£1,399.20	26.670	£2,933.70	51.300	£5,643.00
Base Slab - Reinforcement (Provision & Fix)	£900.00	t	1.413	£1,272.00	2.963	£2,667.00	5.700	£5,130.00
Base Slab - Trenchfill (Grade C20)	£75.00	m^3	42.400	£3,180.00	88.900	£6,667.50	171.000	£12,825.00
Base Slab - Formwork	£50.00	m^2	24.000	£1,200.00	42.000	£2,100.00	114.000	£5,700.00
Wall - Provision & placing of concrete	£110.00	m^3	5.520	£607.20	14.070	£1,547.70	17.100	£1,881.00
Wall - Reinforcement (Provision & Fix)	£900.00	t	0.613	£552.00	1.563	£1,407.00	1.900	£1,710.00
Wall - Formwork (textured on one side)	£75.00	m^2	36.800	£2,760.00	93.800	£7,035.00	114.000	£8,550.00
Wall- Granite finish	£80.00	m^2			-2.100	-£168.00		
Drainage	£35.00	m	40.000	£1,400.00	70.000	£2,450.00	190.000	£6,650.00
Traffic Management		Sum				£10,000.00		
Additional Work								
Sub-total				£12,710.58		£37,353.14		£50,319.87
Preliminaries				£1,906.59		£5,602.97		£7,547.98
TOTAL				£14,617.16		£42,956.12		£57,867.85
			Total Walls Cost	£115,441.12				

Upstream Storage

Embankment

	Rate	Units	Quantity	Cost
Height of embankment		m	1.60	
Crest Width		m	2.00	
Base width		m	23.66	
Core		m^2	17.33	
Topsoil		m^2	0.93	
Geotextile		m	11.49	
Length of section		m	212.72	
Main Elements				
Clearance - Vegetation killing	£230.00	ha	0.50	£115.76
Clearance - Site clearance & disposal	£5.00	m^2	5032.96	£25,164.78
Excavation - Topsoil strip & stockpile	£3.00	m^2	5032.96	£15,098.87
Filling - Provision of topsoil	£16.00	m^3	197.83	£3,165.27
Filling - Topsoil (300mm depth)	£8.50	m^3	197.83	£1,681.55
Filling - Provision of clay fill	£25.00	m^3	3685.37	£92,134.35
Filling - Placing of clay fill	£8.50	m^3	3685.37	£31,325.68
Geotextile mat	£3.00	m^2	2443.48	£7,330.44
Finishing - Grassing out	£1.05	m^2	1832.85	£1,924.49
Drainage	£35.00	m	212.72	£7,445.20
Additional Work		Sum		
Sub-Total				£185,386.39
Preliminaries				£27,807.96
TOTAL				£213,194.34

U1401 Storage Culvert

Width of Embankment	Pipe Diameter	Trench Depth	Price/m	Cost	Inlets/Outlets	Inlet/Outlet Headwall + Screen
23.66	1050	1.9	£311.95	£7,380.74	2	£10,820.00
						£21,640.00
					Sub Total	£29,020.74
					Pelimainaries	£4,353.11
					Total Cost	£33,373.85

U1401 Storage Weir Structure

From CFRAMS

	Length = 20m Total Cost
Weir 2m high	£74,681.08

Adjustment Factor

0.912891643

Total Cost £	68175.73202
Total Cost of Storage on U1401	£314,743.92

Summary

U1401* Improvement of Conveyance	£86,484.53
U1401* Diversion of Flow	£135,254.05
U1402 Diversion of Flow	£89,452.66
Hard Defences: Walls	£115,441.12
EH Storage	£314,743.92
Sub-Total	£741,376.29
Fees & Contingencies (10%)	£74,137.63
Total Option 1 Cost	£815,513.91

U1401 Diversion of Flow

* no SPONS price for 1050mm - using 1200mm prices

	Length	Original Pipe Dia.	Upgraded Pipe Dia.	Trench Depth	Price/m *	Cost	Manhole size
	58.7	1050	1050	2.2-2	325.18	£19,088.07	1200 dia x 1500 depth to invert
	50.8	1050	1050	2-3	344.16	£17,483.33	
	90.9	1050	1050	3-3.2	372.56	£33,865.70	
	90.3	1050	1050	3.2-1.2	372.56	£33,642.17	
	112.6	1050	1050	1.2-1.7	311.95	£35,125.57	
	42	1050	1050	1.7-2.9	344.16	£14,454.72	
Total	445.3					£153,659.56	

Manhole size	Price	No. of Manholes	Manhole Cost	No. of Bends	Extra for Bends	Inlet/Outlet Headwall + Screen
1200 dia x 2000 depth to invert	1532.1	1	1532.1	5	£2,255.23	£10,820.00
1200 dia x 3000 depth to invert	2202.36	2	4404.72			
			£5,936.82		£11,276.15	£10,820.00

Sealed Manholes	Price		Flap Valve Cost
Div2c	6755.4		
Div1b	6755.4		£3,082.84
	£13,510.80		

Total Manholes £ £19,447.62

Road Reinstatement	Unit	Quantity	Price/unit	Cost
Cold milling 1.50m2 (3mx 350m)	m2	1050	£1.50	£1,575.00
Resurfacing Surface course (Full road)	m2	2100	£11.00	£23,100.00
Binder course cold milling (0.6x 350)	m2	210	£2.00	£420.00
Binder course (3.6m x 350m)	m2	1260	£8.00	£10,080.00
Base course (3m x 350)	m2	1050	£10.00	£10,500.00
* May be required by Dfi Concrete surround/back fill (3m x 0.3x 350)	m3	315	£100.00	£31,500.00
Misc for road makings				£3,000.00
				£80,175.00 per 350m
				£229.07 per m

Length of works on road	Cost of road reinstatement
344.6	£78,938.01

Total U1401 New Culvert Cost £277,224.18

Open Watercourse Section (from above)

	a	b	h	L	Area	Volume
1	1	2.5	2.5	21.18	4.375	92.6625
2	1	2.5	3.5	48.84	6.125	299.145
3	1	2.5	1.5	66.22	2.625	173.8275
						565.635 Total Volume

Excavation for Cuttings

Max depth	Cost/m3	Volume	Total Excavation Cost
3.5	11.03	565.635	£6,238.95

Allowance for interaction with water

Factor	Total Cost of New Channel
2	£12,477.91

Sub-Total U1401 Div of Flow Cost	£289,702.08
Pelimainaries	£43,455.31
Total Cost	£333,157.40

U1401* Improvement of Conveyance

	Length	Original Pipe Dia.	Upgraded Pipe Dia.	Trench Depth	Price/m	Pipe Cost
	38.9	450	900	1.3	182.42	7096.138
	48.2	450	900	1.45	182.42	8792.644
	2	450	900	1.5	195.71	391.42
	19.6	450	900	1.8	195.71	3835.916
	52.3	450	900	1.8	195.71	10235.633
up to U1401*/02	53.1	450	900	1.7	195.71	10392.201
up to U1401*/01	53.5	675	900	2	195.71	10470.485
up to SH44611202	15.6	675	900	2	195.71	3053.076
up to U1401B/OU1	25.1	600	900	2	195.71	4912.321
Total	308.3					£59,179.83

Manhole size	Manhole Price	No. of Manholes	Manhole Cost	No. of Bends	Extra for Bends	Inlet/Outlet Headwall + Screen
1200 dia x 1500 depth to invert	1444.28	3	4332.84	3	£1,338.63	£10,820.00
1200 dia x 2000 depth to invert	1532.1	4	6128.4			
			10461.24		£4,015.89	£10,820.00

Road Reinstatement	Unit	Quantity	Price/unit	Cost
Cold milling 1.50m2 (3mx 350m)	m2	1050	£1.50	£1,575.00
Resurfacing Surface course (Full road)	m2	2100	£11.00	£23,100.00
Binder course cold milling (0.6x 350)	m2	210	£2.00	£420.00
Binder course (3.6m x 350m)	m2	1260	£8.00	£10,080.00
Base course (3m x 350)	m2	1050	£10.00	£10,500.00
* May be required by Dfi Concrete surround/back fill (3m x 0.3x 350)	m3	315	£100.00	£31,500.00
Misc for road makings				£3,000.00
				£80,175.00 per 350m
				£229.07 per m

Length of works on road	Cost of road reinstatement
40	£9,162.86

Sub-Total	£93,639.82
Pelimainaries	£14,045.97
Total Cost	£107,685.79

Hard Defences: Walls	Rate	Units	Quantity	Cost	Quantity	Cost	Quantity	Cost
Reinforced concrete retaining wall			Wall 1 - RHS New Bridge		Wall 2 - LHS New Bridge		Wall 3 - Meadowbrook	
Wall thickness		m	0.300		0.300		0.300	
Base thickness		m	0.300		0.300		0.300	
Wall height		m	0.760		0.970		0.600	
Base width		m	1.060		1.270		0.900	
Length of section		m	40.000		70.000		190.000	
Main Elements								
Clearance - Vegetation killing	230	ha	0.004	£0.98	0.009	£2.04	0.017	£7.87
Clearance - Site clearance & disposal	5	m^2	42.400	£212.00	88.900	£444.50	171.000	£1,710.00
Excavation - Topsoil strip & stockpile	3	m^2	42.400	£127.20	88.900	£266.70	171.000	£513.00
Base Slab - Provision & placing of concrete	110	m^3	12.720	£1,399.20	26.670	£2,933.70	51.300	£5,643.00
Base Slab - Reinforcement (Provision & Fix)	900	t	1.413	£1,272.00	2.963	£2,667.00	5.700	£5,130.00
Base Slab - Trenchfill (Grade C20)	75	m^3	42.400	£3,180.00	88.900	£6,667.50	171.000	£12,825.00
Base Slab - Formwork	50	m^2	24.000	£1,200.00	42.000	£2,100.00	114.000	£5,700.00
Wall - Provision & placing of concrete	110	m^3	5.520	£607.20	14.070	£1,547.70	17.100	£1,881.00
Wall - Reinforcement (Provision & Fix)	900	t	0.613	£552.00	1.563	£1,407.00	1.900	£1,710.00
Wall - Formwork (textured on one side)	75	m^2	36.800	£2,760.00	93.800	£7,035.00	114.000	£8,550.00
Wall- Granite finish	80	m^2			-2.100	-£168.00		
Drainage	35	m	40.000	£1,400.00	70.000	£2,450.00	190.000	£6,650.00
Traffic Management		Sum				£10,000.00		
Additional Work								
Sub-total				£12,710.58		£37,353.14		£50,319.87
Preliminaries				£1,906.59		£5,602.97		£7,547.98
TOTAL				£14,617.16		£42,956.12		£57,867.85
			Total Walls Cost	£115,441.12				

U1401 Div of Flow Additional Mahole Sealing				
Manholes to be sealed	Depth to invert	Cost Options	€, 2013	£, 2017
U1401/01	1.6	3, Replace depth 1 - 1.5m	7400	6755.39816
U1401/02	1.4			
U1401/03	1.3			
			SubTotal	£20,266.19
			Preliminaries	£3,039.93
			Total Cost	£23,306.12

Summary	
U1401 Diversion of Flow	£333,157.40
U1401* Improvement of Conveyance	£107,685.79
Hard Defences: Walls	£115,441.12
U1401 Div of Flow Additional Mahole Sealing	£20,266.19
Sub-Total	£576,550.51
Fees & Contingencies (10%)	£57,655.05
Total Option 2 Cost	£634,205.56

Present Value Costs for all options

Sheet Nr. 10

Client/Authority	
DfI Rivers	
Project name	
Fintona Feasibility Study	
Project reference	IBE1298
Base date for estimates (year 0)	Jan-2017
Scaling factor (e.g. £m, £k, £)	£
Initial discount rate	3.5%

Results £

	Option 1	Option 2	Option 3	Option 4	Option 5
	Do-nothing	Option 2	Option 3	Option 4	Option 5
PV total costs	29,813	899,962	715,720	0	0

Prepared (date)	16/10/2017
Printed	16/10/2017
Prepared by	ZM
Checked by	MW
Checked date	16/10/2017

year	Discount Factor	Option 1 Do-nothing Capital	Maint.	Other	Negative costs	TOTALS: Cash	PV Capital	PV Maint	PV Other	PV Negative costs
cash sum		0	100000	0	0	100000.00	0.00	29812.55	0.00	0.00
0	1.000		1000			1000.00	0.00	1000.00	0.00	0.00
1	0.966		1000			1000.00	0.00	966.18	0.00	0.00
2	0.934		1000			1000.00	0.00	933.51	0.00	0.00
3	0.902		1000			1000.00	0.00	901.94	0.00	0.00
4	0.871		1000			1000.00	0.00	871.44	0.00	0.00
5	0.842		1000			1000.00	0.00	841.97	0.00	0.00
6	0.814		1000			1000.00	0.00	813.50	0.00	0.00
7	0.786		1000			1000.00	0.00	785.99	0.00	0.00
8	0.759		1000			1000.00	0.00	759.41	0.00	0.00
9	0.734		1000			1000.00	0.00	733.73	0.00	0.00
10	0.709		1000			1000.00	0.00	708.92	0.00	0.00
11	0.685		1000			1000.00	0.00	684.95	0.00	0.00
12	0.662		1000			1000.00	0.00	661.78	0.00	0.00
13	0.639		1000			1000.00	0.00	639.40	0.00	0.00
14	0.618		1000			1000.00	0.00	617.78	0.00	0.00
15	0.597		1000			1000.00	0.00	596.89	0.00	0.00
16	0.577		1000			1000.00	0.00	576.71	0.00	0.00
17	0.557		1000			1000.00	0.00	557.20	0.00	0.00
18	0.538		1000			1000.00	0.00	538.36	0.00	0.00
19	0.520		1000			1000.00	0.00	520.16	0.00	0.00
20	0.503		1000			1000.00	0.00	502.57	0.00	0.00
21	0.486		1000			1000.00	0.00	485.57	0.00	0.00
22	0.469		1000			1000.00	0.00	469.15	0.00	0.00
23	0.453		1000			1000.00	0.00	453.29	0.00	0.00
24	0.438		1000			1000.00	0.00	437.96	0.00	0.00
25	0.423		1000			1000.00	0.00	423.15	0.00	0.00
26	0.409		1000			1000.00	0.00	408.84	0.00	0.00
27	0.395		1000			1000.00	0.00	395.01	0.00	0.00
28	0.382		1000			1000.00	0.00	381.65	0.00	0.00
29	0.369		1000			1000.00	0.00	368.75	0.00	0.00
30	0.356		1000			1000.00	0.00	356.28	0.00	0.00
31	0.346		1000			1000.00	0.00	345.90	0.00	0.00
32	0.336		1000			1000.00	0.00	335.83	0.00	0.00
33	0.326		1000			1000.00	0.00	326.05	0.00	0.00
34	0.317		1000			1000.00	0.00	316.55	0.00	0.00
35	0.307		1000			1000.00	0.00	307.33	0.00	0.00
36	0.298		1000			1000.00	0.00	298.38	0.00	0.00
37	0.290		1000			1000.00	0.00	289.69	0.00	0.00
38	0.281		1000			1000.00	0.00	281.25	0.00	0.00
39	0.273		1000			1000.00	0.00	273.06	0.00	0.00
40	0.265		1000			1000.00	0.00	265.10	0.00	0.00
41	0.257		1000			1000.00	0.00	257.38	0.00	0.00
42	0.250		1000			1000.00	0.00	249.89	0.00	0.00
43	0.243		1000			1000.00	0.00	242.61	0.00	0.00
44	0.236		1000			1000.00	0.00	235.54	0.00	0.00
45	0.229		1000			1000.00	0.00	228.68	0.00	0.00
46	0.222		1000			1000.00	0.00	222.02	0.00	0.00
47	0.216		1000			1000.00	0.00	215.55	0.00	0.00
48	0.209		1000			1000.00	0.00	209.28	0.00	0.00
49	0.203		1000			1000.00	0.00	203.18	0.00	0.00
50	0.197		1000			1000.00	0.00	197.26	0.00	0.00
51	0.192		1000			1000.00	0.00	191.52	0.00	0.00
52	0.186		1000			1000.00	0.00	185.94	0.00	0.00
53	0.181		1000			1000.00	0.00	180.52	0.00	0.00
54	0.175		1000			1000.00	0.00	175.27	0.00	0.00
55	0.170		1000			1000.00	0.00	170.16	0.00	0.00
56	0.165		1000			1000.00	0.00	165.20	0.00	0.00
57	0.160		1000			1000.00	0.00	160.39	0.00	0.00
58	0.156		1000			1000.00	0.00	155.72	0.00	0.00
59	0.151		1000			1000.00	0.00	151.19	0.00	0.00
60	0.147		1000			1000.00	0.00	146.78	0.00	0.00
61	0.143		1000			1000.00	0.00	142.51	0.00	0.00
62	0.138		1000			1000.00	0.00	138.36	0.00	0.00
63	0.134		1000			1000.00	0.00	134.33	0.00	0.00
64	0.130		1000			1000.00	0.00	130.41	0.00	0.00
65	0.127		1000			1000.00	0.00	126.62	0.00	0.00
66	0.123		1000			1000.00	0.00	122.93	0.00	0.00
67	0.119		1000			1000.00	0.00	119.35	0.00	0.00
68	0.116		1000			1000.00	0.00	115.87	0.00	0.00
69	0.112		1000			1000.00	0.00	112.50	0.00	0.00
70	0.109		1000			1000.00	0.00	109.22	0.00	0.00
71	0.106		1000			1000.00	0.00	106.04	0.00	0.00
72	0.103		1000			1000.00	0.00	102.95	0.00	0.00
73	0.100		1000			1000.00	0.00	99.95	0.00	0.00
74	0.097		1000			1000.00	0.00	97.04	0.00	0.00
75	0.094		1000			1000.00	0.00	94.21	0.00	0.00
76	0.092		1000			1000.00	0.00	91.92	0.00	0.00
77	0.090		1000			1000.00	0.00	89.67	0.00	0.00
78	0.087		1000			1000.00	0.00	87.49	0.00	0.00
79	0.085		1000			1000.00	0.00	85.35	0.00	0.00
80	0.083		1000			1000.00	0.00	83.27	0.00	0.00
81	0.081		1000			1000.00	0.00	81.24	0.00	0.00
82	0.079		1000			1000.00	0.00	79.26	0.00	0.00
83	0.077		1000			1000.00	0.00	77.33	0.00	0.00
84	0.075		1000			1000.00	0.00	75.44	0.00	0.00
85	0.074		1000			1000.00	0.00	73.60	0.00	0.00
86	0.072		1000			1000.00	0.00	71.80	0.00	0.00
87	0.070		1000			1000.00	0.00	70.05	0.00	0.00
88	0.068		1000			1000.00	0.00	68.34	0.00	0.00
89	0.067		1000			1000.00	0.00	66.68	0.00	0.00
90	0.065		1000			1000.00	0.00	65.05	0.00	0.00
91	0.063		1000			1000.00	0.00	63.46	0.00	0.00
92	0.062		1000			1000.00	0.00	61.92	0.00	0.00
93	0.060		1000			1000.00	0.00	60.41	0.00	0.00
94	0.059		1000			1000.00	0.00	58.93	0.00	0.00
95	0.057		1000			1000.00	0.00	57.50	0.00	0.00
96	0.056		1000			1000.00	0.00	56.09	0.00	0.00
97	0.055		1000			1000.00	0.00	54.73	0.00	0.00
98	0.053		1000			1000.00	0.00	53.39	0.00	0.00
99	0.052		1000			1000.00	0.00	52.09	0.00	0.00

year	Option 2 Capital	Maint.	Other	Negative costs	TOTALS: Cash	PV Capital	PV Maint	PV Other	PV Negative costs
cash sum	815513.91	253000	40775.6955	0	1109289.61	787936.14	71250.60	40775.70	0.00
0			40775.6955		40775.70	0.00	0.00	40775.70	0.00
1	815513.91				815513.91	787936.14	0.00	0.00	0.00
2		2000			2000.00	0.00	1867.02	0.00	0.00
3		2000			2000.00	0.00	1803.89	0.00	0.00
4		2000			2000.00	0.00	1742.88	0.00	0.00
5		2000			2000.00	0.00	1683.95	0.00	0.00
6		5000			5000.00	0.00	4067.50	0.00	0.00
7		2000			2000.00	0.00	1571.98	0.00	0.00
8		2000			2000.00	0.00	1518.82	0.00	0.00
9		2000			2000.00	0.00	1467.46	0.00	0.00
10		2000			2000.00	0.00	1417.84	0.00	0.00
11		5000			5000.00	0.00	3424.73	0.00	0.00
12		2000			2000.00	0.00	1323.57	0.00	0.00
13		2000			2000.00	0.00	1278.81	0.00	0.00
14		2000			2000.00	0.00	1235.56	0.00	0.00
15		2000			2000.00	0.00	1193.78	0.00	0.00
16		5000			5000.00	0.00	2883.53	0.00	0.00
17		2000			2000.00	0.00	1114.41	0.00	0.00
18		2000			2000.00	0.00	1076.72	0.00	0.00
19		2000			2000.00	0.00	1040.31	0.00	0.00
20		2000			2000.00	0.00	1005.13	0.00	0.00
21		5000			5000.00	0.00	2427.85	0.00	0.00
22		2000			2000.00	0.00	938.30	0.00	0.00
23		2000			2000.00	0.00	906.57	0.00	0.00
24		2000			2000.00	0.00	875.91	0.00	0.00
25		2000			2000.00	0.00	846.29	0.00	0.00
26		5000			5000.00	0.00	2044.19	0.00	0.00
27		2000			2000.00	0.00	790.02	0.00	0.00
28		2000			2000.00	0.00	763.31	0.00	0.00
29		2000			2000.00	0.00	737.50	0.00	0.00
30		2000			2000.00	0.00	712.56	0.00	0.00
31		5000			5000.00	0.00	1729.51	0.00	0.00
32		2000			2000.00	0.00	671.65	0.00	0.00
33		2000			2000.00	0.00	652.09	0.00	0.00
34		2000			2000.00	0.00	633.10	0.00	0.00
35		2000			2000.00	0.00	614.66	0.00	0.00
36		5000			5000.00	0.00	1491.89	0.00	0.00
37		2000			2000.00	0.00	579.37	0.00	0.00
38		2000			2000.00	0.00	562.50	0.00	0.00
39		2000			2000.00	0.00	546.12	0.00	0.00
40		2000			2000.00	0.00	530.21	0.00	0.00
41		5000			5000.00	0.00	1286.92	0.00	0.00
42		2000			2000.00	0.00	499.77	0.00	0.00
43		2000			2000.00	0.00	485.22	0.00	0.00
44		2000			2000.00	0.00	471.08	0.00	0.00
45		2000			2000.00	0.00	457.36	0.00	0.00
46		5000			5000.00	0.00	1110.10	0.00	0.00
47		2000			2000.00	0.00	431.11	0.00	0.00
48		2000			2000.00	0.00	418.55	0.00	0.00
49		2000			2000.00	0.00	406.36	0.00	0.00
50		2000			2000.00	0.00	394.53	0.00	0.00
51		5000			5000.00	0.00	957.59	0.00	0.00
52		2000			2000.00	0.00	371.88	0.00	0.00
53		2000			2000.00	0.00	361.05	0.00	0.00
54		2000			2000.00	0.00	350.53	0.00	0.00
55		2000			2000.00	0.00	340.32	0.00	0.00
56		5000			5000.00	0.00	826.02	0.00	0.00
57		2000			2000.00	0.00	320.79	0.00	0.00
58		2000			2000.00	0.00	311.44	0.00	0.00
59		2000			2000.00	0.00	302.37	0.00	0.00
60		2000			2000.00	0.00	293.56	0.00	0.00
61		5000			5000.00	0.00	712.53	0.00	0.00
62		2000			2000.00	0.00	276.71	0.00	0.00
63		2000			2000.00	0.00	268.65	0.00	0.00
64		2000			2000.00	0.00	260.83	0.00	0.00
65		2000			2000.00	0.00	253.23	0.00	0.00
66		5000			5000.00	0.00	614.64	0.00	0.00
67		2000			2000.00	0.00	238.69	0.00	0.00
68		2000			2000.00	0.00	231.74	0.00	0.00
69		2000			2000.00	0.00	224.99	0.00	0.00
70		2000			2000.00	0.00	218.44	0.00	0.00
71		5000			5000.00	0.00	530.19	0.00	0.00
72		2000			2000.00	0.00	205.90	0.00	0.00
73		2000			2000.00	0.00	199.90	0.00	0.00
74		2000			2000.00	0.00	194.08	0.00	0.00
75		2000			2000.00	0.00	188.43	0.00	0.00
76		5000			5000.00	0.00	459.58	0.00	0.00
77		2000			2000.00	0.00	179.35	0.00	0.00
78		2000			2000.00	0.00	174.97	0.00	0.00
79		2000			2000.00	0.00	170.71	0.00	0.00
80		2000			2000.00	0.00	166.54	0.00	0.00
81		5000			5000.00	0.00	406.20	0.00	0.00
82		2000			2000.00	0.00	158.52	0.00	0.00
83		2000			2000.00	0.00	154.65	0.00	0.00
84		2000			2000.00	0.00	150.88	0.00	0.00
85		2000			2000.00	0.00	147.20	0.00	0.00
86		5000			5000.00	0.00	359.02	0.00	0.00
87		2000			2000.00	0.00	140.11	0.00	0.00
88		2000			2000.00	0.00	136.69	0.00	0.00
89		2000			2000.00	0.00	133.36	0.00	0.00
90		2000			2000.00	0.00	130.10	0.00	0.00
91		5000			5000.00	0.00	317.32	0.00	0.00
92		2000			2000.00	0.00	123.83	0.00	0.00
93		2000			2000.00	0.00	120.81	0.00	0.00
94		2000			2000.00	0.00	117.87	0.00	0.00
95		2000			2000.00	0.00	114.99	0.00	0.00
96		5000			5000.00	0.00	280.47	0.00	0.00
97		2000			2000.00	0.00	109.45	0.00	0.00
98		2000			2000.00	0.00	106.78	0.00	0.00
99		2000			2000.00	0.00	104.18	0.00	0.00

year	Option 3 Capital	Maint.	Other	Negative costs	TOTALS: Cash	PV Capital	PV Maint	PV Other	PV Negative costs
cash sum	634205.56	253000	31710.278	0	918915.84	612759.00	71250.60	31710.28	0.00
0			31710.278		31710.28	0.00	0.00	31710.28	0.00
1	634205.56				634205.56	612759.00	0.00	0.00	0.00
2		2000			2000.00	0.00	1867.02	0.00	0.00
3		2000			2000.00	0.00	1803.89	0.00	0.00
4		2000			2000.00	0.00	1742.88	0.00	0.00
5		2000			2000.00	0.00	1683.95	0.00	0.00
6		5000			5000.00	0.00	4067.50	0.00	0.00
7		2000			2000.00	0.00	1571.98	0.00	0.00
8		2000			2000.00	0.00	1518.82	0.00	0.00
9		2000			2000.00	0.00	1467.46	0.00	0.00
10		2000			2000.00	0.00	1417.84	0.00	0.00
11		5000			5000.00	0.00	3424.73	0.00	0.00
12		2000			2000.00	0.00	1323.57	0.00	0.00
13		2000			2000.00	0.00	1278.81	0.00	0.00
14		2000			2000.00	0.00	1235.56	0.00	0.00
15		2000			2000.00	0.00	1193.78	0.00	0.00
16		5000			5000.00	0.00	2883.53	0.00	0.00
17		2000			2000.00	0.00	1114.41	0.00	0.00
18		2000			2000.00	0.00	1076.72	0.00	0.00
19		2000			2000.00	0.00	1040.31	0.00	0.00
20		2000			2000.00	0.00	1005.13	0.00	0.00
21		5000			5000.00	0.00	2427.85	0.00	0.00
22		2000			2000.00	0.00	938.30	0.00	0.00
23		2000			2000.00	0.00	906.57	0.00	0.00
24		2000			2000.00	0.00	875.91	0.00	0.00
25		2000			2000.00	0.00	846.29	0.00	0.00
26		5000			5000.00	0.00	2044.19	0.00	0.00
27		2000			2000.00	0.00	790.02	0.00	0.00
28		2000			2000.00	0.00	763.31	0.00	0.00
29		2000			2000.00	0.00	737.50	0.00	0.00
30		2000			2000.00	0.00	712.56	0.00	0.00
31		5000			5000.00	0.00	1729.51	0.00	0.00
32		2000			2000.00	0.00	671.65	0.00	0.00
33		2000			2000.00	0.00	652.09	0.00	0.00
34		2000			2000.00	0.00	633.10	0.00	0.00
35		2000			2000.00	0.00	614.66	0.00	0.00
36		5000			5000.00	0.00	1491.89	0.00	0.00
37		2000			2000.00	0.00	579.37	0.00	0.00
38		2000			2000.00	0.00	562.50	0.00	0.00
39		2000			2000.00	0.00	546.12	0.00	0.00
40		2000			2000.00	0.00	530.21	0.00	0.00
41		5000			5000.00	0.00	1286.92	0.00	0.00
42		2000			2000.00	0.00	499.77	0.00	0.00
43		2000			2000.00	0.00	485.22	0.00	0.00
44		2000			2000.00	0.00	471.08	0.00	0.00
45		2000			2000.00	0.00	457.36	0.00	0.00
46		5000			5000.00	0.00	1110.10	0.00	0.00
47		2000			2000.00	0.00	431.11	0.00	0.00
48		2000			2000.00	0.00	418.55	0.00	0.00
49		2000			2000.00	0.00	406.36	0.00	0.00
50		2000			2000.00	0.00	394.53	0.00	0.00
51		5000			5000.00	0.00	957.59	0.00	0.00
52		2000			2000.00	0.00	371.88	0.00	0.00
53		2000			2000.00	0.00	361.05	0.00	0.00
54		2000			2000.00	0.00	350.53	0.00	0.00
55		2000			2000.00	0.00	340.32	0.00	0.00
56		5000			5000.00	0.00	826.02	0.00	0.00
57		2000			2000.00	0.00	320.79	0.00	0.00
58		2000			2000.00	0.00	311.44	0.00	0.00
59		2000			2000.00	0.00	302.37	0.00	0.00
60		2000			2000.00	0.00	293.56	0.00	0.00
61		5000			5000.00	0.00	712.53	0.00	0.00
62		2000			2000.00	0.00	276.71	0.00	0.00
63		2000			2000.00	0.00	268.65	0.00	0.00
64		2000			2000.00	0.00	260.83	0.00	0.00
65		2000			2000.00	0.00	253.23	0.00	0.00
66		5000			5000.00	0.00	614.64	0.00	0.00
67		2000			2000.00	0.00	238.69	0.00	0.00
68		2000			2000.00	0.00	231.74	0.00	0.00
69		2000			2000.00	0.00	224.99	0.00	0.00
70		2000			2000.00	0.00	218.44	0.00	0.00
71		5000			5000.00	0.00	530.19	0.00	0.00
72		2000			2000.00	0.00	205.90	0.00	0.00
73		2000			2000.00	0.00	199.90	0.00	0.00
74		2000			2000.00	0.00	194.08	0.00	0.00
75		2000			2000.00	0.00	188.43	0.00	0.00
76		5000			5000.00	0.00	459.58	0.00	0.00
77		2000			2000.00	0.00	179.35	0.00	0.00
78		2000			2000.00	0.00	174.97	0.00	0.00
79		2000			2000.00	0.00	170.71	0.00	0.00
80		2000			2000.00	0.00	166.54	0.00	0.00
81		5000			5000.00	0.00	406.20	0.00	0.00
82		2000			2000.00	0.00	158.52	0.00	0.00
83		2000			2000.00	0.00	154.65	0.00	0.00
84		2000			2000.00	0.00	150.88	0.00	0.00
85		2000			2000.00	0.00	147.20	0.00	0.00
86		5000			5000.00	0.00	359.02	0.00	0.00
87		2000			2000.00	0.00	140.11	0.00	0.00
88		2000			2000.00	0.00	136.69	0.00	0.00
89		2000			2000.00	0.00	133.36	0.00	0.00
90		2000			2000.00	0.00	130.10	0.00	0.00
91		5000			5000.00	0.00	317.32	0.00	0.00
92		2000			2000.00	0.00	123.83	0.00	0.00
93		2000			2000.00	0.00	120.81	0.00	0.00
94		2000			2000.00	0.00	117.87	0.00	0.00
95		2000			2000.00	0.00	114.99	0.00	0.00
96		5000			5000.00	0.00	280.47	0.00	0.00
97		2000			2000.00	0.00	109.45	0.00	0.00
98		2000			2000.00	0.00	106.78	0.00	0.00
99		2000			2000.00	0.00	104.18	0.00	0.00

year	Option 4 Capital	Maint.	Other	Negative costs	TOTALS: Cash	PV Capital	PV Maint	PV Other	
cash sum	0	0	0	0	0.00	0.00	0.00	0.00	0.00
0					0.00	0.00	0.00	0.00	0.00
1					0.00	0.00	0.00	0.00	0.00
2					0.00	0.00	0.00	0.00	0.00
3					0.00	0.00	0.00	0.00	0.00
4					0.00	0.00	0.00	0.00	0.00
5					0.00	0.00	0.00	0.00	0.00
6					0.00	0.00	0.00	0.00	0.00
7					0.00	0.00	0.00	0.00	0.00
8					0.00	0.00	0.00	0.00	0.00
9					0.00	0.00	0.00	0.00	0.00
10					0.00	0.00	0.00	0.00	0.00
11					0.00	0.00	0.00	0.00	0.00
12					0.00	0.00	0.00	0.00	0.00
13					0.00	0.00	0.00	0.00	0.00
14					0.00	0.00	0.00	0.00	0.00
15					0.00	0.00	0.00	0.00	0.00
16					0.00	0.00	0.00	0.00	0.00
17					0.00	0.00	0.00	0.00	0.00
18					0.00	0.00	0.00	0.00	0.00
19					0.00	0.00	0.00	0.00	0.00
20					0.00	0.00	0.00	0.00	0.00
21					0.00	0.00	0.00	0.00	0.00
22					0.00	0.00	0.00	0.00	0.00
23					0.00	0.00	0.00	0.00	0.00
24					0.00	0.00	0.00	0.00	0.00
25					0.00	0.00	0.00	0.00	0.00
26					0.00	0.00	0.00	0.00	0.00
27					0.00	0.00	0.00	0.00	0.00
28					0.00	0.00	0.00	0.00	0.00
29					0.00	0.00	0.00	0.00	0.00
30					0.00	0.00	0.00	0.00	0.00
31					0.00	0.00	0.00	0.00	0.00
32					0.00	0.00	0.00	0.00	0.00
33					0.00	0.00	0.00	0.00	0.00
34					0.00	0.00	0.00	0.00	0.00
35					0.00	0.00	0.00	0.00	0.00
36					0.00	0.00	0.00	0.00	0.00
37					0.00	0.00	0.00	0.00	0.00
38					0.00	0.00	0.00	0.00	0.00
39					0.00	0.00	0.00	0.00	0.00
40					0.00	0.00	0.00	0.00	0.00
41					0.00	0.00	0.00	0.00	0.00
42					0.00	0.00	0.00	0.00	0.00
43					0.00	0.00	0.00	0.00	0.00
44					0.00	0.00	0.00	0.00	0.00
45					0.00	0.00	0.00	0.00	0.00
46					0.00	0.00	0.00	0.00	0.00
47					0.00	0.00	0.00	0.00	0.00
48					0.00	0.00	0.00	0.00	0.00
49					0.00	0.00	0.00	0.00	0.00
50					0.00	0.00	0.00	0.00	0.00
51					0.00	0.00	0.00	0.00	0.00
52					0.00	0.00	0.00	0.00	0.00
53					0.00	0.00	0.00	0.00	0.00
54					0.00	0.00	0.00	0.00	0.00
55					0.00	0.00	0.00	0.00	0.00
56					0.00	0.00	0.00	0.00	0.00
57					0.00	0.00	0.00	0.00	0.00
58					0.00	0.00	0.00	0.00	0.00
59					0.00	0.00	0.00	0.00	0.00
60					0.00	0.00	0.00	0.00	0.00
61					0.00	0.00	0.00	0.00	0.00
62					0.00	0.00	0.00	0.00	0.00
63					0.00	0.00	0.00	0.00	0.00
64					0.00	0.00	0.00	0.00	0.00
65					0.00	0.00	0.00	0.00	0.00
66					0.00	0.00	0.00	0.00	0.00
67					0.00	0.00	0.00	0.00	0.00
68					0.00	0.00	0.00	0.00	0.00
69					0.00	0.00	0.00	0.00	0.00
70					0.00	0.00	0.00	0.00	0.00
71					0.00	0.00	0.00	0.00	0.00
72					0.00	0.00	0.00	0.00	0.00
73					0.00	0.00	0.00	0.00	0.00
74					0.00	0.00	0.00	0.00	0.00
75					0.00	0.00	0.00	0.00	0.00
76					0.00	0.00	0.00	0.00	0.00
77					0.00	0.00	0.00	0.00	0.00
78					0.00	0.00	0.00	0.00	0.00
79					0.00	0.00	0.00	0.00	0.00
80					0.00	0.00	0.00	0.00	0.00
81					0.00	0.00	0.00	0.00	0.00
82					0.00	0.00	0.00	0.00	0.00
83					0.00	0.00	0.00	0.00	0.00
84					0.00	0.00	0.00	0.00	0.00
85					0.00	0.00	0.00	0.00	0.00
86					0.00	0.00	0.00	0.00	0.00
87					0.00	0.00	0.00	0.00	0.00
88					0.00	0.00	0.00	0.00	0.00
89					0.00	0.00	0.00	0.00	0.00
90					0.00	0.00	0.00	0.00	0.00
91					0.00	0.00	0.00	0.00	0.00
92					0.00	0.00	0.00	0.00	0.00
93					0.00	0.00	0.00	0.00	0.00
94					0.00	0.00	0.00	0.00	0.00
95					0.00	0.00	0.00	0.00	0.00
96					0.00	0.00	0.00	0.00	0.00
97					0.00	0.00	0.00	0.00	0.00
98					0.00	0.00	0.00	0.00	0.00
99					0.00	0.00	0.00	0.00	0.00