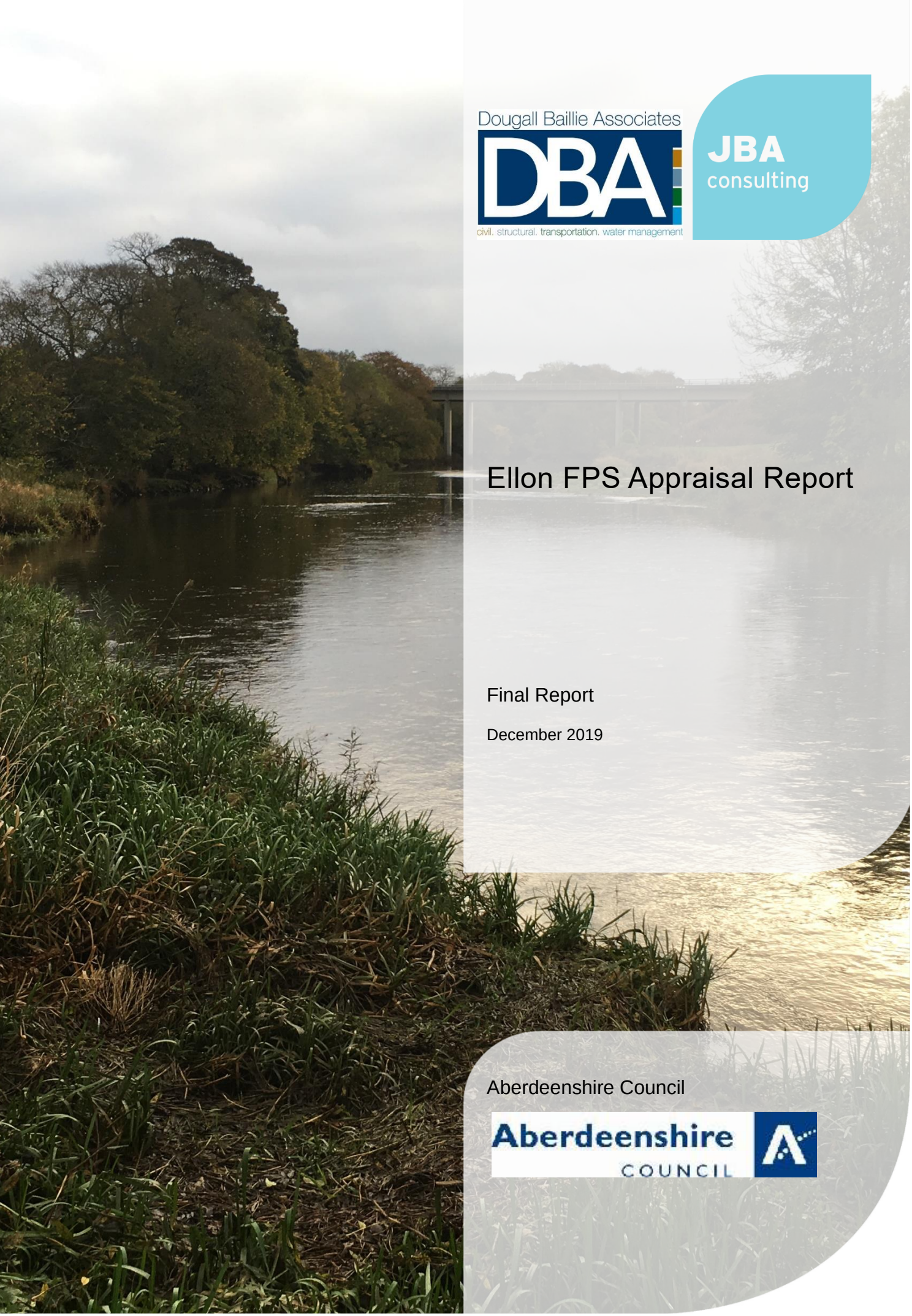

Dougall Baillie Associates

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JBA consulting

Ellon FPS Appraisal Report

Final Report

December 2019

Aberdeenshire Council

Aberdeenshire COUNCIL

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
S3-P01 / 08 April 2019	-	Alistair Scotland, Aberdeenshire Council
S3-P02 / 20 May 2019	Client comments addressed, addition of option 7	Alistair Scotland, Aberdeenshire Council
S3-P04 / 16 Sept 2019	Addition of SEPA comments and updates made following public consultation	Alistair Scotland, Aberdeenshire Council
A1-C01 / 19 Nov 2019	Published	Alistair Scotland, Aberdeenshire Council
A1-C02 / 19 Dec 2019	Sensitive information redacted.	Alistair Scotland, Aberdeenshire Council

Contract

This report describes work commissioned by Gavin Penman, on behalf of Aberdeenshire Council, on 10 October 2017 by Purchase Order Number 1095192. Dougall Baillie's representative for the contract was Scott Macphail and Aberdeenshire Council's representative for the contract was Alistair Scotland. Douglas Scoular of JBA Consulting carried out this work.

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Technical Director

Purpose

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JBA Consulting has no liability regarding the use of this report except to Aberdeenshire Council.

Acknowledgements

JBA wishes to thank SEPA for provision of the hydrometric data and Aberdeenshire Council for the supply of data.

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Ellon FRM Business Case

Context

Ellon located in Aberdeenshire has an extensive history of property flooding. JBA was commissioned in 2017 to carry out a review of past events, determine the likely risk to different properties and to propose a set of 'options' that may reduce the flood risk to an acceptable level. This report is the culmination of this work and aims to provide a detailed explanation of the various steps carried out in order to identify a preferred set of interventions that offer a sustainable method of flood protection whilst seeking to benefit the environment and the community of Ellon.

This report focusses on fluvial flood risk from the following watercourses; River Ythan, Modley Burn, Broomies Burn, Hillhead Burn and Fortree Burn.

A modelling exercise was carried out to estimate river levels on the above-mentioned watercourses from upstream of Bridge of Ardlethen to downstream of where the A90 crosses the River Ythan. A range of possible flood events were modelled from the 50% AP (2 year) event to the 0.1% AP (1000 year) event. Increases to the flow due to predicted climate change was included to the 0.5% AP (200 year) event.

It was found that 30 properties are at risk of flooding from the 0.5% AP (200 year) event and 59 are at risk for the same event with a climate change allowance. A range of flood protection options were then reviewed and short listed based on their viability.

Risk metrics

The following risk metrics are provided to aid prioritisation by SEPA:

Residential properties at risk	28 at the 200 year flood (53 with climate change)
Non-residential properties at risk	2 at the 200 year flood (6 with climate change)
Key receptors at risk	Properties along Patey Road, Hillhead Drive, Bruce Crescent and Modley Place.

Flood Mitigation Options

Due to the number of watercourses investigated, Ellon was split into four different areas and reviewed based on the different mechanisms of flooding:

- Area A (Modley Burn) - Flood risk from Modley Burn, on the left bank of the Ythan
- Area B (Hillhead and Fortree) - Flood risk from Hillhead and Fortree Burn as well as the Ythan on the right bank
- Area C (River Ythan Old Bridge) - Flood risk from the River Ythan around Old Bridge of Ellon and Bridge of Ardlethen
- Area D (The Meadows) - Flood risk from Broomies Burn and the River Ythan primarily at The Meadows

A range of flood protection options were then reviewed and short listed for each area based on their viability. A range of different combinations of options were then put forward as a viable solution for the community of Ellon as follows:

- **Option 1 (standard of protection 0.5% AP (200 year) plus climate change):**
  - Area A - direct defences, bridge removal and two stage channel
  - Area B - 0.5% AP plus climate change storage reservoir, headwall and trash screen replacement, pumping station and direct defence
  - Area C - direct defences
  - Area D - direct defences

- **Option 2 (standard of protection 0.5% AP (200 year)):**
  - Area A - direct defences, bridge removal and two stage channel
  - Area B - 0.5% AP storage area, headwall and trash screen replacement, pumping station and direct defence

- Area C - direct defences
- Area D - direct defences

- **Option 3 (standard of protection 0.5% AP (200 year)):**
  - Area A - direct defences, bridge removal and two stage channel
  - Area B - 0.5% AP storage area, headwall and trash screen replacement, pumping station and direct defence
  - Area C - direct defences and PLP
  - Area D - direct defences

- **Option 4 (standard of protection 0.5% AP (200 year)):**
  - Area A - direct defences, bridge removal and two stage channel
  - Area B - 0.5% AP storage area, headwall and trash screen replacement, pumping station and direct defence
  - Area C - direct defences and PLP
  - Area D - PLP

- **Option 5 (standard of protection 0.5% AP (200 year)):**
  - Area A - direct defences, bridge removal and two stage channel
  - Area B - 0.5% AP storage area, headwall and trash screen replacement, pumping station and direct defence
  - Area C - PLP
  - Area D - PLP

- **Option 6 (standard of protection 0.5% AP (200 year)):**
  - Area A - PLP
  - Area B - PLP
  - Area C - PLP
  - Area D - PLP

- **Option 7 (standard of protection 0.5% AP (200 year)):**
  - Area A - two stage channel
  - Area B - 0.5% AP storage area, headwall and trash screen replacement and pumping station
  - Area C - PLP protected to 0.5% AP (200 year)
  - Area D - PLP protected to 0.5% AP (200 year)

Improving public awareness and resilience

In addition to these short-listed options a number of non-structural options and good practice FRM measures have been investigated and recommended for implementation by Aberdeenshire Council. Some of these could be implemented either in the short term or alongside a Flood Protection Scheme. These include the following:

- Development of a full flood warning system.
- Community engagement should be continued to raise awareness of flood risk and potential short- and longer-term solutions.
- At risk properties could make use of the Council's PLP discount scheme in advance of any possible Flood Protection Scheme on the watercourse.
- Resilient Communities sandbag stores are available in Ellon. The Council should investigate if an additional store needs to be provided. The Council should also consider the use of a flood 'pod' system. Community storage boxes, which contain flood sacks; purpose designed bags filled with absorbent material. The key advantage of this approach

is that they can be distributed before a flood and are ideal for locations with limited warning or response times. It may also save the Council time in filling, distributing and delivering sandbags to communities when sandbag stores run out.

- Scottish Planning Policy should be leveraged to provide the potential for future implementation of other options that are currently not possible or to avoid unnecessary development on the floodplain in Ellon.

Expected benefits

A flood damage assessment has been undertaken for the present-day Do Nothing and Do Minimum scenarios and each of the above options. The Present Value flood damages calculated for the Do Nothing and Do Minimum scenarios are estimated to be £5.9 m and £2.1 m, respectively. The damages avoided for each option are in the range of £4.6-5.6 m (depending on the option assessed). Total damages avoided for each option are provided in the investment appraisal summary table below.

Damages avoided:

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Standard of Protection (SOP) (years)	200 + climate change	200	200	200	200	200	200
Damages avoided (£k)	5,602	5,556	5,535	5,504	5,504	4,637	5,359

Working with natural processes

Natural Flood Management (NFM) is a method whereby wider catchment benefits could be achieved alongside potential reduction to flood flows within Ellon. Opportunities within the upper catchment could to some extent counteract the effects of increasing river flows with climate change. Natural Flood Management opportunities should be progressed where feasible through engagement with landowners and other stakeholders. Should NFM be progressed as part of a scheme funding should be sought through the scheme itself but in the shorter term it may be possible to secure funding through other sources if the focus can be widened from flood risk management to catchment, environmental and land management benefits.

Costs

Costs for each option have been estimated using the Environment Agency's Long Term Costing tool (2012). An optimism bias factor of 60% has been added to the total costs to allow for uncertainties in design at this stage and is typical for schemes at an early stage of appraisal. Whole life present value costs range from £2.3 m to £21.0 m. Total costs for each option are provided in the investment appraisal summary table.

Investment appraisal

The investment appraisal is provided below. The options show the increased level of PLP gives a higher cost-benefit ratio with the highest benefit-cost ratio being a full PLP option (option 6), with a ratio of 1.4 and a net present value of £2.3 m. From a benefit-cost perspective option 6 is the best option as it is the only option which is deemed cost effective.

	DN	DM	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Total PV Costs (£k)	-	-	20,962	18,568	14,345	7,781	6,997	3,346	5,298
PV damage (£k)	5,866	2,078	264	310	313	317	317	346	474
PV damage avoided (£k)	-	3,788	5,602	5,556	5,535	5,504	5,504	4,637	5,359

Net present value (£k)	-	3,788	-15,360	-13,011	-8,810	-2,277	-1,493	1,281	61
Benefit-cost ratio	-	-	0.27	0.30	0.39	0.71	0.79	1.38	1.01

Residual risks and planning for future flooding

A number of measures could be implemented to reduce the residual risk brought by above design standard flood events, particularly likely with climate change:

- Natural Flood Management (NFM) practices could aid in reducing flows experienced within the area of Ellon through good land management practices. In particular, it is recommended that the catchment upstream of Hillhead inlet is investigated as to the potential for leaky bunds to reduce the extent and hence costing of formal storage.
- Continued watercourse maintenance is crucial as highlighted in the large difference between the Do Nothing and Do Minimum scenario damages. Fortree and Hillhead exhibit a significant increase in damage when the large culverts are blocked.
- A surface water study for areas B and D, in particular Hillhead culverted sewer should be investigated to gain a full understanding of the flood risk to the properties. A surface water study should also be conducted on the area which drains off the sports pitches and into The Meadows housing. Scottish Water are due to complete a preliminary investigation within Ellon as part of the FRM Act Section 16 assessment though it is recommended that a more detailed study is conducted.

Conclusions and recommendations

A majority of properties within Ellon currently have a high standard of protection and therefore only predicted to flood during events greater than the 1% AP (100 year). This results in damages being lower than anticipated and this poses a limitation on the extent of hard engineering which can be implemented in the area.

From an economic perspective full PLP is the most viable option, though provision across all areas of 0.5% AP (200 year) standard of protection also results in a positive benefit-cost ratio. It is recommended for the following reasons that options 4 and 5 be taken forward for consideration as they have a number of additional benefits by combining hard defences with PLP while not being largely below a positive cost-benefit ratio:

- Though the modelling has displayed many properties being within the 0.6 m flood depth at the 0.5% AP (200 year) plus climate change it was discussed by the public that depths exceeded this during the 2016 event. This is likely due to the model not accounting for a drainage issue which has been expressed within Ellon as well as other modelling uncertainty with regards to water inside buildings.
- PLP has a large social implication in the area of Ellon where a large number of the public have expressed concern with only having PLP as a solution to the flood risk.
- PLP is not seen as a long-term solution where future increases in flow due to climate change are likely to surpass the 0.6m threshold that the majority of the properties currently do not experience.

Option 7 provides a standard of protection of 0.5% AP (200 year) across all areas and should be considered if the benefit-cost ratio is critical for the scheme as it provides a positive outcome, including hard engineering in the most vulnerable areas. This results in it being more sustainable and socially accepted than full PLP.

The matrix overleaf gives an overview of the consideration of each option against different key criteria.

Option	Minimum Standard of protection	Properties protected from 0.5% AP (200 year) plus CC	Environmental implications	Working with natural processes	Constraints/ limitations	Mitigating residual risks	Improved public awareness	Best use of public money	Wider benefits
Option 1 – Areas A, B, C and D hard defence, storage reservoir, two stage channel	0.5% AP – 200 year plus CC	All properties protected.	Some ecological benefits. Increase in biodiversity through storage areas and two stage channel. Minor disturbance during construction.	RBMP benefit of reconnection to a more naturalised floodplain through a two stage channel. Construction of direct defences on the channel banks will cut off some of the floodplain, although the watercourse is already highly canalised alongside Modley Place. Storage area on Hillhead Burn will also act to regulate sediment from agricultural areas.	Large direct defences required. High walls and embankments around the reservoir and storage area. High walls around The Meadows.	Protection up to the 0.5% AP (200 year event) plus climate change.	Recommendations of continued work with action groups and the community. Importance of flood warning being developed in the area.	Not cost effective due to expense of defences, benefit cost ratio of 0.3.	Minimal impacts on community other than minor aesthetics from direct defences. Standard of protection against future increase in flows.
Option 2 – Areas A, B, C and D hard defence, storage area, two stage channel	0.5% AP – 200 year	A, C and D protected. Majority of B protected.				Room for direct defences to be increased in the future. i.e. walls increased in height. Opportunities for NFM.		Not cost effective due to expense of defences, benefit cost ratio of 0.3.	Minimal impacts on community other than minor aesthetics from direct defences. Results in long term standard of protection.
Option 3 – Areas A, B and D hard defence, storage area and two stage channel. Area C PLP excluding Ythan Court direct defences	0.5% AP – 200 year	A and D protected. Majority of B and C protected.		RBMP benefit of reconnection to a more naturalised floodplain through a two stage channel. Minor implication from some construction of direct defences on the channel banks will cut off some of the floodplain, although the watercourse is already highly canalised alongside Modley Place. Storage area on Hillhead Burn will also act to regulate sediment from agricultural areas.		Room for direct defences to be increased in the future. Opportunities for NFM. Difficulty with mitigating residual risks on areas with PLP. No adaptation for mitigation of future risk.		Not cost effective due to expense of defences, benefit cost ratio of 0.4.	
Option 4 – Areas A and B hard defence, storage area, two stage channel. Areas C and D PLP excluding Ythan Court direct defence	0.5% AP – 200 year	A protected. Majority B, C and D protected.						Not cost effective due to expense of defences, benefit cost ratio of 0.7.	
Option 5 – Areas A and B hard defence, storage area and two stage channel. Areas C and D PLP	0.5% AP – 200 year	A protected. Majority B, C and D protected.		RBMP benefit of reconnection to a naturalised floodplain through a two stage channel. Storage area on Hillhead Burn will also act to regulate sediment from agricultural areas.				Not cost effective due to expense of defences, benefit cost ratio of 0.8.	
Option 6 - Full PLP	0.5% AP – 200 year	Majority A, B, C and D protected.	Little to no impact.	Little to no impact	Social constraint where PLP is not as accepted as a sole option. Lack of flood warning requires more expensive automatic systems.	No adaptation for mitigating future risk.		Benefit cost ratio of 1.4	Aside from individual property works wider community not impacted.
Option 7 – All areas defended to 0.5% AP SoP, Hard defence, areas C and D PLP	0.5% AP – 200 year	No areas protected with inclusion of climate change	Some ecological benefits. Increase in biodiversity through storage areas and two stage channel. Minor disturbance during construction.	RBMP benefit of reconnection to a naturalised floodplain through a two stage channel. Storage area on Hillhead Burn will also act to regulate sediment from agricultural areas.	High walls and embankments around the reservoir and storage area. Social constraint where PLP is not as accepted as a sole option. Lack of flood warning requires more expensive automatic systems.	Opportunities for NFM. Some opportunity for two stage channel to be increased. Difficulty with mitigating residual risks on areas with PLP.		Benefit cost ratio of 1.0	Minimal impacts on community other than minor aesthetics from the reservoir.

Negative			Neutral			Positive

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Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
AMAX	Annual Maximum
CCTV	Closed Circuit Television
DTM	Digital Terrain Model
FCERM	Flood and Coastal Erosion Risk Management (R&D programme)
FEH	Flood Estimation Handbook
FPS	Flood Protection Scheme
FRM	Flood Risk Mapping
GIS	Geographical Information System
GL	General Logistic Distribution
LiDAR	Light Detection And Ranging
mAOD	metres Above Ordnance Datum
NESBreC	North East Scotland Biological Records Centre
NFM	Natural Flood Management
NGR	National Grid Reference
NNR	National Nature Reserve
OS	Ordnance Survey
OS NGR	Ordnance Survey National Grid Reference
PDM	Probability Distributed Model
PLP	Property Level Protection
PV	Present Value
QMED	Median Annual Flood (with return period 2 years)
RBMP	River Basin Management Plan
ReFH	Revitalised Flood Hydrograph method
RR	Rainfall-Runoff
SEPA	Scottish Environment Protection Agency
SoP	Standard of Protection
SPA	Special Protection Area for birds, protected under the EU Habitats Directive
SSSI	Site of Special Scientific Interest

Supporting Documents

Hydrology report - AIZ-JBAU-EL-00-RP-HM-0002-Ellon_Hydrology_Report_A1-C01.pdf

Information review - AIZ-JBAU-EL-00-RP-HM-0001-Information_Review-A1-C01.pdf

Asset condition assessment report - AIZ-JBAU-EL-00-RP-C-0001-Asset_Condition_Assessment-A1-C01.pdf

NFM report - AIZ-JBAU-EL-00-RP-EN-0001-NFM_RBMP_Report-A1-C01.pdf

Preliminary Ecological Appraisal - AIZ-JBAU-EL-00-RP-EN-0007-Ellon_PEAR-A1-C01.pdf

Modelling report - AIZ-JBAU-EL-00-RP-HM-0010-Modelling_Report-A1-C01.pdf

Flood maps - supplied as PDF's for return periods 2-1000 years including climate change runs and for the Do Nothing and Do Minimum scenarios.

Option drawings - supplied as PDF's

1 Introduction

1.1 Legislative framework

Ellon is part of the North East Local Plan District (LPD) and is categorised as a Potentially Vulnerable Area (PVA) (06/12) with an area of 19 km^2. The details for this LPD, are contained in the North-East Flood Risk Management Strategy (FRMS)[1] and the North East Flood Risk Management Plan (LFRMP)[2]. Within this PVA a number of recommendations were made to undertake site specific detailed flood protection studies (amongst other flood risk management activities) to better inform the current flood risk to these communities and to investigate options for mitigation. Nationally Ellon is ranked 55 out of 168 PVA's but 1 out of 12 within the Aberdeenshire Council authority area.

Under the Flood Risk Management (Scotland) Act 2009, this report forms part of the appraisal study for Ellon commissioned by Aberdeenshire Council and follows SEPA's Options appraisal for flood risk management guidance [3].

Background

This flood study was commissioned to gain a greater understanding of the flood mechanisms in each community, improve upon SEPA's flood risk maps, and provide an appraisal of options which could reduce flood risk.

The study aims to better assess current flood risks in the community by undertaking a review of past flood events; generating updated and detailed flood maps, determining the likely risk to different properties; and to propose a set of mitigation measures to reduce the flood risk to an acceptable level. A set of reports has been prepared to summarise the work undertaken and to provide a detailed explanation of the various steps carried out. The short-listed and preferred options will be presented to the public to gain their input into the designs and to ensure that the preferred set of interventions offer a sustainable method of flood protection whilst seeking to benefit the environment and the community of interest.

The major watercourses which cause fluvial flood risk to Ellon are the River Ythan, Modley Burn, Broomies Burn, Hillhead Burn and Fortree Burn. The study area for Ellon is shown in Figure 1-1.

1 North-East Flood Risk Management Strategy http://apps.sepa.org.uk/FRMStrategies/pdf/lpd/LPD_06_Full.pdf [accessed 10 November]

2 North East Flood Risk Management Plan http://www.aberdeenshire.gov.uk/media/17174/north-east-local-flood-risk-management-plan-2016-2022-web-version.pdf [accessed 10 November 2017]

3 Flood Risk Management (Scotland) Act 2009, Options appraisal for flood risk management: Guidance to support SEPA and the responsible authorities, First Edition, May 2016

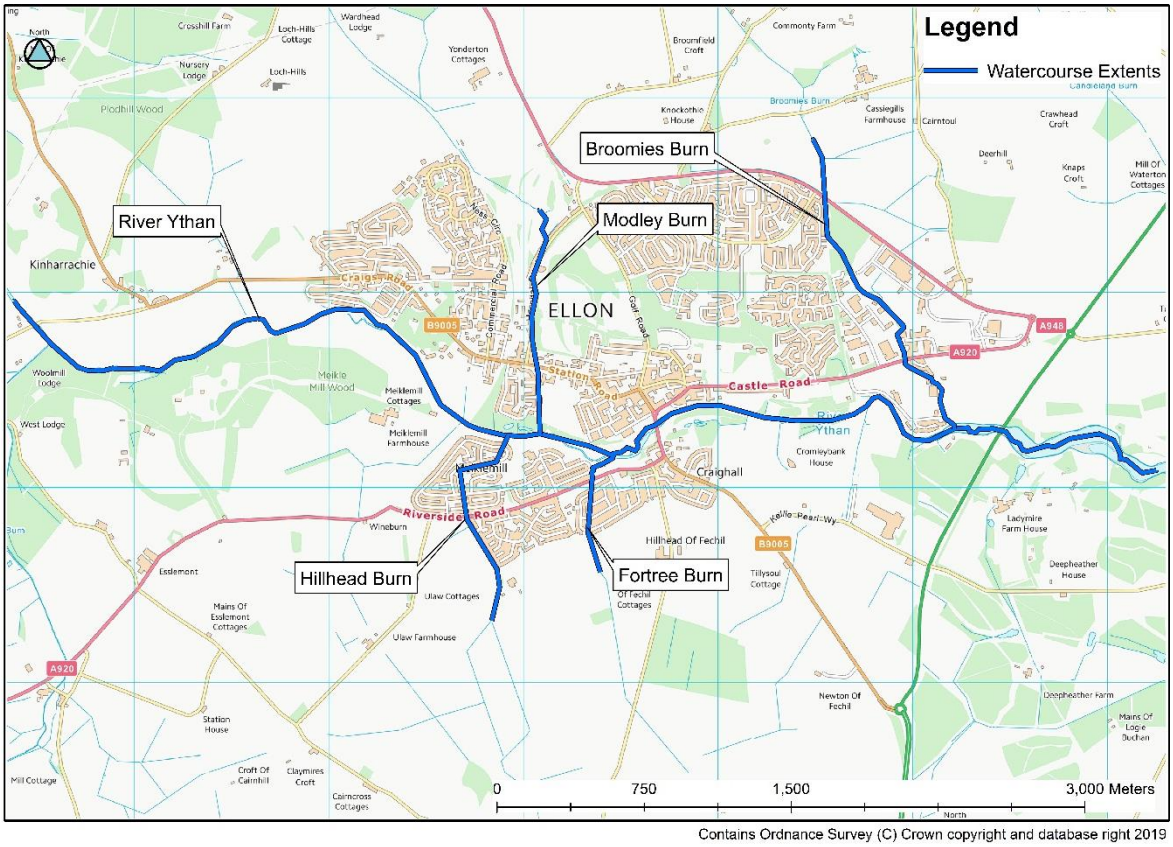

Figure 1-1: Study Extent

There is an extensive flood history within the area of Ellon, the most significant event was experienced in 2016 (Storm Frank). A review of the flood history is explained further in Section 2.1. Many properties have been highlighted at risk from previous flood events where flooding commences during high likelihood events but is far more prominent during the low likelihood events.

1.2 Aims and objectives

The options appraisal seeks to provide information appropriate to Aberdeenshire Council to inform their decision on the most sustainable strategy for flood risk management to the community of Ellon that contributes, where possible, to achieving River Basin Management Planning (RBMP) objectives and is acceptable to key stakeholders and the community. This report describes the information used to form conclusions on the suitability, feasibility and economic viability of different options for flood risk mitigation.

Proposals and conceptual designs have been developed to:

a. Provide protection from a 0.5% AP (200 year) magnitude flood event with the inclusion of a 24% increase to flow from climate change, if feasible or a lower magnitude event in other cases.
b. Highlight opportunities to reduce river flows through Natural Flood Management practices and quick wins.
c. Provide recommendations on further supplementary studies required within Ellon to understand the full flood risk to the properties.

2 Preliminary Investigations

The full reports for each of the sections below are referenced in the Supporting Documents section at the start of this report.

2.1 Flood history

The River Ythan has been susceptible to flooding over the past several decades with the earliest recorded flooding occurring in 1642. Ellon falls within PVA 06/12. The greatest risk is from the River Ythan in addition to the Broomies Burn and Modley Burn. The key events are summarised in Figure 2-1.

The Ythan is gauged at Ellon gauging station (ref. 10003, dating from 1983 to present), this replaced a gauge at Ardlethen Bridge (ref. 10001, dating from 1939 to 1985). The largest recorded flooding since records began occurred in January 2016 with a stage of 4.46 m recorded at the Ellon gauging station.

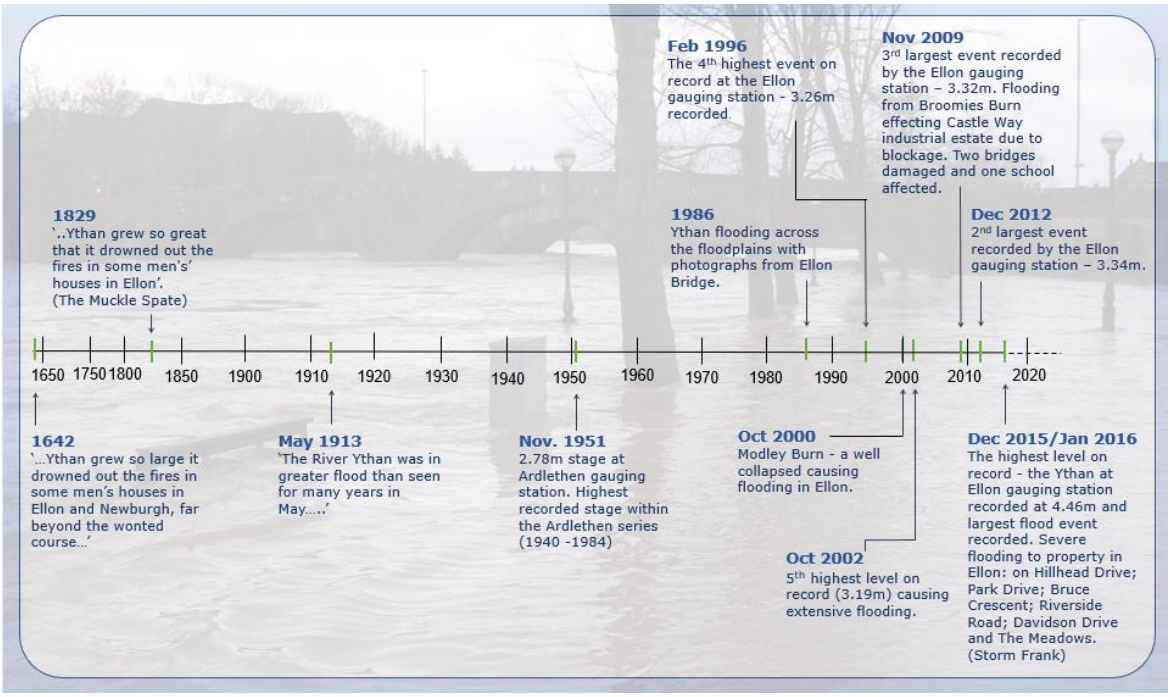

Figure 2-1: Key flood events in Ellon

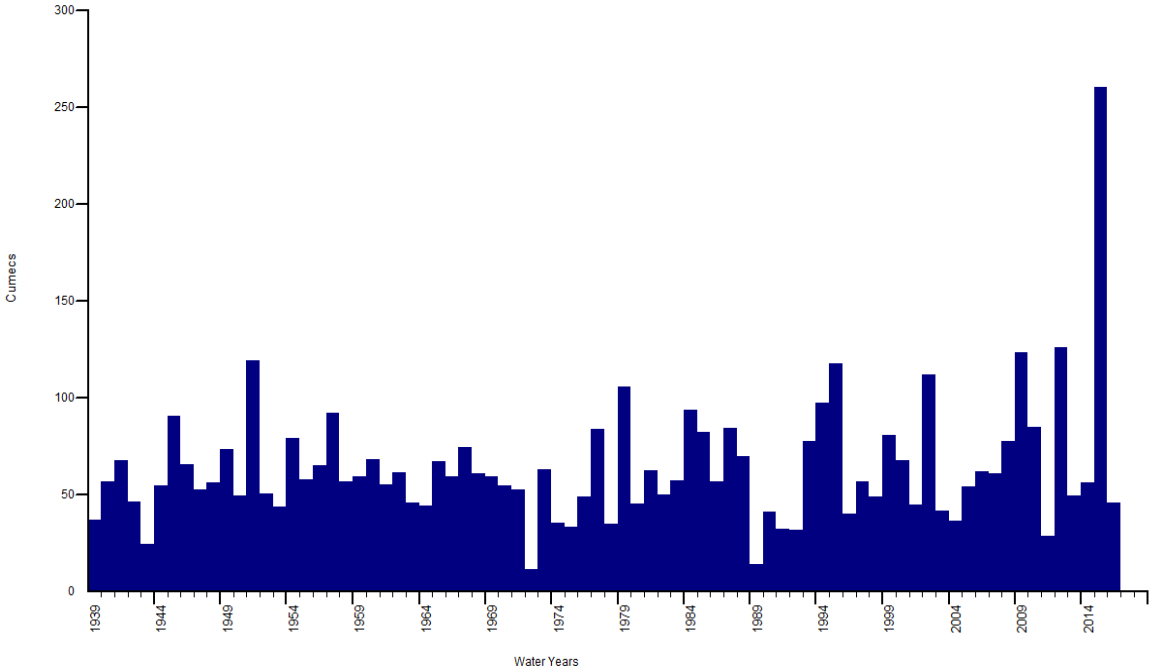

Figure 2-2: AMAX series for the Ythan

Figure 2-2 shows the annual maxima series (AMAX) series for the combined Ardlethen and Ellon gauged records. This shows the significant difference in the 2016 flow compared to previous years. The 2016 event (Storm Frank) is estimated to have a return period of c. 450 years, while the second largest event on record (Dec 2012) is estimated to have a return period of c. 26 years.

2.2 Hydrology

A summary of the flows derived from the hydrological analysis are shown in Table 2-1. The flows were achieved using the Flood Estimation Handbook (FEH) statistical method and applying a generalised logistic (GL) distribution to the single site analysis at the Ellon gauging station.

Table 2-1: Hydrology Inflows

Annual Probability [AP] (%)	Return Period (years)	River Ythan at Ellon Gauging Station. Single Site Statistical Method Flow: GL (m^3/s)
50	2	56.8
20	5	79.7
10	10	97.4
4	25	124.4
3.33	30	130.4
2	50	148.8
1.33	75	165.1
1	100	177.8
0.5	200	212.2
0.2	500	268.2
0.1	1000	320.3
3.33 +CC	-	161.7
0.5 +CC	-	263.2
2016 Event	c. 450	260.0

Table 2-1 shows that the 2016 event has a flow value of 260 m^3/s which is estimated to be equivalent to that of the 0.5% AP (200 year) + climate change (24%). As the appraisal study aims to protect

against 0.5% AP (200 year) + climate change flows it coincides to protect the residents to a value close to the 2016 (Storm Frank) event.

2.3 Survey data

JBA carried out a topographic channel survey in December 2017 as part of this study. This survey covers the full study reach within Ellon including the River Ythan, Modley Burn, Broomies Burn, Hillhead Burn and Fortree Burn, consisting of 111 cross sections in total. In general, 0.25 m resolution LiDAR has been used for the DTM dated 2016 (flown post Storm Frank) where the outer edges of Ellon are made up of 1 m resolution LiDAR dated 2011.

Property threshold levels were also surveyed by JBA in October 2018 for all properties falling within the 0.1% AP (1000 year) event flood envelope, the lowest threshold was taken inclusive of air bricks.

To gain a full appreciation of the study area an asset condition survey was also carried out in April 2018 to understand the condition of all the existing structures that cross the watercourse, including their risk of blockage.

2.4 Preliminary Ecological Appraisal

A preliminary ecology study was undertaken with the following key conclusions identified. A range of habitats were identified on the site walkover, including mixed woodland, tall ruderal vegetation, marshy grassland and standing water. The ecological value of the site was determined to be moderate to high as the structural diversity across the surveyed area offers good foraging and refuge opportunities for birds, small mammals, bats and invertebrate assemblages.

The data search identified four statutory designated nature conservation sites within a 2 km radius of the site extent. Three of these statutory sites, Sands of Forvie and Ythan Estuary SSSI; Forvie NNR; and Ythan Estuary, Sands of Forvie and Meikle Loch SPA, are located within the surveyed extent along the River Ythan. The Ythan Estuary and Meikle Loch RAMSAR is located 0.5 km east of the surveyed extent. Scottish Natural Heritage will need to be consulted prior to works commencing to determine whether further assessments are required, but given the proximity to the designated sites, it is likely that works will require assessment following the Habitat Regulations Appraisal process.

Mature trees throughout the site are protected through Tree Protection Orders, and details of these TPOs can be sought from the local authority. If trees will be impacted by the works (including retained trees where roots may be impacted) then an arboriculture survey should be undertaken.

Within a 2 km radius of the site, the North East Scotland Biological Records Centre holds several records for protected and notable species. The ecological importance of the site to protected species in its current state was considered high for Otter, bats, birds and fish, whilst it was considered moderate for Badger, Red Squirrel, Water Vole and reptiles and low for Great Crested Newts.

The following key points were identified from the desk study and site walkover conducted in November 2017:

- No Badgers, Red Squirrels, Water Voles, Otters or Bats observed during site visit.
- Ecological value for Otters, Bats, birds and fish high.
- Avoid the need for land-take in semi-natural habitats.
- Avoid tree and scrub removal (particularly for bats, birds, Red Squirrels).
- Minimise in-channel works (Otters, Water Voles, fish).
- No in-channel works between October and March (fish, particularly Salmon).
- Avoid night-working in the main active bat season (April - September).

2.5 Natural Flood Management

An NFM study was conducted within the full catchment of the Ythan.

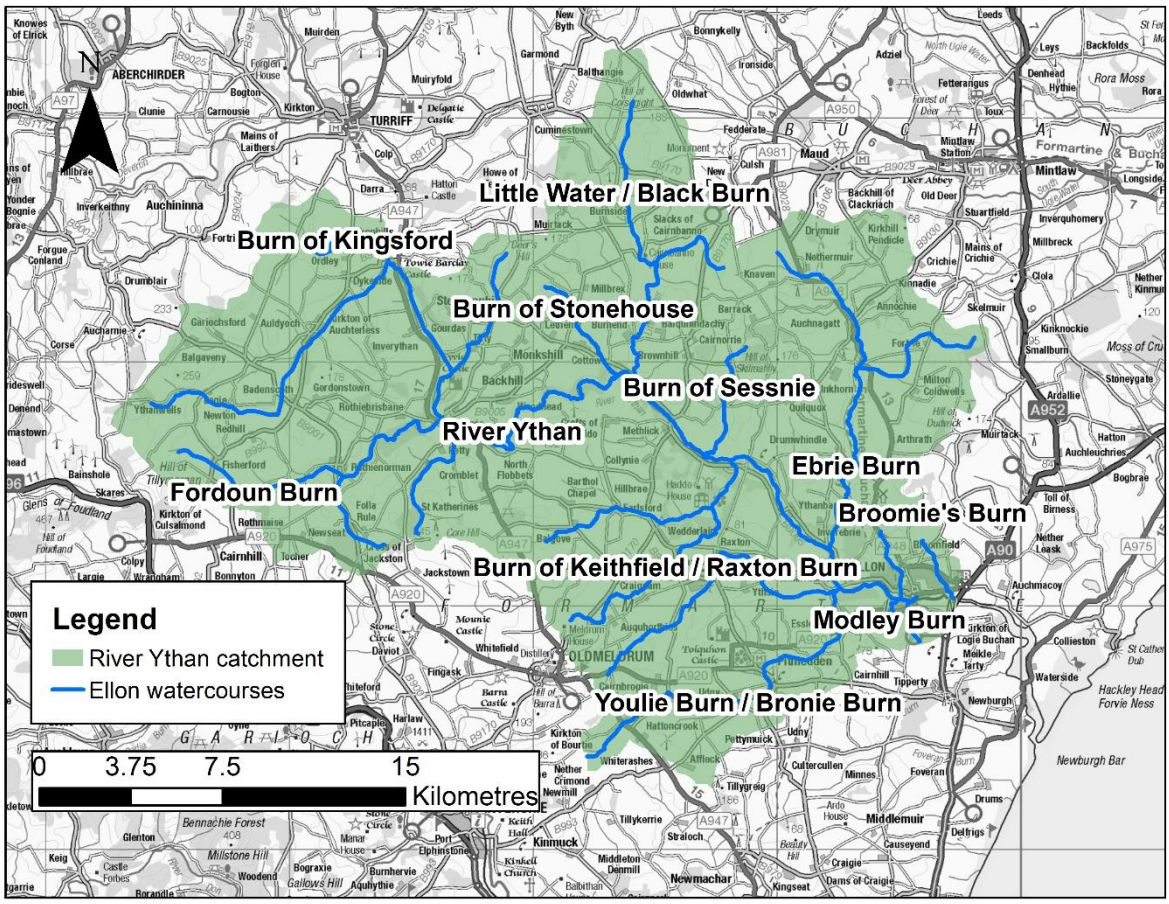

Figure 2-3: Summary of NFM options within the River Ythan catchment

An overview of the key areas that are recommended from the study are shown in Figure 2-4. Key recommendations include:

- Increased vegetation cover.
- Working within and on the banks of the channel.
- Land management.
- Runoff management.

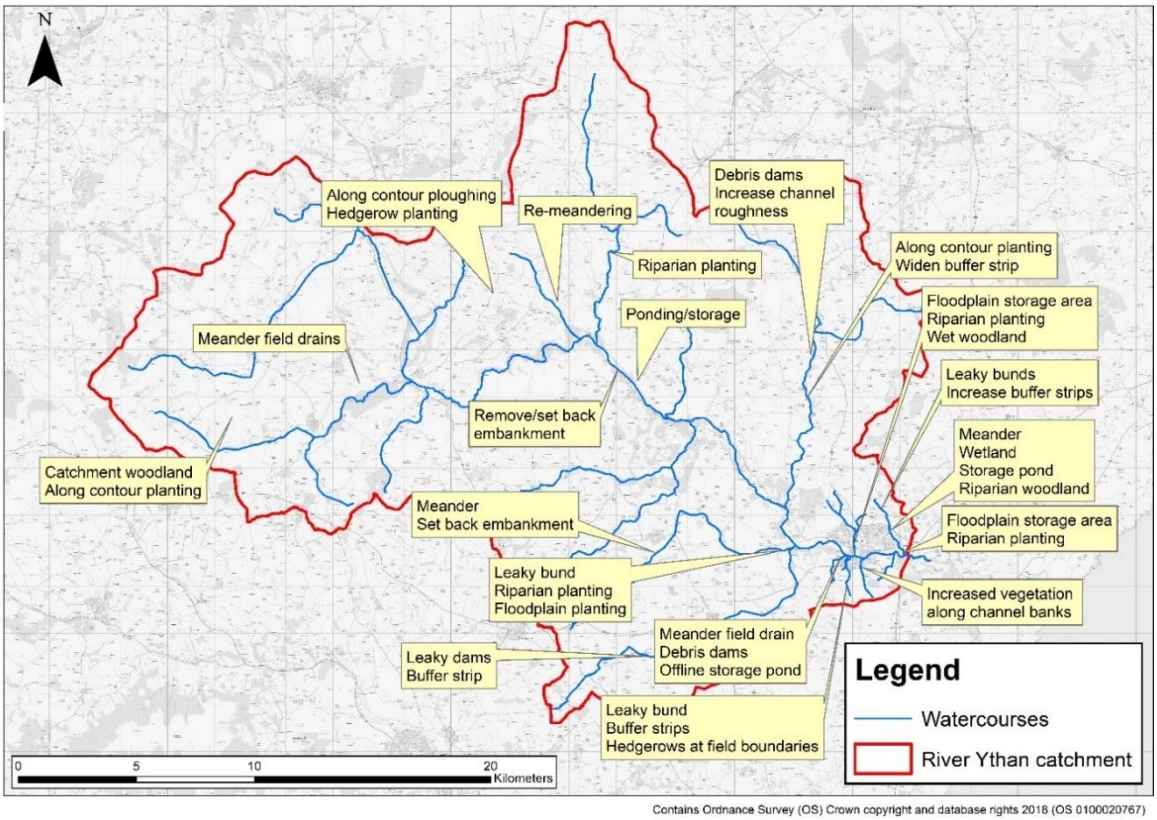

Figure 2-4: Summary of NFM options within the River Ythan catchment

One of the main contributing watercourses to the River Ythan is the Ebrie Burn which is located slightly upstream of Bridge of Ardlethen and flows south west. The following key details from the site walkover of the Ebrie Burn were highlighted:

- Contributes high proportional flow.
- High number of significant morphological pressures.
- High runoff reduction and floodplain storage potential.
- Would benefit from NFM.

As well as the Ebrie Burn, Hillhead and Fortree Burn could also benefit significantly as smaller catchments which can cause significant flood risk to Ellon. In particular, attenuation of the runoff such as leaky bunds and buffer strips could help to reduce the flows and increase sustainability of any scheme put in place.

2.6 Hydraulic modelling

The hydraulic model is a 1D/2D linked model, utilising Flood Modeller Version 4.3.6458.29637 for the 1D and TUFLOW Version 2016-03-AE-iDP-w64 for 2D components respectively. The River Ythan and two tributaries to the north: Broomies Burn and Modley Burn, have been modelled in 1D up to top of bank. Two further tributaries to the south, Fortree Burn and Hillhead Burn, are mainly culverted watercourses which have been modelled using ESTRY-TUFLOW. Fortree Burn is a purely culverted watercourse whereas Hillhead Burn is a watercourse which feeds into a sewer drainage system. The out of bank region has been represented in 2D for the entire extent based primarily on 0.25 m resolution LiDAR flown post 2016 Storm Frank. An overview of the 2D extent and different watercourses is shown in Figure 2-5.

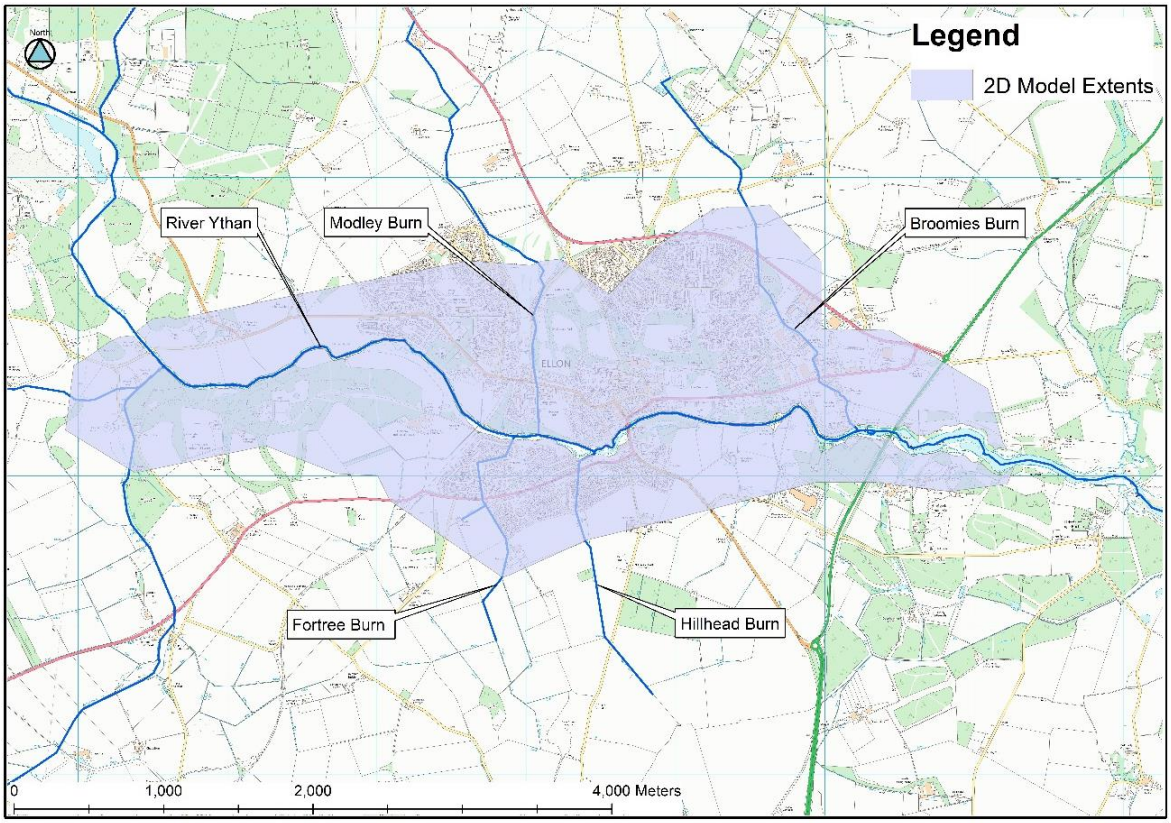

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Figure 2-5: Watercourse locations and model extent

3 Appraisal Approach

3.1 Overview

The purpose of this report is to conclude and appraise the design options which will be taken forward to defend against the flood risk within Ellon. A 1D/2D Flood Modeller and TUFLOW model has been built and calibrated to analyse the flood risk within the study area of Ellon. This model has been used to produce Do Minimum and Do Nothing flood maps as a baseline in order to analyse the damages and flood extent. A long list of options based on this mapping has been created for all potential options to defend the study area, this has then been broken down and feasible options have been shortlisted and then appraised.

3.2 Problem definition

There are currently 116 properties at risk within Ellon from the River Ythan, Modley Burn, Broomies Burn, Hillhead Burn and Fortree Burn. Flooding is estimated to begin at the 50% AP (2 year) flood event or smaller under existing conditions. There are at present no formal defences along the watercourses and there has been some uptake of Property Level Protection (PLP) products by residents.

4 Do Minimum and Do Nothing

4.1 Do Minimum results and assumptions

The Do Minimum results represent the present-day scenario in which all of the watercourses and structures are maintained and replaced if they deteriorate to a point that is unacceptable. Manning's 'n' roughness represents current conditions and no bridge blockage is assumed. Figure 4-1 shows the 0.5% AP (200 year) + climate change results for the Do Minimum scenario.

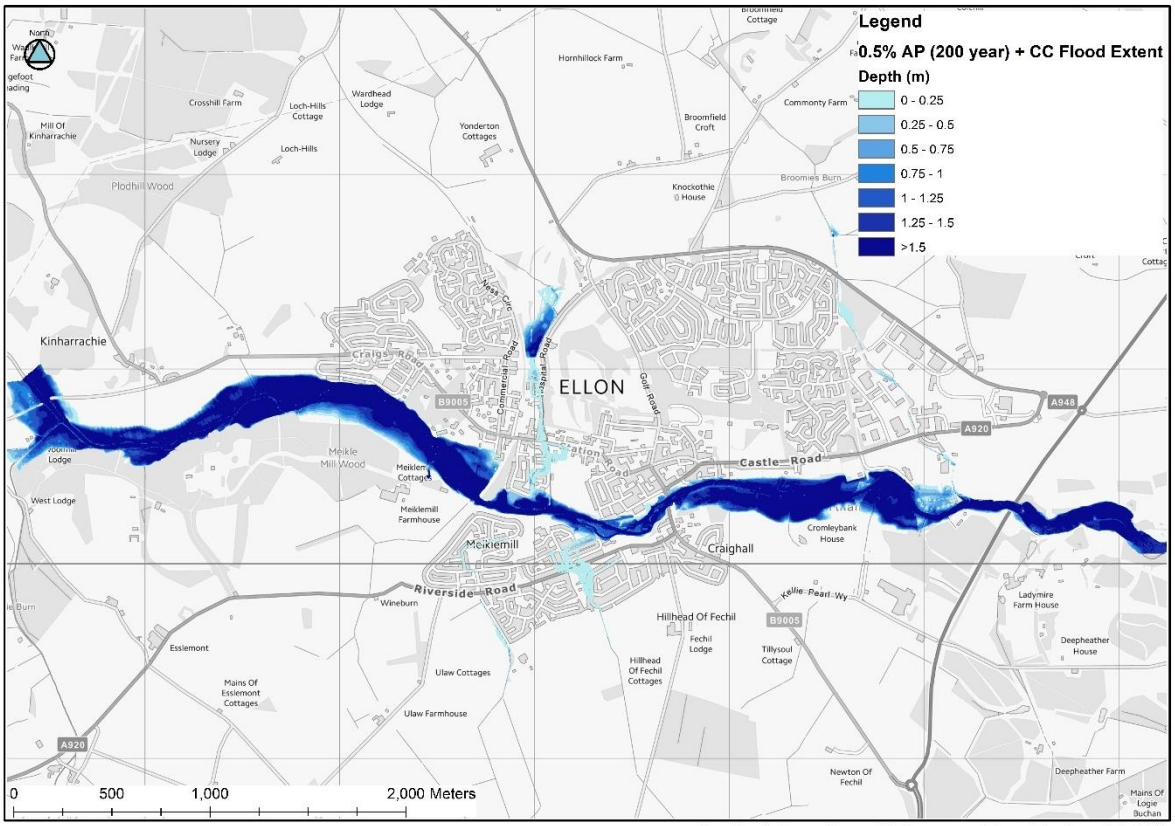

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Figure 4-1: Do Minimum 0.5% AP + climate change flood extent

4.2 Do Nothing results and assumptions

The Do Nothing results represent the 'walk away' scenario where all watercourse and structure maintenance stops. This therefore represents a scenario with no intervention in the natural processes and serves as a baseline against all other options. The Do Nothing assumptions include an increase in Manning's 'n' roughness particularly where banks will no longer be maintained. It also includes blockage to structures at risk, see Appendix C for a full list of the Do Nothing assumptions on each of the watercourses in Ellon. Figure 4-2 shows the 0.5% AP + climate change results for the Do Nothing scenario.

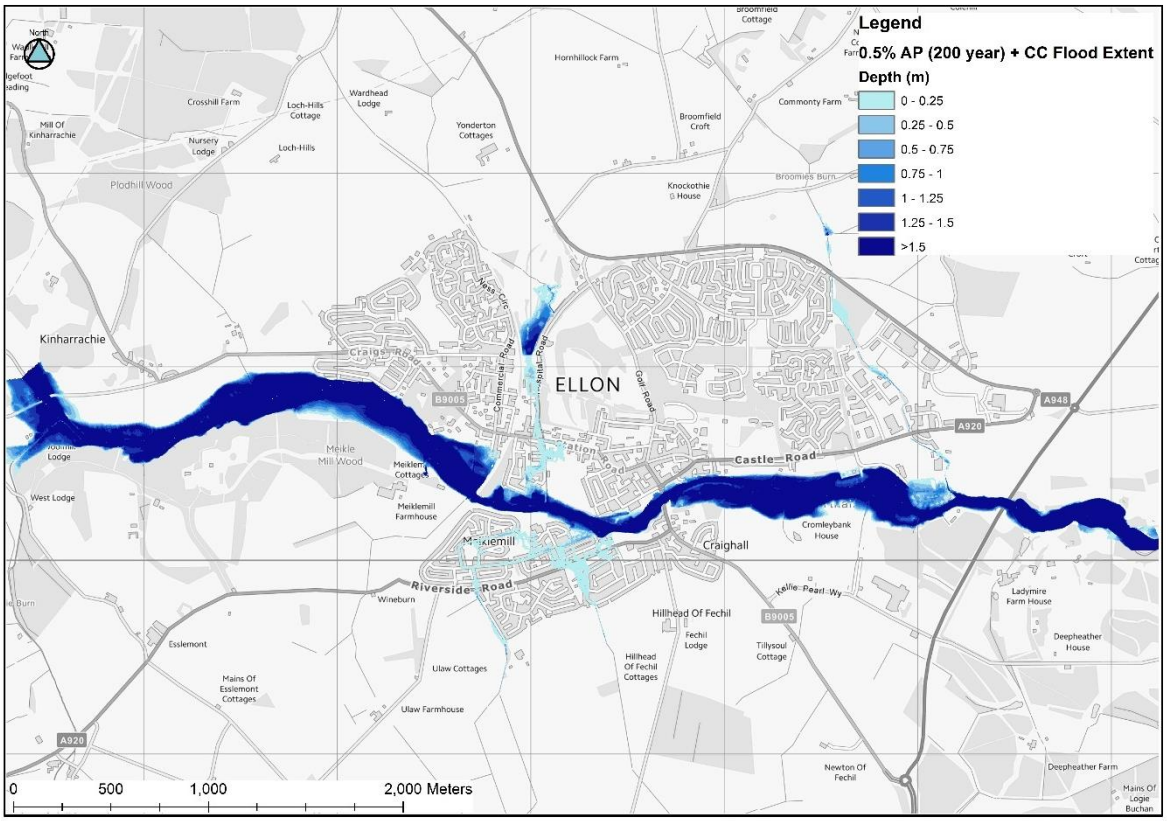

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Figure 4-2: Do Nothing 0.5% AP + climate change flood extent

4.3 Current Standard of Protection (SoP)

The figures overleaf show the SoP each property within Ellon has from fluvial flood risk. SoP is the largest flood event which is not expected to cause flooding to a property, larger magnitude events would be expected to cause property flooding. For example, a property with a 3.33% AP (30 year) SoP would be expected to flood at the 2% AP (50 year) event. Flooding is said to occur when the modelled flood level exceeds the building floor level. Floor level (threshold) data for all properties was collected by JBA surveyors, where properties had air bricks below floor level these were set as the threshold level.

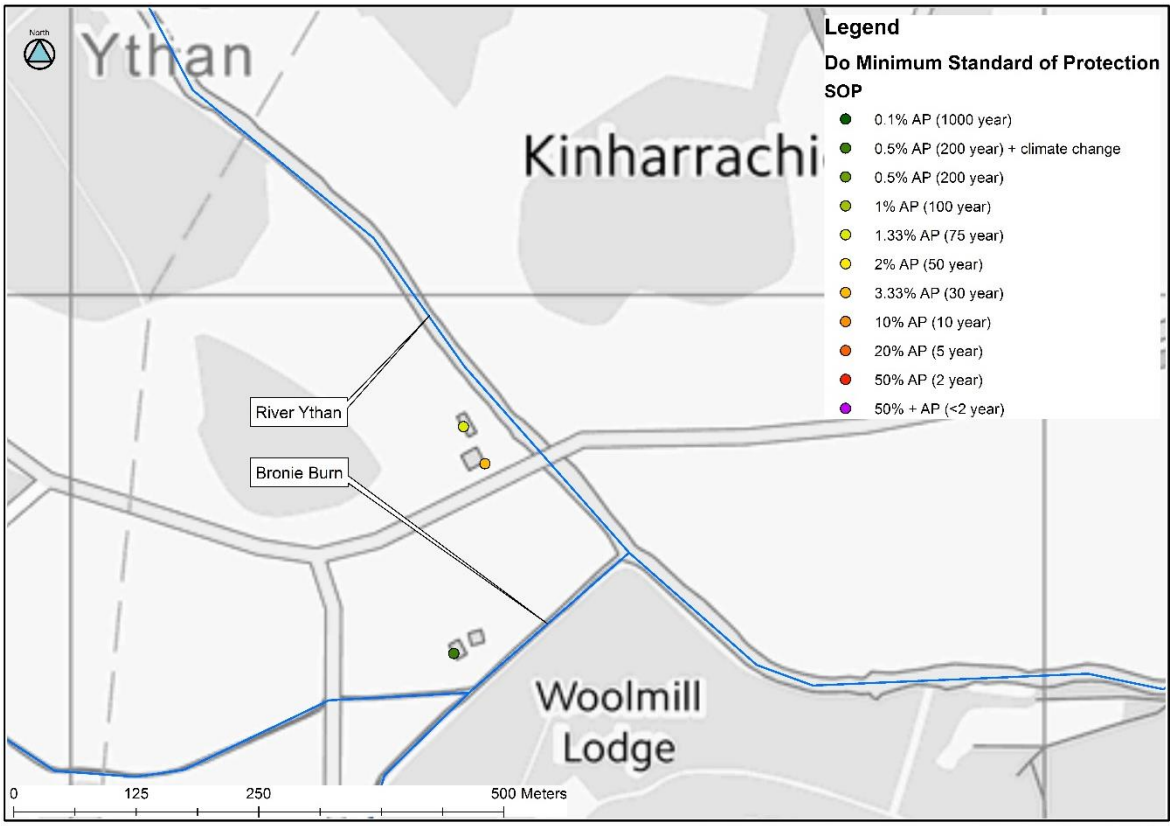

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Figure 4-3: Upstream extent of the model Standard of Protection

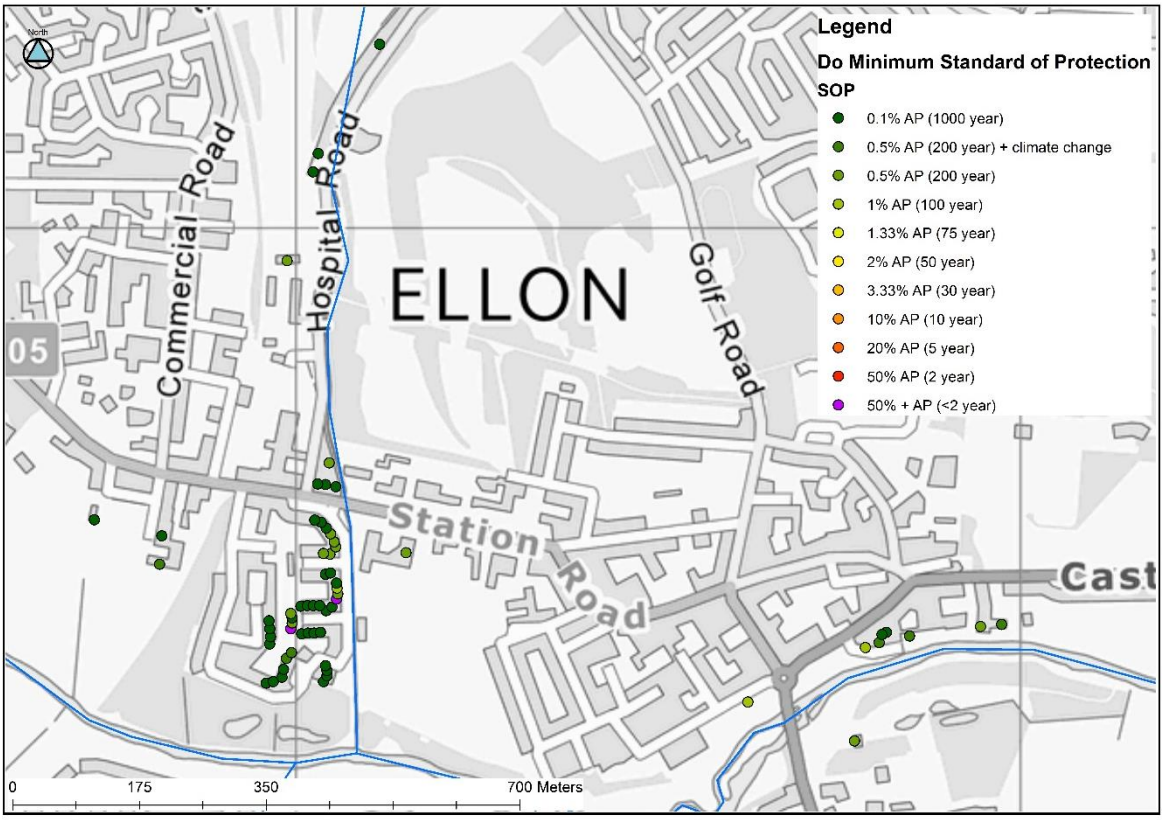

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Figure 4-4: Modley and Old Bridge of Ellon Standard of Protection

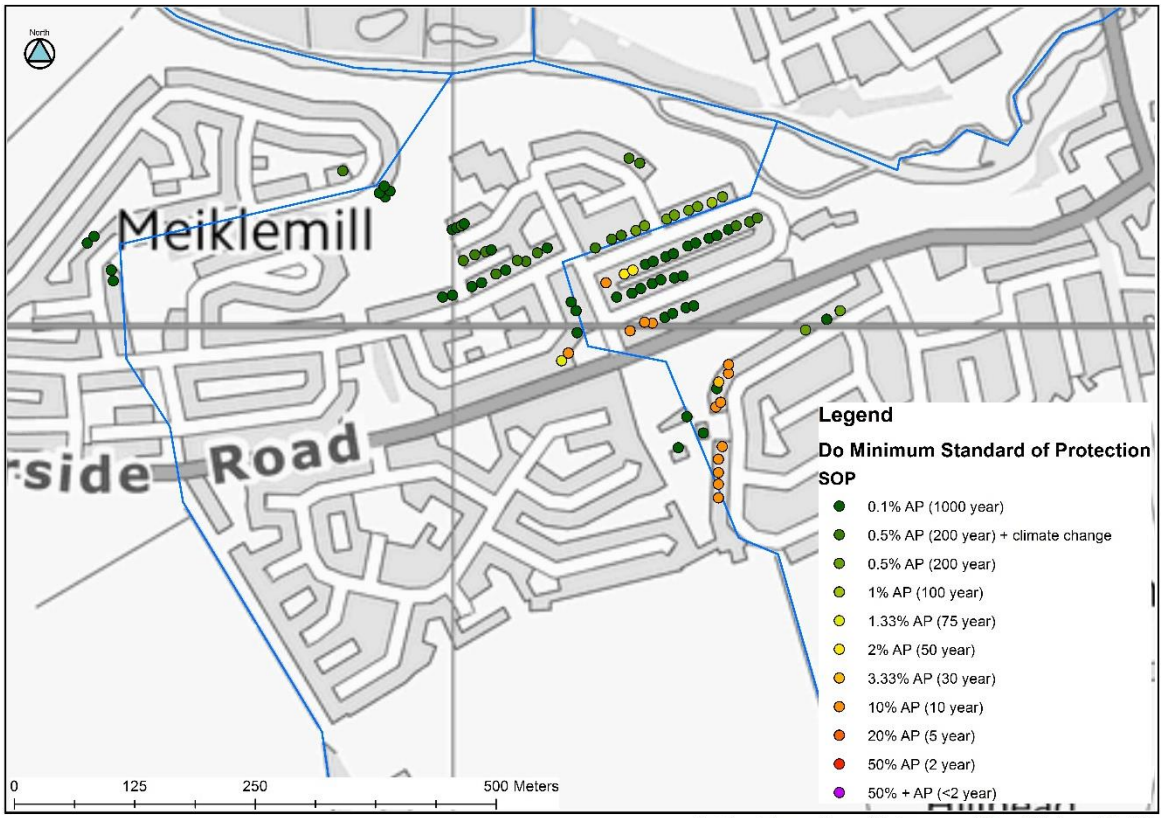

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Figure 4-5: Hillhead and Fortree Standard of Protection

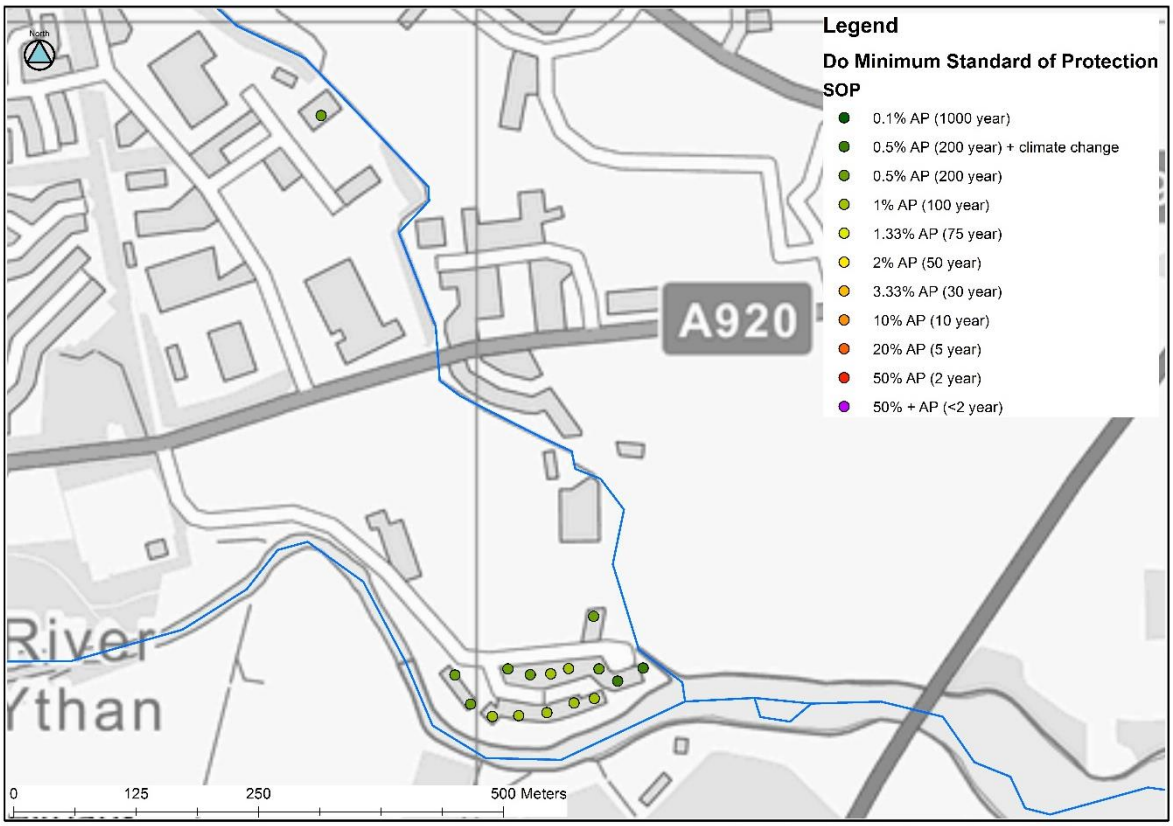

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Figure 4-6: Broomies and The Meadows Standard of Protection

The SoP in Ellon shows that the majority of the properties within Ellon are protected up to the 0.5% AP (200 year) + climate change event. Out of the 116 properties at risk from the fluvial 0.1% AP

event, 59 are not protected to the 0.5% AP + climate change that this appraisal will look to defend against. A breakdown of where these properties are located are as follows:

- Bridge of Ardlethen (upstream extent) - 2 properties
- Modley Burn - 13 properties
- Old Bridge of Ellon - 4 properties
- Hillhead and Fortree - 26 properties
- The Meadows and Broomies Burn - 14 properties

5 Flood Risk Management Options

5.1 Critical success factors (objectives)

The long list of options has been assessed against a number of critical success factors:

1. Options whether in isolation or combination must reduce flood risk providing an appropriate level of protection to people, property, business, community assets and natural environment.
2. Option must be technically appropriate and feasible.
3. Option should help to deliver sustainable flood risk management (e.g. help contribute to amenity and urban regeneration, improve the environment and biodiversity and improve or reduce existing maintenance regimes. Should also be effective for the community in the long term).
4. Options should not have insurmountable or legal constraints (e.g. land ownership, health and safety or environmental protection constraints).
5. Options should represent best value for money and minimise the maintenance burden and costs as much as possible.
6. Desirable Benefit Cost Ratio (BCR) when measured in parallel with other success criteria such as standard of protection, environmental implications, residual risks and wider benefits.
7. Should incorporate National, Regional and Local agendas/objectives.

5.2 Guideline standard of protection

The Scottish Government do not specify design standards for flood protection schemes. However, the standard of protection against flooding typically used in Scotland is the 0.5% AP (200 year) flood. This standard is the level of protection required for most types of residential and commercial/industrial development as defined by Scottish Planning Policy (SPP).

Whilst design standards are a useful tool in terms of engineering goals and useful benchmarks, as well as in clear communication to stakeholders and the public, there is a general move in Scotland away from design standards to a risk based approach. Restricting options to desired standards of protection can limit consideration of factors that influence defence effectiveness and can limit future responses to external factors.

It is expected that a variety of protection levels are considered during the design process including the 0.5% and 1% annual probabilities and, in some cases, a lesser level.

Based on the above guidance the aim of the scheme will be to assess options up to the 0.5% AP (200 year) plus climate change flood if possible, where 0.5% AP (200 year) will also be assessed as the lower standard.

5.3 Short term structural and maintenance recommendations and quick wins

Several measures or short term 'quick wins' have been identified that cover a range of aspects from maintenance to small scale works. They are summarised in Table 5-1.

5.3.1 Short term structural and channel maintenance and quick wins

Table 5-1: Short term structural and channel maintenance and quick wins for Ellon.

Problem	Actions	Photo
Trash screen connection to culvert compromised by loss of fixings.	Remove trash screen	 ***Meiklemill culvert outlet - View from downstream***
Sediment deposition. Trash screen detached.	Remove debris, remove detached trash screen	 ***Hospital Road culvert inlet - View from upstream of culvert***
Heavily vegetated banks Long section in the model looks to have deposited sediment at the inlet	Remove vegetation around culvert's entrance/exit Remove sediment on the bed at culvert	 ***Broomies Bridge A948 - Downstream view of culvert***

Problem	Actions	Photo
Minor settlement of soffit. Minor vegetation growth on soffit	Remove excess vegetation, remove trash screen	 ***Culvert A920 - Upstream view of culvert***
Minor cracks and spalling. Minor settlement. Rust staining. High and stiff vegetation at both sides of bank. Distortion of trash screen's bars. Timber protective fence partially collapsed.	Replace trash screen	 ***Fortree culvert - Upstream view of culvert (inlet)***
High flows bypass the culvert. Poor access to clean trash screen. Not tied in to surrounding ground.	Tie in head wall to surrounding ground	 ***Hillhead Drive culvert - Culvert upstream (inlet with trash screen)***

The majority of the quick wins could be considered as maintenance activities under the CAR regime and hence consultation to the CAR practical guide for more information should be made before the works are carried out[4].

4 SEPA, The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended), A Practical Guide, Version 8.3, February 2019

5.4 Non-structural flood risk management recommendations

5.4.1 Flood warning

A flood warning system should be development making use of the data from the Ellon gauging station. This system would be highly beneficial to the area of Ellon as sufficient delay in peak would allow properties with flood risk from the River Ythan to prepare.

5.4.2 Emergency action plans

Aberdeenshire Council has an overarching Flood Response Plan, which is coordinated through the Responders identified under the Civil Contingencies Act 2004. The aim of the plan is to set out arrangements to deal effectively with flood risk. At predetermined trigger levels flood alerts and warnings will be issued through SEPA's flood forecasting and warning service (Floodline) and Aberdeenshire Council will conduct assessments at known hotspots and prepare resources as required. Aberdeenshire Council will also coordinate measures in conjunction with the other Responders. The emergency response process is coordinated through regional and local resilience partnerships. This response may be supported by the work of voluntary organisations[5].

This emergency plan should be updated regularly as new information becomes available. It is recommended, if it has not already been done, that this is updated with the findings of this study, in particular the revised flood mapping. Regular reviews and preparation of community level emergency plans may be necessary to ensure that the following are up to date:

- Flood maps,
- Properties at risk (and any protected by PLP),
- Safe access and egress routes,
- Flood warning actions and escalation plans,
- Locations of community sandbag stores,
- Dissemination roles and responsibilities,
- Evacuation procedures,
- Onsite and/or temporary refuge locations/planning, and
- Back-up planning.

Emergency planning should encourage communication at a community level to ensure good response rates during a flood. Examples of this include flood group leaders, flood wardens and buddy schemes that encourage communities to act together and to help provide assistance to those needing additional help (e.g. vulnerable residents).

5.4.3 Raising public awareness and community flood action groups

Responsible Authorities have a duty to raise public awareness of flood risk. Helping individuals understand the risks from which they are most vulnerable is the first step in this process.

Everyone is responsible for protecting themselves and their property from flooding. Property and business owners can take simple steps to reduce damage and disruption to their homes and businesses should flooding happen. This includes preparing a flood plan and flood kit, installing property level protection, signing up to the Resilient Communities Initiative, and ensuring that properties and businesses are insured against flood damage. Flood Action Groups are well known to assist with this awareness raising and resilience.

Council awareness raising activities are to be combined with on-going public meetings and consultation for proposed flood schemes as part of further developments associated with this study. Information from the Council is also expected to be disseminated through website, social media and other community engagement activity as appropriate.

5.4.4 Community sandbag stores

Aberdeenshire Council continues to use community sandbag stores located at publicly accessible areas such as adjacent to Meiklemill Primary School. The Council should review the location of the stores and investigate if additional stores are necessary to cover the full area of Ellon.

5 North East Local Plan District - Local Flood Risk Management Plan Ellon, Aberdeenshire Council, pva-06_12-ellon.pdf, https://www.aberdeenshire.gov.uk/media/17357/pva-06_12-ellon.pdf

It is recommended that the Council considers the use of the flood 'pod' system: community storage boxes, which contain flood sacks which are purpose designed bags filled with absorbent material. The key advantage of this approach is that they can be distributed before a flood and are ideal for locations with limited warning or response times. It may also save the Council time in filling, distributing and delivering sandbags to communities when sandbag stores run out. Instead residents whose homes are at risk of flooding can access the boxes and can help themselves prior to and during a flood. Whilst careful review of the siting and number of these pods would be required, they may offer a useful approach in Ellon. This approach would need to be combined once the flood warning system is fully developed and flood awareness campaign is provided by SEPA (i.e. flood alerts).

5.4.5 Property Level Protection (PLP)

Aberdeenshire Council currently offer a discounted PLP scheme to properties at risk of flooding, selling discounted PLP products to residents through a capped council-funded subsidy. The scheme makes manual PLP products more affordable than they would otherwise be and there has been some uptake to date in Ellon. Manual PLP products that must be installed in advance of a flood event are in general seen as a short-term solution. Nevertheless, a full PLP scheme using passive (or 'automatic') products will be considered alongside the other options in the investment appraisal. Whether full funding would be provided through a flood protection scheme or if resident contributions would be sought is not considered at this stage.

5.4.6 Natural Flood Management (NFM)

The catchment of Ellon has a multitude of opportunities to capitalise on in order to provide attenuation of flooding.

As summarised in section 2.5 a number of primary opportunities exist and may be considered by the Council in the future. Suggestions include re-meandering sections of the upper catchment as well as better land management through leaky bunds and buffer strips (Figure 2-4). Additional measures such as woodland or riparian planting will also reduce blockage risk to many structures on the smaller burns.

The key sub-catchments where NFM could influence the flood risk within Ellon are on the Ebrie Burn, Fortree Burn and Hillhead Burn. This is due to the Ebrie Burn being one of the key tributaries on to the River Ythan and Hillhead and Fortree contributing significant flood risk to properties in the Southern region of Ellon.

5.4.7 Planning policy

Scottish Planning Policy and accompanying Planning Advice Notes set out Scottish Ministers' priorities for the operation of the planning system and for the development and use of land. In terms of flood risk management, the policy supports a catchment-scale approach to sustainable flood risk management and aims to build the resilience of our cities and towns, encourage sustainable land management in our rural areas, and to address the long-term vulnerability of parts of our coasts and islands. Under this approach, new development in areas with medium to high likelihood of flooding should be avoided[6].

5.5 Long list of options

The following tables provide an overview of potential flood alleviation options targeting flood risk from the different watercourses in Ellon. The tables have been derived using the non-exhaustive long list options from SEPAs guidance.[7] These have been separated into four different design areas based on source and mechanisms of flood risk. Figure 5-1 shows the four design areas, the Do Minimum 0.5% AP (200 year) + climate change event has been used to show the flood risk to these areas.

6 North East Local Plan District - Local Flood Risk Management Plan Ellon, Aberdeenshire Council, pva-06_12-ellon.pdf, https://www.aberdeenshire.gov.uk/media/17357/pva-06_12-ellon.pdf

7 Local Authority flood study checklist, Flood Risk Management (Scotland) Act 2009 (FRM Act), Version 3, 10 September 2018

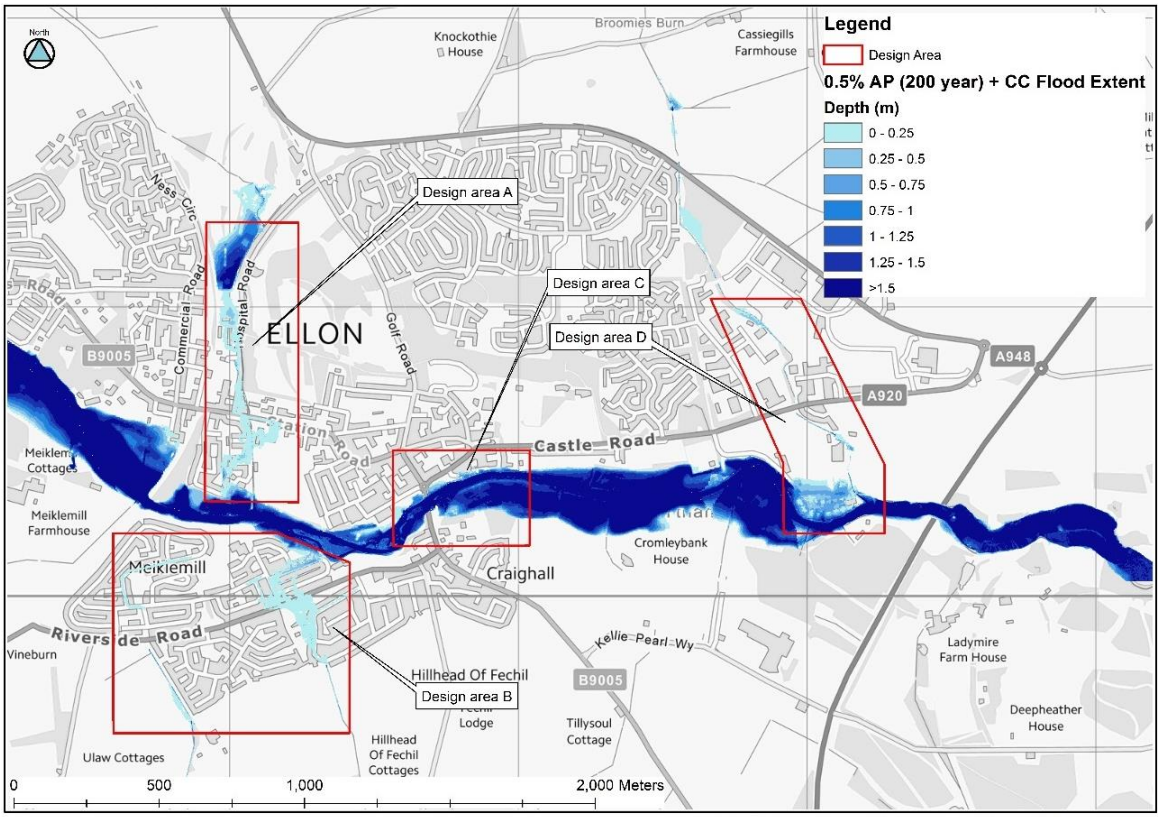

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Figure 5-1: Ellon design areas

The areas were selected as they each have different mechanisms which lead to flooding as follows:

- **Design area A (Modley Burn)** - This location is subject to flooding from the Modley Burn though also has contribution from the River Ythan backing up during higher events.
- **Design area B (Hillhead and Fortree)** - This location is subject to flooding from the Hillhead and Fortree Burns both through surcharging of their manholes as well as overtopping at their inlets. There is direct flood risk from the River Ythan as it flows back along Bruce Crescent.
- **Design area C (Old Bridge of Ellon)** - This location is subject to flooding by out of bank flooding from the River Ythan. This also includes the two properties at the model upstream extent at the Bridge of Ardlethen which flood from the same mechanism.
- **Design area D (The Meadows and Broomies)** - This location floods due to out of bank flooding from the River Ythan and contribution from the Broomies Burn.

Table 5-2: Long list of options for design area A (Modley Burn)

Measure	Discussion
Relocation	**Technical:** Relocation or abandonment of properties not politically or socially viable, well-developed community. Option not cost effective as purchase costs will be same as or greater than capped damages. Key receptors such as the primary school can be protected to the 200 year with climate change through construction of a golf course embankment therefore relocation would be far less cost effective. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Multiple objections likely if carried out via an FPS. **Decision: Option discounted**
Flood warning	**Technical:** There is no existing flood warning scheme, as the Modley Burn catchment is small and likely to be quite flashy there will be a poor lead in time and hence it would be difficult to implement. Structure telemetry could be implemented in problem structures, particularly the school bridge which causes the right bank to flood.

	Environmental: No significant environmental or RBMP benefits or impacts. **Constraints:** Small flashy catchment**.** **Decision: Structure telemetry viable, option taken forward alongside other options**
Property Level Protection (PLP)	**Technical:** Property level protection and resilience will benefit the site but may need to be implemented with another method, where all properties currently have access to products, including a limited number of sandbags. Some properties draw close to the flood depth of 600mm recommended as a maximum for property resistance measures. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** PLP is limited to flood depths up to 600mm. If PLP temporary measures, warning required to allow residents to install the PLP for it to be effective. **Decision: Option taken forward alongside other options**
Local planning policies	**Technical:** Local development plans indicate that the golf course and McDonald Park are to be conserved as green space. The River Ythan also has a designated area for conservation of green space. These locations will have to be considered with all other options**.** **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** The indicated locations should be avoided for development**.** **Decision: No decision as a standalone option though should be considered alongside all other options**
Runoff (NFM)	**Technical:** Encourage good land management practices from the upstream agricultural land would limit the amount of runoff from the upstream catchment. **Environmental:** Good land management will result in better water quality as well as the potential for new habitat creation for example from hedgerows and buffer strips. **Constraints:** Would require landowner buy in and effective consultation. **Decision: Option taken forward alongside other options**
River/floodplain restoration (NFM)	**Technical:** Re-design of the river corridor through Ellon Golf Course to increase sinuosity and slow down flow**.** **Environmental:** Potential to destroy wildlife habitats in the watercourse corridor during construction**.** **Constraints:** Would require landowner buy in and effective consultation. **Decision: Option taken forward**
Sediment management (NFM)	**Technical:** Encourage good land management practices from the upstream agricultural land would limit sediment transfer into the channel, runoff from the agricultural land may increase sediment in the channel and hence blockage of structures over time. **Environmental:** Good land management such as hedgerows, buffer strips and leaky bunds will result in better water quality as well as the potential for new habitat creation. **Constraints:** Would require landowner buy in and effective consultation. **Decision: Option taken forward alongside other options**
Storage	**Technical:** Potential upstream storage making use of the golf course, could be controlled by a sluice or hydrobrake to only occur when required from large floods. Potential storage of agricultural land further upstream. Offline storage not as feasible due to diversity in land use for wildlife and agricultural farming. There is limited offline space close to the watercourse which could provide a feasible volume of storage**.** **Environmental:** Disturbance to wildlife likely during construction. Potential benefits through new habitat creation. **Constraints:** Would require landowner buy in and effective consultation. **Decision: Golf course storage option viable, option taken forward**
Channel modification	**Technical:** Channel is fairly constrained by land use throughout the Modley Burn reach other than at Gordon Park where the flow comes out on the right bank. There is potential to cut into Gordon Park for a two-stage channel or general channel widening. **Environmental:** Destruction of animal habitats within the watercourse and on the banks. No significant environmental benefit. **Constraints:** Existing foundations from multiple bridges and culverts on the

	channel would make construction difficult. **Decision: Option taken forward**
Channel diversion	**Technical:** The area is too built up and any relief channel would require large amounts of demolition to existing infrastructure making it not economically viable. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Not financially viable due to land use. **Decision: Option discounted**
Channel realignment	**Technical:** Channel could be realigned away from Modley Place and through Gordon Park**.** **Environmental:** Destruction of animal habitats within the watercourse and on the banks. No significant environmental benefit**.** **Constraints:** Largely confined watercourse. **Decision: Option taken forward**
Structure modification	**Technical:** The out of bank flooding on the right bank appears to occur around the Ellon Primary School footbridge at MODL01_0251, removal of this structure may allow flow to continue downstream reducing the risk out of bank. This may also move the risk onto structures further downstream (further footbridge South of Ellon Primary School and Gordon Park Bridge), removal of these bridges too could also be a solution. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Flow likely to backup at structure downstream and cause flood risk to the same area**.** **Decision: Option taken forward**
Control structures	**Technical:** The installation or modification of new control structures is unlikely to significantly attenuate flood flows. Likely to cause flood risk upstream. **Environmental:** Disturbance to wildlife likely during construction. Potential benefits through new habitat creation**.** **Constraints:** Likely to cause flood risk upstream. Land ownership constraints**.** **Decision: Option discounted**
Direct defences	**Technical:** In this case direct defences include embankments, walls, adaptable walls and temporary walls. The right bank on Modley Place appears to flood at one location where it has experienced scour, an embankment wall or raising of this bank could remove the flood risk. Depending on the height of the embankment there may not be enough room therefore a wall would be preferable. A direct defence along the bottom of the golf course would prevent overtopping in this area during the higher events. **Environmental:** Groundworks along riverbanks may disturb habitats. Constraining flow to within banks may result in change in habitat characteristics e.g. faster flowing water. May increase morphological pressure on river (negative RBMP impact). No significant environmental benefit. **Constraints:** Unlikely to be enough room on the right bank for an embankment due to the distance between the channel and the road/pavement. A temporary wall may need to be planned and deployed frequently due to the out of bank flooding occurring so regularly. **Decision: Wall option viable, option to be taken forward**
Watercourse maintenance	**Technical:** Will help prevent future flood risk from blockage of the vast amount of structures, particularly the culvert through Hospital Road. No trash screens on the watercourse. **Environmental:** Maintains current habitats and environmental value of the watercourse. Channel maintenance may have minor negative impacts if spawning areas disrupted but these are unlikely to be significant. Fish also require shaded areas to control temperature and require a variety of velocity which may be affected**.** **Constraints: N/A** **Decision: Option taken forward alongside other options**
Self help	**Technical:** Self help could be used in conjunction with other methods including more awareness raising, flood action groups and business continuity planning. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Requires individual and community buy in. **Decision: Option taken forward alongside other options**

Emergency plans	**Technical:** Flood risk areas defined within this study to be incorporated into emergency plans**.** **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** N/A **Decision: Option taken forward alongside other options**

Table 5-3: Long list of options for design area B (Hillhead & Fortree)

Measure	Discussion
Relocation	**Technical:** Relocation or abandonment of properties not politically or socially viable, well-developed community. Option not cost effective as purchase costs will be same as or greater than capped damages. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Multiple objections likely if carried out via an FPS**.** **Decision: Option discounted**
Flood warning	**Technical:** There is no existing flood warning scheme, both Burn catchments are quite flashy, there will be a poor lead in time and hence it would be difficult to implement. Structure telemetry could be used on the inlets. Flood warning could be used on the River Ythan to prepare the residents though a formal scheme may be more applicable. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Hillhead and Fortree are small flashy catchment**.** **Decision: Structure telemetry at the inlets and flood warning on the Ythan are viable, option taken forward alongside other options**
Property Level Protection (PLP)	**Technical:** Property level protection and resilience will benefit the site but may need to be implemented with another method, where all properties currently have access to products, including a limited number of sandbags. Some properties draw close to the flood depth of 600mm recommended as a maximum for property resistance measures. High water table, at least one resident has a pump in the solum. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** PLP is limited to flood depths up to 600mm. If PLP temporary measures, warning required to allow residents to install the PLP for it to be effective. **Decision: Option taken forward alongside other options**
Local planning policies	**Technical:** Location at the inlet of Hillhead has been designated for a housing development with construction currently underway. The River Ythan has a designated area for conservation of green space. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Hillhead inlet options are constrained slightly by space from the housing development. Proposals for the River Ythan backflow must consider preservation of the green space. **Decision: No decision as a standalone option though should be considered alongside all other options**
Runoff storage or River/Floodplain restoration (NFM)	**Technical:** Floodplain storage potential along the Hillhead and Fortree Burns in the form of leaky bunds, ponds and/or wetlands upstream of Hillhead. **Environmental:** Potential to disrupt habitats upon construction. Potential to create new habitats for wildlife. **Constraints:** Would require landowner buy in and effective consultation. **Decision: Option taken forward upstream of the burn inlets**
Sediment management (NFM)	**Technical:** Encourage good land management practices from the upstream agricultural land would limit sediment transfer into the channel, runoff from the agricultural land may increase sediment in the channel and hence blockage of structures, this could reduce the amount of sediment depositing in the tidal limit on the Ythan. **Environmental:** Good land management such as hedgerows**, leaky bunds** and buffer strips will result in better water quality as well as the potential for new habitat creation. **Constraints:** Would require landowner buy in and effective consultation. **Decision: Option taken forward alongside other options**

Storage	**Technical:** Potential storage utilising agricultural land upstream of Hillhead culvert and Fortree culvert. Storage within Gordon Park could prevent backflow into Bruce Crescent. Offline storage not as feasible due to limited offline space close to the watercourse which could provide a feasible volume of storage for the Ythan, may be possible for the two Burns but more likely to work as NFM leaky bunds. **Environmental:** Disturbance to wildlife likely during construction. Potential benefits through new habitat creation. **Constraints:** Would require landowner buy in and effective consultation. As Gordon Park does not currently flood land ownership issues such as the local plan for preserving the park would require consultation, Gordon Park unlikely to provide enough storage to prevent backflow. **Decision: Storage upstream of the Burns viable, option taken forward**
Channel modification	**Technical:** Unlikely to be feasible at the inlets to the Burns as the constriction from the culverts are the key cause of flood risk therefore this would have minimal effect. Removal of the islands in the River Ythan could increase the conveyance of the channel though may not be a sustainable option due to this being the location of the tidal limit and hence islands will reform and are shown in historical mapping. **Environmental:** Potential detriment to animal habitats within the watercourse and on the banks. Destruction of habitat if islands are removed. No significant environmental benefit. **Constraints:** Adoption for additional maintenance. **Decision: Island removal to be analysed further in Section 5.6, option taken forward**
Channel diversion	**Technical:** Diversion channel could be feasible for the Burns to the left of the houses at risk through the old railway, this would not be financially viable as it would need to cut through high land. A collector drain could be used for both burns to divert the flow further downstream to the right of the houses at risk. Once again this would not be feasible at the inlets as it would need to cut though high ground as well as multiple roads. Higher up in the catchment there may have been slight potential though once again this would cut through many roads and also would not capture much of the flow into Hillhead therefore it would not tackle the flood risk. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** If diverting to the left of the houses this may redirect more flow into the Ythan putting the properties that experience backflow from the Ythan at greater risk. Therefore, diversion to the left of the properties would require incorporation of storage**.** **Decision: Option discounted**
Channel realignment	**Technical:** Channel realignment for the Burns would have a negligible effect due to the flood risk occurring from the culvert. Channel realignment for the River Ythan would be extremely costly and non-beneficial. **Environmental:** Potential detriment to animal habitats within the watercourse and on the banks. No significant environmental benefit. **Constraints:** Largely confined culvert. **Decision: Option discounted**
Structure modification	**Technical:** Expanding the culvert size would not be financially viable. Removal of the culvert would not be financially viable, multiple houses would need to be bought in order to re-naturalise the channel. As the first pipe in the culvert at Hillhead is the most vulnerable a quick check of the capacity of the pipe shows it is not currently at full capacity during the 0.5% AP + climate change suggesting that flood risk occurs due to head losses and constrictions in the culvert from changes in pipe diameter and gradient. Due to this increasing the culvert size would add no benefit**.** **Environmental:** A more natural channel would create new habitats. No significant environmental impact. **Constraints:** Culverts run under multiple properties. **Decision: Option discounted**
Control structures	**Technical:** Removal or replacement of the trash screen could be a viable option to remove the blockage risk. Replacement of the headwalls to tie into existing ground. Maintenance and clearing of the Hillhead trash screen. A pumping station may be required in Hillhead where the river is backflowing on the pipe. **Environmental:** Likely to encourage more movement of flora, fauna and sediment

	along the watercourse thus having a net positive impact on the watercourse. No significant environmental impact. **Constraints:** Upstream sediment likely to block the extremely long culvert, trash screen is likely to be required**.** **Decision: Replacement of screens and headwall viable, pumping station at outlet viable, option taken forward alongside other options**
Direct defences	**Technical:** In this case direct defences include embankments, walls, adaptable walls and temporary walls. The use of a direct defence at the culvert inlets would result in water ponding behind it so may not be viable. An embankment or wall could be used to stop the fluvial back flow at Bruce Crescent. **Environmental:** Groundworks along riverbanks may disturb habitats. Constraining flow to within banks may result in change in habitat characteristics e.g. faster flowing water. May increase morphological pressure on river (negative RBMP impact). No significant environmental benefit. **Constraints:** Use of a wall in a flooding event may result in upstream ponding at the culvert inlets. Ponding is likely behind any direct defence from the overland flow. A pumping station or other ponding clearance method would likely be required alongside a direct defence. **Decision: Direct defence for the River Ythan viable, option to be taken forward**
Watercourse maintenance	**Technical:** Routine maintenance of the trash screens are critical to reduce flood risk. **Environmental:** Maintains current habitats and environmental value of the watercourse. Channel maintenance may have minor negative impacts if spawning areas disrupted but these are unlikely to be significant. **Constraints:** N/A **Decision: Option taken forward alongside other options**
Self help	**Technical:** Self help could be used in conjunction with other methods including more awareness raising, flood action groups and business continuity planning. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Requires individual and community buy in. **Decision: Option taken forward alongside other options**
Emergency plans	**Technical:** Flood risk areas defined within this study to be incorporated into emergency plans**.** **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** N/A **Decision: Option taken forward alongside other options**

Table 5-4: Long list of options for design area C (Old Bridge of Ellon) and properties at Bridge of Ardlethen

Measure	Discussion
Relocation	**Technical:** Relocation of the single property on the right bank may be a viable solution compared to the financial implications of constructing a flood defence for a single property. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Multiple objections likely if carried out via an FPS if left bank properties were considered**.** **Decision: Option discounted due to high standard of protection of single property**
Flood warning	**Technical:** Flood warning could be implemented on the Ythan using the gauging station. SEPA are currently in the stage of updating this area for a formal PDM flood warning scheme on the Ythan. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Unlikely to make a difference as a standalone option**.** **Decision: Option taken forward alongside other options**
Property Level Protection (PLP)	**Technical:** Property level protection and resilience will benefit the site but may need to be implemented with another method, where all properties currently have access to products, including a limited number of sandbags. Some properties draw close to the flood depth of 600mm recommended as a maximum for property

	resistance measures. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** PLP is limited to flood depths up to 600mm. If PLP temporary measures, warning required to allow residents to install the PLP for it to be effective. **Decision: Option taken forward alongside other options**
Local planning policies	**Technical:** The River Ythan has a designated area for conservation of green space. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Proposals for the River Ythan must consider preservation of the green space**.** **Decision: No decision as a standalone option though should be considered alongside all other options**
Runoff (NFM)	**Technical:** As properties begin flooding around 100 year event a catchment study of the Ebrie Burn which contributes a proportionally high flow to the River Ythan could reduce flows and have the potential to stop the properties from flooding during higher events. Opportunities include buffer strips, hedgerows, leaky bunds and removal of embankments. **Environmental:** Good land management will result in better water quality as well as the potential for new habitat creation. Constraints: Would require landowner buy in and effective consultation. **Decision: Option taken forward alongside other options**
River/floodplain restoration (NFM)	**Technical:** Reconnection to the floodplain may provide more storage such as removal of agricultural embankments on Ebrie Burn. **Environmental:** No significant environmental benefits or impacts. **Constraints:** Unlikely to provide enough storage to protect the properties though may reduce the frequency of flooding to some areas downstream. **Decision: Option taken forward alongside other options**
Sediment management (NFM)	**Technical:** Encourage good land management practises from the upstream agricultural land would limit sediment transfer into the channel, runoff from the agricultural land may increase sediment in the channel and hence blockage of structures, this could reduce the amount of sediment depositing in the tidal limit. **Environmental:** Good land management such as hedgerows and buffer strips will result in better water quality as well as the potential for new habitat creation. **Constraints:** Would require landowner buy in and effective consultation. **Decision: Option taken forward alongside other options**
Storage	**Technical:** There is some potential for online storage to the River Ythan upstream of Ellon though restrictions with the land use including a large quarry and properties. it is likely the storage pond would need to be extremely large to attenuate the sizeable flows. Offline storage not as feasible due to limited offline space close to the watercourse which could provide a feasible volume of storage for the Ythan. **Environmental:** Disturbance to wildlife likely during construction. Potential benefits through new habitat creation. **Constraints:** Would require landowner buy in and effective consultation. Flood risk to other properties. It is unlikely there is a large enough area offline to store the volume required. This is limited by level of properties along the River. **Decision: Option taken forward and considered further in Section 5.6**
Channel modification	**Technical:** Technically viable though a large amount of out of bank flooding would require a large increase in conveyance therefore won't be economically feasible or sustainable. **Environmental:** Destruction of animal habitats within the watercourse and on the banks. No significant environmental benefit. **Constraints:** Large channel with historical deposition due to tidal limit. **Decision: Option discounted**
Channel diversion	**Technical:** Not feasible due to the channel being constrained by properties on either side. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Not financially viable due to land use. **Decision: Option discounted**

Channel realignment	**Technical:** Channel is too confined for realignment to have any significant effect. **Environmental:** Destruction of habitats within the watercourse and on the banks. No significant environmental benefit. **Constraints:** Confined channel and size would result make this option extremely cost inefficient. **Decision: Option discounted**
Structure modification	**Technical:** There is minimal head loss from the bridges upstream therefore any solution would have a negligible effect. Historic bridge upstream and main bridge within Ellon would likely cause social and economic implications if removed. The Bridge of Ardlethen road bridge at the upstream properties has a head loss of 0.5m for the 0.5% + climate change event therefore structure modification or removal could reduce flood risk to these properties. Due to this being an old arch bridge modification would not be financially or socially viable. **Environmental:** Destruction of habitats within the watercourse and on the banks during demolition. New habitats are likely to form on re-naturalised banks. **Constraints:** Multiple objections likely for removal. **Decision: Option discounted**
Control structures	**Technical:** There are no significant control structures within this section of the River Ythan. Due to further downstream flooding and large flows a pumping station would not be a viable solution. There is no potential for a control outlet due to the size of the channel. **Environmental:** Disturbance to wildlife likely during construction. Potential benefits through new habitat creation. **Constraints:** Likely to cause flood risk upstream. Not viable due to channel size. **Decision: Option discounted**
Direct defences	**Technical:** In this case direct defences include embankments, walls, adaptable walls and temporary walls. An embankment along the left bank is a viable solution to prevent flooding from the channel. This could also tie into high ground and with the existing footpath, where the footpath could form on top of the embankment. A form of wall would also be a viable solution on the left and right banks. A direct defence could also protect the properties at the upstream extent on the right bank of the Ythan**.** **Environmental:** Groundworks along riverbanks may disturb habitats. Constraining flow to within banks may result in change in habitat characteristics e.g. faster flowing water. May increase morphological pressure on river (negative RBMP impact). No significant environmental benefit. **Constraints:** Water may pond on the property side of a direct defence, particularly due to a steep catchment flowing down to the channel. A pumping station or drainage may need to be considered with a direct defence solution. There must be consideration as to how a defence may **impact on** the opposite side of the channel. **Decision: Embankment and wall option viable, option to be taken forward for Old Bridge of Ellon on both banks and on the right bank upstream of the Bridge of Ardlethen**
Watercourse maintenance	**Technical:** As the Ythan is a large channel watercourse maintenance would not be viable as a sole solution though is good practice to prevent any coarse obstructions at structures. **Environmental:** Maintains current habitats and environmental value of the watercourse. Channel maintenance may have minor negative impacts if spawning areas disrupted but these are unlikely to be significant. **Constraints:** N/A **Decision: Option discounted**
Self help	**Technical**: Self help could be used in conjunction with other methods including more awareness raising, flood action groups and business continuity planning. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Requires individual and community buy in. **Decision: Option taken forward alongside other options**
Emergency plans	**Technical:** Flood risk areas defined within this study to be incorporated into emergency plans**.** **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** N/A

	Decision: **Option taken forward alongside other options**

Table 5-5: Long list of options for design area D (The Meadows and Broomies Burn)

Measure	Discussion
Relocation	**Technical:** Relocation or abandonment of properties not politically or socially viable. Well development community. Option not cost effective as purchase costs will be same as or greater than capped damages. The single property flooding further up the Broomies Burn could be feasible for relocation though as it doesn't flood until the 200 year it is not a financially or socially viable option. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Multiple objections likely if carried out via an FPS. **Decision:** **Option discounted**
Flood warning	**Technical:** Flood warning could be implemented on the Ythan using the gauging station for The Meadows. SEPA are currently in the stage of updating this area for a formal PDM flood warning scheme on the Ythan. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Unlikely to make a difference as a standalone option. **Decision:** **Option taken forward alongside other options**
Property Level Protection (PLP)	**Technical:** Encourage property level protection and resilience though will likely need to be implemented with another method. All properties currently have access to products, including a limited number of sandbags. Air vent covers are already in use. Some properties exceed the flood depth of 600mm recommended as a maximum for property resistance measures. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** PLP is limited to flood depths up to 600mm. If PLP temporary measures, warning required to allow residents to install the PLP for it to be effective. **Decision:** **Option taken forward alongside other options**
Local planning policies	**Technical:** Above The Meadows there is a designated area for businesses as well as a protected area for the woodland. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Any options higher in the Broomies catchment will need to take the woodland protected area into account. **Decision:** **No decision as a standalone option though should be considered alongside all other options**
Runoff (NFM)	**Technical:** As properties begin flooding >75 year event, a catchment study of the Ebrie Burn which contributes a proportionally high flow to the River Ythan could reduce flows and have the potential to stop the properties from flooding in higher events. Opportunities include buffer strips, hedgerows, leaky bunds and removal of embankments. **Environmental:** Good land management will result in better water quality as well as the potential for new habitat creation from leaky bunds, hedgerows and buffer strips. **Constraints:** Would require landowner buy in and effective consultation. **Decision:** **Option taken forward alongside other options**
River/floodplain restoration (NFM)	**Technical:** Reconnection to the floodplain may provide more storage such as removal / breaching of agricultural embankment or re-meandering straightened channels. Floodplain on the River Ythan is reasonably connected to its floodplain. **Environmental:** Potential to disrupt habitats upon construction. Potential to create new habitats for wildlife. **Constraints:** Unlikely to provide enough storage to protect the properties though may reduce the frequency of flooding to some areas downstream. **Decision:** **Option taken forward alongside other options**
Sediment management (NFM)	**Technical:** Encourage good land management practices from the upstream agricultural land would limit sediment transfer into the channel, runoff from the agricultural land may increase sediment in the channel and this could reduce the amount of sediment depositing in the tidal limit.

	Environmental: Good land management such as leaky bunds, hedgerows and buffer strips will result in better water quality as well as the potential for new habitat creation. **Constraints:** Would require landowner buy in and effective consultation. **Decision:** **Option taken forward alongside other options**
Storage	**Technical:** There is some potential for online storage to the River Ythan upstream of Ellon though restrictions with the land use including a large quarry and properties. it is likely the storage pond would need to be extremely large to attenuate the sizeable flows. Offline storage not as feasible due to limited offline space close to the watercourse which could provide a feasible volume of storage for the Ythan. Storage on the Broomies Burn would not be economically feasible to protect the single property. **Environmental:** Disturbance to wildlife likely during construction. Potential benefits through new habitat creation. **Constraints:** Would require landowner buy in and effective consultation. Flood risk to other properties. It is unlikely there is a large enough area offline to store the volume required. This is limited by level of properties along the River Ythan. **Decision:** **Option on the Ythan taken forward and considered further in Section 5.6**
Channel modification	**Technical:** channel deepening technically viable though limited to downstream structure (A90 road bridge piers sit in the channel) in order to not interfere with the foundations. **Environmental:** Destruction of animal habitats within the watercourse and on the banks. No significant environmental benefit. **Constraints:** Downstream structure, option is not sustainable therefore constant maintenance is likely to be required. **Decision:** **Option taken forward**
Channel diversion	**Technical:** Diversion channel through the meander will slightly increase conveyance though unlikely to be a sustainable solution. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Unlikely to provide enough storage. **Decision:** **Option discounted**
Channel realignment	Channel could be realigned to a less prominent meander, utilising the space on the right bank. This solution is deemed not to increase the conveyance and is unlikely to be sustainable**. I**t also interferes with the natural historical **sinuous** channel and has therefore been discounted. **Decision:** **Option discounted**
Structure modification	**Technical:** There is minimal head loss from the bridges upstream and downstream therefore any solution would have a negligible effect. **Environmental:** Destruction of animal habitats within the watercourse and on the banks during demolition. New habitats are likely to form on re**-**naturalised banks. **Constraints:** N/A **Decision:** **Option discounted**
Control structures	**Technical:** The installation or modification of new control structures is unlikely to significantly attenuate flood flows. Likely to cause serious flood risk upstream. **Environmental:** Disturbance to wildlife likely during construction. Potential benefits through new habitat creation. **Constraints:** Likely to cause flood risk upstream. Land ownership constraints**.** **Decision:** **Option discounted**
Direct defences	**Technical:** In this case direct defences include embankments, walls, adaptable walls and temporary walls. An embankment or wall along the channel bank is a viable solution to prevent channel flooding for both The Meadows and on the right bank for the single property further up Broomies. **Environmental:** Groundworks along riverbanks may disturb habitats. Constraining flow to within banks may result in change in habitat characteristics e.g. faster flowing water. May increase morphological pressure on river (negative RBMP impact). No significant environmental benefit. **Constraints:** Potential for landowner objections. Water is likely to pond behind the structure therefore drainage or a pumping station will be required. Channel may become highly constrained in this area and affect upstream properties as there are currently constraints from rip rap on the right bank.

	Decision: **Embankment or wall option viable, option to be taken forward**
Watercourse maintenance	**Technical:** As the Ythan is a large channel watercourse maintenance would not be viable as a sole solution though it is good practice to prevent any coarse obstructions at structures. For the property further up Broomies Burn maintenance is crucial as it showed blockage during the 2012 event flooded the property. **Environmental:** Maintains current habitats and environmental value of the watercourse. Channel maintenance may have minor negative impacts if spawning areas disrupted but these are unlikely to be significant. **Constraints:** N/A **Decision:** **Option taken forward alongside other options**
Self help	**Technical:** Self help could be used in conjunction with other methods including more awareness raising, flood action groups and business continuity planning. **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** Requires individual and community buy in. **Decision:** **Option taken forward alongside other options**
Emergency plans	**Technical:** Flood risk areas defined within this study to be incorporated into emergency plans**.** **Environmental:** No significant environmental or RBMP benefits or impacts. **Constraints:** N/A **Decision:** **Option taken forward alongside other options**

5.6 Feasibility study

5.6.1 River Ythan storage analysis

There is a possibility to attenuate the flows on the River Ythan at the upstream extents of the model. A single location was selected to bund across the valley as an initial check to see how much volume would likely be required to reduce the flood risk in Ellon, this location is shown in Figure 5-2.

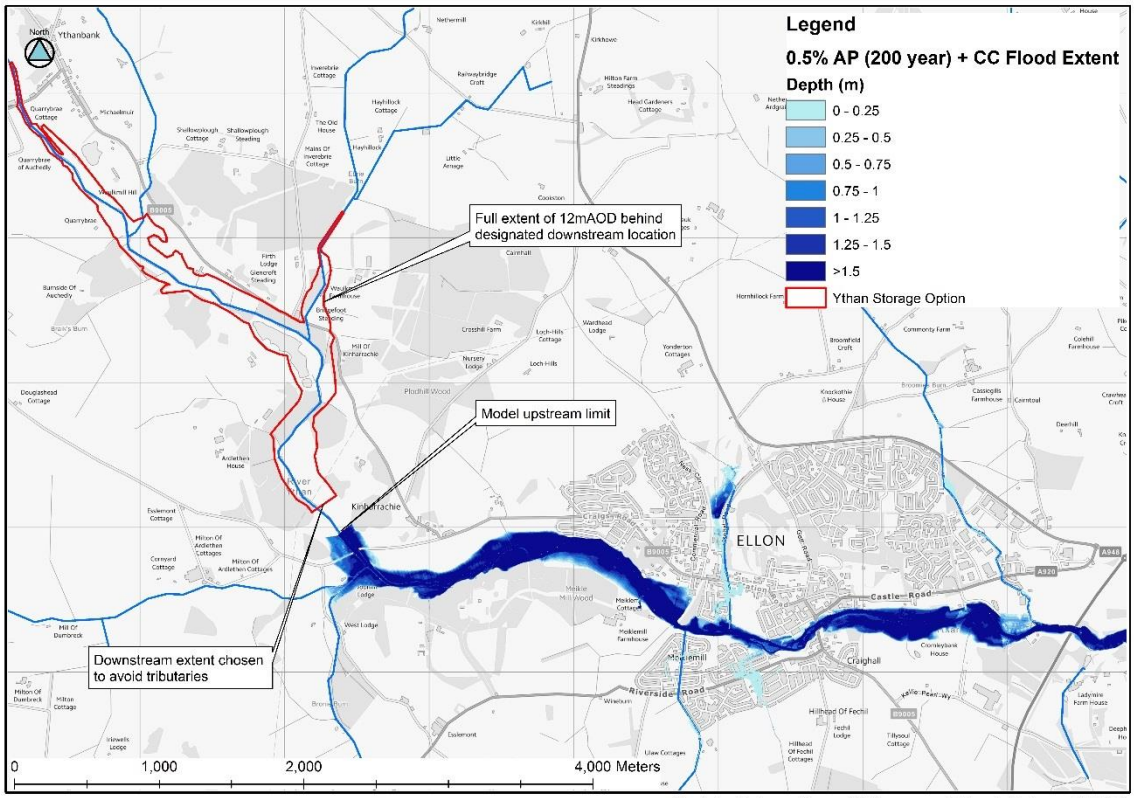

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Figure 5-2: River Ythan Storage Area

Figure 5-2 shows the Ythan storage option which was selected by choosing a downstream location as close to the model extent as possible, without affecting the tributary. A maximum height for the reservoir was selected at 12 mAOD as the B9005 road as well as a property close to the bank are just above this limit and should be unaffected by the reservoir. The red boundary shows this 12 mAOD area. A basic Flood Modeller model was built to test the attenuation of flows by creating an orifice opening through a theoretical dam structure. The storage was calculated using the area within the red line and the 1 m DTM to create an elevation/volume relationship. The orifice area was calculated so that flows could be attenuated to the 1% AP (100 year) event from the 0.5% AP (200 year) + climate change event as the standard of protection for most of the properties on the Ythan are up to the 1% AP (100 year).

Following the testing it was found that to achieve a maximum flow rate equivalent to the 1% AP of 161 m^3/s with an orifice size of 18 m^2 the build-up of water level behind the dam wall would be 16.28 mAOD. This would cause substantial flood risk to the infrastructure upstream of Ellon and therefore would not be a viable solution. As such a sizable volume is required and unobtainable in this large area, it is extremely unlikely any further storage options could be considered, particularly locations of offline storage or storing on tributaries.

This model shows the Ythan is incapable of storing enough water without impacting infrastructure upstream of Ellon. It should also be noted that generally the Ythan has a good connection with its floodplain therefore will already be naturally storing some of its volume. There are also environmental constraints such as sediment and fish movement by damming the river. In order to dam the river to this height storage would also likely be an extremely costly solution particularly during construction as the wall length would also need to be a couple of hundred metres. Due to these reasons the option of storage on the River Ythan has been discounted.

A summary of why this option has been discounted is as follows:

- Unachievable dam / wall heights required due to extremely large volumes required to store.
- Large environmental impacts.
- Current conditions show the Ythan already has good connection with its floodplain therefore already utilising a lot of the storage area.

5.6.2 Channel modification - island removal analysis

Due to Ellon being at the point of the tidal limit there is a lot of sedimentation in the channel due to the reduction in velocity. This has caused islands to form upstream and downstream of the Old Bridge of Ellon as well as near the outlet of Hillhead. An island removal analysis was modelled using the 1D/2D model where the islands were removed in flood modeller at the locations shown in Figure 5-3.

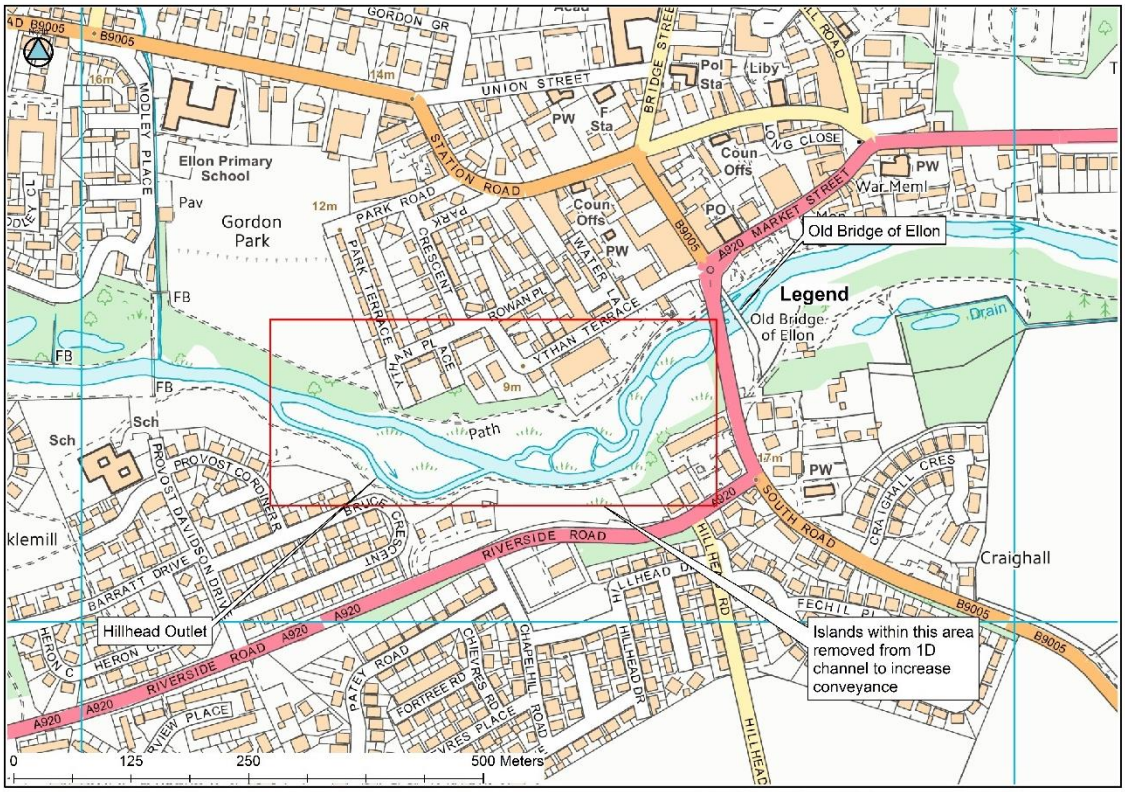

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Figure 5-3: River Ythan island removal location

The islands within the red bounding box were removed from the 1D channel, increasing the conveyance in this location. The model was run using the 0.5% AP (200 year) + climate change event and compared with the original results in Figure 5-4.

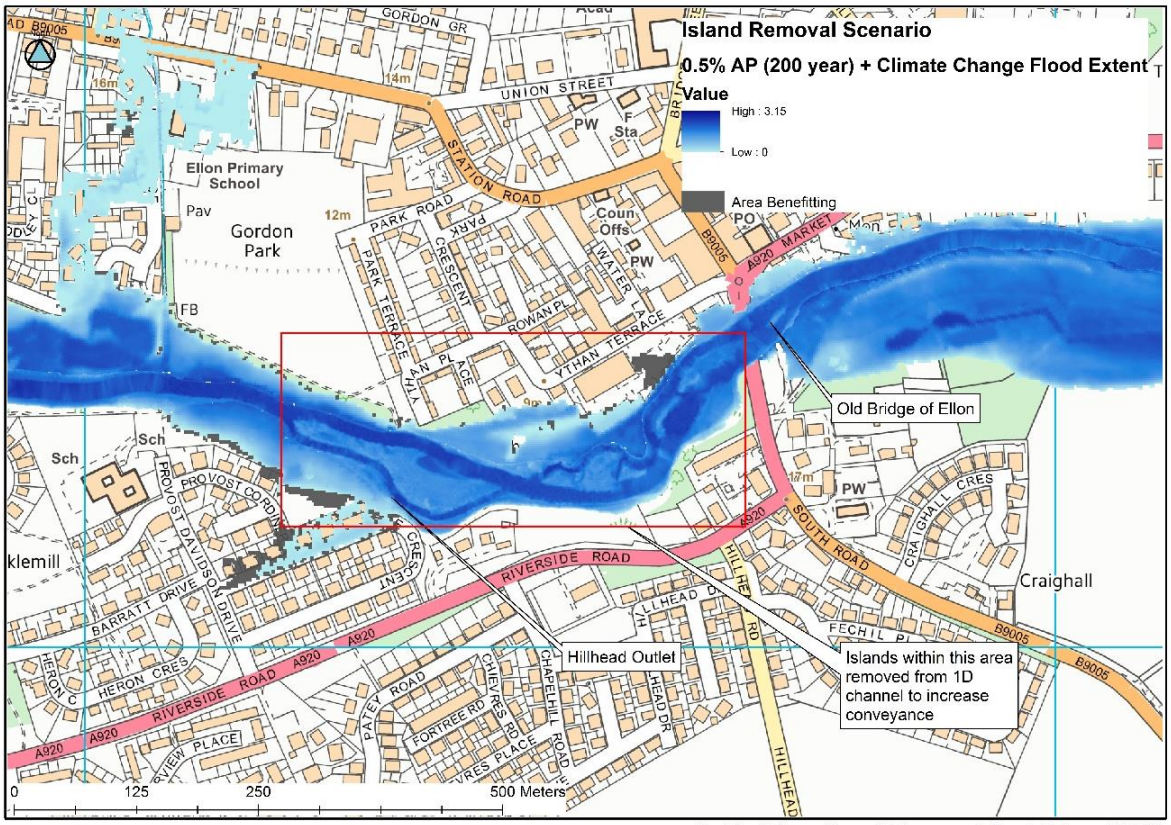

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Figure 5-4: Island removal results

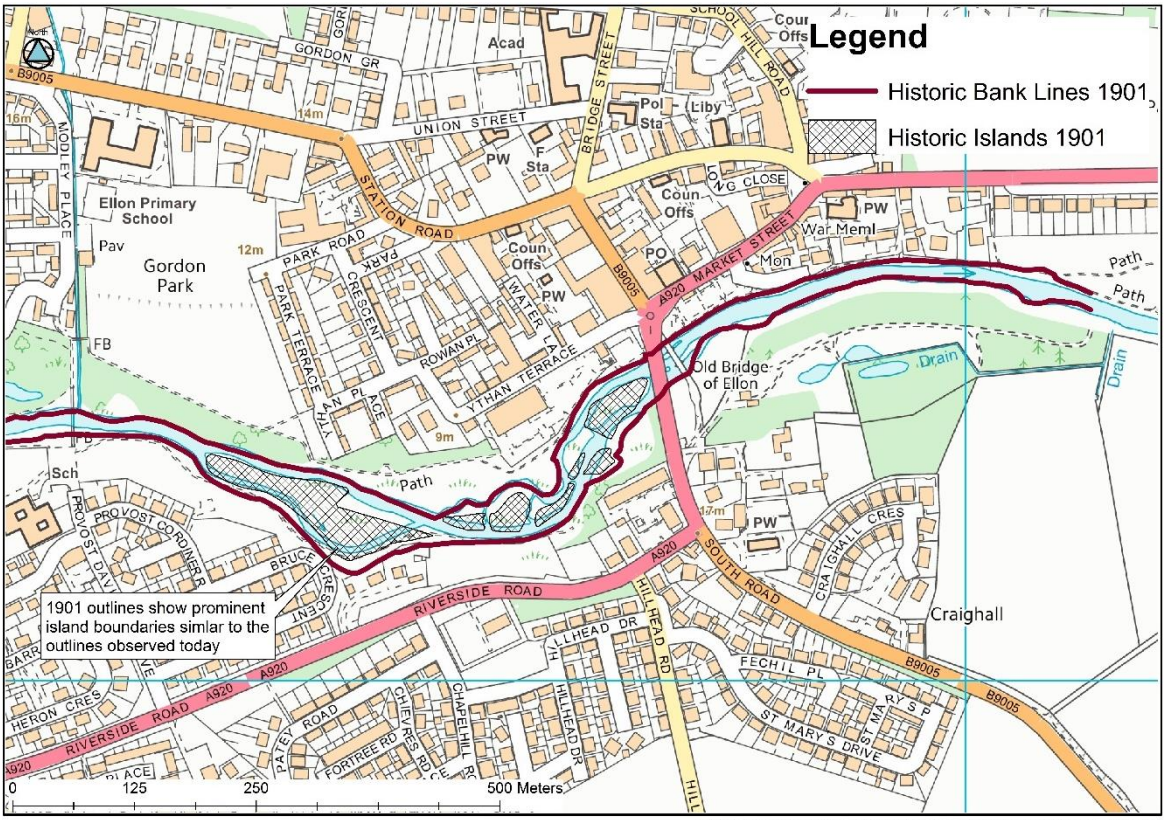

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Figure 5-5: Historical mapping showing the River Ythan islands

Figure 5-4 shows that there is minimal benefit from removing the upstream of the Old Bridge of Ellon as there is still out of bank flow from the River Ythan causing properties to flood. There is little

sign of benefit anywhere else along the Ythan when these islands are removed therefore the additional conveyance is not enough to remove the flood risk. This option is likely to be extremely costly where a full engineered solution may require a concrete channel or sheet piles and will have large implications on environmental habitats within the channel. Furthermore, this solution is unlikely to be sustainable where the islands are likely to reappear resulting in the requirement for their removal often. Figure 5-5 shows historical evidence of these islands which concludes that they are part of the natural process of the River Ythan, the overlay of mapping from 1901[8] shows the islands had a very similar outline to that of today. Due to these reasons island removal has been discounted as an option.

A summary of why this option has been discounted is as follows:

- Full removal of the islands does not alleviate the flood risk to Bruce Crescent.
- This option is not sustainable due to the nature of the river being at the tidal limit, this will result in deposition of sediment on a frequent basis.
- Large environmental impacts.

5.6.3 Channel modification - The Meadows channel deepening

The channel adjacent to The Meadows has historically been deepened to allow for boats to reach this limit from the coast. Deepening around this location has been investigated using the 1D/2D model lowering the channel bed level in the 1D domain. The location of the deepening is shown in Figure 5-6.

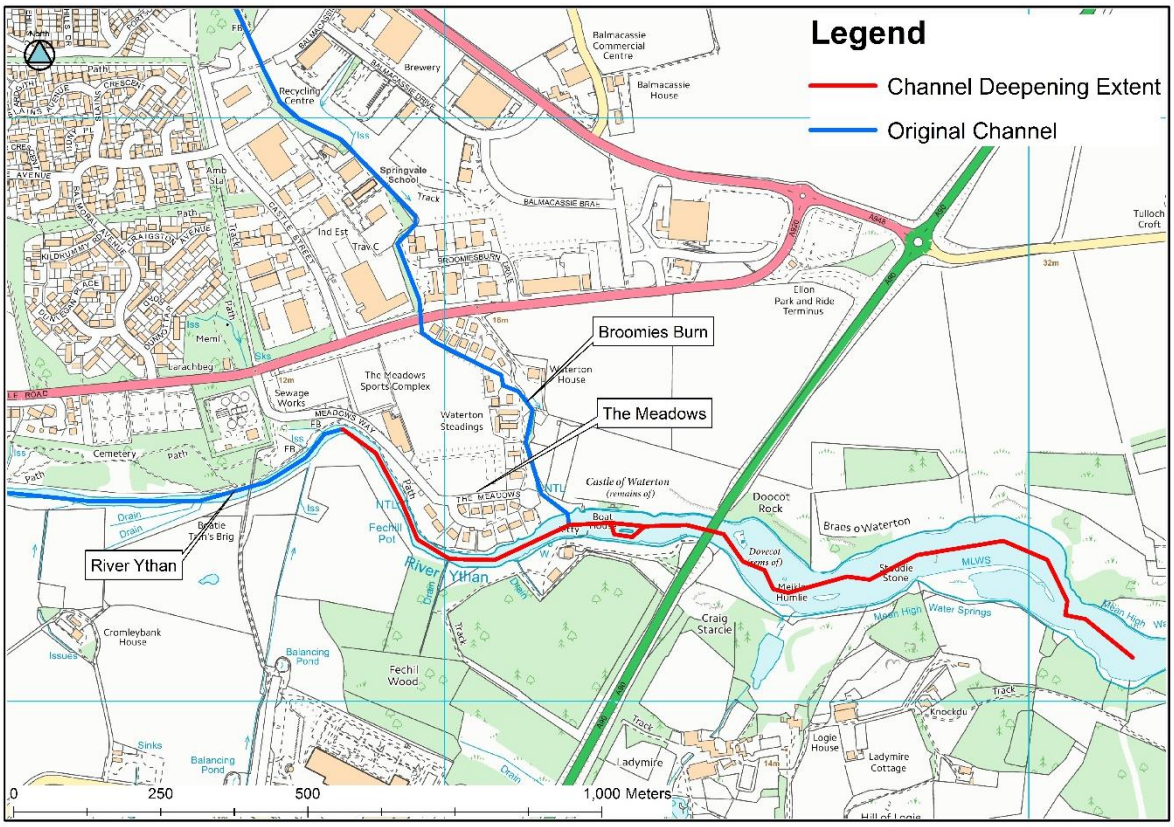

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Figure 5-6: Location of The Meadows channel deepening

The bed level of the cross sections that fall within the red zone above was dropped to the downstream bed level of -1.3 mAOD in order to analyse the effectiveness of this option. The results using the 0.5% AP (200 year) event + climate change are displayed in Figure 5-7.

8 National Library of Scotland, Aberdeenshire Sheet XXXVIII.SE, Publication date 1901, Accessed 24/01/2019

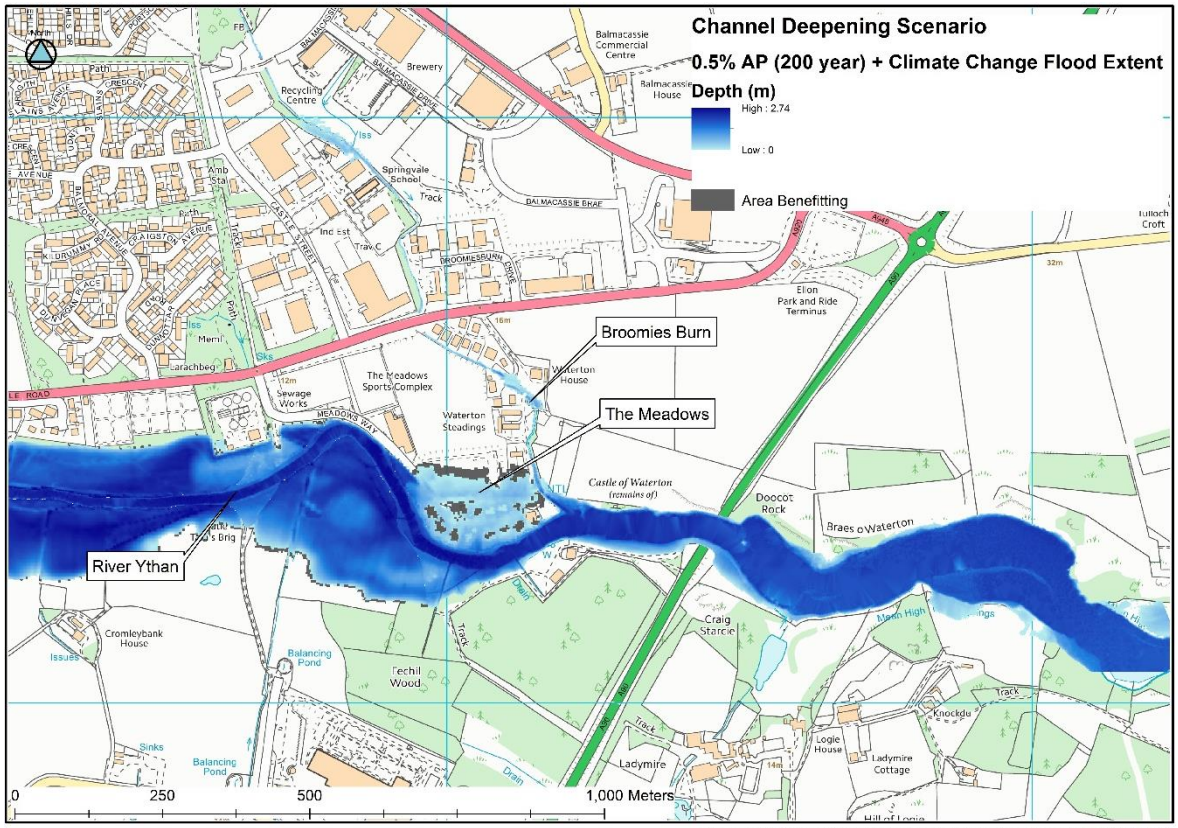

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Figure 5-7: Benefit of channel deepening using the 0.5% AP (200 year) + climate change event

Figure 5-7 shows a reduction in the out of bank flooding within The Meadows though there is still a substantial volume which is likely to cause large damages. This shows that deepening of the channel does not provide enough additional conveyance to remove the flood risk within The Meadows, unrealistic and expensive depths would be required to make a substantial difference. As well as this it is extremely likely that this option would not be sustainable as this part of the channel is within the tidal limit, sediment will likely deposit often from reduction of velocity. This is particularly an issue in this location where the bed slope is extremely shallow as shown in Figure 5-8. Further limitations such as the risk of damaging the unknown extent of the A90 road bridge foundations could add a lot of risk to this option. Environmental implications will also occur where during construction habitats are likely to be destroyed as well as during the life span as it is likely over the full appraisal period the channel will need to be deepened often. Due to these reasons, deepening of the channel within this section has been discounted.

A summary of why this option has been discounted is as follows:

- An unachievable negative bed slope would form from the depths that would be required to remove the flood risk.
- Unsustainable solution due to the nature of the river being at the tidal limit, this will result in deposition of sediment on a frequent basis.
- Risk of erosion and damage to the A90 road bridge.
- Large environmental impacts.

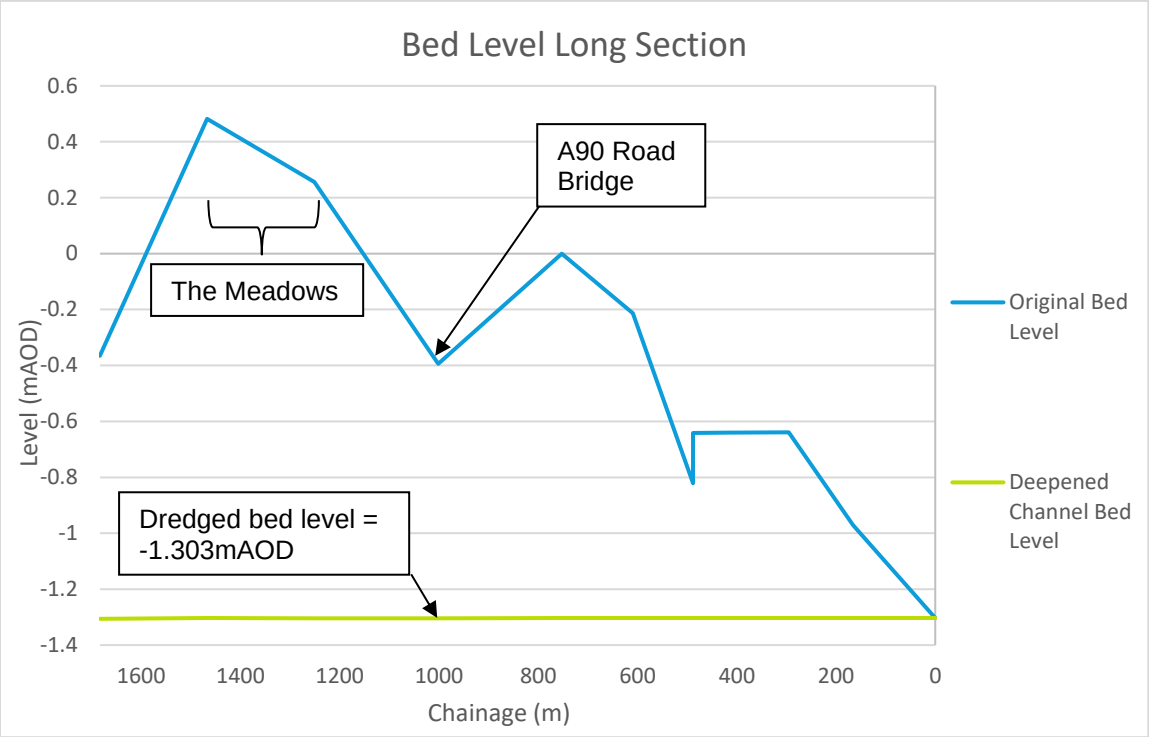

Figure 5-8: Location of The Meadows channel deepening

Figure 5-10 shows that over a distance of 1,680 m the bed level drops from -0.366 mAOD to -1.303 mAOD. In order to deepen the channel, the only likely sustainable tie in would be to drop the entire bed to -1.303 mAOD which has been used for this analysis.

5.6.4 The Meadows - bund at low point

It was identified at the public consultation that during Storm Frank in 2016 there was a low point at The Meadows which caused flood risk as it formed a flow path with high velocities which passed through the properties. The model results replicate this flow pathway which forms in the top left corner of The Meadows as shown in Figure 5-9.

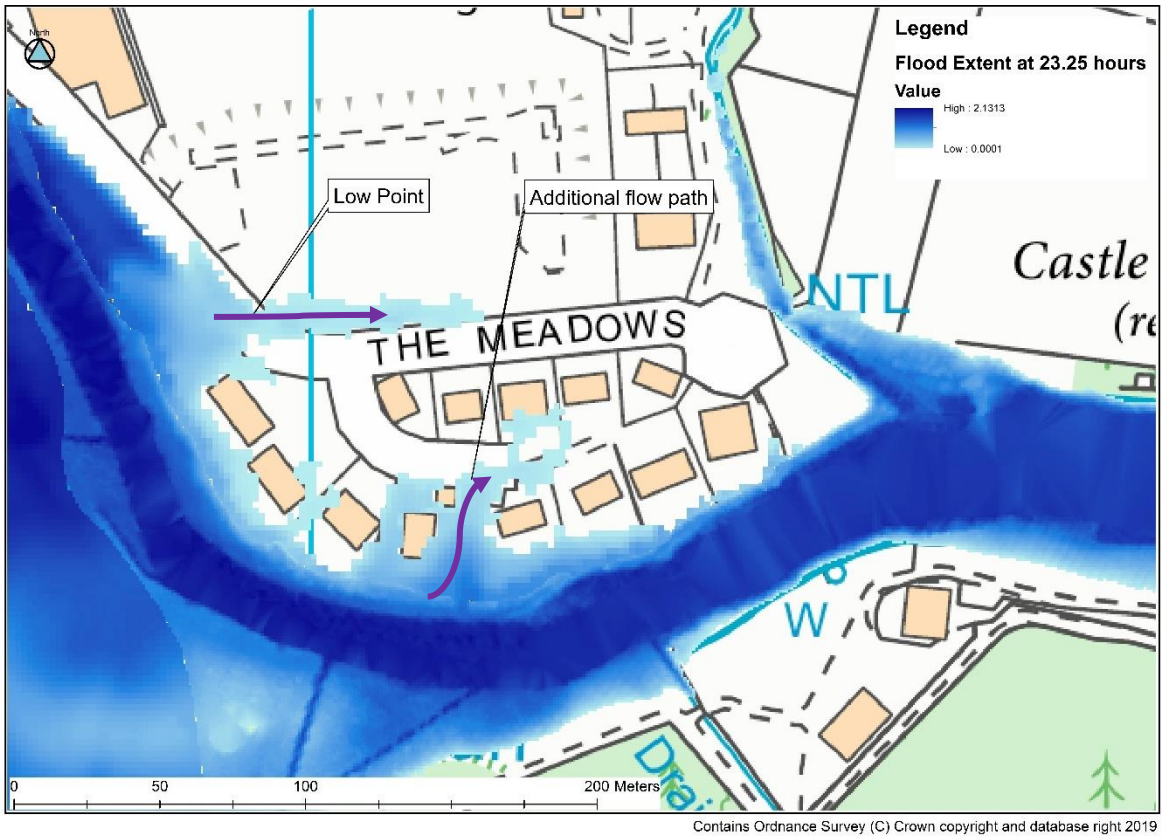

Figure 5-9: Location of low point in The Meadows

During consultation, the residents of the Meadows have requested consideration of a bund to fill in the low point. Figure 5-9 shows that there are two flow pathway which form at The Meadows and therefore a bund to alleviate flooding from the Ythan would need to consider both of these flow pathways. This was investigated further where a bund was added to the 2D floodplain, the location of this bund as well as the results are shown in Figure 5-10. The bund was set to 10 m high in order to ensure it could not be overtopped.

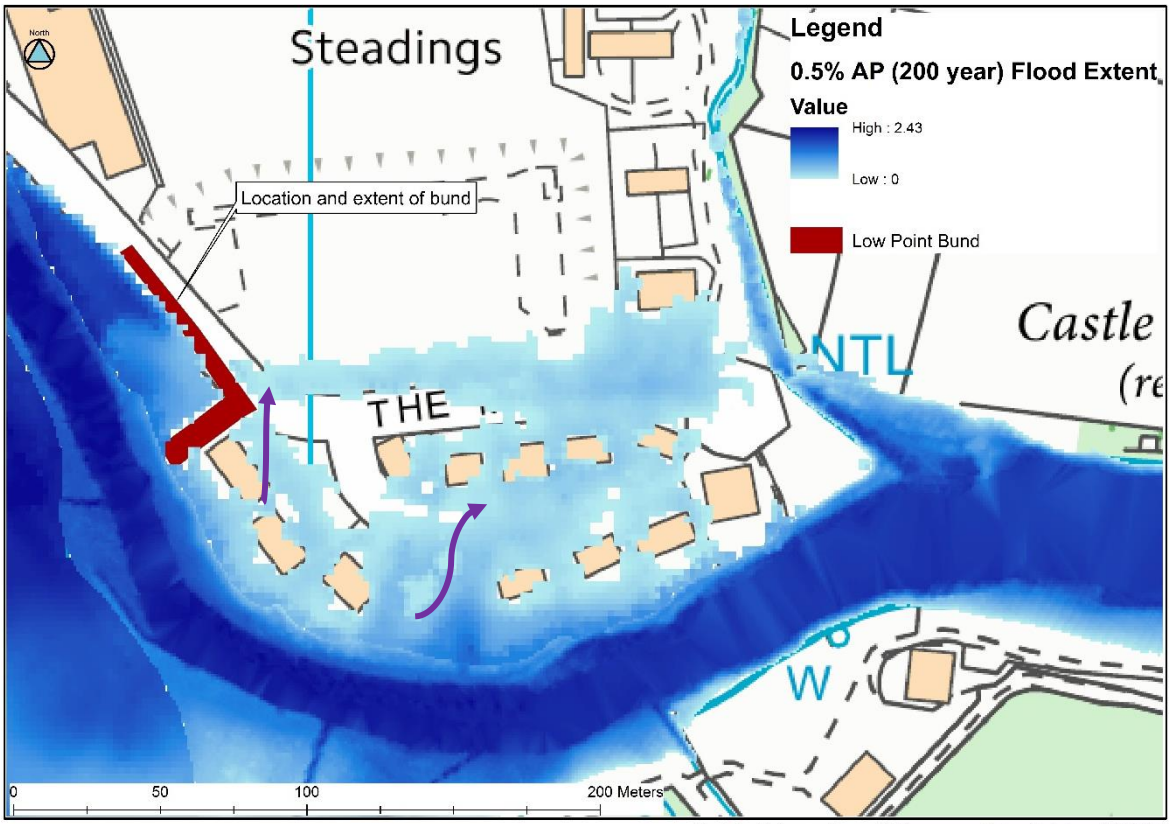

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Figure 5-10: Low point bund results using 0.5% AP (200 year) event

The results show that eliminating this flow pathway does not reduce the flood risk to The Meadows. The bund can easily be bypassed where the flow pathway which was previously forming through the low point is now being filled from the flow pathway to the south. As the bund has minimal impact on the flood risk it has been discounted as a standalone option, an embankment which extends along the south of The Meadows would be required to remove all of the flow pathways and this will be taken forward into the appraisal study.

A summary of why this option has been discounted is as follows:

- Blocking this flow pathway does not remove any flood risk to The Meadows.

5.7 Short list of options

Watercourse maintenance and NFM shall be implemented to some extent with all short-listed options. Following the consideration of the long list and feasibility in Sections 5.5 and 5.6, the following options have been shortlisted:

- Design area A (Modley Burn)
  - Storage on the golf course
  - Gordon Park channel realignment
  - Gordon Park two stage channel
  - Direct defences;
    - Bottom of the golf course
    - Right bank on Modley Place
  - Property Level Protection (PLP)

- Design area B (Hillhead & Fortree)
  - Storage at Hillhead inlet
  - Direct defence on the River Ythan
  - Pumping station at outlet
  - Property Level Protection (PLP)

- Design area C (Old Bridge of Ellon)
  - Direct defence on both banks
  - Property Level Protection (PLP)
- Upstream properties at Ardlethen
  - Direct defence on the right bank
  - Property Level Protection (PLP)

- Design area D (Meadows & Broomies)
  - Direct defence at The Meadows
  - Direct defence on Broomies Burn
  - Property Level Protection (PLP)

Each option should be taken forward alongside non-structural options such as flood warning, emergency planning and by working closely with local flood groups to increase preparedness/resilience.

5.7.1 Designing for climate change

In line with Scottish Planning Policy a 0.5% AP (200 year) standard of protection for any scheme was the goal throughout the short listing process. Wherever possible, options have been short-listed that at least aim to mitigate flooding to this standard and strive to meet the design standard for this event with an allowance for climate change, a 24% increase in the peak river flow.

Where a 0.5% AP (200 year) standard is not feasible interventions will be considered to allow for the greatest flood risk benefit possible after consideration of technical, environmental and social limitations and opportunities. River flood flows are expected to rise and where possible this will be accounted for in the design, for example by allowing for adaptable defences or by targeting a slightly higher standard of protection than may be ideal at the current time.

5.8 Flood Mitigation Options - Design Areas

The following section details the constraints and benefits of the shortlisted options for Ellon. This has initially been analysed within the four design areas separately in order to conclude the most feasible option in each area. These will then be combined to find the most viable solution for Ellon as a whole.

5.8.1 Design area A - Modley Burn

In order to protect against the 0.5% AP (200 year) event plus climate change at Modley Burn two flow pathways need to be resolved. Flooding commences at the 0.5% AP (200 year) plus climate change event when there is overtopping at the south of the McDonald golf course on the west side of Hospital Road. This flow pathway results in a large amount of damages which includes Ellon Primary School. The golf course is predicted to flood in this area at flood events greater than a 0.5% AP (200 year) plus climate change event, but flood waters are held back as the ground rises to the south at the council compound. A feasible solution to resolve this flow pathway is to hold the water within the golf course, this could be achieved by using a direct defence (e.g. embankment), or to formalise the area as a storage reservoir by including a flow control structure at the inlet of the Hospital Road culvert.

A second flow pathway forms out of the right bank at Modley Place from the 50% AP (2 year) event. Figure 5-11 shows the two flow pathways which cause flood risk to the properties adjacent to Modley Burn during the 0.5% AP (200 year) event plus climate change.

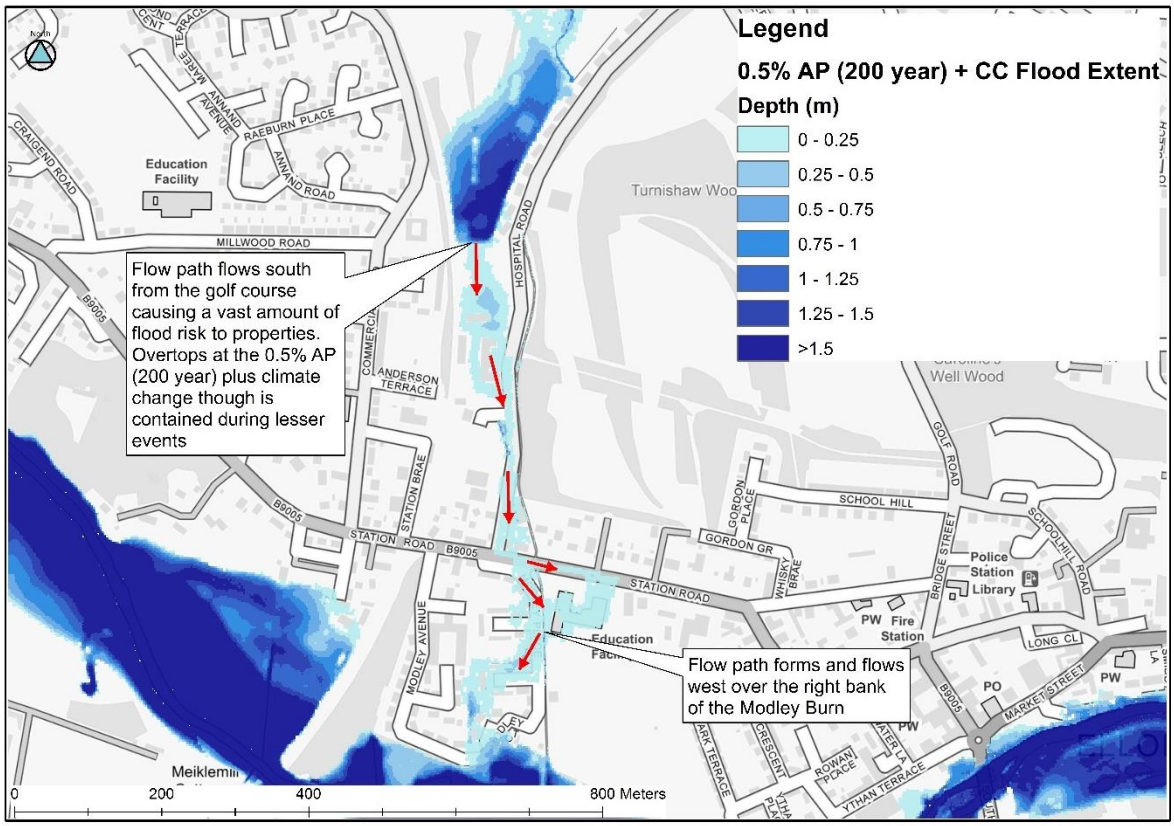

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Figure 5-11: Flow pathways within design area A - Modley Burn

Option A1: Golf course embankment Modley Place direct defence	Option A2: Golf course embankment Modley Place two stage channel	Option A3: Golf course formalised storage Modley Place two stage channel	Option A4: PLP

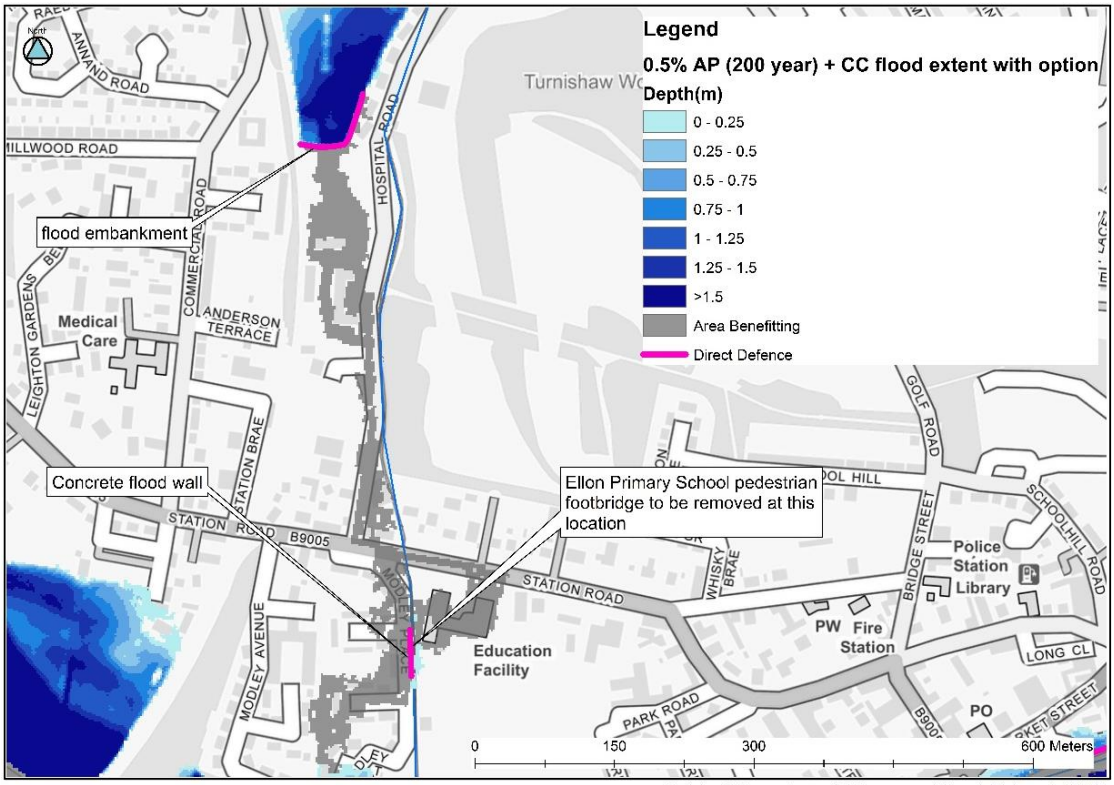
5.8.1.1 Option A1 - Golf course embankment and Modley Place direct defence

Option A1 - Golf course embankment and Modley Place direct defence

Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of an embankment across the south of the golf course to the west of Hospital Road as well as placing a wall along the right bank at Modley Place. The work includes the following:

- Install a flood embankment to the west of Hospital Road along the south side of the golf course for a distance of approximately 110 m. The embankment would tie into high ground on the west to the old railway embankment and on the north east to the raised houses. The maximum embankment height will be 2.25 m with an embankment defence level of 23.23 mAOD including a 0.6 m freeboard.
- Install a 60 m length concrete wall on the right bank of Modley Burn at Modley Place. The wall has a varying height, stepping down at 0.1 m intervals with a defence level of 11.8 mAOD to 11.1 mAOD. This gives an average height of 0.5 m ranging from 0.37 m to 0.63 m including a 0.3 m freeboard.
- Removal of the footbridge located at Modley Place crossing the burn towards Ellon Primary School. The footbridge spans for 4.9 m with a width of 1.2 m.



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Standard of Protection (SoP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 3.79 m^3/s.

Alternative quick wins / Preliminary investigations

Option is only required to protect properties from events greater than the 0.5% AP (200 year) if a SoP required is less than this then other options would be more cost effective, in particular solely implementing the right bank wall and bridge removal would provide a SoP to 0.5% AP (200 year).

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off is likely to be needed to avoid seepage beneath both defences, particularly in Modley Place with a wall height of around 0.5 m. Piling may be difficult in this material and

other forms of cut-off may need to be investigated.

Services

- A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access for the golf course embankment from Hospital Road: Pedestrian path closure required and likelihood of re-laying the surface after use. Section of golf course would be required to close during construction.
- Construction access from Modley Place: Public road path closure required, high risk due to being close to Ellon Primary School.

Waste

- Expected quantity of waste material for embankment: 982 m^3
- Expected quantity of waste material for wall: 32 m^3
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located away from the river (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.
- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: Public footpath next to proposed embankment. Both public road and footpath next to the proposed wall.
- Walls: Properties along Hospital Road have a wall segregating their gardens from the golf course.
- Houses: Properties along Hospital Road are in close proximity to the embankment.
- Ellon Primary School is in close proximity to the wall at Modley Place.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology, in particular to ensure any reduction in sediment transport does not affect the Sands of Forvie SSSI downstream of Ellon.
- Known fish migration route, ensure all solutions ensure continued migration on the Modley Burn.
- Consultation required with SNH and SEPA.
- Ensure bridge removal does not release a large build-up of sediment behind the abutments.
- Rhododendron and Wall Cotoneaster were identified in the study area. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction. Any identified INNS near any watercourses should be reported to the local SISI officer.

Health and safety hazards noted

Construction in close proximity to Ellon Primary School.

Social and community issues

Some aesthetic issues as this option will require embankments up to 2.25 m high which is on the upper limit of what is deemed acceptable in terms of wall heights in a community space. Landowner engagement will be required as landscaping around the new embankments will be required. Further, during events exceeding the 0.5% AP (200 year) the golf course will experience higher water levels than before therefore permission for this increase in land take during extremely large flooding events will need approval. During events less than the 0.5% AP (200 year) plus climate change the depth and length of time flood water will remain in the

golf course will be unchanged by this option.

Removal of footbridge may require public engagement as to whether a replacement structure may be required though many alternate routes in close proximity are available.

Impact on other reaches

The works are not deemed to impact on the watercourse or any subsequent watercourses as the normal flow paths will still be intact including the Modley Burn and the Hospital Road culvert.

Additional information required

- A full CCTV survey or equivalent method should be conducted on the Hospital Road culvert to find the exact path. A drain in the south east corner of the golf course was identified which may link to this culvert and so could be used to discharge during the high events.
- A detailed topographic survey.
- A detailed buried services survey, plotting their position with regards to site works.
- A ground investigation.
- A grated drain was identified on the site walkover next to where the embankment is proposed to be placed on the golf course, investigation into whether this is discharging into the culvert should be conducted.
- Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).

Additional works required to account for increase in flow due to climate change

Consider constructing the embankment and walls so that a wall could be added (or increased) in the future to defend against higher levels.

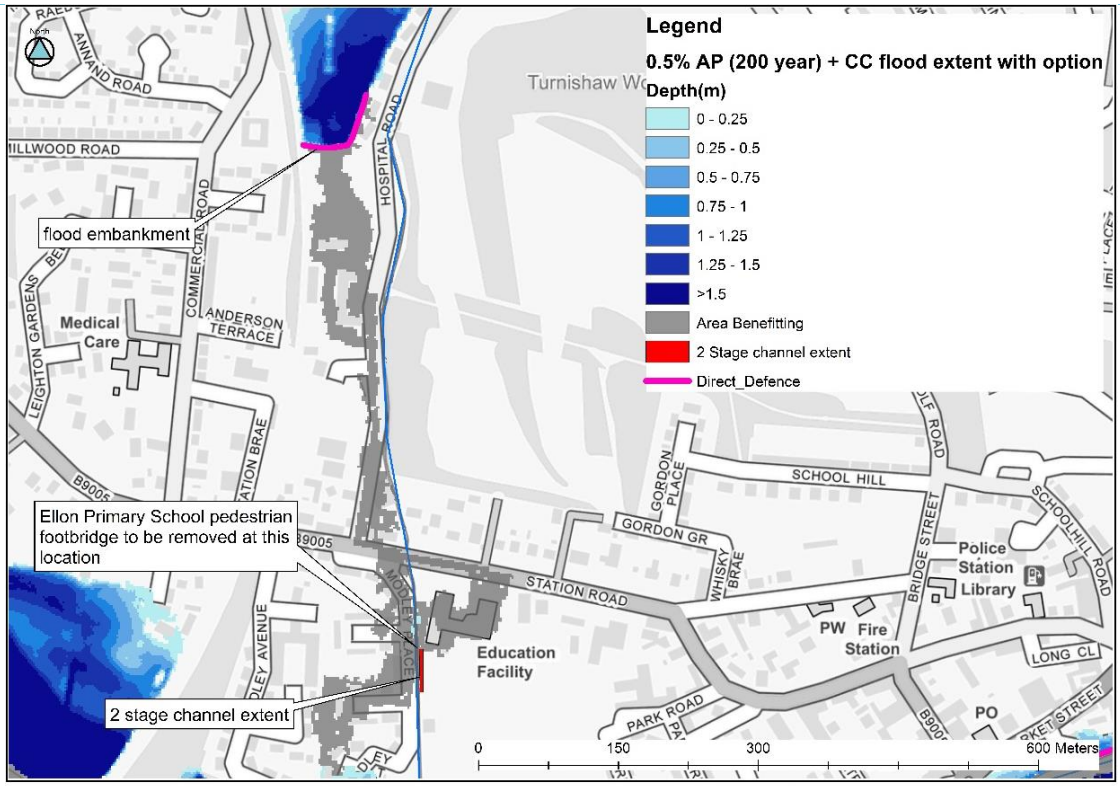
5.8.1.2 Option A2 - Golf course embankment and Gordon Park two stage channel

Option A2 - Golf course embankment and Gordon Park two stage channel

Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of an embankment across the south of the golf course to the west of Hospital Road as well as construction of a two stage channel, utilising the space on the left bank of the Modley Burn at Gordon Park. The work includes the following:

- Install a flood embankment to the west of Hospital Road along the south side of the golf course for a distance of approximately 110 m. The embankment would tie into high ground on the west to the old railway embankment and on the north east to the raised houses. The maximum embankment height will be 2.25 m with an embankment defence level of 23.23 mAOD including a 0.6 m freeboard.
- Re-profile the channel over a 47 m stretch downstream of Ellon Primary School so that the left bank is widened by 5 m to carry the additional flow required that is spilling out of the right bank. The sizing of the reprofiled channel is shown in the figure below.
- Plastic sheet piles will be placed into the right bank along the length of the two stage channel stretch to provide a 0.3 m freeboard in the channel, they will be submerged and backfilled by soil with an assumed 1.2 m foundation depth and 0.45 m trench width. The pile height above ground level will vary from 0.26 m to 0.04 m high.
- Removal of the footbridge located at Modley Place crossing the burn towards Ellon Primary School. The footbridge spans for 4.9 m with a width of 1.2 m.



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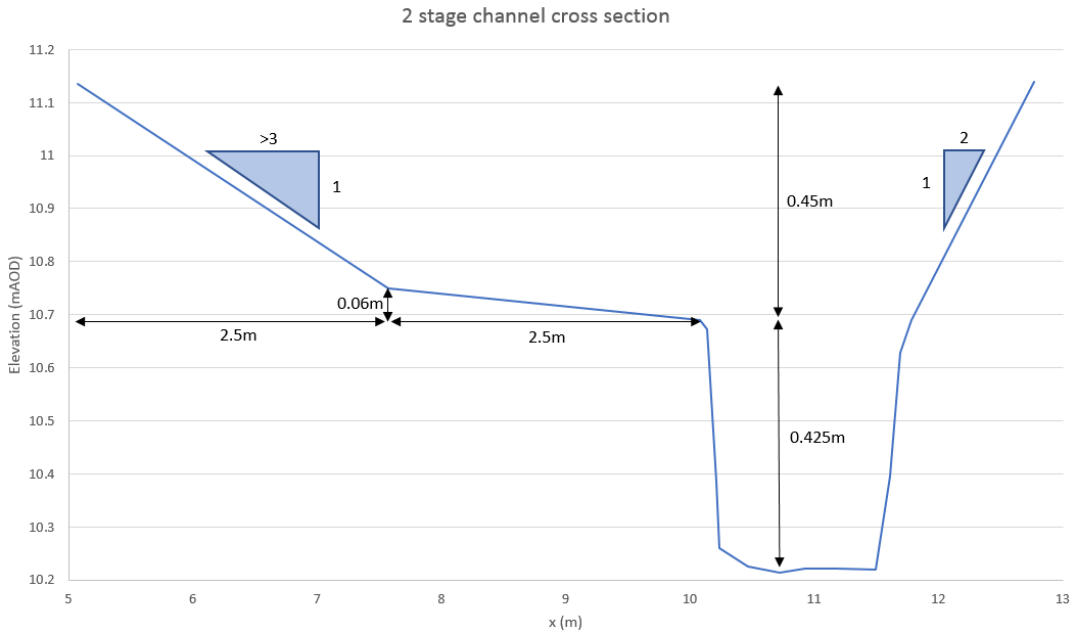


Standard of Protection (SoP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 3.79 m^3/s.

Alternative quick wins / Preliminary investigations

Option is only required to protect properties from events greater than the 0.5% AP (200 year) if a SoP required is less than this then other options would be more cost effective, in particular solely implementing the two stage channel and bridge removal would provide a SoP to 0.5% AP (200 year).

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off is likely to be needed to avoid seepage beneath the embankment. Piling may be

difficult in this material and other forms of cut-off may need to be investigated.

Services

A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access for the golf course embankment from Hospital Road: Pedestrian path closure required and likelihood of re-laying the surface after use. Section of golf course would be required to close during construction.
- Construction access from Modley Place: Public road path closure required, high risk due to being close to Ellon Primary School.

Waste

- Expected quantity of waste material for embankment: 982 m^3
- Unknown volume for two stage channel, detailed design and topographical survey required to calculate volume, rough estimate: 105 m^3 (based on a uniform excavation to the left bank).
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located away from the river (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.
- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: Public footpath next to proposed embankment. Public footpath in Gordon Park and pavement on Modley Place.
- Walls: Properties along Hospital Road have a wall segregating their gardens from the golf course.
- Houses: Properties along Hospital Road are in close proximity to the embankment.
- Ellon Primary School is in close proximity to the two stage channel at Modley Place, foundations for the tennis court are also in close proximity.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology, in particular to ensure any reduction in sediment transport does not affect Sands of Forvie SSSI downstream of Ellon.
- Two stage channel should be designed with the idea to improve morphology in it with good riparian vegetation in the benched high flow channel to benefit the watercourse.
- Consultation required with SNH and SEPA.
- Ensure bridge removal does not release a large build-up of sediment behind the abutments.
- Known fish migration route, ensure all solutions ensure continued migration on the Modley Burn.
- Rhododendron and Wall Cotoneaster were identified in the study area. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction. Any identified INNS near any watercourses should be reported to the local SISI officer.

Health and safety hazards noted

- Construction in close proximity to Ellon Primary School.
- The existing right bank is slightly steeper than 1 in 3.

Social and community issues

Some aesthetic issues as this option will require embankments up to 2.25 m high which is deemed to be on the upper limit of what is acceptable in terms of wall heights in a community space. Landowner engagement will be required as landscaping around the new embankments will be required. Further, during events exceeding the 0.5% AP (200 year) the golf course will experience higher levels than before therefore permission for this increase in land take during extremely large flooding events will need approved. During events less than the 0.5% AP (200 year) plus climate change the depth and length of time flood water will remain in the golf course will be unchanged by this option.

Removal of footbridge may require public engagement as to whether a replacement structure may be required though many alternate routes in close proximity are available.

Impact on other reaches

The works are not deemed to impact on the watercourse or any subsequent watercourses as the normal flow paths will still be intact including the Modley Burn and the Hospital Road culvert.

Additional information required

- A detailed topographic survey on the channel extent which will be widened.
- A detailed buried services survey, plotting their position with regards to site works.
- A ground investigation.
- An arboriculture survey of the trees which may need to be removed on the left bank.
- A grated drain was identified on the site walkover next to where the embankment is proposed to be placed on the golf course, investigation into whether this is discharging into the culvert should be conducted.
- Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).

Additional works required to account for increase in flow due to climate change

Consider constructing the embankment so that a wall could be added in the future to tackle higher levels.

Consider extending the two stage channel further upstream and downstream to add more freeboard to the solution hence making it more sustainable. This would also add significant RBMP benefit where the Burn currently scours downstream and re-naturalising the channel.

As a two stage channel is an effective way of alleviating the flood risk it will be a lot more economically and socially viable than diverting the channel through the park therefore channel diversion has been discounted.

5.8.1.3 Option A3 - Golf course storage and Gordon Park two stage channel

Option A3 - Golf course embankment and Gordon Park two stage channel

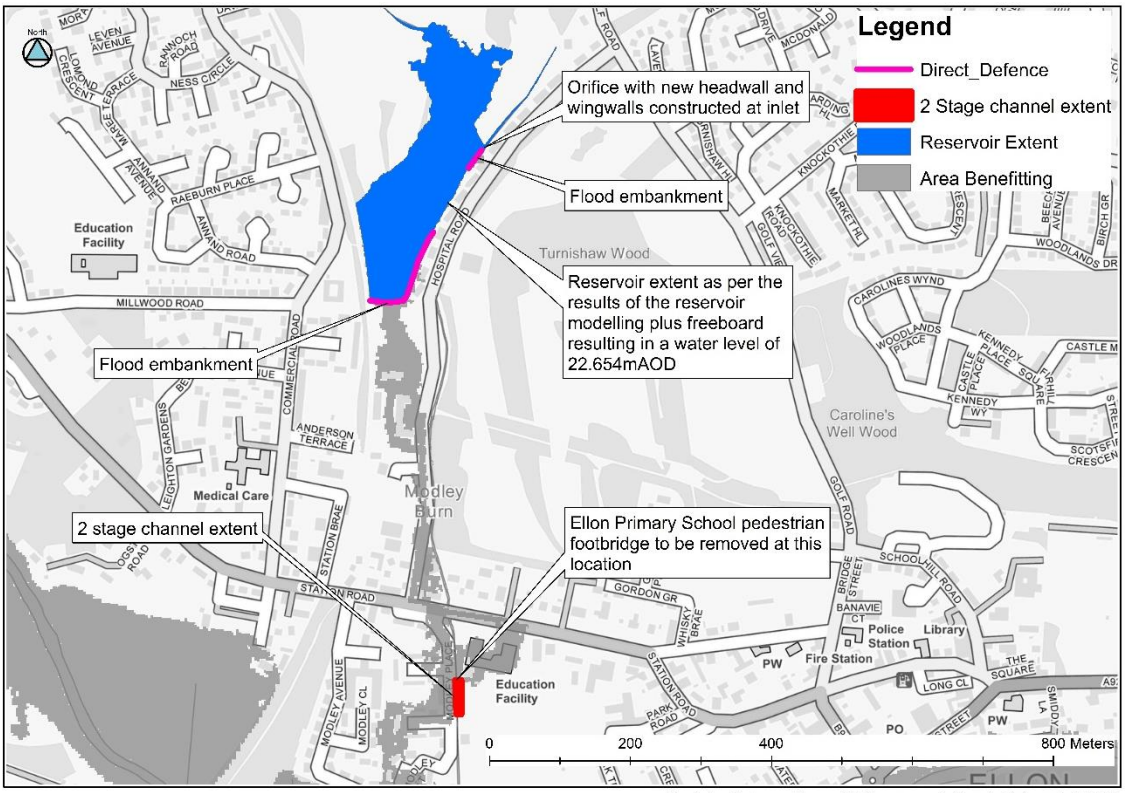
Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of an embankment across the south of the golf course to the west of Hospital Road as well as construction of a two stage channel, utilising the space on the left bank of Modley Burn at Gordon Park. This option includes formalisation of the golf course as a storage reservoir limiting the flow downstream equivalent to the 1% AP (100 year) flow using an orifice or similar flow control unit. This also includes an embankment to the right of the orifice due to slightly higher water levels. The 1% AP (100 year) flow was selected as other than works on the southern embankment and the construction of a small embankment to the right of the inlet, no further construction to contain the water is required during this limitation. This option will provide a more sustainable solution than the direct defence (embankment only option) as this option while preventing the flow pathway also attenuates flows which are passing downstream along the Modley Burn, hence providing substantial freeboard to the channel downstream. The work includes the following:

- Install a flood embankment to the west of Hospital Road along the south side of the golf course for a distance of approximately 156 m which ties into high ground on the west to the old railway embankment and on the north east to the raised houses. The maximum embankment height will be 3.66 m with an embankment defence level of 24.64 mAOD

including a 1.1 m freeboard (0.6 m for modelling uncertainty and 0.5 m due to the area being a formal reservoir as volumes are >10,000 m^3).

- Install a flood embankment to the right of the Hospital Road culvert inlet for a distance of approximately 30 m which ties into high ground at either side using 1 in 3 slopes. The maximum embankment height will be 1.1 m to account for the freeboard required in the reservoir.
- Re-profile the channel over a 47 m stretch downstream of Ellon Primary School so that the left bank is widened by 5 m to carry the additional flow required that is spilling out of the right bank. The sizing of the reprofiled channel is shown in the figure within section 3.4.1.2.
- Plastic sheet piles will be placed into the right bank along the length of the two stage channel stretch to provide a 0.3 m freeboard in the channel, they will be submerged and backfilled by soil with an assumed 1.2 m foundation depth and 0.45 m trench width. The pile height above ground level will vary from 0.26 m to 0.04 m high.
- Removal of the footbridge located at Modley Place crossing the burn towards Ellon Primary School. The footbridge spans for 4.9 m with a width of 1.2 m.
- Construction of an orifice at the inlet of Hospital Road culvert with an opening area of 0.65 m^2 in order to limit the flow to the 1% AP (100 year).



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Standard of Protection (SoP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 3.79 m^3/s.

Alternative quick wins / Preliminary investigations

Option is only required to protect properties from events greater than the 0.5% AP (200 year) if a SoP required is less than this then other options would be more cost effective, in particular solely implementing the two stage channel and bridge removal would provide a standard of protection to 0.5% AP (200 year).

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off is likely to be needed to avoid seepage beneath the embankment. Piling may be difficult in this material and other forms of cut-off may need to be investigated.

Services

A full survey identifying overhead and underground services will be required at a later stage

of the project.
Construction access • Construction access for golf course embankment from Hospital Road: Pedestrian path closure required and likelihood of re-laying the surface after use. Section of golf course would be required to close during construction. • Construction access from Modley Place: Public road path closure required, high risk due to being close to Ellon Primary School. • Construction access to the orifice unit will be more constrained due to the need for landscaping the golf course to fit a temporary track along the eastern edge of the golf course.
Waste • Expected quantity of waste material for embankment: 1437 m^3 • Unknown volume for two stage channel, detailed design and topographical survey required to calculate volume, rough estimate: 105 m^3 (based on a uniform excavation to the left bank). • Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste. • Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located away from the river (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works. • Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.
Proximity of defence to other structures • Private and Public: Public footpath next to proposed embankment. Public footpath in Gordon Park. • Walls: Properties along Hospital Road have a wall segregating their gardens from the golf course. • Houses: Properties along Hospital road are in close proximity to the embankment and orifice unit. • Ellon Primary School is in close proximity to the two stage channel at Modley Place, foundations for tennis court are also in close proximity.
Environmental issues • Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology, in particular to ensure any reduction in sediment transport does not affect Sands of Forvie SSSI downstream of Ellon. • Two stage channel should be designed with the idea to improve morphology in it with good riparian vegetation in the benched high flow channel to benefit the watercourse. • Consultation required with SNH and SEPA. • Ensure bridge removal does not release a large build-up of sediment behind the abutments. • Known fish migration route, ensure all solutions ensure continued migration on Modley Burn. • Rhododendron and Wall Cotoneaster were identified in the study area. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction. Any identified INNS near any watercourses should be reported to the local SISI officer.
Health and safety hazards noted • Construction in close proximity to Ellon Primary School. • Existing right bank is slightly steeper than 1 in 3.

Social and community issues Some aesthetic issues as this option will require embankments up to 3.66m high which is likely to be unacceptable in terms of wall heights in a community space therefore further community engagement is likely to be required. Minor land take of the golf course will be required therefore landowner engagement and buyout will be required. Further, during events exceeding the 0.5% AP (200 year) the golf course will experience higher levels than before therefore permission for this increase in land take during extremely large flooding events will need approval. Removal of footbridge may require public engagement as to whether a replacement structure may be required though many alternate routes in close proximity are available.
Impact on other reaches The works are not deemed to impact on the watercourse or any subsequent watercourses as the normal flow paths will still be intact including the Modley Burn and the Hospital Road culvert.
Additional information required • A detailed topographic survey on the channel extent which will be widened. • A detailed buried services survey, plotting their position with regards to site works • A ground investigation. • An arboriculture survey of the trees which may need to be removed on the left bank. • A grated drain was identified on the site walkover next to where the embankment is proposed to be placed on the golf course, investigation into whether this is discharging into the culvert should be conducted. • Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).
Additional works required to account for increase in flow due to climate change Consider constructing the embankment so that a wall could be added in the future to tackle higher levels. Consider extending the two stage channel further upstream and downstream to add more freeboard to the solution hence making it more sustainable.

5.8.1.4 Option A4 - Property Level Protection (PLP)

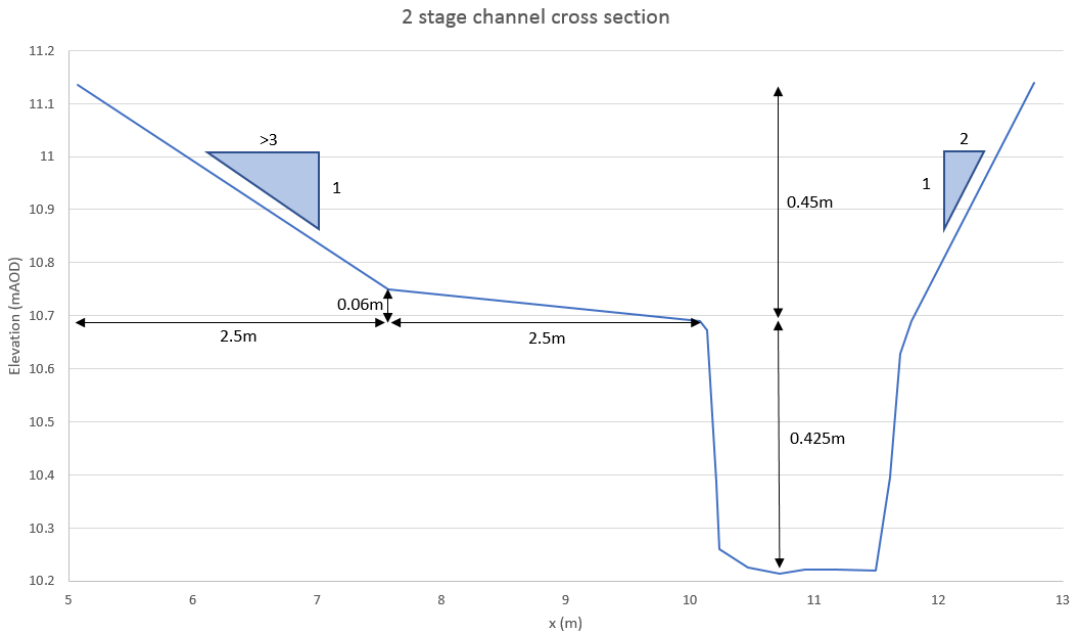
Option A4 - Property Level Protection
Description This option aims to provide an increase in SoP for all properties where possible by protecting them up to a maximum flood depth of 0.6 m. Beyond this water depth a buildings integrity can potentially be compromised. This option includes the survey, design and implementation of relevant PLP products to each property experiencing flooding. The number of properties expecting to benefit from PLP within Area A are as follows: • 11 properties out of the 13 at risk during the 0.5% AP (200 year) plus climate change. • Both of the 2 properties at risk during the 0.5% AP (200 year).
Standard of Protection (SoP) PLP offers a variable SoP dependent on the property and expected flood depths. Importantly, the property with the lowest standard would be protected to a maximum of the 0.5% AP (200 year) plus climate change event, at which point water levels would overtop standard 0.6 m high PLP products.
Technical Issues All properties would require surveying by competent parties to determine which products are appropriate. Properties with non-standard or large entrances may require bespoke options which can significantly increase costs. The Scottish Government's Blueprint on PLP[9] should be considered when implementing this

9 Scottish Government (2014). Assessing the Flood Risk Management Benefits of Property Level Protection; Blueprint for Local Authorities and Scottish Water. Final Report v2.0. 13 November 2014

option. Due to no formal flood warning in the area all PLP options are assumed to be automatic.
Construction issues Some commercial properties may require bespoke PLP products and building remedial works to ensure the products work effectively. The installation and periodic replacement of PLP products on multiple properties may become a maintenance burden for the Council.
Environmental issues None identified.
Social and community issues Due to the highly engaged community PLP alone may not be an acceptable option. Residents are likely to expect more significant measures to be undertaken.
Impact on other reaches There will be a negligible impact on other reaches due to a small diverted volume that would otherwise flow through the properties.
Additional information required • Public engagement meetings. • Flood risk reviews on each property.
Additional works required to account for increase in flow due to climate change Some properties identified as suitable for PLP may become unsuitable with increasing river flows. Additionally, some properties that are not expected to flood frequently enough to make PLP worthwhile at present may be expected to flood more frequently in the future.

5.8.1.5 Option A5 - Gordon Park 2 stage channel

Option A2 - Gordon Park two stage channel
Description This option aims to provide a SoP of 0.5% AP (200 year) through construction of a two stage channel, utilising the space on the left bank of the Modley Burn at Gordon Park. The work includes the following: • Re-profile the channel over a 47 m stretch downstream of Ellon Primary School so that the left bank is widened by 5 m to carry the additional flow required that is spilling out of the right bank. The sizing of the reprofiled channel is shown in the figure below. • Plastic sheet piles will be placed into the right bank along the length of the two stage channel stretch to provide a 0.3 m freeboard in the channel, they will be submerged and backfilled by soil with an assumed 1.2 m foundation depth and 0.45 m trench width. The pile height above ground level will vary from 0.26 m to 0.04 m high. • Removal of the footbridge located at Modley Place crossing the burn towards Ellon Primary School. The footbridge spans for 4.9 m with a width of 1.2 m.



Standard of Protection (SoP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) is achievable. This equates to a flow of 3.25 m^3/s.

Alternative quick wins / Preliminary investigations

N/A

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off is likely to be needed to avoid seepage beneath the embankment. Piling may be difficult in this material and other forms of cut-off may need to be investigated.

Services

A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access from Modley Place: Public road path closure required, high risk due to being close to Ellon Primary School.

Waste

- Unknown volume for two stage channel, detailed design and topographical survey required to calculate volume, rough estimate: 105 m^3 (based on a uniform excavation to the left bank).
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located away from the river (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.
- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: Public footpath in Gordon Park and pavement on Modley Place.
- Ellon Primary School is in close proximity to the two stage channel at Modley Place, foundations for the tennis court are also in close proximity.

Environmental issues • Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology, in particular to ensure any reduction in sediment transport does not affect Sands of Forvie SSSI downstream of Ellon. • Two stage channel should be designed with the idea to improve morphology in it with good riparian vegetation in the benched high flow channel to benefit the watercourse. • Consultation required with SNH and SEPA. • Ensure bridge removal does not release a large build-up of sediment behind the abutments. • Known fish migration route, ensure all solutions ensure continued migration on the Modley Burn. • Rhododendron and Wall Cotoneaster were identified in the study area. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction. Any identified INNS near any watercourses should be reported to the local SISI officer.
Health and safety hazards noted • Construction in close proximity to Ellon Primary School. • The existing right bank is slightly steeper than 1 in 3.
Social and community issues Removal of footbridge may require public engagement as to whether a replacement structure may be required though many alternate routes in close proximity are available.
Impact on other reaches The works are not deemed to impact on the watercourse or any subsequent watercourses as the normal flow paths will still be intact including the Modley Burn and the Hospital Road culvert.
Additional information required • A detailed topographic survey on the channel extent which will be widened. • A detailed buried services survey, plotting their position with regards to site works. • A ground investigation. • An arboriculture survey of the trees which may need to be removed on the left bank. • Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).
Additional works required to account for increase in flow due to climate change Consider extending the two stage channel further upstream and downstream to add more freeboard to the solution hence making it more sustainable. This would also add significant RBMP benefit where the Burn currently scours downstream and re-naturalising the channel.

5.8.1.6 Design area A summary

In summary there are two comparisons for design area A, at the golf course this is the use of either an embankment or formalising the area as storage and at Modley Place this is the use of a flood wall or a two stage channel:

- McDonald Golf Course - Formalising the golf course as a reservoir would be a more sustainable solution though this has much larger cost implications. This should be considered if land use discussions are positive with the golf course and the cost benefit is not the critically determining parameter.
- Modley Place - It is more economically viable to use a two stage channel rather than a flood wall. There is also less impact both socially and environmentally where it utilises the space better and reconnects the burn to the floodplain. The two stage channel also has environmental and RBMP benefits but re-naturalising the channel and providing a solution to previously identified scouring in this area.
- Construction of a two stage channel with no embankment in the golf course would be a less costly solution to protect to the 0.5% AP (200 year) design event but would not provide protection against climate change.

Due to the above summaries the most practical solution due to a more practical economic and social benefit is blocking the golf course flow pathway by use of an embankment and constructing a two stage channel within Modley Place.

5.8.2 Design area B - Hillhead Burn

In order to protect against the 0.5% AP (200 year) event plus climate change at Hillhead Burn two flow pathways need to be resolved. This is the out of bank flow from the River Ythan as well as the manhole surcharge and overtopping of the Hillhead culverted sewer. Figure 5-12 shows the two flow pathways which cause flood risk to the properties within the Hillhead Burn vicinity during the 0.5% AP (200 year) event plus climate change. As the properties on Fortree Burn do not flood until the 0.1% AP (1000 year) event they have been excluded from this analysis.

Flooding over the inlet commences from the 3.33% AP (30 year) event where flooding out of bank on the River Ythan commences from the 0.5% AP (200 year) event.

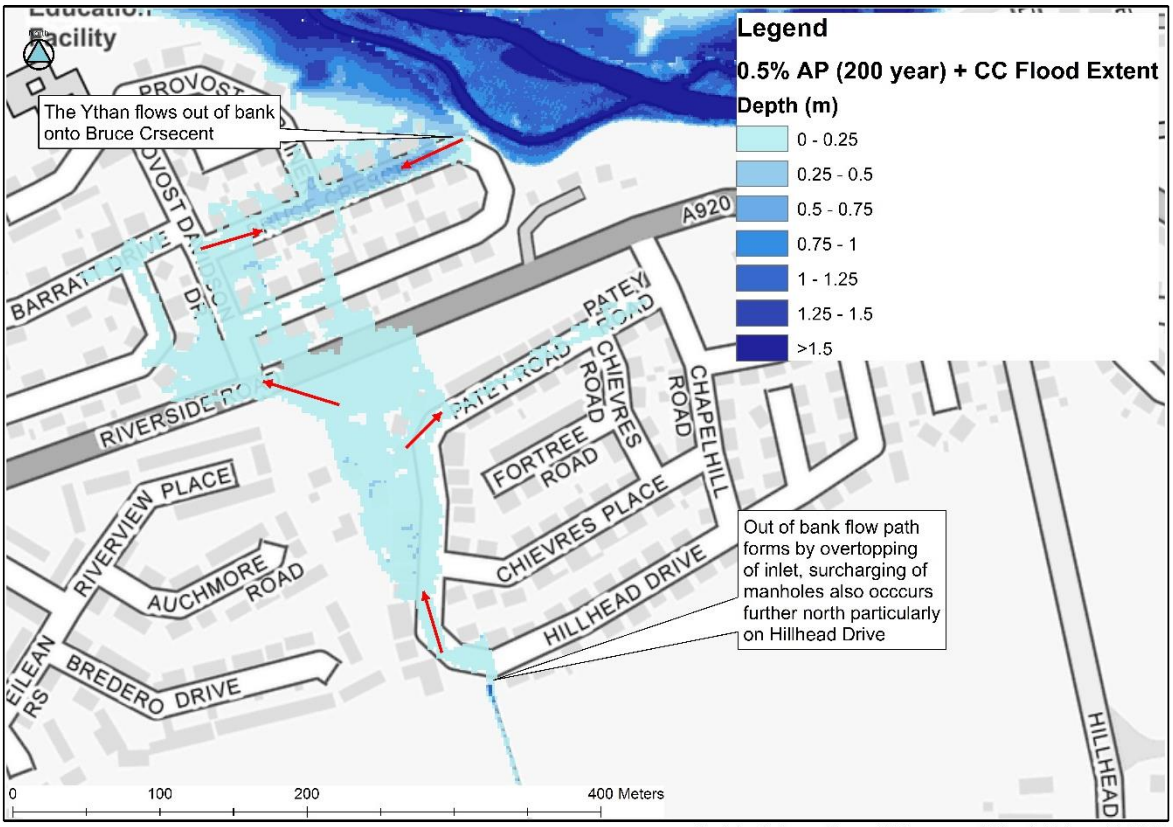


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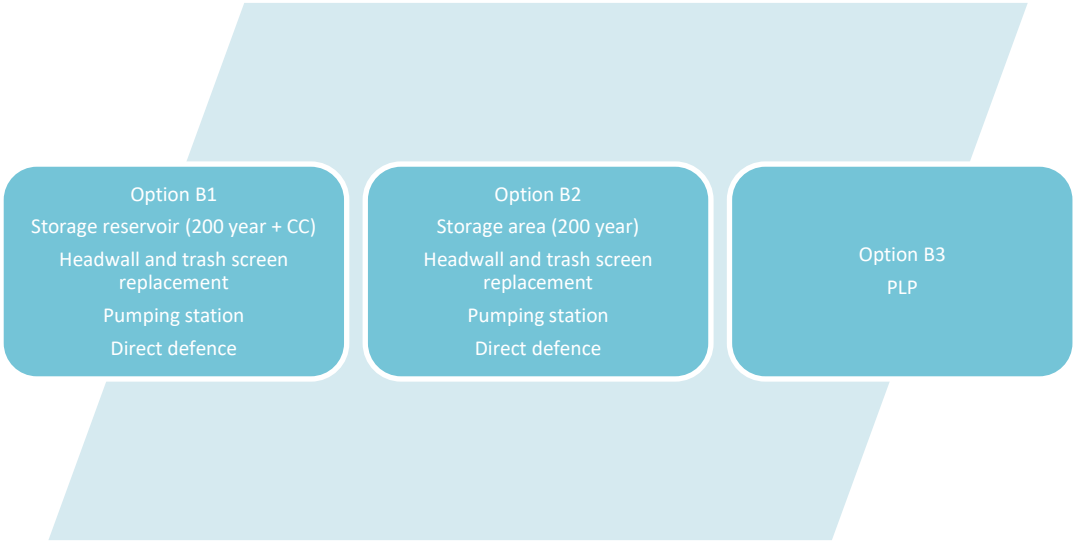
Figure 5-12: Flow paths within design area B - Hillhead Burn



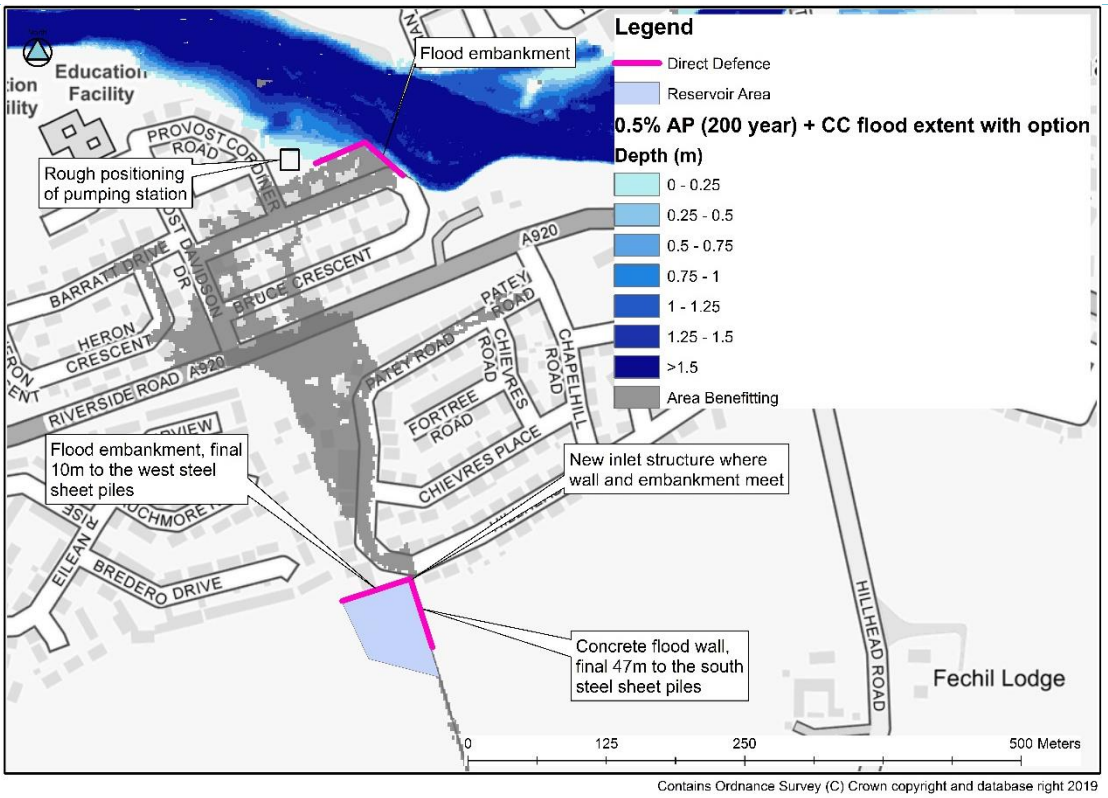
5.8.2.1 Option B1 - Storage protecting against 0.5% AP (200 year) plus climate change and headwall replacement at Hillhead inlet, pumping station on Hillhead sewer, trash screen replacement on Fortree inlet and direct defence on River Ythan

Option B1 - Storage protecting against 0.5% AP (200 year) plus climate change at Hillhead inlet, pumping station on Hillhead sewer and direct defence on River Ythan

Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of a formalised reservoir (>10,000m^3) cutting in to the left bank at the Hillhead culverted sewer inlet as well as an embankment at the north east of Bruce Crescent and a pumping station near the outlet of the sewer. A formalised reservoir results in higher enabling costs and an additional 0.5 m freeboard. The work includes the following:

- Reservoir installation on the left bank at the inlet (due to local plan this is utilised on the left bank only):
- Cut 22,334 m^3 of soil over an area of 4,646 m^2 on the left bank so that the base of the reservoir is at an invert level of 31.87 mAOD.
- Construct an embankment tying into high ground on the north west corner along the property boundaries and into the inlet structure for a length of 65 m with a maximum height of 2.88 m from the northern face including 1.1 m freeboard to a defence level of 36.43 mAOD.
- Construct a concrete wall tying into the inlet structure and high ground to the south for a distance of 46 m at a maximum height of 2.33 m including 0.8 m freeboard to a defence level of 36.13 mAOD.
- Placement of steel piling to protect the sides of the reservoir for the extent where the existing ground is higher than the defence level, for a length of 57 m.
- Replace the existing outfall, trash screen, headwall and wingwalls with a new inlet structure with an orifice pipe diameter of 0.25 m in order to limit to the 10% AP (10 year) flow (equivalent to a flow of 0.27 m^3/s). This has been selected as it is the highest flow before the inlet is overtopped.
- Install a flood embankment to the north east of Bruce Crescent to defend against the out of bank flow from the Ythan for a distance of approximately 95 m which ties into high ground either end of the embankment. The maximum embankment height will be 1.71 m with an embankment defence level of 7.50 mAOD including a 0.6 m freeboard.
- Due to the high water table and submerged outlet during high events, install a pumping station near the end of the culverted sewer, likely within the recreational area on the right bank of the Ythan with a pump capacity of 270 l/s. Pumps would be constructed underground in the large recreational space therefore would not impact aesthetics, currently there is a small utility building sitting over the culvert which could be utilised.
- Replacement of Fortree Burn inlet trash screen.



Standard of Protection (SoP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 0.51 m^3/s on Hillhead Burn and a flow of 263.2 m^3/s on the River Ythan.

Alternative quick wins / Preliminary investigations

NFM in the form of leaky bunds could provide the SoP required if enough were implemented along the Hillhead Burn upstream of the inlet and could be used to reduce the volume of cut and requirement for direct defences.

A full drainage study is required to investigate whether tackling the surface water issue will increase the SoP to the properties. This may also increase the capacity of the sewer and hence reduce the sizing of the reservoir.

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off or piling is likely to be needed to avoid seepage beneath all defences. Piling may be difficult in this material and other forms of cut-off may need to be investigated.

Services

A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access for storage reservoir: Use of public roads, unlikely closure will be required.
- Construction access for pumping station and embankment: Public road may require closure as well as public paths along the River Ythan.

Waste

- Expected quantity of waste material for embankment: 23,400 m^3
- Expected quantity of waste material for wall: 38 m^3
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and

prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located away from the river (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.

- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: Public footpath and road next to Bruce Crescent embankment and storage reservoir.
- Walls: Storage reservoir is in close proximity to wall along right bank of the burn.
- Houses: Properties on Bruce Crescent are in close proximity to embankment.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology.
- Ensure sediment transport from deposition in the storage area does not affect Sands of Forvie SSSI downstream of Ellon.
- No fish with the Fortree or Hillhead burns.
- Consultation required with SNH and SEPA.
- Rhododendron and Wall Cotoneaster were identified in the study area. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction. Any identified INNS near any watercourses should be reported to the local SISI officer.

Health and safety hazards noted

Construction in close proximity to Meiklemill Primary School.

Social and community issues

Some aesthetic issues as this option will require embankments up to 1.7 m high at Bruce Crescent which is on the upper limit of what is deemed acceptable in terms of wall heights in a community space, this may also limit the view to the watercourse. Land take of the farmland for the reservoir will be required therefore landowner engagement and buyout will be required.

Impact on other reaches

The works will not affect the watercourse or any subsequent watercourses.

Surface water

Surface water mapping has been produced for the entire extent of Ellon which includes Area B using JFlow (JBA's in-house software). This has indicated that a sizable amount of surface water flow passes down Hillhead Drive which may store behind the embankments. As JFlow makes use of the DTM and extracts the 5 year rainfall to account for drainage, it does not contain the actual drainage network, making it a high level, coarse analysis that may over-estimate the flow which has been calculated with a peak of 0.88 m^3/s. Drainage should be considered in this area in the form of piped drainage through the embankment with non-return valves or calculated additional pumping on the proposed pumping station which will be located in close proximity to this defence.

In order to achieve the above, it is recommended that a more detailed drainage study be conducted to give a more accurate representation of the drainage that will be required.

Additional information required

- A full drainage study is required for Area B to determine more detailed drainage and surface water issues.
- A detailed topographic survey.
- A detailed buried services survey, plotting their position with regards to site works
- A ground investigation.
- Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).

- The hydromorphology impact of the Bruce Crescent embankment would need to be assessed as part of the CAR licence.

Additional works required to account for increase in flow due to climate change

Consider implementing NFM on the upper catchment of both Hillhead and the Ythan to account for additional flows from climate change.

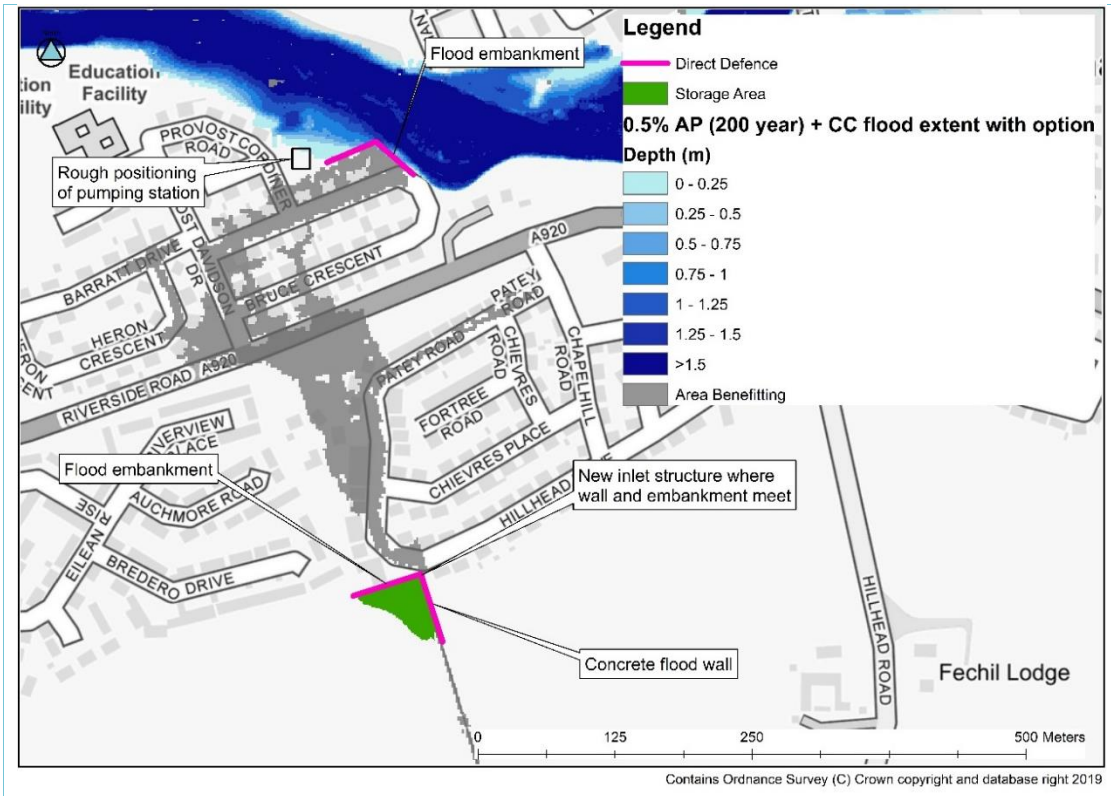
5.8.2.2 Option B2 - Storage protecting against 0.5% AP (200 year) and headwall replacement at Hillhead inlet, pumping station on Hillhead sewer, trash screen replacement on Fortree inlet and direct defence on River Ythan

Option B2 - Storage protecting against 0.5% AP (200 year) at Hillhead inlet, pumping station on Hillhead sewer and direct defence on River Ythan

Description

This option aims to provide a SoP of 0.5% AP (200 year) through construction of a storage area cutting into the left bank at the Hillhead culverted sewer inlet as well as an embankment at the north east of Bruce Crescent and a pumping station near the outlet of the sewer. The work includes the following:

- Storage installation on the left bank at the inlet (due to local plan this is utilised on the left bank only):
- Cut 8305 m^3 of soil over an area of 2323 m^2 on the left bank so that the base of the storage area is at an invert level of 31.87 mAOD. The storage area is designed to hold 8,985m^3 of water.
- Construct an embankment tying into high ground on the north west corner along the property boundaries and into the inlet structure for a length of 65 m with a maximum height on the north side of 2.8 m including 0.6 m freeboard to a defence level of 36.34 mAOD.
- Construct a concrete wall tying into the inlet structure and high ground to the south for a distance of 46 m at a maximum height on the eastern face of 2.25 m including 0.3 m freeboard to a defence level of 36.04 mAOD.
- Replace the existing outfall, trash screen, headwall and wingwalls with a new inlet structure with an orifice pipe diameter of 0.25 m in order to limit the flow to the 10% AP (10 year) flow (equivalent to a flow of 0.27 m^3/s). This has been selected as it is the highest flow before the inlet is overtopped.
- Install a flood embankment to the north-east of Bruce Crescent to defend against the out of bank flow from the Ythan for a distance of approximately 95 m which ties into high ground either end of the embankment. The maximum embankment height will be 1.71 m with an embankment defence level of 7.50 mAOD including a 0.6 m freeboard.
- Due to the high water table and submerged outlet during high events, install a pumping station near the end of the culverted sewer, likely within the recreational area on the right bank of the Ythan with a pump capacity of 270 l/s. Pumps would be constructed underground in the large recreational space therefore would not impact aesthetics, currently there is a small utility building sitting over the culvert which could be utilised.
- Replacement of Fortree Burn inlet trash screen.



Standard of Protection (SoP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) is achievable. This equates to a flow of 0.51 m^3/s on Hillhead Burn and a flow of 193.9 m^3/s on the River Ythan.

Alternative quick wins / Preliminary investigations

NFM in the form of leaky bunds could provide the SoP required if enough were implemented along the Hillhead Burn upstream of the inlet and could be used to reduce the volume of cut and requirement for direct defences.

A full drainage study is required to investigate whether tackling the surface water issue will increase the SoP to the properties. This may also increase the capacity of the sewer and hence reduce the sizing of the storage area.

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off or piling is likely to be needed to avoid seepage beneath all defences. Piling may be difficult in this material and other forms of cut-off may need to be investigated.

Services

A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access for storage reservoir: Use of public roads, unlikely closure will be required.
- Construction access for pumping station and embankment: Public road may require closure as well as public paths along the River Ythan.

Waste

- Expected quantity of waste material for embankment: 9,371 m^3
- Expected quantity of waste material for wall: 38 m^3
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located away from the river (at least c.10 m) and covered.

SEPA pollution prevention guidelines should be adhered to throughout the works.

- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: Public footpath and road next to Bruce Crescent embankment and storage reservoir.
- Walls: Storage reservoir in close proximity to wall along right bank of the Burn.
- Houses: Properties on Bruce Crescent in close proximity to embankment.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology.
- ensure sediment transport from deposition in the storage area does not affect Sands of Forvie SSSI downstream of Ellon.
- Consultation required with SNH and SEPA.
- Rhododendron and Wall Cotoneaster were identified in the study area. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction. Any identified INNS near any watercourses should be reported to the local SISI officer.

Health and safety hazards noted

Construction in close proximity to Primary School.

Social and community issues

Some aesthetic issues as this option will require embankments up to 1.7 m high at Bruce Crescent which is on the upper limit of what is acceptable in terms of wall heights in a community space, this may also limit the view to the watercourse. Land take of the farmland for the reservoir will be required therefore landowner engagement and buyout will be required.

Impact on other reaches

The works will not affect the watercourse or any subsequent watercourses.

Surface water

Surface water mapping has been produced for the entire extent of Ellon which includes Area B using JFlow. This has indicated that a sizable amount of surface water flow passes down Hillhead drive which may store behind the embankments. As JFlow makes use of the DTM, making it a high level, coarse analysis and does not contain the full drainage network it is likely that it is over-estimating the flow which has been calculated with a peak of 0.88 m^3/s. Drainage should be considered in this area in the form of piped drainage through the embankment with non-return valves or calculated additional pumping on the proposed pumping station which will be located in close proximity to this defence.

In order to achieve the above, it is recommended that a more detailed drainage study be conducted to give a more accurate representation of the drainage that will be required.

Additional information required

- A full drainage study is required for Area B to determine more detailed surface water issues.
- A detailed topographic survey.
- A detailed buried services survey, plotting their position with regards to site works
- A ground investigation.
- Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).
- The hydromorphology impact of the Bruce Crescent embankment would need to be assessed as part of the CAR licence.

Additional works required to account for increase in flow due to climate change

Consider implementing NFM on the upper catchment of both Hillhead and the Ythan to account for additional flows from climate change.

5.8.2.3 Option B3 - Property Level Protection (PLP)

Option B3 - Property Level Protection (PLP)
Description This option aims to provide an increase in SoP for all properties where possible by protecting them up to a maximum flood depth of 0.6 m. Beyond this water depth a buildings integrity can potentially be compromised. This option includes the survey, design and implementation of relevant PLP products to each property experiencing flooding. The number of properties expecting to benefit from PLP within Area B are as follows: • All 26 properties at risk during the 0.5% AP (200 year) plus climate change • All 19 properties at risk during the 0.5% AP (200 year)
Standard of Protection (SoP) PLP offers a variable standard of protection dependent on the property and expected flood depths. Importantly, the property with the lowest standard would be protected to a maximum of the 0.1% AP (1000 year) event, at which point water levels would overtop standard 0.6 m high PLP products.
Technical Issues All properties would require surveying by competent parties to determine which products are appropriate. Properties with non-standard or large entrances may require bespoke options which can significantly increase costs. The Scottish Government's Blueprint on PLP[10] should be considered when implementing this option. Due to no formal flood warning in the area all PLP options are assumed to be automatic.
Construction issues Some commercial properties may require bespoke PLP products and building remedial works to ensure the products work effectively. The installation and periodic replacement of PLP products on multiple properties may become a maintenance burden for the Council.
Environmental issues None identified.
Social and community issues Due to the highly engaged community PLP alone may not be an acceptable option. Residents are likely to expect more significant measures to be undertaken
Impact on other reaches There will be a negligible impact on other reaches due to a small diverted volume that would otherwise flow through the properties.
Additional information required • Public engagement meetings. • Flood risk reviews on each property.
Additional works required to account for increase in flow due to climate change Some properties identified as suitable for PLP may become unsuitable with increasing river flows. Additionally, some properties that are not expected to flood frequently enough to make PLP worthwhile at present may be expected to flood more frequently in the future.

10 Scottish Government (2014). Assessing the Flood Risk Management Benefits of Property Level Protection; Blueprint for Local Authorities and Scottish Water. Final Report v2.0. 13 November 2014

5.8.2.4 Option B4 - Storage protecting against 0.5% AP (200 year) at Hillhead inlet, pumping station on Hillhead sewer

Option B4 - Storage protecting against 0.5% AP (200 year) at Hillhead inlet, pumping station on Hillhead sewer

Description

This option aims to provide a SoP of 0.5% AP (200 year) through construction of a storage area cutting into the left bank at the Hillhead culverted sewer inlet as well as an embankment at the north east of Bruce Crescent and a pumping station near the outlet of the sewer. The work includes the following:

- Storage installation on the left bank at the inlet (due to local plan this is utilised on the left bank only):
- Cut 8305 m^3 of soil over an area of 2323 m^2 on the left bank so that the base of the storage area is at an invert level of 31.87 mAOD. The storage area is designed to hold 8,985m^3 of water.
- Construct an embankment tying into high ground on the north west corner along the property boundaries and into the inlet structure for a length of 65 m with a maximum height on the north side of 2.8 m including 0.6 m freeboard to a defence level of 36.34 mAOD.
- Construct a concrete wall tying into the inlet structure and high ground to the south for a distance of 46 m at a maximum height on the eastern face of 2.25 m including 0.3 m freeboard to a defence level of 36.04 mAOD.
- Replace the existing outfall, trash screen, headwall and wingwalls with a new inlet structure with an orifice pipe diameter of 0.25 m in order to limit the flow to the 10% AP (10 year) flow (equivalent to a flow of 0.27 m^3/s). This has been selected as it is the highest flow before the inlet is overtopped.
- Due to the high water table and submerged outlet during high events, install a pumping station near the end of the culverted sewer, likely within the recreational area on the right bank of the Ythan with a pump capacity of 270 l/s. Pumps would be constructed underground in the large recreational space therefore would not impact aesthetics, currently there is a small utility building sitting over the culvert which could be utilised.
- Replacement of Fortree Burn inlet trash screen.

Standard of Protection (SoP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) is achievable. This equates to a flow of 0.51 m^3/s on Hillhead Burn and a flow of 193.9 m^3/s on the River Ythan.

Alternative quick wins / Preliminary investigations

NFM in the form of leaky bunds could provide the SoP required if enough were implemented along the Hillhead Burn upstream of the inlet and could be used to reduce the volume of cut and requirement for direct defences.

A full drainage study is required to investigate whether tackling the surface water issue will increase the SoP to the properties. This may also increase the capacity of the sewer and hence reduce the sizing of the storage area.

Geotechnical issues

- A full GI will be required at a later stage in the project.
- A cut-off or piling is likely to be needed to avoid seepage beneath all defences. Piling may be difficult in this material and other forms of cut-off may need to be investigated.

Services

A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access for storage reservoir: Use of public roads, unlikely closure will be required.
- Construction access for pumping station: Public road may require closure as well as public paths along the River Ythan.

Waste

- Expected quantity of waste material for embankment: 8,780 m^3

- Expected quantity of waste material for wall: 38 m^3
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located away from the river (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.
- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: Public footpath and road next to storage area.
- Walls: Storage area in close proximity to wall along right bank of the Burn.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology.
- ensure sediment transport from deposition in the storage area does not affect Sands of Forvie SSSI downstream of Ellon.
- Consultation required with SNH and SEPA.
- Rhododendron and Wall Cotoneaster were identified in the study area. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction. Any identified INNS near any watercourses should be reported to the local SISI officer.

Health and safety hazards noted

N/A

Social and community issues

Land take of the farmland for the reservoir will be required therefore landowner engagement and buyout will be required.

Impact on other reaches

The works will not affect the watercourse or any subsequent watercourses.

Surface water

Surface water mapping has been produced for the entire extent of Ellon which includes Area B using JFlow. This has indicated that a sizable amount of surface water flow passes down Hillhead drive which may store behind the embankments. As JFlow makes use of the DTM, making it a high level, coarse analysis and does not contain the full drainage network it is likely that it is over-estimating the flow which has been calculated with a peak of 0.88 m^3/s. Drainage should be considered in this area in the form of piped drainage with non-return valves or calculated additional pumping on the proposed pumping station which will be located in close proximity to Bruce Crescent.

In order to achieve the above, it is recommended that a more detailed drainage study be conducted to give a more accurate representation of the drainage that will be required.

Additional information required

- A full drainage study is required for Area B to determine more detailed surface water issues.
- A detailed topographic survey.
- A detailed buried services survey, plotting their position with regards to site works
- A ground investigation.
- Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).

Additional works required to account for increase in flow due to climate change

Consider implementing NFM on the upper catchment of both Hillhead and the Ythan to account for additional flows from climate change.

5.8.2.5 Scottish Water Model Data

The Scottish Water S16 mapping also shows the drainage risk to the Hillhead and Fortree areas. Figure 5-13 below shows the drainage risk during the 3.3% AP (30 year) and 0.5% AP (200 year) events, the mapping is filtered to a minimum depth of 0.1 m.

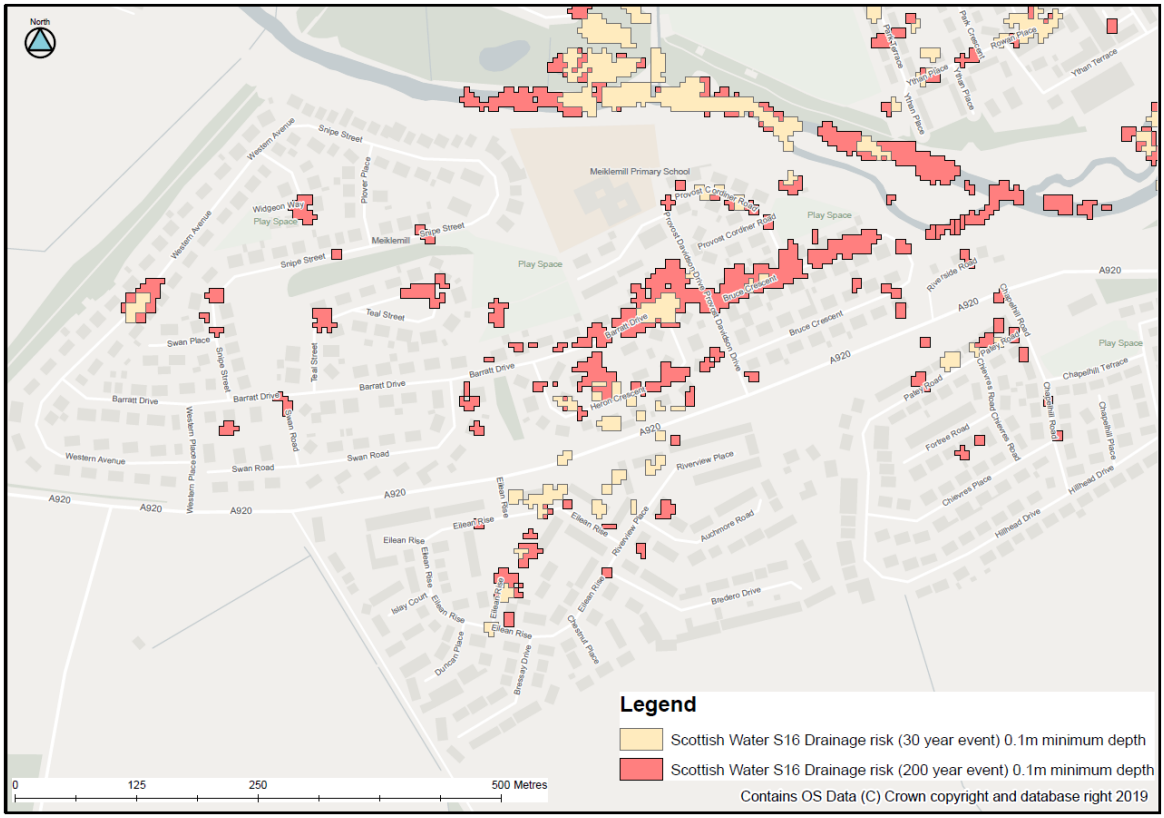


Figure 5-13: Scottish Water S16 mapping

Figure 5-13 corroborates the perceived drainage risk at Hillhead therefore a recommendation will be made for a full drainage impact assessment to be conducted as a result of this study in order to ensure all risks are properly assessed before a full option can be detailed in this area.

5.8.3 Design area C - Old Bridge of Ellon and Bridge of Ardlethen

Properties are estimated to flood in the vicinity of Ardlethen Bridge and the Old Bridge of Ellon due to out of bank flow from the River Ythan. Figure 5-14 and Figure 5-15 shows the flow pathways and properties at risk during the 0.5% AP (200 year) event plus climate change. Flooding commences from the 1% AP (100 year) event at the Old Bridge of Ellon and commences from the 2% AP (50 year) event at Bridge of Ardlethen.

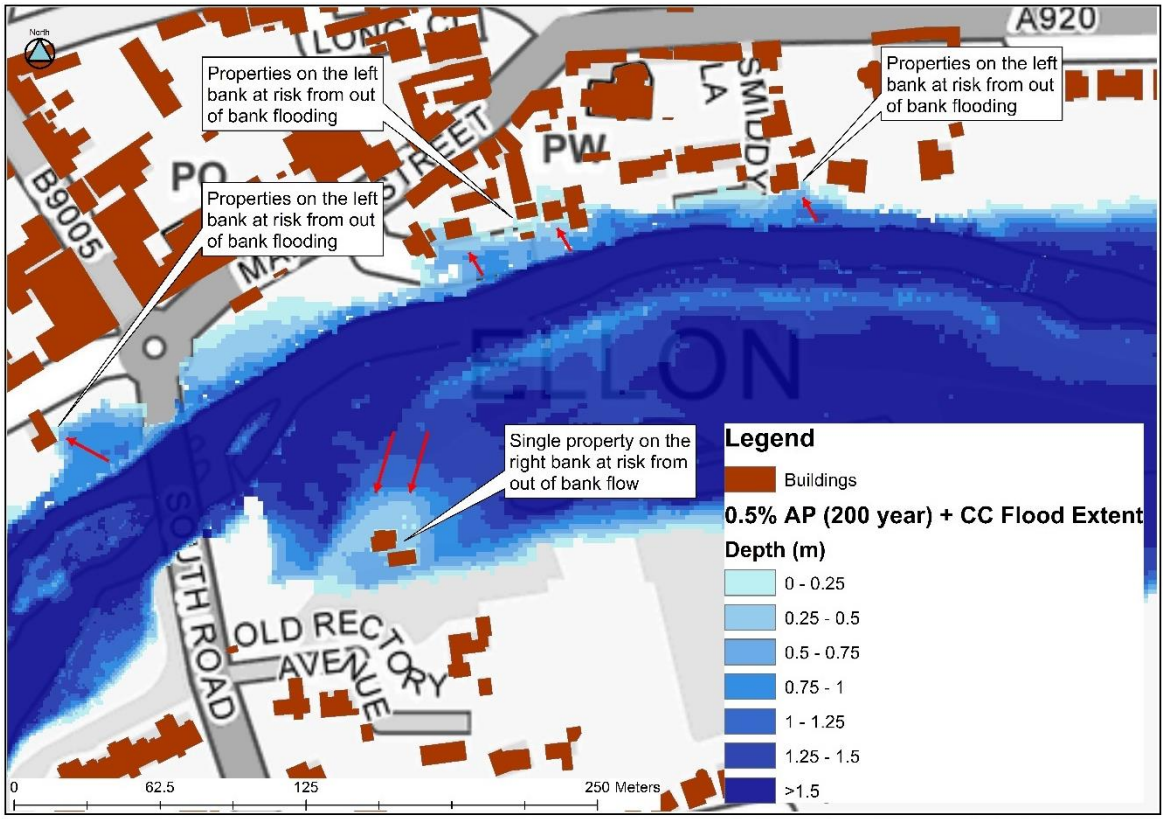


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Figure 5-14: Flow paths within design area C - Old Bridge of Ellon

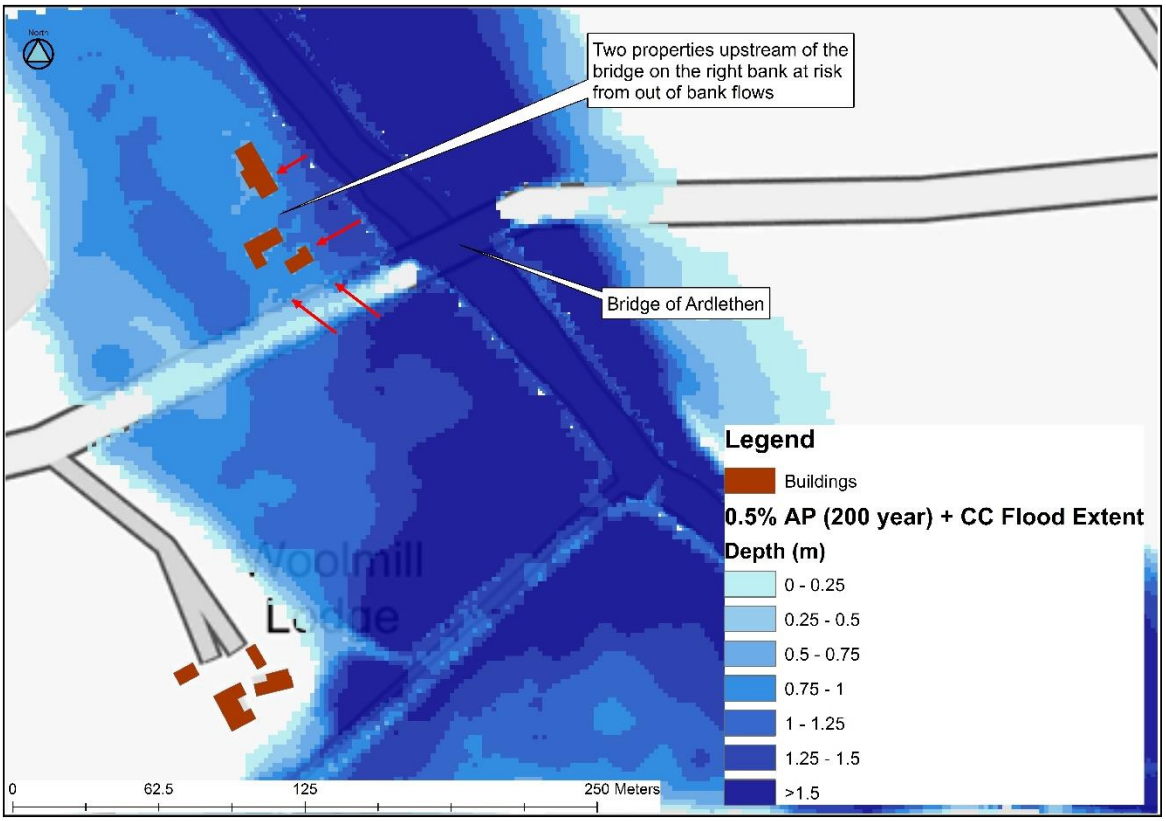

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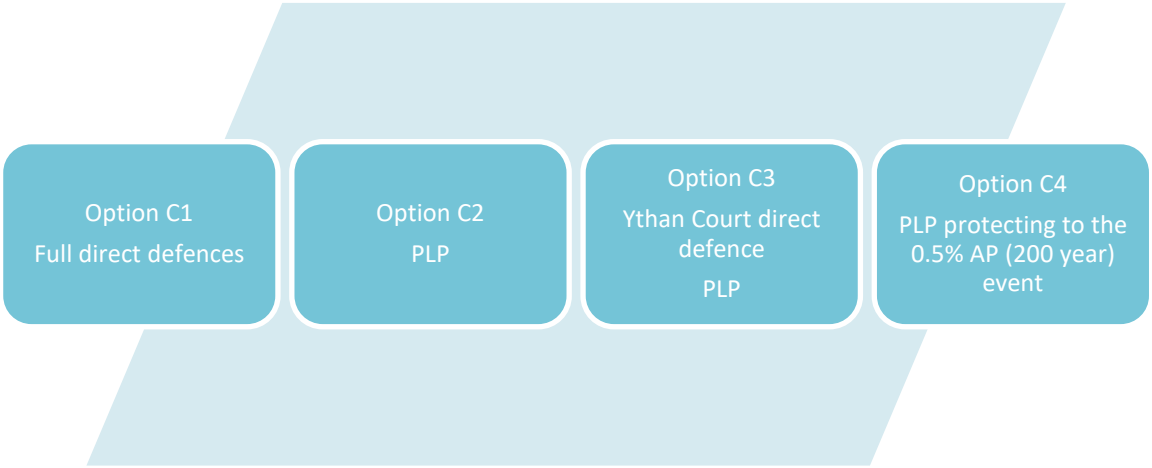
Figure 5-15: Flow paths within design area C - Bridge of Ardlethen



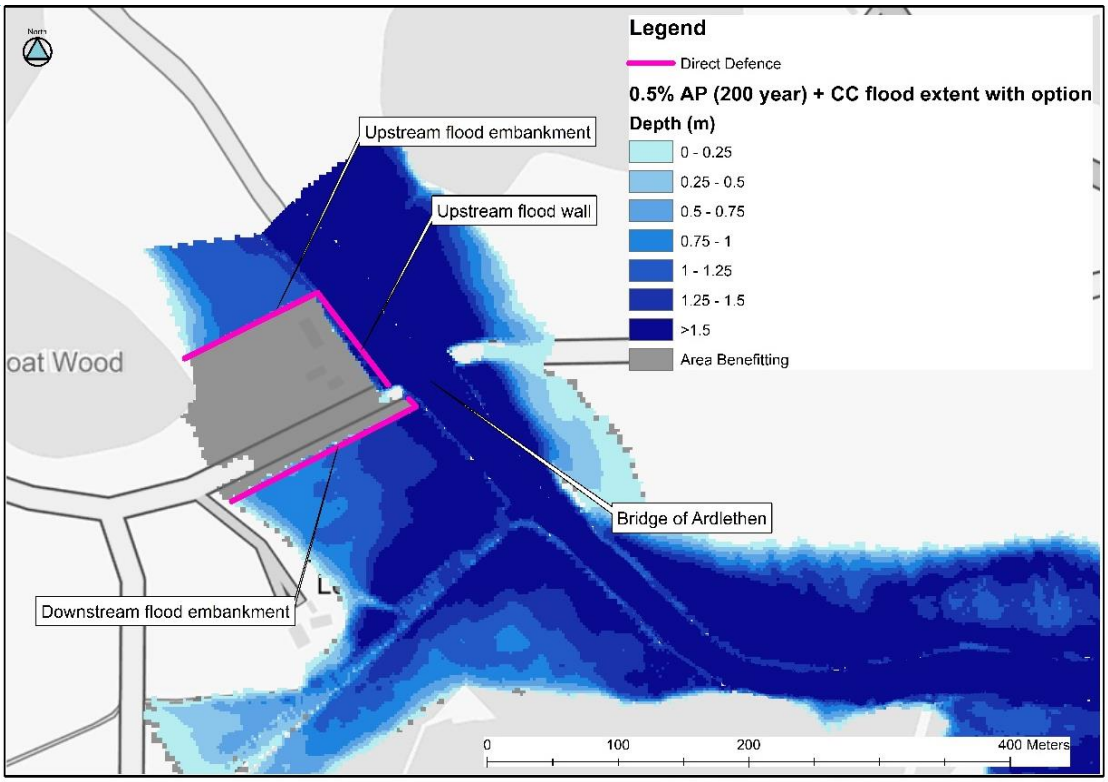
5.8.3.1 Option C1 - Direct defences on both banks around Old Bridge of Ellon and the right bank at Ardlethen Bridge

Option C1 - Direct defences on both banks around Old Bridge of Ellon and the right bank at Ardlethen Bridge

Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of a multitude of different direct defences (embankments and walls) to protect all the properties at risk. This includes properties around the Old Bridge of Ellon as well as the two properties upstream of Bridge of Ardlethen. The work includes the following:

- Install a flood embankment to the north west of the properties at Bridge of Ardlethen for a distance of approximately 113 m which ties into high ground on the west and is sloped towards the channel on the east. The maximum embankment height will be 1.93 m with an embankment defence level of 11.70 mAOD including a 0.6 m freeboard.
- Install a flood embankment to the downstream of Bridge of Ardlethen on the right bank, running along the side of the road for a distance of approximately 167 m which ties into high ground on the west and ties into the bridge on the east. The maximum embankment height will be 2.28 m with an embankment defence level of 11.10 mAOD including a 0.6 m freeboard.
- Install an 89 m length concrete wall on the right bank of the River Ythan between the channel and the upstream properties at the Bridge of Ardlethen. The wall has a defence level of 11.40 mAOD. This gives an average height of 2.2 m ranging from 1.76 m to 2.43 m including a 0.3 m freeboard.
- Install a flood embankment to protect the single property on the right bank of the Ythan downstream of Bridge of Ellon from 3 different sides for a distance of approximately 125 m which ties into high ground either end. The maximum embankment height will be 1.92 m with an embankment defence level varying from 6.50 mAOD to 6.20 mAOD including a 0.6 m freeboard.
- Install a 61 m length concrete wall on the left bank of the River Ythan upstream of the Old Bridge of Ellon. The wall has a defence level of 6.60 mAOD. This gives an average height of 1.3 m ranging from 1.12 m to 1.41 m including a 0.3 m freeboard.
- Install a 217 m length concrete wall on the left bank of the River Ythan downstream of the Old Bridge of Ellon, including Ythan Court. The wall has a varying height, stepping down at 0.1 m intervals with a defence level of 6.00 mAOD to 5.70 mAOD. This gives an average height of 1.1 m ranging from 0.49 m to 1.47 m including a 0.3 m freeboard.



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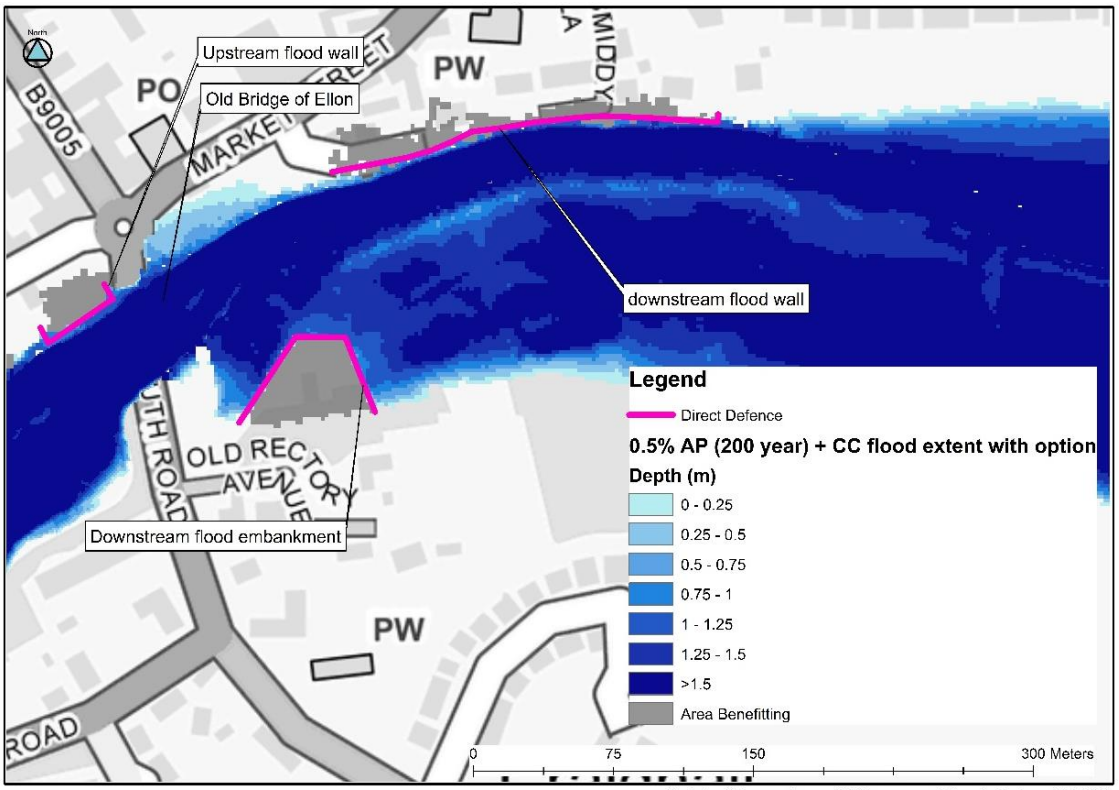

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Standard of Protection (SoP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 263.15 m^3/s.

Alternative quick wins / Preliminary investigations

Implementation of natural flood management upstream of Ellon could provide a more sustainable solution for the currently high standard of protection in place for Area C.

Geotechnical issues • A full GI will be required at a later stage in the project. • A cut-off or piling is likely to be needed to avoid seepage beneath the defences. Piling may be difficult in this material and other forms of cut-off may need to be investigated.
Services A full survey identifying overhead and underground services will be required at a later stage of the project.
Construction access • Construction access for properties around the Old Bridge: Simple construction access via the roads and footpaths in the area. Private and public road closure during construction, public footpath on the right bank may require closure. An investigation of a reasonable space for site buildings and plant will be required. • Construction access for properties around Bridge of Ardlethen: Private road and potential public road closure during construction.
Waste • Expected quantity of waste material for embankment: 3124 m^3 • Expected quantity of waste material for wall: 198 m^3 • Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste. • Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located away from the river (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works. • Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.
Proximity of defence to other structures • Private and Public: Old Bridge of Ellon area construction is near public footpaths and roads. Bridge of Ardlethen area construction in close proximity to public and private roads. • Walls: Ythan Court defence is in close proximity to a wall separating the footpath along the channel bank to the road. Upstream of Old Bridge of Ellon is in close proximity to the bridge abutment and wall holding up high ground. • Upstream of Bridge of Ardlethen is in close proximity to Bridge of Ardlethen abutments. • Houses: All direct defences are in close proximity to the properties they are defending. • Both Old Bridge of Ellon and Bridge of Ardlethen are listed buildings therefore permission may be required to conduct work in close proximity to them.
Environmental issues • Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology. • Consultation required with SNH and SEPA. • Defences while in the floodplain are set back from the watercourse. • Rhododendron and Wall Cotoneaster were identified in the study area. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction. Any identified INNS near any watercourses should be reported to the local SISI officer.
Health and safety hazards noted Public access.
Social and community issues Some aesthetic issues as this option will require embankments up to 2.43 m high which is on the upper limit of what is deemed acceptable in terms of wall heights in a community space. Obstruction of the view from residential properties to the river using a large direct defence

will require consultation with the property owners. Construction of direct defences may require tying into Bridge of Ardlethen slightly obscuring some of the aesthetic benefits.
Impact on other reaches The works have minimal impacts on other tributaries connecting into the Ythan.
Additional information required • A detailed topographic survey. • A detailed buried services survey, plotting their position with regards to site works. • A ground investigation. • Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).
Additional works required to account for increase in flow due to climate change Consider constructing the embankments and walls so that a wall could be added or replaced in the future to defend against higher levels. Consider upstream land management with NFM measures to control overland runoff.

5.8.3.2 Option C2 - Property Level Protection (PLP)

Option C2 - Property Level Protection (PLP)
Description This option aims to provide an increase in SoP for all properties where possible by protecting them up to a maximum flood depth of 0.6 m. Beyond this water depth a buildings integrity can potentially be compromised. This option includes the survey, design and implementation of relevant PLP products to each property experiencing flooding. The number of properties expecting to benefit from PLP within Area C are as follows: • 5 properties out of the 6 at risk during the 0.5% AP (200 year) plus climate change • All 4 properties at risk during the 0.5% AP (200 year)
Standard of Protection (SoP) PLP offers a variable SoP dependent on the property and expected flood depths. Importantly, the property with the lowest standard would be protected to a maximum of the 0.5% AP (200 year) plus climate change event, at which point water levels would overtop standard 0.6 m high PLP products.
Technical Issues All properties would require surveying by competent parties to determine which products are appropriate. Properties with non-standard or large entrances may require bespoke options which can significantly increase costs. The Scottish Government's Blueprint on PLP[11] should be considered when implementing this option. Due to no formal flood warning in the area all PLP options are assumed to be automatic.
Construction issues Some commercial properties may require bespoke PLP products and building remedial works to ensure the products work effectively. The installation and periodic replacement of PLP products on multiple properties may become a maintenance burden for the Council.
Environmental issues None identified.
Social and community issues Due to the highly engaged community PLP alone may not be an acceptable option. Residents are likely to expect more significant measures to be undertaken
Impact on other reaches There will be a negligible impact on other reaches due to a small diverted volume that would

11 Scottish Government (2014). Assessing the Flood Risk Management Benefits of Property Level Protection; Blueprint for Local Authorities and Scottish Water. Final Report v2.0. 13 November 2014

otherwise flow through the properties.

Additional information required

- Public engagement meetings.
- Flood risk reviews on each property.

Additional works required to account for increase in flow due to climate change

Some properties identified as suitable for PLP may become unsuitable with increasing river flows. Additionally, some properties that are not expected to flood frequently enough to make PLP worthwhile at present may be expected to flood more frequently in the future.

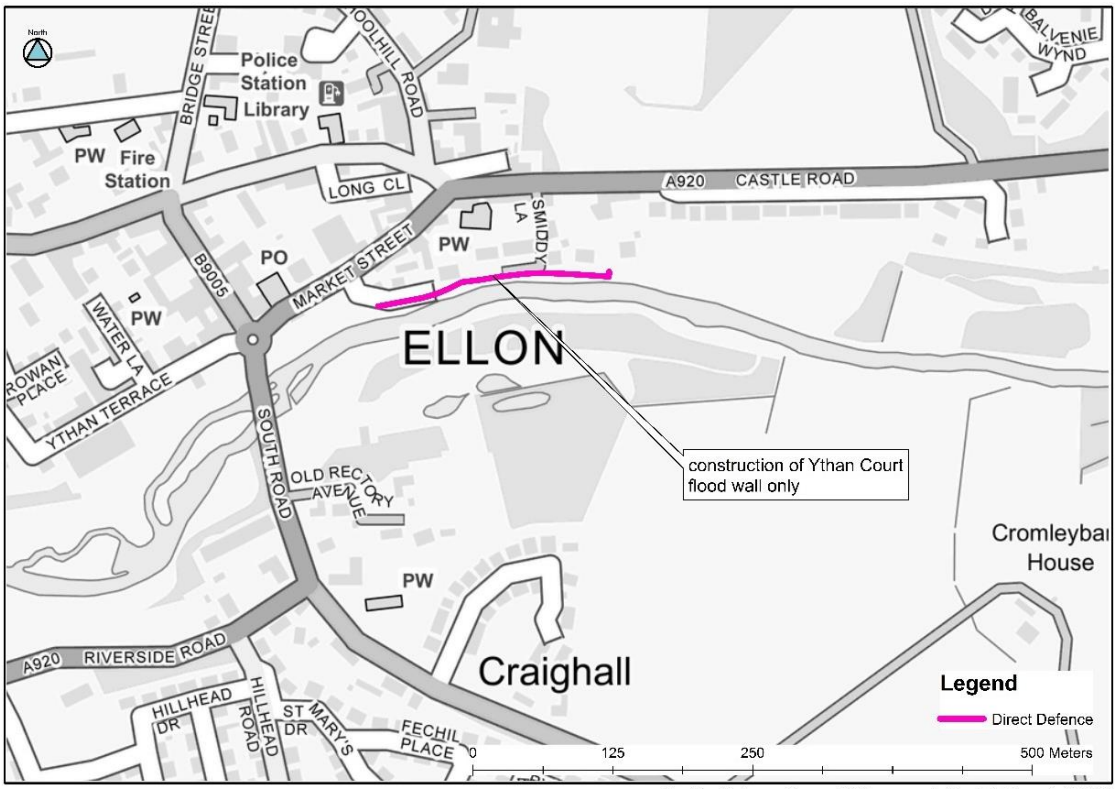
5.8.3.3 Option C3 - Ythan Court embankment and Property Level Protection (PLP) to remaining properties

Option C3 - Ythan Court embankment and Property Level Protection (PLP) to remaining properties

Description

This option aims to provide a SoP of 0.5% AP (200 year) targeting the location which has the most properties at risk to protect and a known history of flooding by constructing a wall at Ythan Court while all other properties within Area C would have PLP installed. The work includes the following:

- Install a 217 m length concrete wall on the left bank of the River Ythan downstream of the Old Bridge of Ellon, including Ythan Court. The wall has a varying height, stepping down at 0.1 m intervals with a defence level of 6.00 mAOD to 5.70 mAOD. This gives an average height of 1.1 m ranging from 0.49 m to 1.47 m including a 0.3 m freeboard.
- 4 properties provided with PLP to protect to the 0.5% AP (200 year)



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Standard of Protection (SoP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 263.15 m^3/s.

Alternative quick wins / Preliminary investigations

Implementation of natural flood management upstream of Ellon could provide a more sustainable solution for the currently high standard of protection currently in place for Area C.

Geotechnical issues • A full GI will be required at a later stage in the project. • A cut-off or piling is likely to be needed to avoid seepage beneath the defence. Piling may be difficult in this material and other forms of cut-off may need to be investigated.
Services A full survey identifying overhead and underground services will be required at a later stage of the project.
Construction access Construction access for properties around the Old Bridge: Simple construction access via the roads and footpaths in the area. Private and public road closure during construction, public footpath on the right bank may require closure. An investigation of a reasonable space for site buildings and plant will be required.
Waste • Expected quantity of waste material for wall: 117 m^3 • Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste. • Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located away from the river (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works. • Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.
Proximity of defence to other structures Potential constructability issues due to the following • Private and Public: construction is near public footpaths and roads. • Walls: Ythan Court defence is in close proximity to a wall separating the footpath along the channel bank to the road. • Houses: Direct defence is in close proximity to the properties it is defending.
Environmental issues • Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology. • Consultation required with SNH and SEPA. • Rhododendron and Wall Cotoneaster were identified in the study area. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction. Any identified INNS near any watercourses should be reported to the local SISI officer.
Health and safety hazards noted Public access.
Social and community issues Some aesthetic issues as this option will require a wall up to 1.47 m high which is on the upper limit of what is deemed acceptable in terms of wall heights in a community space. Obstruction of the view from residential properties to the river using a large direct defence will require consultation with the property owners.
Impact on other reaches The works have minimal impacts on other tributaries connecting into the Ythan. Defence is set back from the watercourse.
Additional information required • A detailed topographic survey. • A detailed buried services survey, plotting their position with regards to site works.

• A ground investigation. • Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).
Additional works required to account for increase in flow due to climate change Consider constructing the wall so that it may be adapted in the future to defend against higher levels. Consider upstream land management with NFM measures to control overland runoff.

5.8.3.4 Option C4 - Property Level Protection (PLP) protecting against 0.5% AP (200 year) event

Option C4 - Property Level Protection (PLP) protecting against 0.5% AP (200 year) event
Description This option aims to provide an increase in SoP for all properties where possible by protecting them up to a maximum flood depth of 0.6 m. Beyond this water depth a buildings integrity can potentially be compromised. This option includes the survey, design and implementation of relevant PLP products to each property experiencing flooding. The number of properties expecting to benefit from PLP within Area C are as follows: • All 4 properties at risk during the 0.5% AP (200 year)
Standard of Protection (SoP) PLP offers a variable SoP dependent on the property and expected flood depths. Importantly, the property with the lowest standard would be protected to a maximum of the 0.5% AP (200 year) event, at which point water levels would overtop standard 0.6 m high PLP products.
Technical Issues All properties would require surveying by competent parties to determine which products are appropriate. Properties with non-standard or large entrances may require bespoke options which can significantly increase costs. The Scottish Government's Blueprint on PLP[12] should be considered when implementing this option. Due to no formal flood warning in the area all PLP options are assumed to be automatic.
Construction issues Some commercial properties may require bespoke PLP products and building remedial works to ensure the products work effectively. The installation and periodic replacement of PLP products on multiple properties may become a maintenance burden for the Council.
Environmental issues None identified.
Social and community issues Due to the highly engaged community PLP alone may not be an acceptable option. Residents are likely to expect more significant measures to be undertaken
Impact on other reaches There will be a negligible impact on other reaches due to a small diverted volume that would otherwise flow through the properties.
Additional information required • Public engagement meetings. • Flood risk reviews on each property.
Additional works required to account for increase in flow due to climate change Some properties identified as suitable for PLP may become unsuitable with increasing river flows. Additionally, some properties that are not expected to flood frequently enough to make PLP worthwhile at present may be expected to flood more frequently in the future.

12 Scottish Government (2014). Assessing the Flood Risk Management Benefits of Property Level Protection; Blueprint for Local Authorities and Scottish Water. Final Report v2.0. 13 November 2014

5.8.4 Design area D - The Meadows and Broomies Burn

In order to protect against the 0.5% AP (200 year) event plus climate change at both the properties within The Meadows and the single property at risk on the Broomies Burn, out of bank flow pathways from the River Ythan extent in these locations requires alleviation. Figure 5-16 shows the flow pathways and properties at risk during the 0.5% AP (200 year) event plus climate change. Flooding commences from the 1% AP (100 year) event at The Meadows and the 0.5% AP (200 year) on Broomies Burn.

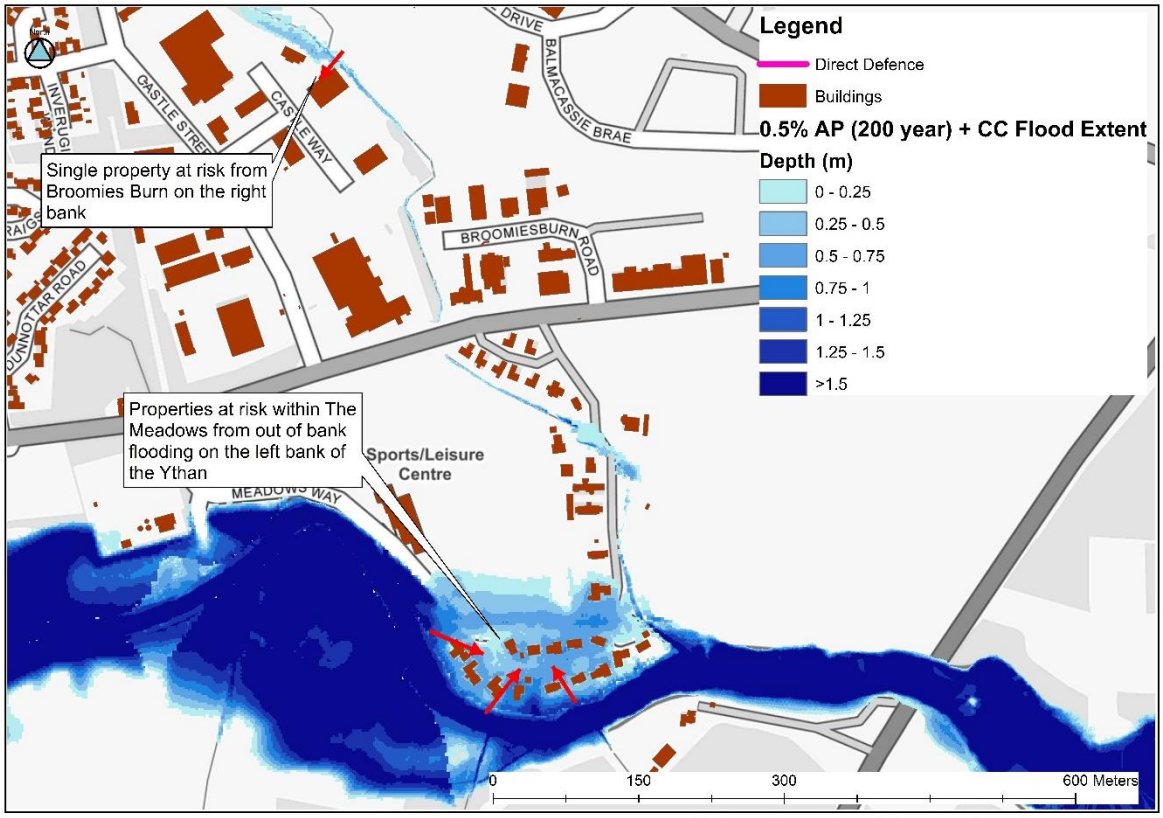

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Figure 5-16: Flow paths within design area D - The Meadows and Broomies Burn

Option D1 Direct defences	Option D2 PLP	Option D3 PLP protecting to the 0.5% AP (200 year) event

5.8.4.1 Option D1 - Direct defences on Broomies Burn and around The Meadows

Option D1 - Direct defences on Broomies Burn and around The Meadows

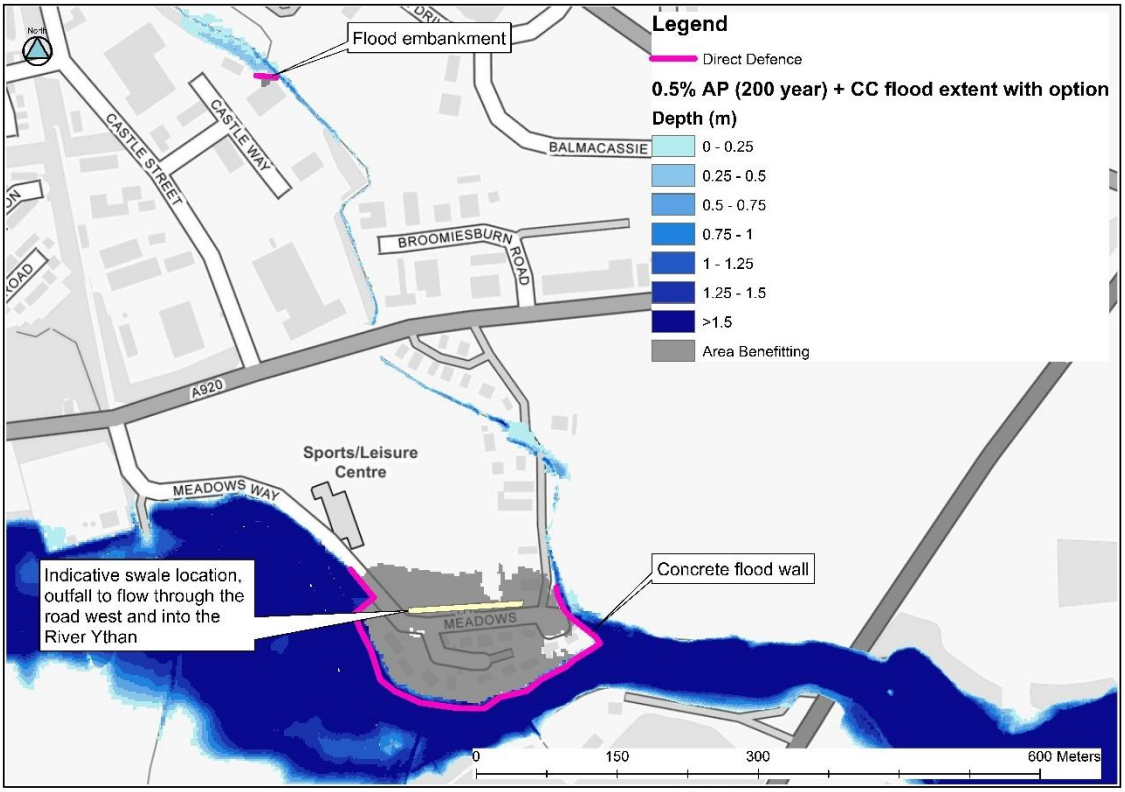
Description

This option aims to provide a SoP of 0.5% AP (200 year) plus climate change through construction of an embankment protecting the property on the right bank of Broomies Burn and a wall to protect the properties within The Meadows. The work includes the following:

- Install a flood embankment on the right bank of Broomies Burn to protect the property on

Castle Way for a length of 8.5 m which ties into high ground at either end. The maximum embankment height will be 0.83 m with an embankment defence level of 19.56 mAOD including a 0.6 m freeboard.

- Install a 485 m length concrete wall on the left bank of the River Ythan between 40 m along Meadows Way, around The Meadows estate, ending 80 m up Broomies Burn. The wall has a stepped defence level varying with a drop of 0.1 m at a time of 4.90 mAOD to 4.30 mAOD. This gives an average height of 1.99 m ranging from 0.58 m to 2.81 m including a 0.3 m freeboard.
- Construct a swale to collect the surface water flow from the playing field into The Meadows estate. Based on initial high level surface water modelling the swale is required to hold 1369 m^3 of water therefore pricing for 125 m length, 7.5 m wide and 1.5 m deep has been taken forward. A pipe outfall fitted with a non-return valve will be constructed to drain the water into the River Ythan.



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Standard of Protection (SoP)

Modelling of the above option indicates that a SoP of 0.5% AP (200 year) plus climate change is achievable. This equates to a flow of 263.15 m^3/s on the River Ythan and 5.51 m^3/s on Broomies Burn.

Alternative quick wins / Preliminary investigations

Successful implementation of NFM on the upper catchment of Broomies and the River Ythan may reduce flows and hence wall heights.

A drainage study of the area may help to reduce the known surface water issues particularly flowing through the playing fields, this could reduce the land runoff and increase the SoP of the properties.

Geotechnical issues

- A full GI will be required at a later stage in the project.
- Piling is likely to be required on the flood wall to avoid seepage beneath the defence. Piling may be difficult in this material and other forms of cut-off may need to be investigated.

Services

- A full survey identifying overhead and underground services will be required at a later stage of the project.

Construction access

- Construction access to The Meadows: Construction access initially through the public road then use of the private path on the river bank, likely for path closure and potential for compaction of the area to allow plant onto the site. Closure of Meadows Way during construction in this section.
- Construction access for Castle Way property: Public road then use of the industrial buildings car park for site and construction traffic, closure will be required in this area.

Waste

- Expected quantity of waste material for embankment: 33 m^3
- Expected quantity of waste material for wall: 262 m^3
- Nature (inert, non-hazardous, hazardous): It is unknown as to the level of contamination to the soil from industry therefore it will require testing as to whether it is hazardous or non-hazardous waste.
- Proposed disposal: All waste produced during construction should be contained and prevented from entering the watercourse. Stockpiles of soil and non-toxic spoil and construction waste should be located away from the river (at least c.10 m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.
- Any waste materials removed from the site must be disposed of at a suitably licensed or exempt waste management facility under the Waste Management Licensing (Scotland) Regulations 2011. All waste should be carried off site by registered carriers and should be aware of the furnishing and keeping of waste transfer notes.

Proximity of defence to other structures

- Private and Public: The Meadows construction is near public roads as well as a private footpath along the river bank. Construction of the Castle Way embankment is in close proximity to a private car park and private land.
- Walls: No walls in close proximity to the defences.
- Houses: Flood wall runs along property boundaries in The Meadows.

Environmental issues

- Additional surveys and assessments may be required for otter, fish, habitat, bats (works affecting trees, walls, built structures and bridges), breeding birds, water quality, flow and hydromorphology in particular assessing any issues on the right bank of the Ythan from construction of The Meadows direct defence
- Consultation required with SNH and SEPA.
- Rhododendron and Wall Cotoneaster were identified in the study area. It is an offense to spread these invasive non-native species therefore control measures should be put in place during construction. Any identified INNS near any watercourses should be reported to the local SISI officer.

Health and safety hazards noted

Flood wall in close proximity to potentially unstable banks on the Ythan.

Social and community issues

Some aesthetic issues as this option will require walls up to 2.81 m high which is on the upper limit of what is deemed acceptable in terms of wall heights in a community space. High walls are likely to be intrusive causing obstruction of the view from residential properties to the river using a large direct defence will require consultation with the property owners.

Impact on other reaches

The works have minimal impacts on other tributaries connecting into the Ythan.

Surface water

It is known that The Meadows is subject to a risk of flooding from surface water flows via the playing fields to the north of the estate. An assessment of the surface water runoff which affects The Meadows was investigated, applying rainfall to the 2D grid in TUFLOW. Two different events were investigated, a worst case 3 hour summer storm event and a 17 hour winter storm event. As it is unknown whether the pitch drainage is effective or not due to recurring issues with surface water in this area, the playing fields were given losses on par with an urban catchment therefore a reduction of 30% was applied to the rainfall rather than a higher loss percentage for rural.

After testing it was calculated that a volume of 1370 m^3 flowed into The Meadows estate from the playing fields. An assumption was made that any flow above the A920 was either captured within the Broomies Burn or within the drainage network.

This gave an initial indication of costing however it is recommended that a full surface water study be conducted before finalising the sizing of the swale and outfall, this may involve the need for a pumping station if flows were to greatly increase.

Additional information required

- A detailed topographic survey.
- A detailed buried services survey, plotting their position with regards to site works.
- A ground investigation.
- Authorisation from SEPA will be required prior to construction under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) (CAR).
- The discharge of surface water from the swale shall conform with the General Binding Rule (GBR) 6 of CAR. SEPAs CAR Practical Guide should be consulted further for more information[13].

Additional works required to account for increase in flow due to climate change

Consider upstream land management with NFM measures to control overland runoff.

Consider constructing the walls so that they may be adapted in the future for increased flows.

5.8.4.2 Option D2 - Property Level Protection (PLP)

Option D2 - Property Level Protection (PLP)

Description

This option aims to provide an increase in SoP for all properties where possible by protecting them up to a maximum flood depth of 0.6 m. Beyond this water depth a buildings integrity can potentially be compromised. This option includes the survey, design and implementation of relevant PLP products to each property experiencing flooding.

The number of properties expecting to benefit from PLP within Area D are as follows:

- 13 properties out of the 14 at risk during the 0.5% AP (200 year) plus climate change.
- 7 properties at risk during the 0.5% AP (200 year).

Standard of Protection (SoP)

PLP offers a variable SoP dependent on the property and expected flood depths. Importantly, the property with the lowest standard would be protected to a maximum of the 0.5% AP (200 year) plus climate change event, at which point water levels would overtop standard 0.6 m high PLP products.

Technical Issues

All properties would require surveying by competent parties to determine which products are appropriate. Properties with non-standard or large entrances may require bespoke options which can significantly increase costs.

The Scottish Government's Blueprint on PLP[14] should be considered when implementing this option.

Due to no formal flood warning in the area all PLP options are assumed to be automatic.

Construction issues

Some commercial properties may require bespoke PLP products and building remedial works to ensure the products work effectively.

The installation and periodic replacement of PLP products on multiple properties may become a maintenance burden for the Council.

Environmental issues

None identified.

13 SEPA, The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended), A Practical Guide, Version 8.3, February 2019

14 Scottish Government (2014). Assessing the Flood Risk Management Benefits of Property Level Protection; Blueprint for Local Authorities and Scottish Water. Final Report v2.0. 13 November 2014

Social and community issues Due to the highly engaged community PLP alone may not be an acceptable option. Residents in this area have expressed that they want more of a hard-engineered approach to protect their properties.
Impact on other reaches There will be a negligible impact on other reaches due to a small diverted volume that would otherwise flow through the properties.
Additional information required • Public engagement meetings. • Flood risk reviews on each property.
Additional works required to account for increase in flow due to climate change Some properties identified as suitable for PLP may become unsuitable with increasing river flows. Additionally, some properties that are not expected to flood frequently enough to make PLP worthwhile at present may be expected to flood more frequently in the future.

5.8.4.3 Option D3 - Property Level Protection (PLP) protecting against 0.5% AP (200 year) event

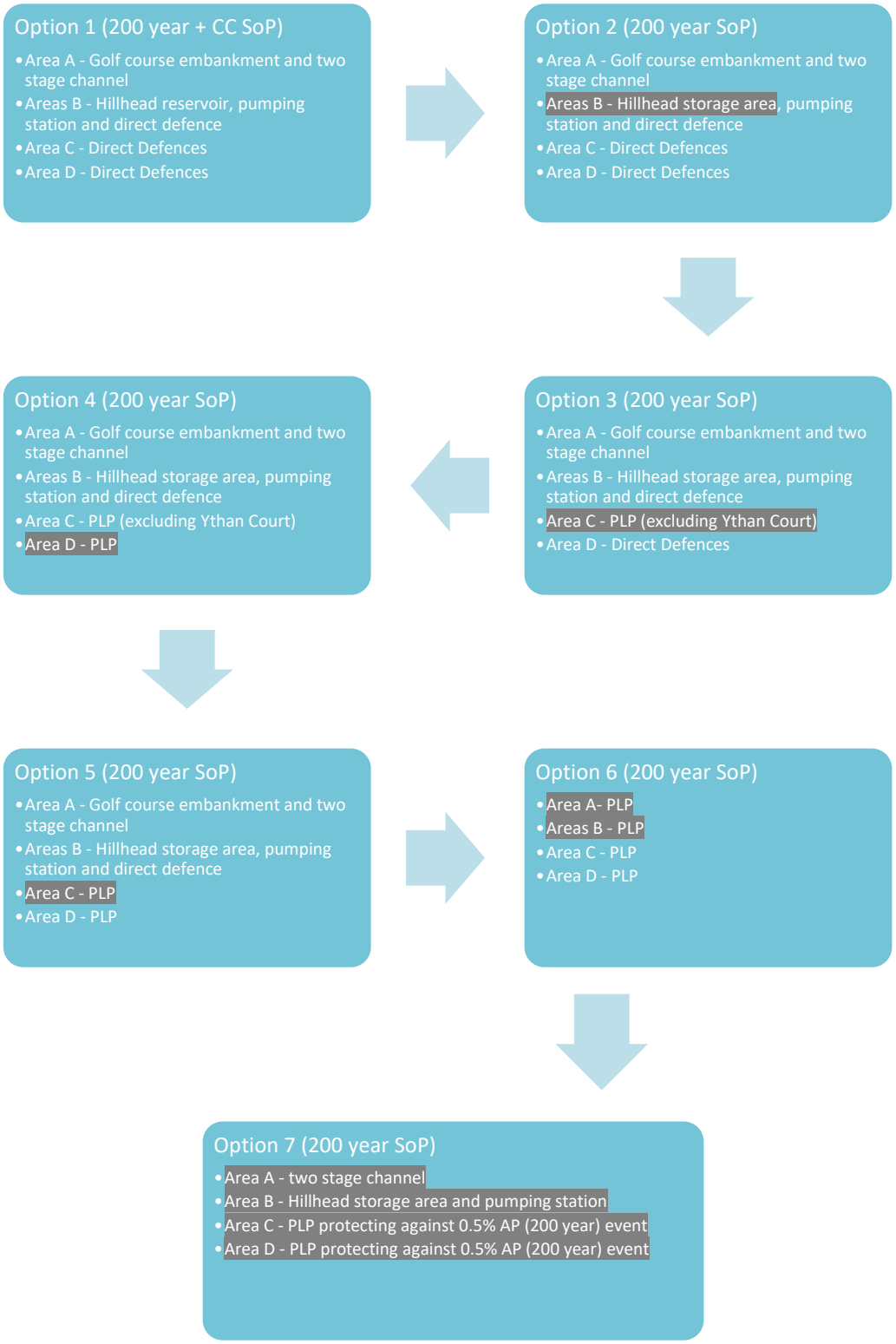
Option D3 - Property Level Protection (PLP) protecting against 0.5% AP (200 year) event
Description This option aims to provide an increase in SoP for all properties where possible by protecting them up to a maximum flood depth of 0.6 m. Beyond this water depth a buildings integrity can potentially be compromised. This option includes the survey, design and implementation of relevant PLP products to each property experiencing flooding. The number of properties expecting to benefit from PLP within Area D are as follows: • 7 properties at risk during the 0.5% AP (200 year).
Standard of Protection (SoP) PLP offers a variable SoP dependent on the property and expected flood depths. Importantly, the property with the lowest standard would be protected to a maximum of the 0.5% AP (200 year), at which point water levels would overtop standard 0.6 m high PLP products.
Technical Issues All properties would require surveying by competent parties to determine which products are appropriate. Properties with non-standard or large entrances may require bespoke options which can significantly increase costs. The Scottish Government's Blueprint on PLP[15] should be considered when implementing this option. Due to no formal flood warning in the area all PLP options are assumed to be automatic.
Construction issues Some commercial properties may require bespoke PLP products and building remedial works to ensure the products work effectively. The installation and periodic replacement of PLP products on multiple properties may become a maintenance burden for the Council.
Environmental issues None identified.
Social and community issues Due to the highly engaged community PLP alone may not be an acceptable option. Residents in this area have expressed that they want more of a hard-engineered approach to protect their properties.
Impact on other reaches There will be a negligible impact on other reaches due to a small diverted volume that would

15 Scottish Government (2014). Assessing the Flood Risk Management Benefits of Property Level Protection; Blueprint for Local Authorities and Scottish Water. Final Report v2.0. 13 November 2014

otherwise flow through the properties.
Additional information required • Public engagement meetings. • Flood risk reviews on each property.
Additional works required to account for increase in flow due to climate change Some properties identified as suitable for PLP may become unsuitable with increasing river flows. Additionally, some properties that are not expected to flood frequently enough to make PLP worthwhile at present may be expected to flood more frequently in the future.

5.9 Flood Mitigation Options

The following section details the flood mitigation options for the full study area taking different combinations of options from the previous sections in each design area, these will ultimately be used as the decision for the preferred option in Ellon. Each sequential option progressively adds less formal engineered solutions to analyse the cost benefit ratios, predominantly the gradual introduction of PLP. This initially is introduced into area C as other than Ythan Court, there are few properties to protect which have a high existing SoP. PLP is then introduced into area D, then at Ythan Court, this is due to Ythan Court having a more extensive flood history. The graphic below shows how each option changes where the grey highlight shows the change from the previous option.



Within the following reporting sections 5.9.1, 5.9.2, 5.9.3, 5.9.4, 5.9.5, 5.9.6 and 5.9.7 titles are coloured with respect their corresponding SoP achieved and coloured as follows:

200 year plus CC SoP achieved

200 year SoP achieved (however, SoP ranges between 200 year plus CC and 200 year SoP)

200 year SoP achieved

5.9.1 Option 1 - Fully hard engineering - SoP 0.5% AP (200 year) plus climate change

Option 1 is a combination of the following options discussed in Section 5.8:

- Option A2: Golf course embankment, removal of Modley Place footbridge and Gordon Park two stage channel.
- Option B1: 0.5% AP (200 year) plus climate change SoP Hillhead reservoir and headwall replacement at Hillhead inlet, pumping station on Hillhead sewer outlet, trash screen replacement on Fortree inlet and direct defence on River Ythan.
- Option C1: Direct defences on both banks around Old Bridge of Ellon and the right bank at Ardlethen Bridge.
- Option D1: Direct defences on Broomies Burn and around The Meadows, surface water swale north of The Meadows.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- AIZ-JBAU-EL-00-DR-HM-0001-Option1_Key_Plan-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0002-Option1_A1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0003-Option1_A2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0004-Option1_B-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0005-Option1_C1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0006-Option1_C2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0007-Option1_D-A1-C01.pdf

5.9.2 Option 2 - Fully hard engineering - SoP 0.5% AP (200 year)

Option 2 is a combination of the following options discussed in Section 5.8, this differs from option 1 as it reduces the SoP of the Hillhead storage to 0.5% AP (200 year), while Areas A, C and D have an SoP of 0.5% AP (200 year) plus climate change:

- Option A2: Golf course embankment, removal of Modley Place footbridge and Gordon Park two stage channel.
- Option B2: 0.5% AP (200 year) SoP Hillhead storage and headwall replacement at Hillhead inlet, pumping station on Hillhead sewer outlet, trash screen replacement on Fortree inlet and direct defence on River Ythan.
- Option C1: Direct defences on both banks around Old Bridge of Ellon and the right bank at Ardlethen Bridge.
- Option D1: Direct defences on Broomies Burn and around The Meadows, surface water swale north of The Meadows.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- AIZ-JBAU-EL-00-DR-HM-0008-Option2_Key_Plan-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0009-Option2_A1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0010-Option2_A2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0011-Option2_B-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0012-Option2_C1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0013-Option2_C2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0014-Option1_D-A1-C01.pdf

5.9.3 Option 3 - Hard engineering, Area C PLP with the exception of Ythan Court

Option 3 is a combination of the following options discussed in Section 5.8, this option differs from option 2 as it introduces PLP into Area C though retains the flood wall for Ythan Court:

- Option A2: Golf course embankment, removal of Modley Place footbridge and Gordon Park two stage channel.
- Option B2: 0.5% AP (200 year) SoP Hillhead Storage and headwall replacement at Hillhead inlet, pumping station on Hillhead sewer outlet, trash screen replacement on Fortree inlet and direct defence on River Ythan.
- Option C3: Direct defences on Ythan Court, PLP for the remaining properties.

- Option D1: Direct defences on Broomies Burn and around The Meadows, surface water swale north of The Meadows.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- AIZ-JBAU-EL-00-DR-HM-0015-Option3_Key_Plan-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0016-Option3_A1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0017-Option3_A2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0018-Option3_B-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0019-Option3_C1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0020-Option3_C2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0021-Option3_D-A1-C01.pdf

5.9.4 Option 4 - Hard engineering, Area C and Area D PLP with the exception of Ythan court

Option 4 is a combination of the following options discussed in Section 5.8, this option differs from option 3 as it introduces PLP into both Areas C and D though retains the flood wall for Ythan Court:

- Option A2: Golf course embankment, removal of Modley Place footbridge and Gordon Park two stage channel.
- Option B2: 0.5% AP (200 year) SoP Hillhead storage and headwall replacement at Hillhead inlet, pumping station on Hillhead sewer outlet, trash screen replacement on Fortree inlet and direct defence on River Ythan.
- Option C3: Direct defences on Ythan Court, PLP for the remaining properties.
- Option D2: Full PLP.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- AIZ-JBAU-EL-00-DR-HM-0022-Option4_Key_Plan-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0023-Option4_A1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0024-Option4_A2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0025-Option4_B-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0026-Option4_C1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0027-Option4_C2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0028-Option4_D-A1-C01.pdf

5.9.5 Option 5 - Hard engineering, Area C and Area D PLP

Option 5 is a combination of the following options discussed in Section 5.8, this option differs from option 4 as it introduces full PLP to Area C and Area D:

- Option A2: Golf course embankment, removal of Modley Place footbridge and Gordon Park 2 stage channel.
- Option B2: 0.5% AP (200 year) SoP Hillhead Storage and headwall replacement at Hillhead inlet, pumping station on Hillhead sewer outlet, trash screen replacement on Fortree inlet and direct defence on River Ythan.
- Option C2: Full PLP.
- Option D2: Full PLP.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- AIZ-JBAU-EL-00-DR-HM-0029-Option5_Key_Plan-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0030-Option5_A1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0031-Option5_A2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0032-Option5_B-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0033-Option5_C1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0034-Option5_C2-A1-C01.pdf

- AIZ-JBAU-EL-00-DR-HM-0035-Option5_D-A1-C01.pdf

5.9.6 Option 6 - All areas PLP

Option 6 is a combination of the following options discussed in Section 5.8, this differs from option 5 as it introduces full PLP across all design areas:

- Option A4: Full PLP.
- Option B2: Full PLP.
- Option C2: Full PLP.
- Option D2: Full PLP.

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- AIZ-JBAU-EL-00-DR-HM-0036-Option6_Key_Plan-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0037-Option6_A1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0038-Option6_A2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0039-Option6_B-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0040-Option6_C1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0041-Option6_C2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0042-Option6_D-A1-C01.pdf

5.9.7 Option 7 - Hard engineering, Area C and Area D PLP, SoP 0.5% AP (200 year)

Option 7 provides a standard of protection of 0.5% AP (200 year) in all locations, removing any additional protection such as the Bruce Crescent embankment, McDonald Golf Course embankment and any PLP for higher events:

- Option A5: two stage channel
- Option B4: 0.5% AP (200 year) SoP Hillhead Storage and headwall replacement at Hillhead inlet, pumping station on Hillhead sewer outlet and trash screen replacement on Fortree inlet
- Option C4: PLP protecting against 0.5% AP (200 year) event
- Option D3: PLP protecting against 0.5% AP (200 year) event

A technical drawing related to this option has been produced and is provided alongside this report, named as follows:

- AIZ-JBAU-EL-00-DR-HM-0044-Option7_Key_Plan-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0045-Option7_A1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0046-Option7_A2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0047-Option7_B-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0048-Option7_C1-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0049-Option7_C2-A1-C01.pdf
- AIZ-JBAU-EL-00-DR-HM-0050-Option7_D-A1-C01.pdf

6 Investment appraisal

6.1 Damage methodology

Flood damage assessment can include direct, indirect, tangible and intangible aspects of flooding, as shown in Figure 6-1. Direct damages are the most significant in monetary terms, although the FHRC Multi Coloured Manual (MCM)[16] and additional research provide additional methodologies, recommendations and estimates to account for the indirect and intangible aspects of flood damage.

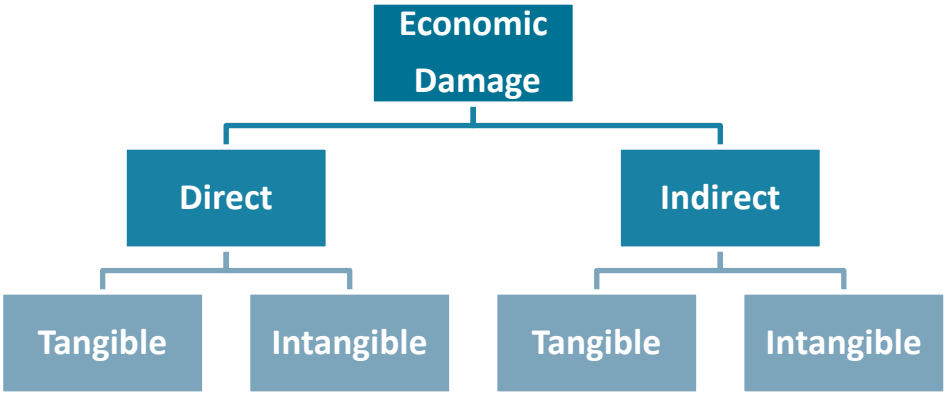


Figure 6-1: Aspects of flood damage

Flood damage estimates have been derived for the following items:

1. Direct damages to residential properties;
2. Direct damages to commercial and industrial properties;
3. Indirect damages (emergency services);
4. Intangible damages associated with the impact of flooding;
5. Damage to vehicles;
6. Emergency evacuation and temporary accommodation costs.

The assumptions and additional data used to calculate the flood damages is provided in Appendix A.

6.2 Baseline damages

Baseline damage results are presented for the Do Nothing and Do Minimum options below.

Do Nothing

Assumptions:

Maintenance ceased, increasing hydraulic roughness due to vegetation growth and degradation of banks.

Bridges and culverts are blocked using a risk-based approach by either widening their piers by 0.5 m on the River Ythan or lowering their soffits by 0.2 m on the burns.

Properties at risk:

The total number of properties inundated above threshold level for the Do Nothing scenario within Ellon has been assessed and is provided in the table below:

Return period (years)	2	5	10	30	50	75	100	200	200 CC	1000
Residential	16	20	23	32	34	35	37	48	80	109
Non-residential	0	0	0	0	0	0	2	5	7	7

16 Handbook for economic appraisal, MCM, Flood and coastal erosion risk management, 2017

Total	16	20	23	32	34	35	39	53	87	116

Key beneficiaries:

The flood damages derived have been ranked and assessed in terms of the proportion of flood damages per property. This highlights key beneficiaries of the scheme and is a useful auditing tool. The top nine properties are listed in the table below (rank 10 has been omitted due to a large number of properties sharing the same value due to capping of damages based on average property values).

Rank	Property address	PVd (£k)	Percentage of total PVd
1	[redacted] HILLHEAD DRIVE, ELLON AB41 9WA	247.12	5.4
1	[redacted] HILLHEAD DRIVE, ELLON AB41 9WA	247.12	5.4
1	[redacted] PATEY ROAD, ELLON AB41 9WL	247.12	5.4
1	[redacted] PATEY ROAD, ELLON AB41 9WL	247.12	5.4
1	[redacted] PATEY ROAD, ELLON AB41 9WL	247.12	5.4
1	[redacted] BRUCE CRESCENT, ELLON AB41 9BW	247.12	5.4
7	[redacted] MODLEY PLACE, ELLON AB41 9BB	203.31	4.4
7	[redacted] MODLEY PLACE, ELLON AB41 9BB	203.31	4.4
9	ELLON PRIMARY SCHOOL, 0 MODLEY PLACE, ELLON AB41 9BB	189.86	4.1

Event property damages:

JBA's damage calculation method provides event damages based on MCM depth damage curves. Full results are provided in Appendix B. These represent the total potential flood damages based on the modelled flood level. Damages include all direct and indirect property flood damages and are presented in £k.

Return period (years)	2	5	10	30	50	75	100	200	200 CC	1000
Residential	500	537	612	717	761	811	883	1,407	2,594	3,904
Non-residential	0	0	0	0	0	0	18	833	1,556	1,737
Total	500	537	612	717	761	811	900	2,240	4,149	5,642

The above damages are used to calculate Annual Average Damages (AAD). Plotting the damages against the frequency of flooding (annual probabilities) allows us to determine the AAD.

Indirect and intangible damages:

A summary of the proportion of total damages by each damage component is provided in the table below.

Do Nothing flood damages (£k):

Property PVd	Capped Property PVd	Indirect PVd	Intangible PVd	Total Capped PVd
9,065	4,589	970	336	5,559

Do Minimum

Assumptions:

Maintenance continued in the channel and on the banks. No bridge blockage assumed.

Properties at risk:

The total number of properties inundated above threshold level for the Do Minimum scenario within Ellon has been assessed and is provided in the table below:

Return period (years)	2	5	10	30	50	75	100	200	200CC	1000
Residential	2	2	2	15	16	15	21	28	53	81
Non-residential	0	0	0	0	0	0	0	2	6	6
Total	2	2	2	15	16	15	21	30	59	87

Key beneficiaries:

The flood damages derived have been ranked and assessed in terms of the proportion of flood damages per property. This highlights key beneficiaries of the scheme and is a useful auditing tool. The top ten properties are listed in the table below.

Rank	Property address	PVd (£k)	Percentage of total PVd
1	[redacted] MODLEY PLACE, ELLON AB41 9BB	203.31	12
1	[redacted] MODLEY PLACE, ELLON AB41 9BB	203.31	12
3	[redacted]PATEY ROAD, ELLON AB41 9WL	136.66	8.1
4	ELLON PRIMARY SCHOOL, 0 MODLEY PLACE ELLON AB41 9BB	107.21	6.3
5	[redacted] PATEY ROAD, ELLON AB41 9WL	97.28	5.7
6	[redacted] HILLHEAD DRIVE, ELLON AB41 9WA	96.70	5.7
7	[redacted] PATEY ROAD, ELLON AB41 9WL	74.54	4.4
8	[redacted] BRUCE CRESCENT, ELLON AB41 9BW	74.00	4.4
9	[redacted] HILLHEAD DRIVE, ELLON AB41 9WA	73.80	4.3
10	[redacted] PATEY ROAD, ELLON AB41 9WL	63.19	3.7

Event property damages:

JBA's damage calculation method provides event damages based on MCM depth damage curves. Full results are provided in Appendix B. These represent the total potential flood damages based on the modelled flood level. Damages include all direct and indirect property flood damages and are presented in £k.

Return period (years)	2	5	10	30	50	75	100	200	200CC	1000
Residential	46	46	47	455	509	499	613	900	1,901	3,032
Non-residential	0	0	0	0	0	0	0	23	1,422	1,559
Total	46	46	47	455	509	499	613	923	3,323	4,591

The above damages are used to calculate Annual Average Damages (AAD). Plotting the

damages against the frequency of flooding (annual probabilities) allows us to determine the AAD.

Indirect and intangible damages:

A summary of the proportion of total damages by each damage component is provided in the table below.

Do Nothing flood damages (£k):

Property PVd	Capped Property PVd	Indirect PVd	Intangible PVd	Total Capped PVd
1,981	1,697	212	186	1909

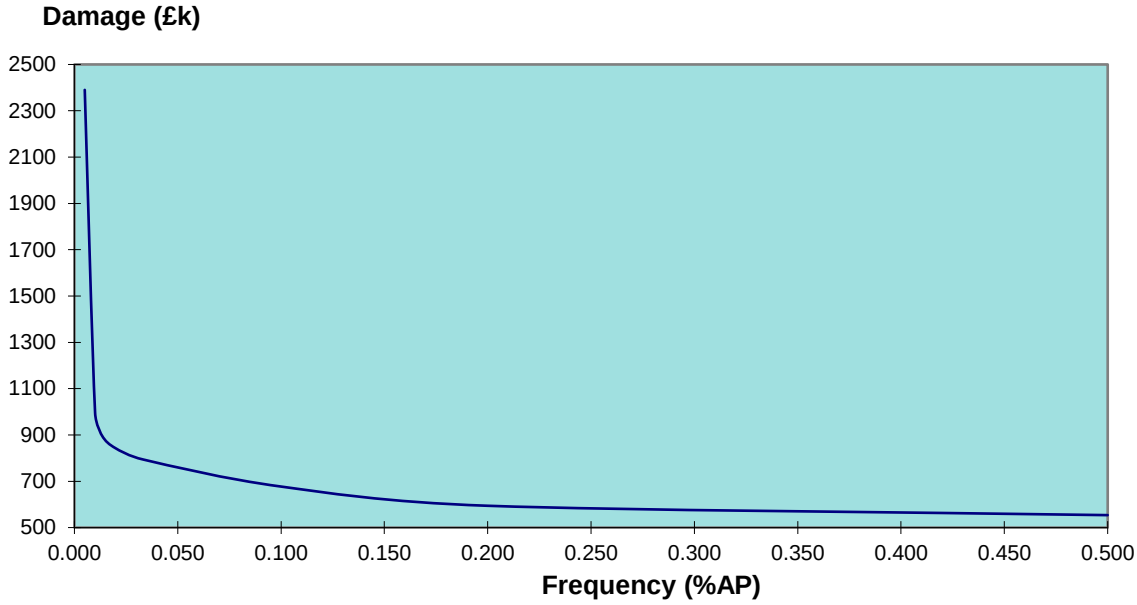


Figure 6-2: Do-Nothing damage curve

Figure 6-2 shows how damages increase during the higher events for the Do Nothing scenario against the probability of that event occurring, in order to obtain a Present value Damage (PVd) the probability of the event occurring over the 100 year appraisal period is considered. Analysis of the frequency that damages are expected to occur shows that the lower return periods have a dominant impact on flood damages, as is often the case. However, events above the 1% AP (100 year) event also make a large contribution to the overall damages, meaning that within Ellon there would be great benefit in protecting against the largest magnitude flood events.

6.3 Options

The flood damages for each option were calculated for each return period up to the 0.1% AP (1000 year) event. Average annual flood damages were converted to present value damages using the discount factor and the residual damages for each option were compared against the flood damages estimated for the Do Nothing scenario. This comparison shows the damages avoided as a result of the options' interventions, also known as the benefit.

In line with current guidance[17] the PLP option was factored to account for the effectiveness and performance of measures and availability of homeowners to install and operate the measures. PLP was assumed to be 84 % effective.

17 Post-Installation Effectiveness of Property Level Flood Protection, Final Report FD2668, (2014) DEFRA

6.4 Damage benefit summary

The table below summarises the damages avoided for each option. The results show that each of the options assessed significantly reduce flood damages in the order of £3.8 m-£5.6 m, leaving comparatively low residual present value damages in the range £0.26 m-£2.1 m. The Do Minimum option reduces the Do Nothing damages by roughly 65 % and the defended options reduce this further by varying degrees.

Table 6-1: Damage benefit summary

	DN	DM	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Option name	Do Nothing	Do Minimum	Full hard engineering	Full hard engineering with reduced Hillhead storage	Hard engineering, Area C (excluding Ythan Court) is PLP	Hard engineering, Areas C and D (excluding Ythan Court) is PLP	Hard engineering, Area C and Area D PLP	Full PLP	Hard engineering to 200 year SoP, areas C and D PLP to 200 year SoP
Standard of Protection	<2	<2	0.5% AP (200 year) + climate change	0.5% AP (200 year)	0.5% AP (200 year)	0.5% AP (200 year)	0.5% AP (200 year)	0.5% AP (200 year)	0.5% AP (200 year)
BENEFITS:									
PV monetised flood damages (£k)	5,866	2,078	264	310	313	317	317	346	474
Total PV damages avoided/ benefits (£k)	-	3,788	5,602	5,556	5,535*	5,504*	5,504*	4,637*	5,359*
***Note:** PLP benefits are scaled down by 16 % to account for the likelihood of PLP products only being 84 % effective									

7 Cost estimates

7.1 Price Base Date

The price base date is January 2019. The costs and benefits have been discounted over the 100 year life of the scheme to determine present values.

7.2 Whole life cost estimates

Whole life costs are typically compiled from the following four key cost categories:

1. **Enabling costs.** These costs relate to the next stage of appraisal, design, site investigation, consultation, planning and procurement of contractors.
2. **Capital costs.** These costs relate to the construction of the flood mitigation measures and include all relevant costs such as project management, construction and materials, licences, administration, supervision and land purchase costs (if relevant).
3. **Operation and maintenance costs.** Maintenance of assets is essential to ensure that the assets remain fit for purpose and to limit asset deterioration. Costs may include inspections, maintenance and intermittent asset repairs/replacement.
4. **End of life replacement or decommissioning costs.** These costs are only required when the design life of assets is less than the appraisal period. Most assets are likely to have a design life in excess of the 100 year financial period but PLP is expected to have a 25 year design life, so this has been included in the cost estimate for PLP.

The Environment Agency's 'Long Term Costing' tool (2012) was the basis of all costs for this assessment to provide a uniform approach to costing across the flood studies.

Whole life (present value) costs have been estimated based on the above enabling, capital and maintenance costs. The following assumptions have been made:

1. The life span of the scheme and appraisal period is 100 years.
2. Discounting of costs are based on the standard Treasury discount rates as recommended by the 2003 revision to the HM Green Book (3.5 % for years 0-30, 3.0 % for years 31-75 and 2.5 % for years 76-99).
3. Capital costs are assumed to occur in year 1 (equivalent to 2019).
4. Enabling costs occur in year 0.
5. An optimism bias of 60 % has been applied and is representative of a scheme at the appraisal design stage of development. This provides a significant safety factor for cost implications and risks.

7.3 Maintenance costs

The Environment Agency Long Term Costing tool was used to calculate maintenance costs. These maintenance costs account for a default set of maintenance regimes for associated annual or frequent operation and maintenance activities.

The costs used assume efforts are made to maintain assets at condition grade 2 (Good) using the grading system described in the Environment Agency's asset condition assessment manual[18]. Average costs were used - between lower and upper bounds reproduced in the report - given the absence of detailed maintenance plans at this early design stage of development.

7.3.1 Optimism bias

An optimism bias of 60 % has been applied and is representative of a scheme at the appraisal design stage of development. This provides a significant safety factor for cost implications and risks. This uplift is applied to present value capital, present value maintenance and present value enabling costs after their calculation.

18 Condition Assessment Manual (CAM) (2012) Environment Agency

7.4 Option 1 - Full hard engineering

This option consists of the following:

- Area A
  - Two stage channel approximately 362 m^2 over a 47 m stretch
  - Plastic sheet piles assumed 1.2 m deep, 0.45 m wide trench and backfilled over the 47 m stretch
  - Pedestrian bridge removal, 4.9 m span, 1.2 m wide
  - Golf course embankment, 110 m long, max height 2.25 m, total volume 3300 m^3
- Area B
  - Excavation of 22,809 m^3 soil
  - Reservoir embankment 65 m long, with a maximum 2.88 m height on the north face and 4.56 m height within the reservoir, total volume 4,398 m^3
  - Reservoir wall, 46 m long, 4.3 m height within the reservoir
  - Steel sheet piling totalling 57 m long
  - Bruce Crescent embankment 95 m long, max height 1.71 m, total volume 1498 m^3
  - New orifice with headwall and wingwalls for a 0.2 m diameter inlet
  - Replacement trash screen on Fortree culvert inlet
  - Install a pumping station on the culvert outlet, pump size 270 l/s
- Area C
  - Old Bridge of Ellon embankment, 125 m long, max height 1.92 m, total volume 2754 m^3
  - Bridge of Ardlethen upstream embankment, 113 m long, max height 1.93 m, total volume 2833 m^3
  - Bridge of Ardlethen downstream embankment, 167 m long, max height 2.28 m, total volume 4459 m^3
  - Old Bridge of Ellon upstream concrete wall, 61 m long, average height 1.3 m
  - Old Bridge of Ellon downstream concrete wall, 217 m long, average height 1.1 m
  - Bridge of Ardlethen concrete wall, 89 m long, average height 2.2 m
- Area D
  - The Meadows concrete wall, 485 m long, average height 1.99 m
  - Broomies Burn embankment, 10.9 m long, max height 0.83 m, total volume 41 m^3
  - Surface water swale north of The Meadows approximately 937 m^2 over a 125 m stretch

Costs are based on achieving a 0.5% AP (200 year) plus climate change standard of protection and on near immediate initiation of works.

Table 7-1: Option 1 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Area A: Modley Place two stage channel	-	361.6m^2	£16	£5,874
Area A: Modley Place plastic sheet piles	1.5m	82m^2	£25	£2,050
Area A: Modley Place plastic sheet pile trench	1.2 x 0.45m	47m	£75	£3,525
Area A: Modley Place pedestrian bridge removal	-	5.9m^2	£64	£376
Area A: McDonald golf course embankment	2.25m	3,300m^3	£115	£380,765
Area B: Hillhead reservoir excavation	-	22,809m^3	£79	£1,791,850

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Area B: Hillhead reservoir embankment	4.56m	4398m^3	£115	£507,456
Area B: Hillhead reservoir wall	4.3m	46m	£9,771	£449,455
Area B: Hillhead steel sheet piling	-	57m	£2,262	£128,270
Area B: Hillhead reservoir land acquisition	-	0.47ha	£11,882	£5,543
Area B: Bruce Crescent embankment	1.71m	1,498m^3	£115	£172,844
Area B: Hillhead replacement inlet	-	<1000mm dia	£78,494	£78,494
Area B: Fortree replacement trash screen	-	5.4m^2	£1,200	£6,480
Area B: Hillhead pumping station	-	270l/s	£419,390	£419,390
Area C: Old Bridge of Ellon embankment	1.92m	2,754m^3	£115	£317,766
Area C: Bridge of Ardlethen upstream embankment	1.93m	2,833m^3	£115	£326,881
Area C: Bridge of Ardlethen downstream embankment	2.28m	4,459m^3	£115	£514,494
Area C: Old Bridge of Ellon upstream concrete wall	1.3m	61m	£6,345	£387,036
Area C: Old Bridge of Ellon downstream concrete wall	1.1m	217m	£2,659	£576,944
Area C: Bridge of Ardlethen concrete wall	2.2m	89m	£9,771	£869,598
Area D: The Meadows concrete wall	1.99m	485m	£8,567	£4,154,783
Area D: Broomies Burn embankment	0.83m	41m^3	£231	£9,461
Area D: The Meadows swale	-	937.5m^2	£16	£15,229
			Total Capital cost	£11,124,564

Table 7-2: Option 1 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	1,234	1,234
Capital cost	11,120	11,120
Maintenance cost	2,566	747
Total	**14,920**	**13,101**
Total incl. Optimism Bias	-	20,962

7.5 Option 2 - Full hard engineering with reduced Hillhead storage

This option consists of the following:

- **Area A**
  - Two stage channel approximately 362 m^2 over a 47 m stretch
  - Plastic sheet piles assumed 1.2 m deep, 0.45 m wide trench and backfilled over the 47 m stretch
  - Pedestrian bridge removal, 4.9 m span, 1.2 m wide
  - Golf course embankment, 110 m long, max height 2.25 m, total volume 3300 m^3

- **Area B**
  - Excavation of 8,780 m^3 soil
  - Reservoir embankment 65 m long, with a maximum 2.8 m height on the north face and 4.47 m height within the reservoir, total volume 4,256 m^3
  - Reservoir wall, 46 m long, 4.17 m height within the reservoir
  - Bruce Crescent embankment 95 m long, max height 1.71 m, total volume 1498 m^3
  - New orifice with headwall and wingwalls for a 0.2 m diameter inlet
  - Replacement trash screen on Fortree culvert inlet
  - Install a pumping station on the culvert outlet, pump size 270 l/s
- **Area C**
  - Old Bridge of Ellon embankment, 125 m long, max height 1.92 m, total volume 2754 m^3
  - Bridge of Ardlethen upstream embankment, 113 m long, max height 1.93 m, total volume 2833 m^3
  - Bridge of Ardlethen downstream embankment, 167 m long, max height 2.28 m, total volume 4459 m^3
  - Old Bridge of Ellon upstream concrete wall, 61 m long, average height 1.3 m
  - Old Bridge of Ellon downstream concrete wall, 217 m long, average height 1.1 m
  - Bridge of Ardlethen concrete wall, 89 m long, average height 2.2 m
- **Area D**
  - The Meadows concrete wall, 485 m long, average height 1.99 m
  - Broomies Burn embankment, 10.9 m long, max height 0.83 m, total volume 41 m^3
  - Surface water swale north of The Meadows approximately 937 m^2 over a 125 m stretch

Costs are based on achieving a 0.5% AP (200 year) standard of protection and on near immediate initiation of works.

Table 7-3: Option 2 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Area A: Modley Place 2 stage channel	-	361.6m^2	£16	£5,874
Area A: Modley Place plastic sheet piles	1.5m	82m^2	£25	£2,050
Area A: Modley Place plastic sheet pile trench	1.2 x 0.45m	47m	£75	£3,525
Area A: Modley Place pedestrian bridge removal	-	5.9m^2	£64	£376
Area A: McDonald golf course embankment	2.25m	3,300m^3	£115	£380,765
Area B: Hillhead reservoir excavation	-	8,780m^3	£79	£689,747
Area B: Hillhead reservoir embankment	4.47m	4,256m^3	£115	£491,072
Area B: Hillhead reservoir wall	4.17m	46m	£9,771	£449,455
Area B: Hillhead reservoir land acquisition	-	0.23ha	£11,882	£2,760
Area B: Bruce Crescent embankment	1.71m	1,498m^3	£115	£172,844
Area B: Hillhead replacement inlet	-	<1000m m dia	£78,494	£78,494

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Area B: Fortree replacement trash screen	-	5.4m^2	£1,200	£6,480
Area B: Hillhead pumping station	-	270l/s	£419,390	£419,390
Area C: Old Bridge of Ellon embankment	1.92m	2,754m^3	£115	£317,766
Area C: Bridge of Ardlethen upstream embankment	1.93m	2,833m^3	£115	£326,881
Area C: Bridge of Ardlethen downstream embankment	2.28m	4,459m^3	£115	£514,494
Area C: Old Bridge of Ellon upstream concrete wall	1.3m	61m	£6,345	£387,036
Area C: Old Bridge of Ellon downstream concrete wall	1.1m	217m	£2,659	£576,944
Area C: Bridge of Ardlethen concrete wall	2.2m	89m	£9,771	£869,598
Area D: The Meadows concrete wall	1.99m	485m	£8,567	£4,154,783
Area D: Broomies Burn embankment	0.83m	41m^3	£231	£9,461
Area D: The Meadows swale	-	937.5m^2	£16	£15,229
			Total Capital cost	£9,875,024

Table 7-4: Option 2 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	986	986
Capital cost	9,873	9,873
Maintenance cost	2,565	746
Total	**13,424**	**11,605**
Total incl. Optimism Bias	-	18,568

7.6 Option 3 - Hard engineering, Area C (excluding Ythan Court) is PLP

This option consists of the following:

- Area A
  - Two stage channel approximately 362 m^2 over a 47 m stretch
  - Plastic sheet piles assumed 1.2 m deep, 0.45 m wide trench and backfilled over the 47 m stretch
  - Pedestrian bridge removal, 4.9 m span, 1.2 m wide
  - Golf course embankment, 110 m long, max height 2.25 m, total volume 3300 m^3
- Area B
  - Excavation of 8,780 m^3 soil
  - Reservoir embankment 65 m long, with a maximum 2.8 m height on the north face and 4.47 m height within the reservoir, total volume 4,256 m^3
  - Reservoir wall, 46 m long, 4.17 m height within the reservoir
  - Bruce Crescent embankment 95 m long, max height 1.71 m, total volume 1498 m^3
  - New orifice with headwall and wingwalls for a 0.2 m diameter inlet
  - Replacement trash screen on Fortree culvert inlet
  - Install a pumping station on the culvert outlet, pump size 270 l/s
- Area C

- Old Bridge of Ellon downstream concrete wall, 217 m long, average height 1.1 m
- PLP for 2 residential and 1 non-residential properties

- Area D
  - The Meadows concrete wall, 485 m long, average height 1.99 m
  - Broomies Burn embankment, 10.9 m long, max height 0.83 m, total volume 41 m^3
  - Surface water swale north of The Meadows approximately 937 m^2 over a 125 m stretch

Costs are based on achieving a 0.5% AP (200 year) standard of protection and on near immediate initiation of works.

Table 7-5: Option 3 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Area A: Modley Place 2 stage channel	-	361.6m^2	£16	£5,874
Area A: Modley Place plastic sheet piles	1.5m	82m^2	£25	£2,050
Area A: Modley Place plastic sheet pile trench	1.2 x 0.45m	47m	£75	£3,525
Area A: Modley Place pedestrian bridge removal	-	5.9m^2	£64	£376
Area A: McDonald golf course embankment	2.25m	3,300m^3	£115	£380,765
Area B: Hillhead reservoir excavation	-	8,780m^3	£79	£689,747
Area B: Hillhead reservoir embankment	4.47m	4,256m^3	£115	£491,072
Area B: Hillhead reservoir wall	4.17m	46m	£9,771	£449,455
Area B: Hillhead reservoir land acquisition	-	0.23ha	£11,882	£2,760
Area B: Bruce Crescent embankment	1.71m	1,498m^3	£115	£172,844
Area B: Hillhead replacement inlet	-	<1000m m dia	£78,494	£78,494
Area B: Fortree replacement trash screen	-	5.4m^2	£1,200	£6,480
Area B: Hillhead pumping station	-	270l/s	£419,390	£419,390
Area C: Old Bridge of Ellon downstream concrete wall	1.1m	217m	£2,659	£576,944
Area D: The Meadows concrete wall	1.99m	485m	£8,567	£4,154,783
Area D: Broomies Burn embankment	0.83m	41m^3	£231	£9,461
Area D: The Meadows swale	-	937.5m^2	£16	£15,229
			Total Capital cost	£7,459,249

Table 7-6: Option 3 - PLP total estimated costs

Property type	Cost range	Cost type	Number	Unit Cost
Residential	High	Premium*	2	£14,088
Non-residential	High	Premium*	1	£19,902
			Total Capital Cost	£48,077

*Assumes automatic PLP defences

Costs are slightly increased below assuming replacement of PLP every 25 years.

Table 7-7: Option 3 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	750	750
Capital cost	7,506	7,542
Maintenance cost	2,314	673
Total	**10,570**	**8,965**
Total incl. Optimism Bias	-	14,344

7.7 Option 4 - Hard engineering, Areas C and D (excluding Ythan Court) is PLP

This option consists of the following:

- Area A
  - Two stage channel approximately 362 m^2 over a 47 m stretch
  - Plastic sheet piles assumed 1.2 m deep, 0.45 m wide trench and backfilled over the 47 m stretch
  - Pedestrian bridge removal, 4.9 m span, 1.2 m wide
  - Golf course embankment, 110 m long, max height 2.25 m, total volume 3300 m^3
- Area B
  - Excavation of 8,780 m^3 soil
  - Reservoir embankment 65 m long, with a maximum 2.8 m height on the north face and 4.47 m height within the reservoir, total volume 4,256 m^3
  - Reservoir wall, 46 m long, 4.17 m height within the reservoir
  - Bruce Crescent embankment 95 m long, max height 1.71 m, total volume 1498 m^3
  - New orifice with headwall and wingwalls for a 0.2 m diameter inlet
  - Replacement trash screen on Fortree culvert inlet
  - Install a pumping station on the culvert outlet, pump size 270 l/s
- Area C
  - Old Bridge of Ellon downstream concrete wall, 217 m long, average height 1.1 m
  - PLP for 2 residential properties and 1 non-residential property
- Area D
  - PLP for 13 residential properties and 1 non-residential property

Costs are based on achieving a 0.5% AP (200 year) standard of protection and on near immediate initiation of works.

Table 7-8: Option 4 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Area A: Modley Place 2 stage channel	-	361.6m^2	£16	£5,874
Area A: Modley Place plastic sheet piles	1.5m	82m^2	£25	£2,050
Area A: Modley Place plastic sheet pile trench	1.2 x 0.45m	47m	£75	£3,525
Area A: Modley Place pedestrian bridge removal	-	5.9m^2	£64	£376
Area A: McDonald golf course embankment	2.25m	3,300m^3	£115	£380,765

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Area B: Hillhead reservoir excavation	-	8,780m^3	£79	£689,747
Area B: Hillhead reservoir embankment	4.47m	4,256m^3	£115	£491,072
Area B: Hillhead reservoir wall	4.17m	46m	£9,771	£449,455
Area B: Hillhead reservoir land acquisition	-	0.23ha	£11,882	£2,760
Area B: Bruce Crescent embankment	1.71m	1,498m^3	£115	£172,844
Area B: Hillhead replacement inlet	-	<1000m m dia	£78,494	£78,494
Area B: Fortree replacement trash screen	-	5.4m^2	£1,200	£6,480
Area B: Hillhead pumping station	-	270l/s	£419,390	£419,390
Area C: Old Bridge of Ellon downstream concrete wall	1.1m	217m	£2,659	£576,944
			Total Capital cost	£3,279,776

Table 7-9: Option 4 - PLP total estimated costs

Property type	Cost range	Cost type	Number	Unit Cost
Residential	High	Premium*	15	£14,088
Non-residential	High	Premium*	2	£19,902
			Total Capital Cost	£251,124

*Assumes automatic PLP defences

Costs are slightly increased below assuming replacement of PLP every 25 years.

Table 7-10: Option 4 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	359	359
Capital cost	3,532	3,731
Maintenance cost	2,657	773
Total	**6,548**	**4,863**
Total incl. Optimism Bias	-	7,781

7.8 Option 5 - Hard engineering, Area C and Area D PLP

This option consists of the following:

- Area A
  - Two stage channel approximately 362 m^2 over a 47 m stretch
  - Plastic sheet piles assumed 1.2 m deep, 0.45 m wide trench and backfilled over the 47 m stretch
  - Pedestrian bridge removal, 4.9 m span, 1.2 m wide
  - Golf course embankment, 110 m long, max height 2.25 m, total volume 3300 m^3
- Area B
  - Excavation of 8,780 m^3 soil
  - Reservoir embankment 65 m long, with a maximum 2.8 m height on the north face and 4.47 m height within the reservoir, total volume 4,256 m^3

- Reservoir wall, 46 m long, 4.17 m height within the reservoir
- Bruce Crescent embankment 95 m long, max height 1.71 m, total volume 1498 m^3
- New orifice with headwall and wingwalls for a 0.2 m diameter inlet
- Replacement trash screen on Fortree culvert inlet
- Install a pumping station on the culvert outlet, pump size 270 l/s

- Area C
  - PLP for 2 residential properties and 4 non-residential property
- Area D
  - PLP for 13 residential properties and 1 non-residential property

Costs are based on achieving a 0.5% AP (200 year) standard of protection and on near immediate initiation of works.

Table 7-11: Option 5 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Area A: Modley Place 2 stage channel	-	361.6m^2	£16	£5,874
Area A: Modley Place plastic sheet piles	1.5m	82m^2	£25	£2,050
Area A: Modley Place plastic sheet pile trench	1.2 x 0.45m	47m	£75	£3,525
Area A: Modley Place pedestrian bridge removal	-	5.9m^2	£64	£376
Area A: McDonald golf course embankment	2.25m	3,300m^3	£115	£380,765
Area B: Hillhead reservoir excavation	-	8,780m^3	£79	£689,747
Area B: Hillhead reservoir embankment	4.47m	4,256m^3	£115	£491,072
Area B: Hillhead reservoir wall	4.17m	46m	£9,771	£449,455
Area B: Hillhead reservoir land acquisition	-	0.23ha	£11,882	£2,760
Area B: Bruce Crescent embankment	1.71m	1,498m^3	£115	£172,844
Area B: Hillhead replacement inlet	-	<1000mm dia	£78,494	£78,494
Area B: Fortree replacement trash screen	-	5.4m^2	£1,200	£6,480
Area B: Hillhead pumping station	-	270l/s	£419,390	£419,390
			Total Capital cost	£2,702,832

Table 7-12: Option 5 - PLP total estimated costs

Property type	Cost range	Cost type	Number	Unit Cost
Residential	High	Premium*	15	£14,088
Non-residential	High	Premium*	5	£19,902
			Total Capital Cost	£310,830

*Assumes automatic PLP defences

Costs are slightly increased below assuming replacement every 25 years.

Table 7-13: Option 5 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	308	308
Capital cost	3,261	3,261
Maintenance cost	2,762	804
Total	**6,331**	**4,373**
Total incl. Optimism Bias	-	6,997

7.9 Option 6 - Full PLP

This option consists of the following:

- Area A
  - PLP for 10 residential properties and 1 non-residential property
- Area B
  - PLP for 26 residential properties
- Area C
  - PLP for 2 residential properties and 4 non-residential properties
- Area D
  - PLP for 13 residential properties and 1 non-residential property

Costs are based on achieving a 0.5% AP (200 year) standard of protection and on near immediate initiation of works.

Table 7-14: Option 6 - PLP total estimated costs

Property type	Cost range	Cost type	Number	Unit Cost
Residential	High	Premium*	51	£14,088
Non-residential	High	Premium*	6	£19,902
			Total Capital Cost	£843,900

*Assumes automatic PLP defences

Costs are slightly increased below assuming replacement of PLP every 25 years.

Table 7-15: Option 6 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	102	102
Capital cost	1,508	1,508
Maintenance cost	1,672	487
Total	**3,282**	**2,097**
Total incl. Optimism Bias	-	3,355

7.10 Option 7 - SoP 0.5% AP (200 year) hard engineering, Area C and Area D PLP

This option consists of the following:

- Area A
  - Two stage channel approximately 362 m^2 over a 47 m stretch
  - Plastic sheet piles assumed 1.2 m deep, 0.45 m wide trench and backfilled over the 47 m stretch
  - Pedestrian bridge removal, 4.9 m span, 1.2 m wide
- Area B

- Excavation of 8,780 m³ soil
- Reservoir embankment 65 m long, with a maximum 2.8 m height on the north face and 4.47 m height within the reservoir, total volume 4,256 m³
- Reservoir wall, 46 m long, 4.17 m height within the reservoir
- New orifice with headwall and wingwalls for a 0.2 m diameter inlet
- Replacement trash screen on Fortree culvert inlet
- Install a pumping station on the culvert outlet, pump size 270 l/s

- Area C
  - PLP for 2 residential properties and 2 non-residential property
- Area D
  - PLP for 6 residential properties

Costs are based on achieving a 0.5% AP (200 year) standard of protection and on near immediate initiation of works.

Table 7-16: Option 7 - Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Area A: Modley Place 2 stage channel	-	361.6m²	£16	£5,874
Area A: Modley Place plastic sheet piles	1.5m	82m²	£25	£2,050
Area A: Modley Place plastic sheet pile trench	1.2 x 0.45m	47m	£75	£3,525
Area A: Modley Place pedestrian bridge removal	-	5.9m²	£64	£376
Area B: Hillhead reservoir excavation	-	8,780m³	£79	£689,747
Area B: Hillhead reservoir embankment	4.47m	4,256m³	£115	£491,072
Area B: Hillhead reservoir wall	4.17m	46m	£9,771	£449,455
Area B: Hillhead reservoir land acquisition	-	0.23ha	£11,882	£2,760
Area B: Hillhead replacement inlet	-	<1000m m dia	£78,494	£78,494
Area B: Fortree replacement trash screen	-	5.4m²	£1,200	£6,480
Area B: Hillhead pumping station	-	270l/s	£419,390	£419,390
			Total Capital cost	£2,149,223

Table 7-17: Option 7 - PLP total estimated costs

Property type	Cost range	Cost type	Number	Unit Cost
Residential	High	Premium*	8	£14,088
Non-residential	High	Premium*	2	£19,902
			Total Capital Cost	£152,508

*Assumes automatic PLP defences

Costs are slightly increased below assuming replacement of PLP every 25 years.

Table 7-18: Option 7 - Total cash and Present Value (PV) costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	233	233
Capital cost	2,419	2,419
Maintenance cost	2,265	659
Total	**4,917**	**3,311**
Total incl. Optimism Bias	-	5,298

7.11 Summary of whole life costs

Table 7-16 summarises all Present Value costs for all of the short-listed options:

Table 7-19: Summary of PV costs for all options

Option	PV Cost (£k)
Option 1 - full hard engineering	20,962
Option 2 - full hard engineering with reduced Hillhead storage	18,568
Option 3 - Hard engineering, Area C (excluding Ythan Court is PLP)	14,345
Option 4 - Hard engineering, Areas C and D (excluding Ythan Court) is PLP	7,781
Option 5 - Hard engineering, Area C and Area D PLP	6,997
Option 6 - Full PLP	3,356
Option 7 - SoP 0.5% AP (200 year) hard engineering, Areas C and D PLP	5,298

8 Benefit-cost analysis

8.1 Introduction

This section discusses the economic appraisal carried out during this study. The methods of calculating the benefits and costs are outlined together with an assessment of the benefit-cost ratios for the range of options assessed. Benefit cost analysis looks at a flood risk management strategy or practice and compares all the benefits that will be gained by its implementation to all the costs that will be incurred during the lifetime of the project. In accordance with the FCERM appraisal guidance, benefits are taken as annual average damages avoided, expressed as their present value using Treasury discount rates. These are compared with the whole life cost of the capital and maintenance costs of selected options, expressed as present value. If the benefits exceed the costs for the option, the scheme is deemed to be cost effective and worthwhile for promotion.

Benefits are assessed as the flood damages that will be avoided by the implementation of a project. To calculate the benefits it is necessary to assess the damages that are likely to occur under both the Do Nothing and Do Minimum scenarios. The benefits of any particular Do Minimum option can then be calculated by deducting the Do Minimum damages from the Do Nothing damages.

8.2 Benefit-cost results

The benefit cost results for the shortlisted options are provided in the Table 8-1.

Table 8-1: Benefit cost ratio for options on the Ellon (£k)

	DN	DM	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
PV Costs (£k)	-	-	13,101	11,605	8,965	4,863	4,373	2,098	3,311
Optimism Bias (60%)	-	-	7,861	6,963	5,380	2,918	2,624	1,258	1,987
Total PV Costs (£k)	-	-	20,962	18,568	14,345	7,781	6,997	3,356	5,298
PV damage (£k)	5,866	2,078	264	310	313	317	317	346	474
PV damage avoided (£k)	-	3,788	5,602	5,556	5,535	5,504	5,504	4,637	5,359
Net present value (£k)	-	3,788	-15,360	-13,011	-8,810	-2,277	-1,493	1,281	61
Benefit-cost ratio	-	-	0.3	0.3	0.4	0.7	0.8	1.4	1.0

The results show that either a full introduction of PLP or protecting to a standard of 0.5% AP (200 year) across all options is required to gain a benefit-cost ration of above 1.

Despite being cost-effective the full PLP option does not provide a holistic long-term form of flood protection, in particular, though the modelling has displayed many properties being within the 0.6 m flood depth at the 0.5% AP (200 year) plus climate change it was discussed by the public that depths exceeded this during the 2016 event. This is likely due to the model not accounting for a drainage issue which has been expressed within Ellon as well as other modelling uncertainty and interaction of flood waters once in the property. Due to this a combination of PLP and hard defence is a better candidate where option 4 implements hard defences at the properties with the largest recorded flood history as well as targeting the areas where most properties are at risk. If a benefit-cost ration

above 1 is critical to the study then option 7 should be looked at before option 6 as it has a positive cost ratio but does not include any allowance for climate change.

8.3 Residual risks

The only way to protect all properties to an event in line with climate change is option 1. Option 1 has an extremely poor cost benefit ratio and is therefore unlikely to be put forward. Other options, excluding option 7, do provide a standard of protection to include climate change for a majority of the properties though due to reduction of cost, options such as PLP have been implemented which results in a couple of properties only being protected to the 0.5% AP (200 year).

Since it is unlikely to be possible to protect against flooding at these extreme events due to future increases in peak river flows, NFM or a scaled abandonment of the lowest lying properties could be an option in the future.

8.4 Testing of climate change inclusion in damages

As the starting point for appraisal was to achieve a SoP of 0.5% AP (200 year) plus climate change, a sensitivity check was conducted to determine whether including climate change in the do nothing and do minimum scenarios would be beneficial to the study, increasing the damages and ultimately the BCR. The climate change uplift being used in this study is 24% which is in line with the updated climate projections as of 2019 for the North East[19]. A sensitivity check was conducted where the current probability for each storm event was recalculated using the 24% uplift to determine how much more frequently it would occur e.g. the damages incurred during the 1% AP (100 year) event now has a probability of occurring during the 2.17% AP (46 year) event. A new baseline damage was then calculated; £7,372,000. The damages have increased by roughly £1,866,000 which does not result in any option defending against climate change becoming cost effective, where option 1 still produces a BCR of 0.27. The only benefit of including climate change in the damages is that option 5's BCR has increased above 1 though this option has a similar level of sustainability as the already economically viable option; option 7. This is mainly due to the lack of properties at risk during the low return periods and hence due to only a slight incremental increase in BCRs a full climate change analysis was not undertaken.

19 Climate change allowances for flood risk assessment in land use planning, Version 1, SEPA, 26/04/2019

8.5 Analysis of options outwith area benefiting

A check was made on the flood extents in the study area to ensure the flood options detailed in option 4 had no detrimental effect outwith the area immediately benefitting from defences. Option 4 was selected as it covers option 4 and all subsequent likely options that will be taken forward. The 0.5% AP (200 year) flow was used and defences included the bund at Hillhead Crescent, the two stage channel at Modley Place and the flood wall at Ythan Court. The results are shown in Figure 8-1 below.

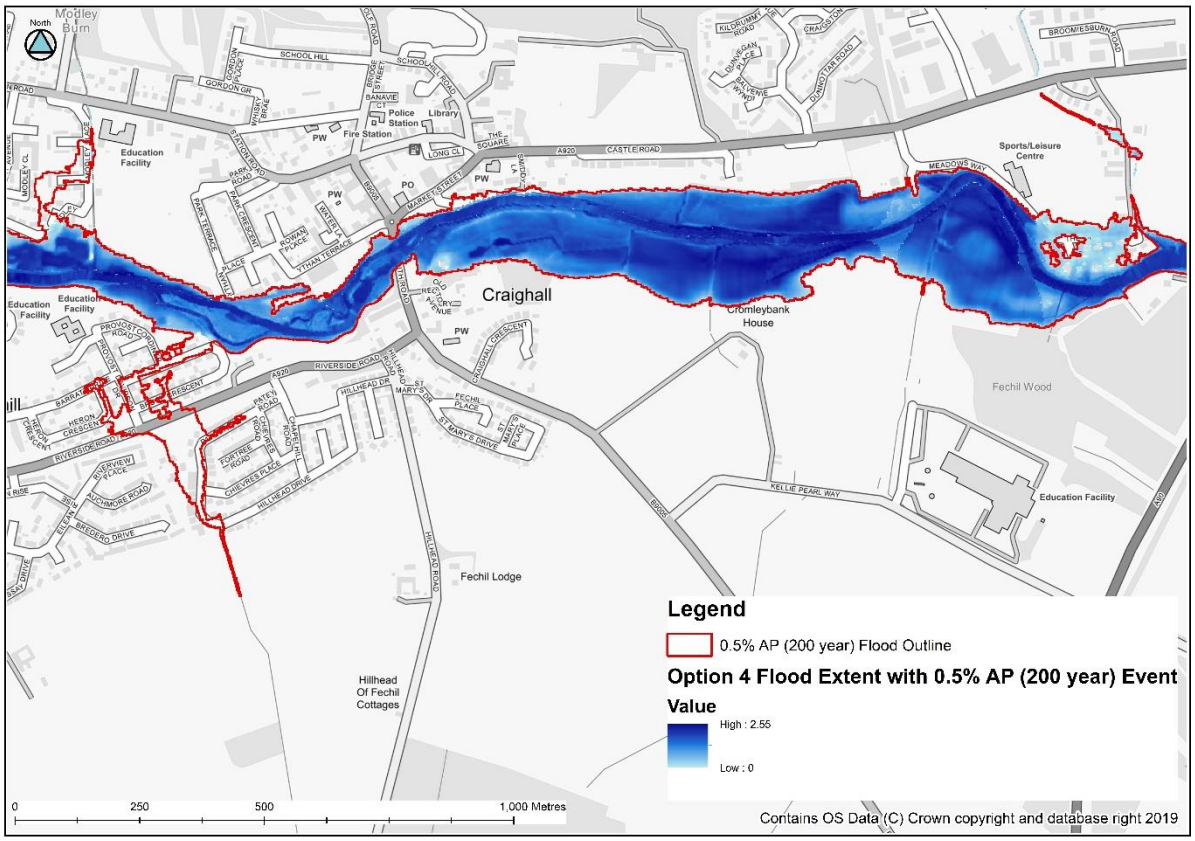


Figure 8-1: Option 4 flood extent

Figure 8-1 shows how the flood extent has not been altered when the defences from the option are put into place. This is due to the amount of additional volume that is potentially constrained in the channel being insignificant in comparison to the volume passing down the Ythan. Furthermore, when analysing the flood depths within the most downstream area (The Meadows) between the 0.5% AP (200 year) both with and without the option defences the values were either identical or ± 0.01 m. Due to these results it has been concluded that the option has no detrimental effects.

9 Stakeholder engagement

A stakeholder engagement meeting took place on 7 March 2019 to get a better understanding of how key stakeholders respond to the options that have been proposed by this study.

The options within the different design areas were presented and the following comments were made:

- Within design area A use of the golf course to store any higher flood waters was generally accepted particularly as during high flood events the golf course would not be in use as it stands. It was noted that fish migration through Hospital Road culvert is known and therefore use of control structures should be planned accordingly. A two stage channel was well received where altering a canalised channel to establish a more sinuous natural channel was encouraged.
- It was agreed that a drainage study seemed sensible within design area B, it was noted that drainage studies may conclude on a reduction to the effectiveness of PLP.
- It was noted that direct defences within area C would struggle to be a cost-effective solution as a standalone area and that the solution should focus on retaining the river bank footpath.
- It was noted that direct defences within area D would struggle to be a cost-effective solution as a standalone area.

A further discussion was made via telecon with Scottish Water where the following key points were added:

- Scottish Water requested that a check was made on the threshold levels for the properties on Bruce Crescent and Barratt Drive.
- Scottish Water suggested that they had no documented records of flooding within the area of interest.
- It was noted that if flooding is from groundwater this is not covered by Scottish Water.
- It was confirmed that a flap valve was installed on Hillhead Burn in April 2018. If the flap valve was installed correctly it should work well if the rise in head is on the river side. There is an active seal, not under compression on day to day basis – therefore no maintenance burden.

10 Public engagement

A public engagement event was held in Ellon on 4 September 2019 to gauge public opinion on the flood mitigation options proposed as part of this study. Approximately 21 residents attended the event, and many offered their views on the options proposed. Of the residents who attended the breakdown of attendance by area was as follows:

- Area A (Modley Burn) - 1
- Area B (Fortree and Hillhead Burns) - 9
- Area C (Old Bridge of Ellon) - 1
- Area D (The Meadows) - 6
- Other areas (including 1 from Newburgh) - 4

The overall feedback was provided for each area based on the above attendance through both verbal conversations and returned written feedback forms:

- **Area A (Modley Burn):** In general, the residents were happy with the solutions (scoring 4/5 for all solutions to area A). There were requests for including bank repairs within the option, particularly downstream of the two-stage channel proposal. There was also the suggestion of the Ythan backing up towards Modley Court during the Storm Frank event, the model demonstrates this is the case.
- **Area B (Fortree and Hillhead Burns):** The residents appear happy with the proposed solutions where most options were scored either a 4 or 5 in Area B. All responses indicate that there is a drainage issue in the area, numerous residents discussed how maintenance of the drainage network and gullies was poor. Some residents suggested that there were properties which were not highlighted at flood risk on the display posters, but which flooded during the 2016 event. A check has been made on the surveyed thresholds and these are deemed to be appropriate and the modelling does show these properties flooding at the 1000 year. This corroborates JBA's concerns highlighted in the report that water levels in this area are likely to be underestimated as we are not including flooding from the drainage system, hence the recommendation made for a drainage study where these properties are on the boundary of flooding at lower events and may have happened in reality due to more flow in the network from property drainage. If these additional flows were added to the model, then it's likely these properties would be shown at risk during the 200 year + climate change (and Storm Frank model run).
- **Area C (Old Bridge of Ellon):** No feedback on options has been provided on area C. The resident who attended the event took the questionnaire away to complete and discussions on the day were with regards to the flooding previously experienced.
- **Area D (The Meadows):** The Meadows gave a mixed response from the public engagement. The Meadows Flood Action group opposed the options where they feel PLP is not adequate to protect their properties due to observed high levels above 0.6m. They understand that the flood wall shown is not economically viable and continue to request a smaller bund across the north-west low point and disagree with the feasibility test which has already been carried out showing this option to not work. Other residents in The Meadows agreed that it is difficult to gain an economical solution here where they could accept the north-west bund was not feasible and one resident confirmed flow did come out from the southern edge of The Meadows. It was also raised that surface water was still an issue at The Meadows from the sports pitches, therefore the recommendation of study this drainage system should also be investigated as per JBA's recommendations.

11 Conclusions and recommendations

11.1 Summary

This report presents the results of a detailed flood risk appraisal for the community of Ellon, focussing on the risk from five different watercourses; River Ythan, Modley Burn, Broomies Burn, Hillhead Burn and Fortree Burn. There has been an extensive flood history within the area of Ellon with a particularly extreme event in 2016 which has been calculated to be roughly equivalent to a 0.22% AP (450 year) event, furthermore the 2016 event is the largest on record (1983 to present). Using a 24% uplift to the 0.5% AP (200 year) event to account for climate change this produces the equivalent of a 0.22% AP (464 year) event, therefore designing to this standard will account for climate change and an event that has recently been experienced. During the Do Minimum scenario which follows conditions experienced today 59 properties are at risk from the 0.5% AP (200 year) plus climate change event.

A detailed set of preliminary investigations was carried out in precedence to this appraisal such that it was possible to inform discussion of flood protection options for Ellon. These investigations involved a review of Ellon's flood history, an assessment of the hydrological inputs to the watercourses studied, collection and review of survey data, a review of the potential for Natural Flood Management, a Preliminary Ecological Appraisal, asset condition assessment and hydraulic modelling of the watercourses.

The hydraulic model, consisting of a 1D/2D Flood Modeller and TUFLOW model covering an area from the Bridge of Ardlethen to downstream of Ellon, allowed generation of flood inundation maps for a range of Annual Probability (AP) flood events ranging from 50% AP (2 year) to 0.1% AP (1000 year). A number of scenarios were modelled to provide sufficient information on which to base the economic appraisal at a later stage in the study. These included the Do Nothing and Do Minimum scenarios with the former representing a 'walkaway' scenario where maintenance of the watercourse ceases, and the latter representing the present-day watercourse condition. Once these maps were produced it was possible to review flood flow pathways and progress from a wide-ranging long list of potential flood protection options to a short-list of feasible solutions tailored to Ellon's flood risk problem. A feasibility analysis was conducted on a number of options which were likely to be unrealistic, any feasible options were taken forward into the shortlist appraisal.

Ellon was split into 4 different design areas to tackle the flood risk in Ellon based on differing flood mechanisms, after extensive review of the shortlisted options the following options for each design area were taken forward where different combinations were analysed to reach a preferred solution:

- **Design area A - Modley Burn**
  - Golf course embankment, Modley Place two stage channel, Modley Place bridge removal
  - Property Level Protection (PLP)
- **Design area B - Hillhead Burn**
  - Storage at Hillhead inlet, Hillhead inlet replacement, Fortree trash screen replacement, pumping station on the outlet and an embankment at Bruce Crescent.
  - Property Level Protection (PLP)
- **Design area C - Old Bridge of Ellon and Bridge of Ardlethen**
  - Direct defences (flood walls and flood embankments) around all properties
  - Direct defence around Ythan Court and Property Level Protection (PLP) to all other properties at risk
  - Property Level Protection (PLP)
- **Design area D - The Meadows and Broomies Burn**
  - Direct defences and surface water drainage
  - Property Level Protection (PLP)

A benefit-cost analysis has been undertaken for the present-day (Do Minimum) scenario and each of the above options. Costs for each option have been estimated using the Environment Agency's Long Term Costing tool (2012). An optimism bias factor of 60 % has been added to the total capital costs to allow for uncertainties in design at this level of appraisal and is typical for schemes at an early stage of appraisal.

11.2 Additional information and regulation requirements

If an option is taken forward the additional information outlined in the option descriptions in Section 5.8 should be addressed. As well as this the following regulations should be adhered to alongside all options:

- Should any options be taken forward the SEPA local regulatory team should be promptly contacted to discuss in particular the construction of the two-stage channel and flood embankments.
- Continued engagement with the River Ythan Fisheries Board is advised to ensure the desired proposal does not impact fish spawning habitats.
- A Controlled Activities Regulations (CAR) construction site licence will be required for management of surface water run-off from a construction site, including access tracks, which:
    - Is more than 4 hectares,
    - Is in excess of 5 km, or
    - Includes an area of more than 1 hectare or length of more than 500 m on ground with a slope in excess of 25˚.
- It is strongly encouraged that pre-CAR application engagement with a member of the regulatory services team is made as early as possible.
- Below the thresholds listed above will need to comply with the CAR general binding rule 10[20] which requires, amongst other things, that all reasonable steps must be taken to ensure that the discharge does not result in pollution of the water environment.

11.3 Recommendations

The above analysis resulted in the following key recommendations for Ellon:

Option 7 (BCR of 1.01) provides a standard of protection (SoP) of 0.5% AP (200 year) across all areas and should be considered as the preferred option if the benefit-cost ratio is critical for the scheme as it provides a positive outcome, including hard engineering in the most vulnerable areas.

Options 4, 5 and 6 should be considered further (BCR of 0.71, 0.79 and 1.38 respectively), this will produce a SoP of 0.5% AP (200 year) with both hard defences and PLP. Of these three options, option 4 would be the preferred solution as it places hard defences in design areas A and B which record the most flood damages and lowest SoP during the Do Minimum scenario but also includes a hard defence to protect Ythan Court which has been recorded as an area which is prone to past flooding. Whilst the SoP for this option is 0.5% AP (200 year) (based on the lowest SoP afforded by the scheme) the majority of the properties are provided with a 0.5% AP (200 year) plus climate change SoP.

Options 5 and 6 have been included for consideration as they produce higher cost benefit ratios where option 6 is the only option which achieves an effective cost benefit. This is due to the gradual increase of PLP where option 6 is solely a PLP solution. Though this is the case there are many additional negatives to using a PLP only based solution such as:

- Though the modelling has displayed many properties being within the 0.6 m flood depth at the 0.5% AP (200 year) plus climate change it was discussed by the public that depths exceeded this during the 2016 event. This is likely due to the model not accounting for a drainage issue which has been expressed within Ellon as well as other modelling uncertainty.
- PLP has a large social implication in the area of Ellon where a large number of the public have expressed concern with only having PLP as a solution to the flood risk. Uptake may also be hard for those properties that are located further from the watercourse who don't see themselves at risk.
- PLP is not seen as a long-term solution where increases in flow from climate change is likely to surpass the 0.6 m threshold that the majority of the properties currently do not experience.
- The costs of implementing PLP may rise once the full PLP surveys have been carried out. i.e. the requirements to make each house waterproof may vary.

20 SEPA, The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended), A Practical Guide, Version 8.3, February 2019

- The maintenance will fall with the homeowner, so there is a risk the PLP won't maintained.

It is recommended that a drainage study within Hillhead and The Meadows is conducted following this study to capture all flood risk within Ellon, it has been expressed by the public and stakeholders that the drainage within these areas is surcharging and causing surface water flood risk. This is also highlighted in Scottish Waters S16 mapping which is shown in Figure 5-13 of this report. This would also ensure that if PLP is taken forward it is fully understood how effective it will be, where more properties may pass above the 0.6 m threshold when considering surface water problems.

The difference in damages between the Do Minimum and Do Nothing scenario is significant (roughly 65 % reduction) this highlights the need for watercourse maintenance within Ellon showing its sensitivity to structure blockage and increased roughness. One key recommendation would be for routine maintenance in the area, in particular within Fortree and Hillhead where the Fortree trash screen has degraded making it far more likely to block.

Due to the option recommendation involving a level of PLP a greater understanding of flow within the catchment such as gauges on all of the named watercourses would be beneficial. A formal flood warning scheme would help to reduce cost of PLP by allowing for more manual choices to be used.

Due to the high costing of the structured options investigation into the effectiveness of implementing more Natural Flood Management (NFM) into the area could be beneficial. The preliminary investigation highlighted multiple areas where NFM could be utilised well, in particular the use of leaky bunds could help to significantly reduce the costs at Hillhead, replacing the storage area which has been proposed.

Appendices

A Appendix A - Damage Methodology

A.1 Direct damages - methodology

The process to estimate the benefits of an intervention option is to plot the two loss-probability curves: that for the situation now, and that with the proposed option as shown in Figure A-1. The scale on the y axis is the event loss (£); the scale on the x axis is the probability of the flood events being considered. When the two curves are plotted the difference in the areas beneath the curve is the annual reduction in flood losses to be expected from the scheme or mitigation approach.

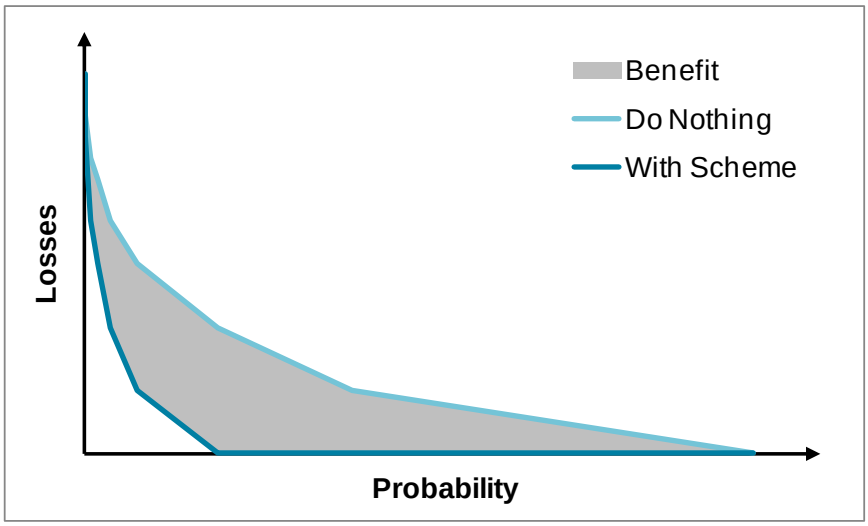


Figure A-1: Loss Probability Curve

To derive these two curves, straight lines are drawn between the floods for which there are data from the threshold event (the most extreme flood which does not cause any damage) to an extreme flood above the intended standard of protection. The greater the number of flood event probabilities, the more accurately the curves can be plotted.

A.1.1 Flood damage calculation and data

The FHRC Multi Coloured Manual (MCM) provides standard flood depth/direct damage datasets for a range of property types, both residential and commercial. This standard depth/damage data for direct and indirect damages has been utilised in this study to assess the potential damages that could occur under each of the options. Flood depths within each property have been calculated from the hydraulic modelling by comparing predicted water levels at each property to the surveyed threshold levels.

A flood damage estimate was generated using JBA's in-house flood damage tools. These estimate flood damages using FHRC data and the modelled flood level data. Each property data point was mapped on to its building's footprint. A mean, minimum and maximum flood level within each property is derived using GIS tools based on the range of flood levels around the building footprint. The inundation depth is calculated by comparing water levels with the surveyed threshold level. The mean (based on mean flood water level across the buildings floor area) flood damage estimates have been calculated and are presented in section 6.2.

The following assumptions, presented in the Table A-1, were used to generate direct flood damage estimates.

Table A-1: Damage considerations and method

Aspect	Values used	Justification
Flood duration	<12hrs	Flood water is not anticipated to inundate properties for prolonged periods.
Residential property type	MCM codes broken down by type and age.	Appropriate for this level of analysis.
Non-residential property type	Standard 2017 MCM codes applied.	Best available data used.
Upper floor flats	Upper floor flats have been removed from the flood damage estimates.	Whilst homeowners may be affected it is assumed that no direct flood damages are applicable.
MCM damage type	MCM 2017 data with no basements.	Most up to date economic analysis data used. Basements are not appropriate for the type of properties within the study area.
MCM flood type	MCM 2017 fluvial depth damages for combined fluvial-tidal scenario.	Best available data used.
Threshold level	Thresholds surveyed by surveyor for the majority of properties in area of interest.	Best available data used.
Property areas	OS MasterMap used to define property areas	Best available data used.
Capping value	Residential properties based on house prices from Zoopla. Commercial properties valued from rateable values for individual properties (supplied by SAA).	Best available data used.

A.1.2 Property data set

The property dataset was compiled for all residential and commercial properties. These properties were visited by a JBA Surveyor during the threshold survey.

A.1.3 Capping

The FHRC and appraisal guidance suggests that care should be exercised for properties with high total (Present Value) damages which might exceed the market value of the property. In most cases it is prudent to assume that the long-term economic losses cannot exceed the capital value of the property. The present value flood damages for each property were capped at the market value using average property values obtained from internet sources (e.g. Zoopla).

Market values for non-residential properties were initially estimated from a properties rateable value based on the following equation:

Capital Valuation = (100/Equivalent Yield) x Rateable Value

Rateable values for all available properties in Peebles were obtained from the Scottish Assessors Association website[21]. Equivalent yield varies regionally and temporarily, but is recommended to be a value of 10-12.5 for flood defence purposes[22]. A value of 12.5 was used.

However, the resulting property valuations were judged as being undervalued. An alternative approach was used whereby the estimated value is 3 times the max depth damage MCM curve damage value for the commercial property type multiplied by the properties ground floor area.

21 www.saa.gov.uk
22 Environment Agency (2009). Flood and Coastal Erosion Risk Management - Appraisal Guidance.

A.1.4 Updating of Damage Values

The MCM data used are based on January 2017 values and therefore do not need to be brought up to date to compare the costs and benefits.

A.2 Intangible damages

Current guidance indicates that the value of avoiding health impacts of fluvial flooding is of the order of £286 per year per household. This value is equivalent to the reduction in damages associated with moving from a Do Nothing option to an option with an annual flood probability of 1% (100 year) standard. A risk reduction matrix has been used to calculate the value of benefits for different pre-scheme standards and designed scheme protection standards.

A.3 Indirect damages

The multi coloured manual provides guidance on the assessment of indirect damages. It recommends that a value equal to 10.7 % of the direct property damages is used to represent emergency costs. These include the response and recovery costs incurred by organisations such as the emergency services, the local authority and SEPA.

A.3.5 Indirect commercial damages

Obtaining accurate data on indirect flood losses is difficult. Indirect losses are of two kinds:

- losses of business to overseas competitors, and
- the additional costs of seeking to respond to the threat of disruption or to disruption itself which fall upon firms when flooded.

The first of these losses is unusual and is limited to highly specialised companies which are unable to transfer their productive activities to a branch site in this country, and which therefore lose to overseas competitors. The second type of loss is likely to be incurred by most Non-Residential Properties (NRPs) which are flooded. They exclude post-flood clean-up costs but include the cost of additional work and other costs associated with inevitable efforts to minimise or avoid disruption. These costs include costs of moving inventories, hiring vehicles and costs of overtime working. These costs also include the costs of moving operations to an alternative site or branch and may include additional transport costs.

Chapter 5, Section 5.7 of the MCM[23] recommends estimating and including potential indirect costs where these are the additional costs associated with trying to minimise indirect losses. This is by calculating total indirect losses as an uplift factor of 3 % of estimated total direct NRP losses at each return period included within the damage estimation process.

23 Penning-Rowsell et al., 2013. Flood and Coastal Erosion Risk Management - A Manual for Economic Appraisal

B Appendix B - Economic Appraisal

Ellon Final Options Benefit Cost Summary

Appendix B: Page 1

Client/Authority				Prepared (date)	06/03/2019
Aberdeenshire Council				Printed	19/11/2019
Project name				Prepared by	DS
Ellon, Inverurie & Insch FPS				Checked by	BB
Project reference	2017s6743			Checked date	28/03/2019
Base date for estimates (year 0	Jan-2019				
Scaling factor (e.g. £m, £k, £)	£k	(used for all costs, losses and benefits)			
Year	0	30	75		
Discount Rate	3.5%	3.00%	2.50%		
Optimism bias adjustment factor	60%				

Costs and benefits of options

	Costs and benefits £k								
Option number	**Do-nothing**	**Do-minimum**	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**	**Option 7**
Option name	Do-nothing	Do-minimum	A - embankment and 2 stage channel B - Q200CC Storage, direct defence and pumping C - full direct defence D - full direct defence	A - embankment and 2 stage channel B - Q200 Storage, direct defence and pumping C - full direct defence D - full direct defence	A - embankment and 2 stage channel B - Q200 Storage, direct defence and pumping C - Ythan Court direct defence, rest PLP D - full direct defence	A - embankment and 2 stage channel B - Q200 Storage, direct defence and pumping C - Ythan Court direct defence, rest PLP D - PLP	A - embankment and 2 stage channel B - Q200 Storage, direct defence and pumping C - PLP D - PLP	A - PLP B - PLP C - PLP D - PLP	A - 2 stage channel B - Q200 Storage and pumping C - Q200 PLP D - Q200 PLP
AEP or SoP (where relevant)	<50% AP (<2 year)	<50% AP (<2 year)	0.5% AP (200 year) + climate change	0.5% AP (200 year)	0.5% AP (200 year)	0.5% AP (200 year)	0.5% AP (200 year)	0.5% AP (200 year)	0.5% AP (200 year)
COSTS:									
PV capital costs	0	0	11,119	9,872	7,542	3,731	3,261	1,508	2,419
PV operation and maintenance costs	0	0	747	746	673	773	804	487	659
PV Enabling	0	0	1,234	986	750	359	308	102	233
Optimism bias adjustment	0	0	7,860	6,962	5,380	2,918	2,624	1,258	1,987
PV negative costs (e.g. sales)	0	0	0	0	0	0	0	0	0
PV contributions									
Total PV Costs £k excluding contributions	0	0	20,960	18,567	14,345	7,781	6,997	3,356	5,298
Total PV Costs £k taking contributions into account	0	0	20,960	18,567	14,345	7,781	6,997	3,356	5,298
BENEFITS:									
PV monetised flood damages	5,866	2,078	264	310	313	317	317	346	474
PV monetised flood damages avoided		3,788	5,602	5,556	5,535	5,504	5,504	4,637	5,359
Total PV damages £k	5,866	2,078	264	0	0	0	317	346	474
Total PV benefits £k		3,788	5,602	5,556	5,535	5,504	5,504	4,637	5,359
Net Present Value **NPV**		3,788	-15,358	-13,011	-8,810	-2,277	-1,493	1,281	61
Average benefit/cost ratio **BCR**			0.27	0.30	0.39	0.71	0.79	1.38	1.01
Best practicable environmental option (WFD)									

Brief description of options

Do-nothing	Do-nothing
Do-minimum	Do-minimum
Option 1	A - embankment and 2 stage channel B - Q200CC Storage, direct defence and pumping C - full direct defence D - full direct defence
Option 2	A - embankment and 2 stage channel **B - Q200 Storage, direct defence and pumping** C - full direct defence D - full direct defence
Option 3	A - embankment and 2 stage channel B - Q200 Storage, direct defence and pumping **C - Ythan Court direct defence, rest PLP** D - full direct defence
Option 4	A - embankment and 2 stage channel B - Q200 Storage, direct defence and pumping C - Ythan Court direct defence, rest PLP **D - PLP**
Option 5	A - embankment and 2 stage channel B - Q200 Storage, direct defence and pumping **C - PLP** **D - PLP**
Option 6	**A - PLP** **B - PLP** **C - PLP** **D - PLP**
Option 7	**A - 2 stage channel** **B - Q200 Storage and pumping** **C - Q200 PLP** **D - Q200 PLP**

Area A Benefit Cost Analysis

Appendix B: Page 2

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k	(used for all costs, losses and benefits)	
Year	0	30	75
Discount Rate	3.5%	3.00%	2.50%
Optimism bias adjustment factor	60%		

Costs and benefits of options

	Costs and benefits £k						
Option number	**Do-nothing**	**Do-minimum**	**Option 1**	**Option 2**	**Option 3**	**Option 200yr**	**Option 4**
Option name	Do-nothing	Do-minimum	Option 1 - Golf course embankment and right bank wall	Option 2 - Golf course embankment and 2 stage	Option 3 - Golf course storage and 2 stage	Option 200yr - 2 stage	Option 4 - PLP
AEP or SoP (where relevant)	<50% AP (<2 year)	<50% AP (<2 year)	0.5% AP (200 year) + climate change	0.5% AP (200 year) + climate change	0.5% AP (200 year) + climate change	0.5% AP (200 year)	0.5% AP (200 year)
COSTS:							
PV capital costs	0	0	464	393	625	12	293
PV operation and maintenance costs	0	0	32	32	101	1	95
PV Enabling	0	0	47	39	62	1	20
Optimism bias adjustment	0	0	325	278	473	8	244
PV negative costs (e.g. sales)	0	0	0	0	0	0	0
PV contributions							
Total PV Costs £k excluding contributions	0	0	867	742	1,262	22	652
BENEFITS:							
PV monetised flood damages	979	652	76	76	76	160	151
PV monetised flood damages avoided		327	903	903	903	819	696
Total PV damages £k	979	652	76	76	76	160	151
Total PV benefits £k		327	903	903	903	492	696
DECISION-MAKING CRITERIA:							
Based on monetised PV benefits (excludes benefits from scoring and weighting and ecosystem services)							
Net Present Value **NPV**		327	35	161	-359	797	176
Average benefit/cost ratio **BCR**			1.0	1.2	0.7	36.5	1.1
							IBCR>1
Best practicable environmental option (WFD)							

Brief description of options:

Do-nothing	Do-nothing
Do-minimum	Do-minimum
Option 1	Option 1 - Golf course embankment and right bank wall
Option 2	Option 2 - Golf course embankment and 2 stage
Option 3	Option 3 - Golf course storage and 2 stage
Option 200yr	Option 200yr - 2 stage
Option 4	Option 4 - PLP

Area B Benefit Cost Analysis

Appendix B: Page 3

Client/Authority			Prepared (date)	06/03/2019
Aberdeenshire Council			Printed	19/11/2019
Project name			Prepared by	DS
Ellon, Inverurie & Insch FPS			Checked by	BB
Project reference	2017s6743		Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019			
Scaling factor (e.g. £m, £k, £)	£k	(used for all costs, losses and benefits)		
Year	0	30	75	
Discount Rate	3.5%	3.00%	2.50%	
Optimism bias adjustment factor	60%			

Costs and benefits of options

	Costs and benefits £k					
Option number	**Do-nothing**	**Do-minimum**	**Option 1**	**Option 2**	**Option 200yr**	**Option 3**
Option name	Do-nothing	Do-minimum	Option 1 - 200CC Storage, embankment and pumping station	Option 2 - 200 Storage, embankment and pumping station	Option 200yr - 200 Storage and pumping station	Option 3 - PLP
AEP or SoP (where relevant)	<50% AP (<2 year)	<50% AP (<2 year)	0.5% AP (200 year) + climate change	0.5% AP (200 year)	0.5% AP (200 year)	0.5% AP (200 year) + climate
COSTS:						
PV capital costs	0	0	3,554	2,307	2,135	654
PV operation and maintenance costs	0	0	591	591	570	211
PV Enabling	0	0	480	231	214	44
Optimism bias adjustment	0	0	2,775	1,877	1,751	546
PV negative costs (e.g. sales)	0	0	0	0	0	0
PV contributions						
Total PV Costs £k excluding contributions	0	0	7,400	5,007	4,669	1,456
Total PV Costs £k taking contributions into account	0	0	7,400	5,007	4,669	1,456
BENEFITS:						
PV monetised flood damages	4,495	1,170	81	127	127	81
PV monetised flood damages avoided		3,325	4,414	4,367	4,367	3,707
Total PV damages £k	4,495	1,170	81	127	127	81
Total PV benefits £k		3,325	4,414	4,367	4,367	3,707
DECISION-MAKING CRITERIA:						
Based on monetised PV benefits (ex cludes benefits from scoring and weighting and ecosystem services)						
Net Present Value **NPV**		3,325	-2,986	-639	-302	2,958
Average benefit/cost ratio **BCR**			0.6	0.9	0.9	2.5
						Highest bcr
Best practicable environmental option (WFD)						

Brief description of options:

Do-nothing	Do-nothing
Do-minimum	Do-minimum
Option 1	Option 1 - 200CC Storage, embankment and pumping station
Option 2	Option 2 - 200 Storage, embankment and pumping station
Option 3	Option 3 - PLP
Option 200yr	Option 200yr - 200 Storage and pumping station

Area C Benefit Cost Analysis

Appendix B: Page 4

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k	(used for all costs, losses and benefits)	
Year	0	30	75
Discount Rate	3.5%	3.00%	2.50%
Optimism bias adjustment factor	60%		

Costs and benefits of options

	Costs and benefits £k					
Option number	**Do-nothing**	**Do-minimum**	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Option name	Do-nothing	Do-minimum	Option 1 - Direct Defence	Option 2 - PLP	Option 3 - PLP and Ythan Court DD	Option 4 - PLP 200 year SOP
AEP or SoP (where relevant)	<50% AP (<2 year)	<50% AP (<2 year)	0.5% AP (200 year) + climate change	0.5% AP (200 year)	0.5% AP (200 year)	0.5% AP (200 year)
COSTS:						
PV capital costs	0	0	2,993	193	663	121
PV operation and maintenance costs	0	0	104	62	32	39
PV Enabling	0	0	299	13	64	8
Optimism bias adjustment	0	0	2,038	161	455	101
PV negative costs (e.g. sales)	0	0	0	0	0	0
PV contributions						
Total PV Costs £k excluding contributions	0	0	5,434	428	1,213	270
BENEFITS:						
PV monetised flood damages	140	81	26	29	29	42
PV monetised flood damages avoided		58	113	93	93	82
Total PV damages £k	140	81	26	29	29	42
Total PV benefits £k		58	113	93	93	82
DECISION-MAKING CRITERIA:						
Based on monetised PV benefits (excludes benefits from scoring and weighting and ecosystem services)						
Net Present Value **NPV**		58	-5,321	-318	-1,103	-172
Average benefit/cost ratio **BCR**			0.0	0.2	0.1	0.4
						Highest bcr
Best practicable environmental option (WFD)						

Brief description of options:

Do-nothing	Do-nothing
Do-minimum	Do-minimum
Option 1	Option 1 - Direct Defence
Option 2	Option 2 - PLP
Option 3	Option 3 - PLP and Ythan Court DD
Option 4	Option 4 - PLP 200 year SOP

Area D Benefit Cost Analysis

Appendix B: Page 5

Prepared (date)	06/03/2019
Printed	19/11/2019
Prepared by	DS
Checked by	BB
Checked date	28/03/2019

Client/Authority
Aberdeenshire Council
Project name
Ellon, Inverurie & Insch FPS
Project reference 2017s6743
Base date for estimates (year 0) Jan-2019
Scaling factor (e.g. £m, £k, £) £k (used for all costs, losses and benefits)

Year	0	30	75
Discount Rate	3.5%	3.00%	2.50%

Optimism bias adjustment factor 60%

Costs and benefits of options

	Costs and benefits £k				
Option number	**Do-nothing**	**Do-minimum**	**Option 1**	**Option 2**	**Option 3**
Option name	Do-nothing	Do-minimum	Option 1 - Direct defences	Option 2 - PLP	Option 3 - PLP 200 SOP
AEP or SoP (where relevant)	<50% AP (<2 year)	<50% AP (<2 year)	0.5% AP (200 year) + climate change	0.5% AP (200 year)	0.5% AP (200 year)
COSTS:					
PV capital costs	0	0	4,179	369	151
PV operation and maintenance costs	0	0	19	119	49
PV Enabling	0	0	416	25	10
Optimism bias adjustment	0	0	2,769	307	126
PV negative costs (e.g. sales)	0	0	0	0	0
PV contributions					
Total PV Costs £k excluding contributions	0	0	7,384	820	336
BENEFITS:					
PV monetised flood damages	252	175	80	84	145
PV monetised flood damages avoided		77	172	141	90
Total PV damages £k	252	175	80	84	145
Total PV benefits £k		77	172	141	90
DECISION-MAKING CRITERIA:					
Based on monetised PV benefits (ex cludes benefits from scoring and weighting and ecosystem services)					
Net Present Value **NPV**		77	-7,211	-679	-246
Average benefit/cost ratio **BCR**			0.0	0.2	0.3
					Highest bcr
Best practicable environmental option (WFD)					

Brief description of options:

Do-nothing	Do-nothing
Do-minimum	Do-minimum
Option 1	Option 1 - Direct defences
Option 2	Option 2 - PLP
Option 3	Option 3 - PLP 200 SOP

Area A Option 1 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	**Costs in £k**
Enabling Costs	£46.53
Capital Costs	£463.78
O & M Costs	£109.34
Other Costs	£0.00
Total Real Cost	£619.65
Total Cost PV	£542.13
Total Cost PV + OB	**£867.40**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment			£38.08	£380.77	£106.06	£0.00	£524.90	£449.71
	Wall			£8.26	£82.63	£3.28	£0.00	£94.18	£91.85
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various			£0.19	£0.38	£0.00	£0.00	£0.56	£0.56
User Defined 2	Various								
User Defined 3	Various								

Area A Option 2 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	**Costs in £k**
Enabling Costs	£38.82
Capital Costs	£392.59
O & M Costs	£111.03
Other Costs	£0.00
Total Real Cost	£542.44
Total Cost PV	£463.73
Total Cost PV + OB	**£741.96**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment			£38.08	£380.77	£106.06	£0.00	£524.90	£449.71
	Wall								
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various			£0.00	£5.87	£4.97	£0.00	£10.85	£7.32
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various			£0.19	£0.38	£0.00	£0.00	£0.56	£0.56
User Defined 2	Various			£0.56	£5.58	£0.00	£0.00	£6.13	£6.13
User Defined 3	Various								

Area A Option 3 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£62.26
Capital Costs	£625.48
O & M Costs	£347.67
Other Costs	£0.00
Total Real Cost	£1,035.41
Total Cost PV	£788.93
Total Cost PV + OB	**£1,262.28**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment			£50.95	£509.50	£147.74	£0.00	£708.19	£603.45
	Wall								
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall			£10.47	£104.66	£196.70	£0.00	£311.83	£172.37
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various			£0.00	£4.37	£3.22	£0.00	£7.60	£5.31
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various			£0.19	£0.38	£0.00	£0.00	£0.56	£0.56
User Defined 2	Various			£0.66	£6.57	£0.00	£0.00	£7.23	£7.23
User Defined 3	Various								

Area A - Option 4 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£19.86
Capital Costs	£164.07
O & M Costs	£324.86
Other Costs	£541.44
Total Real Cost	£1,050.23
Total Cost PV	£407.45
Total Cost PV + OB	**£651.92**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall								
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various			£19.86	£164.07	£324.86	£541.44	£1,050.23	£407.45
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area A Option 5 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£0.75
Capital Costs	£11.83
O & M Costs	£4.97
Other Costs	£0.00
Total Real Cost	£17.55
Total Cost PV	£14.02
Total Cost PV + OB	**£22.43**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall								
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various			£0.00	£5.87	£4.97	£0.00	£10.85	£7.32
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various			£0.19	£0.38	£0.00	£0.00	£0.56	£0.56
User Defined 2	Various			£0.56	£5.58	£0.00	£0.00	£6.13	£6.13
User Defined 3	Various								

Area B Option 1 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£479.59
Capital Costs	£3,554.24
O & M Costs	£2,031.27
Other Costs	£0.00
Total Real Cost	£6,065.09
Total Cost PV	£4,626.57
Total Cost PV + OB	**£7,402.52**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment			£370.82	£2,472.15	£134.06	£0.00	£2,977.03	£2,881.99
	Wall			£44.95	£449.46	£3.05	£0.00	£497.45	£495.29
	Sheet Piling			£12.83	£128.27	£2.10	£0.00	£143.19	£141.71
Channel management	N/A								
Culvert & screen	N/A			£0.65	£6.48	£178.93	£0.00	£186.05	£59.20
Control assets	Weir								
	Pumping station			£41.94	£419.39	£1,579.77	£0.00	£2,041.10	£922.67
	Flood gate								
	Outfall			£7.85	£78.49	£133.37	£0.00	£219.71	£125.16
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A			£0.55	£0.00	£0.00	£0.00	£0.55	£0.55
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area B Option 2 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	**Costs in £k**
Enabling Costs	£231.02
Capital Costs	£2,307.48
O & M Costs	£2,029.17
Other Costs	£0.00
Total Real Cost	£4,567.68
Total Cost PV	£3,130.64
Total Cost PV + OB	**£5,009.03**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment			£135.37	£1,353.66	£134.06	£0.00	£1,623.09	£1,528.05
	Wall			£44.95	£449.46	£3.05	£0.00	£497.45	£495.29
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A			£0.65	£6.48	£178.93	£0.00	£186.05	£59.20
Control assets	Weir								
	Pumping station			£41.94	£419.39	£1,579.77	£0.00	£2,041.10	£922.67
	Flood gate								
	Outfall			£7.85	£78.49	£133.37	£0.00	£219.71	£125.16
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A			£0.28	£0.00	£0.00	£0.00	£0.28	£0.28
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area B Option 3 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£44.43
Capital Costs	£366.28
O & M Costs	£725.23
Other Costs	£1,208.71
Total Real Cost	£2,344.65
Total Cost PV	£909.70
Total Cost PV + OB	**£1,455.52**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall								
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various			£44.43	£366.28	£725.23	£1,208.71	£2,344.65	£909.70
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area B Option 4 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£213.74
Capital Costs	£2,134.64
O & M Costs	£1,957.78
Other Costs	£0.00
Total Real Cost	£4,306.16
Total Cost PV	£2,919.74
Total Cost PV + OB	**£4,671.58**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

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Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment			£118.08	£1,180.82	£62.67	£0.00	£1,361.57	£1,317.14
	Wall			£44.95	£449.46	£3.05	£0.00	£497.45	£495.29
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A			£0.65	£6.48	£178.93	£0.00	£186.05	£59.20
Control assets	Weir								
	Pumping station			£41.94	£419.39	£1,579.77	£0.00	£2,041.10	£922.67
	Flood gate								
	Outfall			£7.85	£78.49	£133.37	£0.00	£219.71	£125.16
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A			£0.28	£0.00	£0.00	£0.00	£0.28	£0.28
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area C Option 1 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£299.27
Capital Costs	£2,992.72
O & M Costs	£358.99
Other Costs	£0.00
Total Real Cost	£3,650.99
Total Cost PV	£3,396.47
Total Cost PV + OB	**£5,434.35**

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Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment			£115.91	£1,159.14	£337.31	£0.00	£1,612.37	£1,373.22
	Wall			£183.36	£1,833.58	£21.68	£0.00	£2,038.62	£2,023.25
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area C Option 2 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£13.18
Capital Costs	£107.78
O & M Costs	£213.41
Other Costs	£355.69
Total Real Cost	£690.06
Total Cost PV	£267.80
Total Cost PV + OB	**£428.48**

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Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall								
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various			£13.18	£107.78	£213.41	£355.69	£690.06	£267.80
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area C Option 3 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£63.85
Capital Costs	£625.02
O & M Costs	£108.32
Other Costs	£158.65
Total Real Cost	£955.84
Total Cost PV	£758.19
Total Cost PV + OB	**£1,213.10**

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Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall			£57.69	£576.94	£13.12	£0.00	£647.76	£638.46
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various			£6.16	£48.08	£95.19	£158.65	£308.08	£119.73
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area C Option 4 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£8.30
Capital Costs	£67.98
O & M Costs	£134.60
Other Costs	£224.33
Total Real Cost	£435.21
Total Cost PV	£168.89
Total Cost PV + OB	**£270.22**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall								
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various			£8.30	£67.98	£134.60	£224.33	£435.21	£168.89
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area D Option 1 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	**Costs in £k**
Enabling Costs	£416.42
Capital Costs	£4,179.47
O & M Costs	£65.25
Other Costs	£0.00
Total Real Cost	£4,661.15
Total Cost PV	£4,614.89
Total Cost PV + OB	**£7,383.82**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

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Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment			£0.95	£9.46	£15.08	£0.00	£25.48	£14.80
	Wall			£415.48	£4,154.78	£37.28	£0.00	£4,607.54	£4,581.11
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various			£0.00	£15.23	£12.90	£0.00	£28.13	£18.98
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area D Option 2 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£24.98
Capital Costs	£206.33
O & M Costs	£408.54
Other Costs	£680.91
Total Real Cost	£1,320.77
Total Cost PV	£512.42
Total Cost PV + OB	**£819.87**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

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Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall								
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various			£24.98	£206.33	£408.54	£680.91	£1,320.77	£512.42
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

Area D Option 3 Costing

Client/Authority		Prepared (date)	06/03/2019
Aberdeenshire Council		Printed	19/11/2019
Project/Option name		Prepared by	DS
Ellon, Inverurie & Insch FPS		Checked by	BB
Project reference	2017s6743	Checked date	28/03/2019
Base date for estimates (year 0)	Jan-2019		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	
	Costs in £k
Enabling Costs	£10.25
Capital Costs	£84.53
O & M Costs	£167.36
Other Costs	£278.93
Total Real Cost	£541.07
Total Cost PV	£209.93
Total Cost PV + OB	**£335.89**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

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Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall								
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various			£10.25	£84.53	£167.36	£278.93	£541.07	£209.93
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various								
User Defined 2	Various								
User Defined 3	Various								

C Appendix C - Do Nothing Assumptions

C.1 Outline of the problem

Based on the 1000 year design event there are 387 properties at risk of flooding within Ellon; 76 properties at risk from the River Ythan, 202 properties at risk from the Fortree and Hillhead Burns, 108 properties at risk from Modley Burn and 1 property at risk from Broomies Burn. Flooding is expected to begin at a 2 year return period under the existing site conditions from Modley Burn and a 50 year return period for the River Ythan.

C.2 Consequences of Doing Nothing

The starting point for a scheme appraisal is always to develop a suitable Do Nothing and Do Minimum option that can be used as a consistent baseline against which other options are compared. The Do Nothing represents the 'walk-away' option; cease all maintenance and repairs to the existing defences and watercourse activities. This therefore represents a scenario with no intervention in the natural process and serves as a baseline against which all other options are compared.

Assessing the level of risk for both the Do Nothing and Do Minimum options needs to consider how the watercourse will change and how any flow controlling assets or flood defences will react or deteriorate over the appraisal period. The following recommendations are therefore used for the Do Nothing and Do minimum options.

C.3 Do Nothing

C.3.1 River Ythan

Under the Do Nothing scenario the watercourses would not be maintained. This would lead to a gradual degradation of the banks and vegetation growth. Due to reasonable bank growth already observed and recreational footpaths which would likely continue to be maintained a +20% Manning's 'n' roughness has been applied out of bank throughout the River Ythan for the entire appraisal period. Due to the Ythan being a large watercourse sediment build up and blockage is less likely therefore the in-bank Manning's 'n' roughness value will only be increased by 10%.

It is recommended that bridge blockage is included in the Do Nothing scenario. A full list of the structures to be blocked can be found in Section 2 which have been determined using a risk-based analysis.

There are no formal flood defences throughout Ellon.

C.3.2 Broomies Burn

Under the Do Nothing scenario the watercourses would not be maintained. This would lead to a gradual degradation of the banks and vegetation growth. The full extent of Broomies Burn has high growth with little recreational use therefore a constant increase of 20% to Manning's 'n' value out of bank will be applied. As this is a small watercourse it is likely for the channel to build up with sediment, vegetation and litter therefore a constant increase of 20% to Manning's 'n' value in bank will also be applied.

It is recommended that bridge blockage is included in the Do Nothing scenario. A full list of the structures to be blocked can be found in Section 2 which have been determined using a risk-based analysis.

C.3.3 Modley Burn

Under the Do Nothing scenario the watercourses would not be maintained. This would lead to a gradual degradation of the banks and vegetation growth. The upstream extent of Modley Burn is within a golf course therefore it is unlikely to experience low maintenance, Manning's 'n' within this region will be unaltered. Downstream of the golf course there is likely to be high growth with little recreational use therefore a constant increase of 20% to Manning's 'n' value out of bank will be applied. As this is a small watercourse it is likely for the channel to build up with sediment, vegetation and litter therefore a constant increase of 20% to Manning's 'n' value in bank will also be applied.

It is recommended that bridge blockage is included in the Do Nothing scenario. A full list of the structures to be blocked can be found in Section 2 which have been determined using a risk-based analysis.

C.3.4 Fortree / Hillhead Burn

Under the Do Nothing scenario the watercourses would not be maintained. This would lead to a gradual degradation of the banks and vegetation growth. The banks and channel of both Fortree and Hillhead burns would become overgrown therefore a constant increase of 20% to Manning's 'n' value both in and out of bank will be applied.

It is recommended that structure blockage is included in the Do Nothing scenario. A full list of the structures to be blocked can be found in Section 2 which have been determined using a risk-based analysis.

The culvert trash screen at Hillhead has had previous issues with blockage. A relatively new trash screen as well as a coarse trash screen have been installed. The upstream land use also does not contain woodland therefore it is likely the risk of blockage would be sediment related. In a Do Nothing scenario it is likely sediment would build up along the base of the culvert though the trash screen would still be maintained due to legal obligation. The culvert will therefore be blocked by reducing the diameter size by 2/3 for the Do Nothing scenario.

The Fortree culvert screen is in poor condition and will also experience similar problems to Hillhead although its blockage history is not known. It will also be modelled by reducing the diameter size by 2/3 to represent sediment blockage in a Do Nothing scenario.

C.4 Do Minimum

The Do Minimum scenario effectively represents the current scenario whereby the watercourse and all structures are maintained and replaced if they deteriorate to a point that is unacceptable. There are no flood defences within the community.

C.5 Blockage Scenario

A risk based analysis for all the structures in Ellon was carried out to determine which structures are most likely to block in a Do Nothing Scenario. The tables below show the parameters and results that were evaluated as these are the most likely to pose a risk of blockage.

The following bridges or culverts, determined by either a B (bridge) or C (culvert) after the structure name, will be modelled using the following method:

- YTHA01_6758B - Central pier has been extended by 0.5m in both directions.
- YTHA01_4000B - Central pier has been extended by 0.5m in both directions.
- YTHA01_2931B - Central pier has been extended by 0.5m in both directions.
- YTHA01_2891B - Central pier has been extended by 0.5m in both directions.
- MODL01_1237C - Diameter of upstream conduit decreased by 0.1m.
- MODL01_1063C - Soffit of upstream conduit dropped by 0.2m.
- MODL01_0648B - Soffit level dropped by 0.2m.
- MODL01_0297B - Soffit level dropped by 0.2m.
- MODL01_0083B - Soffit level dropped by 0.2m.
- BROO01_1527C - Soffit level dropped by 0.2m.
- BROO01_0507C - Diameter of upstream conduit decreased by 0.1m.
- BROO01_0315C - Diameter of upstream conduit decreased by 0.1m.
- BROO01_0268C - Soffit on both upstream conduits has been reduced by 0.2m.
- BROO01_0234C - Soffit on both upstream conduits has been reduced by 0.2m.

Blockage Scenario - River Ythan								
Structure	**Flow Area (m^2)**	**History of blockage**	**Screen**	**Central pier**	**Upstream land use**	**Would blockage pose a risk to upstream and downstream properties**	**To be included in blockage scenario**	**Explanation**
YTHA01_6758B	95	no	no	yes	Arable farmland	Yes	**yes**	Smaller flow area than the rest of the Ythan with a central pier, particularly vulnerable from upstream
YTHA01_4000B	550	no	no	yes	Amenity grassland	yes	**yes**	Central pier may cause blockage
YTHA01_2931B	234	no	no	yes	Scrub	yes	**yes**	Central pier may cause blockage
YTHA01_2891B	177	no	no	yes	Scrub	yes	**yes**	Central pier may cause blockage
YTHA01_1883B	441	no	no	no	Amenity grassland / scattered woodland	no	no	Very large flow area
YTHA01_0931B	567	no	no	no	Amenity grassland / scattered woodland	yes	no	Very large flow area

Blockage Scenario - Broomies Burn								
Structure	**Flow Area (m^2)**	**History of blockage**	**Screen**	**Central pier**	**Upstream land use**	**Would blockage pose a risk to upstream properties**	**To be included in blockage scenario**	**Explanation**
BROO01_1718C	1.10	no	no	no	Arable farmland	no	no	Though flow area is small the dimension is tall and the upstream land use is not as likely to cause blockage
BROO01_1527C	1.87	no	no	no	Arable farmland	yes	**yes**	Low soffit for upstream land use to block
BROO01_1237B	3.48	no	no	no	Woodland	no	no	Larger flow area, high soffit single span
BROO01_1151B	4.45	no	no	no	Woodland	no	no	Larger flow area, high soffit single span
BROO01_1097C	3.32	no	no	no	Woodland	no	no	Larger flow area, tall dimension
BROO01_0507C	2.17	no	no	no	Bare ground	yes	**yes**	Due to dimensions, much more likely for debris from the woodland to block this culvert, low soffit
BROO01_0315C	1.13	no	no	no	Amenity grassland, scattered trees	yes	**yes**	Small flow area
BROO01_0268C	1.70	no	no	yes	Amenity grassland, scattered trees	yes	**yes**	Small flow area with central pier for the double culvert
BROO01_0234C	1.49	no	no	yes	Amenity grassland, scattered trees	yes	**yes**	Small flow area with central pier for the double culvert

Blockage Scenario - Modley Burn								
Structure	**Flow Area (m^2)**	**History of blockage**	**Screen**	**Central pier**	**Upstream land use**	**Would blockage pose a risk to upstream properties**	**To be included in blockage scenario**	**Explanation**
MODL01_1237C	0.48	no	no	no	Grassland / arable farmland	no	**yes**	Small flow area, vulnerable to large upstream debris
MODL01_1179B	2.50	no	no	no	Grassland / golf course	no	no	Upstream more likely to block, larger area, grassland
MODL01_1063C	1.63	yes	no	no	Grassland / golf course	yes	**yes**	Image shows trash and debris in front of culvert, history of blockage
MODL01_0648B	2.86	no	no	no	Woodland	yes	**yes**	Woodland upstream
MODL01_0356C	1.98	no	no	no	Amenity grassland / some woodland	yes	no	Less likely to block than others, no to all answers
MODL01_0297B	1.19	no	no	no	Amenity grassland, scattered trees	yes	**yes**	Small area, more likely to block than others around it, low soffit
MODL01_0251B	1.78	no	no	no	Amenity grassland, scattered trees	yes	no	Less likely to block than others, no to all answers
MODL01_0178B	1.96	no	no	no	Amenity grassland, scattered trees	no	no	Less likely to block than others, no to all answers
MODL01_0083B	0.87	no	no	no	Amenity grassland, scattered trees	yes	**yes**	Small area, scattered woodland

Section Number and Bridge Name (Highlighted names have been selected for blockage)	Structure Unit Type (Highlighted names have been selected for blockage)	Photo
River Ythan		
YTHA01_6758B Bridge of Ardlethen Road Bridge	Arch Bridge	
YTHA01_4000B Meiklemill Railway Bridge	Arch Bridge	
YTHA01_2931B Ellon Bridge A920	Arch Bridge	

YTHA01_ 2891B Old Bridge of Ellon (now used as a footbridge)	Arch Bridge	
YTHA01_ 1883B Boatie Tam's Brig Footbridge	USBPR Bridge	
YTHA01_ 0931B River Ythan Bridge A90	USBPR Bridge	
Broomies Burn		
BROO01_ 1718C Masonry culvert at Unnamed Road	Sprung arch culvert	

BROO01_ 1527C Broomies Bridge A948	Rectangular culvert	
BROO01_ 1237B Timber bridge at Balmacassie Community Woodland	USBPR Bridge	
BROO01_ 1151B Footbridge at Balmacassie Community Woodland	USBPR Bridge	
BROO01_ 1097C Culvert at Balmacassie Way	Full arch culvert	

BROO01_0507C Culvert A920	Rectangular culvert	
BROO01_0315C Culvert at The Meadows	Rectangular culvert	
BROO01_0268C Double culvert at The Meadows	Double rectangular culvert	
BROO01_0234C Double culvert at The Meadows	Double rectangular culvert	

Modley Burn		
MODL01_ 1237C Culvert on the golf course	Circular culvert	
MODL01_ 1179B Footbridge on the golf course	USBPR bridge	
MODL01_ 1063C Hospital Road culvert	Rectangular culvert	
MODL01_ 0648B Culvert at Hospital Road	Arch bridge	

MODL01_ 0356C Station Road culvert B9005	Rectangular culvert	
MODL01_ 0297B Modley Burn Bridge	Arch bridge	
MODL01_ 0251 Ellon Primary School footbridge	Arch bridge	
MODL01_ 0178 Footbridge South of Ellon Primary School	Arch bridge	

MODL01_ 0083 Gordon Park footbridge	Arch bridge		

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