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**JBA**  
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# Ellon FPS Study Information Review Report

Final Report

February 2018

Aberdeenshire Council





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## Contract

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## Purpose

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## Acknowledgements

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

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## Abbreviations

1D .....	One Dimensional (modelling)
AMAX.....	Annual Maximum
ARF .....	Areal Reduction Factor
BGS .....	British Geological Survey
CCTV .....	Closed Circuit Television
CEH .....	Centre for Ecology and Hydrology
DDF.....	Depth Duration Frequency
DTM .....	Digital Terrain Model
EC .....	European Community
FEH.....	Flood Estimation Handbook
FPS .....	Flood Protection Scheme
GIS.....	Geographical Information System
HES.....	Historic Environment Scotland
ID .....	Identifier
LiDAR.....	Light Detection And Ranging
mAOD .....	metres Above Ordnance Datum
NNR .....	National Nature Reserve
OS.....	Ordnance Survey
PRFA.....	Preliminary Flood Risk Assessment
QMED .....	Median Annual Flood (with return period 2 years)
RBMP.....	River Basin Management Plan
ReFH.....	Revitalised Flood Hydrograph method
SAC.....	Special Area of Conservation, protected under the EU Habitats Directive
SEPA .....	Scottish Environment Protection Agency
SPA.....	Special Protection Area for birds, protected under the EU Habitats Directive
SSSI.....	Site of Special Scientific Interest
TBR.....	Tipping Bucket Raingauge
Tp.....	Time to Peak



# 1 Introduction

## 1.1 Site Extent

Ellon, in Aberdeenshire, is located on the River Ythan approximately 10 kilometres upstream of its discharge point into the North Sea, at Newburgh. The area surrounding Ellon is largely agricultural with some forest cover; the terrain is relatively low lying with some small hills. The geology of the area, as described by the British Geological Survey (BGS)<sup>1</sup>, is made up of impermeable metamorphic Lower Dalradian formations overlain with boulder clay and morainic drift; to the north west there are intrusions of Old Red Sandstone (ORS). Thus, due to the impermeable geology, the response hydrograph is rapid, making the catchment prone to flash floods. The mean elevation across the Ellon catchment is 106.1 mAOD.

Ellon is part of the North East Local Plan District (LPD). The details for this LPD, are contained in the North-East Flood Risk Management Strategy (FRMS)<sup>2</sup> and the North East Flood Risk Management Plan (LFRMP)<sup>3</sup>.

Ellon is categorised as a Potentially Vulnerable Area (06/12) in the North East LPD with an area of 19 km<sup>2</sup>. Key roads including the A920; A948; B9005 and part of the A90 pass through the PVA, making them at potential risk of flooding. The population of Ellon is approximately 9860, with 110 residential properties and 40 non-residential properties shown as at risk of flooding in SEPA maps, as well as Meiklemill Primary School. The River Ythan is the main source of river flooding, usually causing damage to The Meadows area, Ythan Terrace and Bruce Crescent. However, the smaller tributaries of the Modley Burn and Broomies Burn also contribute to the flood risk, and have been known to cause flooding to Castle Way Industrial Estate, Hospital Road, and McDonald Golf Club. These flood events cause damage or inaccessibility to residential properties and local transport infrastructure and amenities. Annual Average Damages (AAD) equate to £300,000 annually<sup>2</sup>, primarily due to river flooding (75%) and surface water flooding (25% of flood events in Ellon).

There are three international landscape designations (SAC, SPA and RAMSAR) and three national landscape designations (SSSI and NNR) located within 5 km of Ellon, which support up to 51,265 individual birds.

Table 1-1: Landscape designations within 5 km

Site	Designation	Reason for designation	Distance downstream of Ellon
Sands of Forvie	Special Area of Conservation (SAC)	<b>Coast:</b> Humid dune slacks, Lime-deficit dune heathland with crowberry, Shifting dunes, Shifting dunes with Marram Grass	7.7 km
Ythan Estuary, Sands of Forvie and Meikle Loch	Special Protection Area (SPA)	<b>Birds:</b> Common Tern, Eider, Lapwing, Little Tern, Pink Footed Goose, Redshank, Sandwich Tern, Waterfowl assemblage	2.2 km
Ythan Estuary and Meikle Loch	RAMSAR (international convention for the protection and wise	<b>Birds:</b> Pink Footed Goose, Sandwich Tern and Waterfowl assemblage	2.2 km

<sup>1</sup> British Geological Survey. Geology of Britain Viewer - <http://mapapps.bgs.ac.uk/geologyofbritain/home.html> [accessed 10 November 2017]

<sup>2</sup> North-East Flood Risk Management Strategy [http://apps.sepa.org.uk/FRMStrategies/pdf/lpd/LPD\\_06\\_Full.pdf](http://apps.sepa.org.uk/FRMStrategies/pdf/lpd/LPD_06_Full.pdf) [accessed 10 November]

<sup>3</sup> 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]

	use of wetlands)		
Sands of Forvie and Ythan Estuary	Site of Special Scientific Interest (SSSI)	<b>Birds:</b> Arctic Tern, Breeding bird assemblage, Common Tern, Eider, Little Tern, Pink-footed Goose, Sandwich Tern, Waterfowl assemblage <b>Earth sciences:</b> Coastal geomorphology of Scotland <b>Marine:</b> Estuary <b>Coast:</b> Saltmarsh, Sand dunes	2.2 km
Foveran Links	Site of Special Scientific Interest (SSSI)	<b>Earth sciences:</b> Coastal geomorphology of Scotland <b>Coast:</b> Saltmarsh, Sand dunes	9.6 km
Forvie	National Nature Reserve (NNR)	No listed features (for NNR). Forvie also classified as a SAC and SSSI for the reasons indicated above.	2.2 km

Notable cultural sites within 5km of Ellon include: the Ellon Castle and gardens; The Hill of Logie monument, which lies east of Ellon; and the East Kinharrachie Cairn monument which lies west of Ellon, all of which are designated as scheduled monuments by Historic Environment Scotland<sup>4</sup> (HES). However, none of these Cultural sites lie within the SEPA flood map fluvial flood extents.

The River Ythan at Ellon is part of the River Ythan (Methlick to Ellon) (ID 23231) reach in the River Basin Management Plan (RBMP) and was ranked as being of 'Moderate' condition in 2016. Pre-2010 the reach was classed as being of overall 'Poor' condition so there has been an improvement in the status. However, the reason that the reach is not classed as having a 'High' status is due to the 'Moderate' ranking of water quality, as indicated by the nutrient enrichment and pollution status of phytobenthos (microscopic plants which exist attached to rocks or plants). All of the other categories against which reaches are assessed (access for fish migration, water flows and levels, physical condition and freedom from invasive species) are ranked as 'High' or 'Good'<sup>5</sup>. The eastern section of the River Ythan within Ellon is also designated salmonid waters<sup>6</sup> (defined as waters that support or become capable of supporting fish belonging to species such as salmon, trout, grayling, char and whitefish) under the 2008 Freshwater Fish Directive assessment (Directive 2006/44/EC).

The River Ythan is gauged by SEPA at the Ellon gauging station. The winter storms during January 2016 recorded the highest level since records started in 1989 4.46 m (109.4 m<sup>3</sup>/s) at the gauge since the gauge began operating in 1983. Previous to this, the 2012 event was the second highest gauging of 3.34 m, 2009 the third at 3.32 m and the 1996 flood event was fourth highest on record with a level of 3.26 m (105.26 m<sup>3</sup>/s). Due to SEPA's concerns with regards to the high flow rating for this gauge, a rating review will be carried out for the gauge and used within this study.

4 Historic Scotland - <http://historicscotland.maps.arcgis.com/apps/Viewer/index.html?appid=18d2608ac1284066ba3927312710d16d> [accessed 10/11/2017]

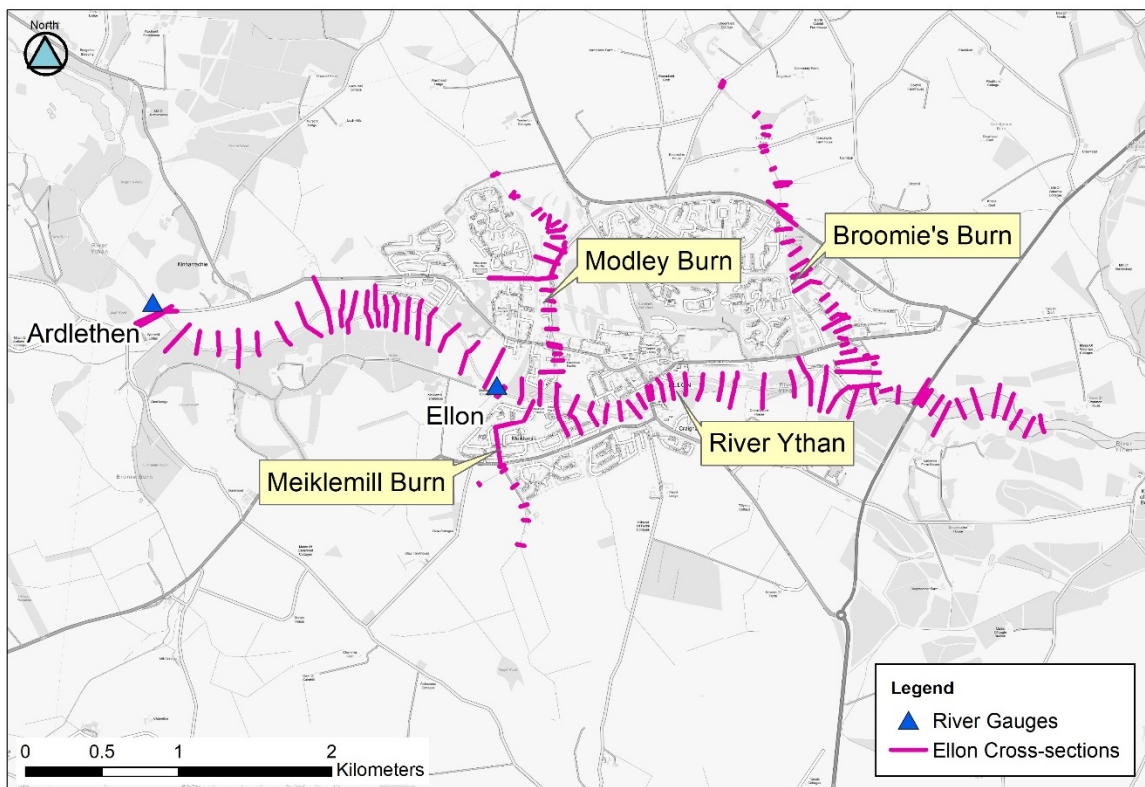
5 SEPA RBMP website (2017) <http://www.sepa.org.uk/data-visualisation/water-environment-hub/> [accessed 22/11/2017]

6 RBMP website (2017) <http://www.sepa.org.uk/data-visualisation/water-environment-hub/> [accessed 22/11/2017]

## 1.2 Ellon model extent

The model survey extents requested for Ellon within the ITT, can be seen in Figure 1-1, the SEPA flood map extents including fluvial; surface water and coastal water flooding can be seen in Figure 1-5 and Figure 1-6.

Figure 1-1: Model survey extents requested for Ellon.



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## 1.3 Historical Flooding

From a review of SEPA data and other sources such as the Chronology of British Hydrological Events (CBHE) historical flooding information for the catchment of Ellon has been collected in the table below.

Table 1-2: Historical flooding events in Ellon

Date	Description	Source
1829	'...Ythan grew so great that it drowned out the fires in some men's houses in Ellon and Newburgh, far beyond the wonted course, many thinking this to be prodigious tokens.'	Muckle Spate <sup>7</sup> , Found online at: <a href="https://archive.org/stream/greatfloodsaugu00laudgoog#page/n6/mode/2up">https://archive.org/stream/greatfloodsaugu00laudgoog#page/n6/mode/2up</a> [accessed on 16.11.17]
21/07/1893	1893 July 21 p[22]: "Thunderstorms and very heavy rain, producing floods at Fraserburgh and Banff, in the N.E. of Scotland."	CBHE <sup>7,8</sup>
08/02/1894	1894 August 2 p[21]: "along the Don and Ury many fields were swept clean of all their crops, also along the Ythan in Buchan."	CBHE <sup>7,8</sup>
08/05/1913	1913 May 8-11 Rainfall observer at House of Schivas noted (p[14]) "Rain 3.10 in. causing the highest flood in the river remember in May."	CBHE <sup>7,8</sup>
08/05/1913	1913 May 8-11 Observer, Haddo, at Ellon (house of	CBHE <sup>7,8</sup>

<sup>7</sup> Sourced from JBA flood study report 'The Ythan at Ellon' - 2006,

<sup>8</sup> CBHE found online at <http://cbhe.hydrology.org.uk/> [accessed on 10/11/17]



	Schivas), Aberdeenshire, noted p[59] "The river Ythan was in greater flood than seen for many years in May, when 3.1 fell from 8th to 11th inclusive...."	
06/11/1951	97.31 m <sup>3</sup> /s recorded at Ardlethen gauging station (10001) highest recorded flow within the Ardlethen series (1940-1984)	SEPA hydrometric data <sup>7</sup>
1986	River Ythan flooding across the floodplain with photographs from Ellon Bridge.	BBC, found online at: <a href="http://www.bbc.co.uk/history/domesday/dblock/GB-392000-828000/picture/2">http://www.bbc.co.uk/history/domesday/dblock/GB-392000-828000/picture/2</a> [accessed on 10/11/17]
September 1995	SEPA extent-Babties interpolated flood outlines from a limited number of points. Ellon Gauging station 12/09/1995 achieved 6.82 mAOD River Ythan reported to have risen by approx. 1.2 m (C. 350 m downstream of Old Bridge of Ellon)	SEPA Extent <sup>7</sup>
10/02/1996	105.26 m <sup>3</sup> /s recorded at Ellon gauging station (10003) - 4th highest recorded flow in record (including Ardlethen data)	SEPA hydrometric data <sup>7</sup>
2000	Modley Burn in Ellon, a wall collapsed causing flooding	SEPA FRMS <sup>7,9</sup>
22/10/2002	22-23 October 2002	Flood Risk Report <sup>7</sup>
21/11/2002	21-22 November 2002	Flood Risk Report <sup>7</sup>
Oct/Nov 2002	SEPA received letter from resident at 3 Provost Cordiner Road, Ellon. Photographs showing river near to garden, resident wanted an embankment built.	SEPA <sup>7</sup>
Oct/Nov 2002	7 Properties flooded by River Ythan. Woodhead Road, Methlick. Flooding from blocked culvert in private land-Balqholly-Auchterless	4th Biennial Report-Aberdeenshire County Council <sup>7-</sup>
Nov 2002	SEPA extent-Trash line survey SEPA	SEPA Extent <sup>7</sup>
2002	Modley Burn, Ellon - a basement of a property located on the culvert section of the burn flooded due to water backing up.	SEPA FRMS <sup>7</sup>
2002	SEPA flood photos of Ellon catchment	Photos supplied by SEPA
2004	Two properties in Findhorn Gardens flooded due to runoff from the adjacent housing development.	SEPA FRMS <sup>9</sup>
2009	Flood from Broomies Burn, which affected Castle Way Industrial Estate, Ellon and damaged two bridges. Two industrial units and a school were affected.	SEPA FRMS <sup>9</sup>
Sept 2009	Ellon Golf course flooded	YouTube. Found online at: <a href="https://www.youtube.com/watch?v=fUrmZi8UzLI">https://www.youtube.com/watch?v=fUrmZi8UzLI</a> [accessed on 20/10/17]
04/01/2016	Main road (A90) outside of Ellon closed due to flooding	Press and Journal, found online at: <a href="https://www.pressandjournal.co.uk/fp/news/aberdeenshire/795688/road-outside-ellon-closed-due-flooding/">https://www.pressandjournal.co.uk/fp/news/aberdeenshire/795688/road-outside-ellon-closed-due-flooding/</a> [accessed on 10/11/17]
08/01/2016	River Ythan floods the centre of Ellon. Flooding on fields beside Esslemont Circle.	YouTube. Found online at: <a href="https://www.youtube.com/watch?v=9u3RUvxaDaw">https://www.youtube.com/watch?v=9u3RUvxaDaw</a> [accessed on 20/10/17]
08/01/2016	'The River Ythan also burst its banks, with flow levels breaking previous records at Ellon.....18 homes in	BBC News found online at: <a href="http://www.bbc.co.uk/news/">http://www.bbc.co.uk/news/</a>

9 SEPA FRM Strategies [http://apps.sepa.org.uk/FRMStrategies/pdf/pva/PVA\\_06\\_12\\_Full.pdf](http://apps.sepa.org.uk/FRMStrategies/pdf/pva/PVA_06_12_Full.pdf) [accessed on 10/11/17]

	Ellon were evacuated'	uk-scotland-35259398 [accessed on 10/11/17]
08/01/2016	' In Ellon, the Ythan stood at 4.4m (14.4ft) at its peak, 1.2m (3.93ft) above the previous record level in 1983, according to Scottish Environmental Protection Agency (SEPA) figures.' <i>[4.4m was recorded at Ellon gauging station on 08/01/2016. Previous record level was 3.34m on 23/12/2012. See Figure 1-2 for an overview of the SEPA data. It is suggested 1983 is a mis-print in this article.]</i>	Press and Journal, found online at: <a href="https://www.pressandjournal.co.uk/fp/news/aberdeenshire/799591/pictures-ellon-flooded-ythan-explodes-town/">https://www.pressandjournal.co.uk/fp/news/aberdeenshire/799591/pictures-ellon-flooded-ythan-explodes-town/</a> [accessed on 10/11/17]
08/01/2016	SEPA gauging station Ythan at Ellon; Highest event on record - 183.25 m <sup>3</sup> /s	SEPA gauging station information. Found online at: <a href="http://apps.sepa.org.uk/waterlevels/default.aspx?sd=t&amp;lc=234210">http://apps.sepa.org.uk/waterlevels/default.aspx?sd=t&amp;lc=234210</a> [accessed on 16/11/17]
08/01/2016	Overtopping of Burn opposite 87 Hillhead Drive; flow pathway down Hillhead drive. Trash line evident from photos (see appendix A) near 32 and 34 Patey Road.  River Ythan overtopped into Bruce Crescent adjacent to 32 Bruce Crescent. Flooding exasperated by surface water from Riverside Road/Provost Davidson Drive and drainage backing up in Bruce Crescent.  Flooding to Ythan Court, The Meadows flooding.  Overland flow path from playing fields to the North and flooding from the Broomies Burn to the east of the flood area. Flooding from the River Ythan evident from the west of the flood area.	Client record. (See photos in Appendix A)
08/01/2016	Video footage of the highest flow on record at Ythan, showing flood extents.	YouTube. Found online at: <a href="https://www.youtube.com/watch?v=_SzdPOEmK8g">https://www.youtube.com/watch?v=_SzdPOEmK8g</a> [accessed on 20/10/17]
2016	Flood levels and extents supplied by SEPA	Data supplied by SEPA

Figure 1-2 and Figure 1-3 below shows the Annual Maximum (AMAX, the largest recorded event at the gauging station per hydrological year defined as the period between 1 October in one year and 30 September in the next year) data for the Ellon and Ardlethen gauging stations respectively. Table 3-1 gives the stage and rank of the events highlighted in Table 1-2<sup>10</sup>.

<sup>10</sup> An up-to-date AMAX series for Ellon has been provided by SEPA (January 2018). The Ardlethen stage data is from the NRFA (Ythan at Ardlethen <http://nrfa.ceh.ac.uk/data/station/peakflow/10001>, accessed February 2017). Discharge varies depending on the rating (which converts stage to flow) applied. Ratings are updated on an approximately annual basis to allow for changes in natural flow regime. A Rating Review of the Ellon gauging station is currently being carried out by JBA Consulting (2017s7016 Rating Review Ellon Gauge). Therefore, the AMAX series and events in Table 1-3 are discussed on the basis on stage only. Surface water flooding, flooding from the burns and the 1986 flood are not with the AMAX series for the River Ythan and are therefore not included in the table. Pre-1940 there is no gauged data available.

Figure 1-2: AMAX series for the Ythan at Ellon gauging station

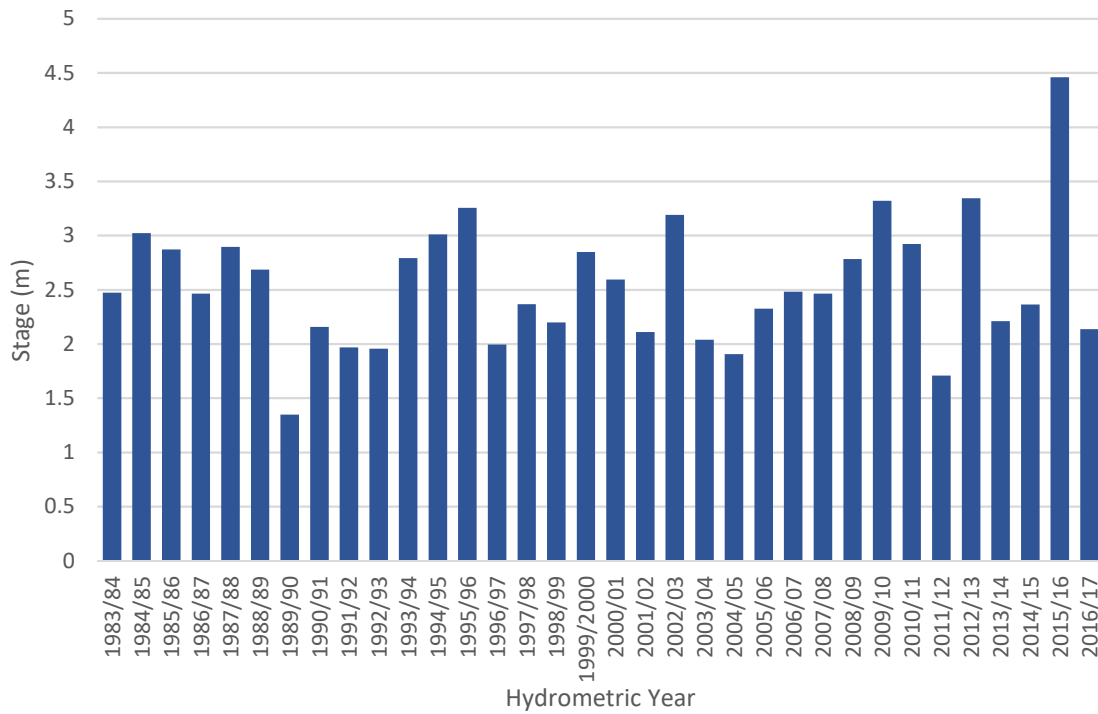


Figure 1-3: AMAX series for the Ythan at Ardlethen gauging station

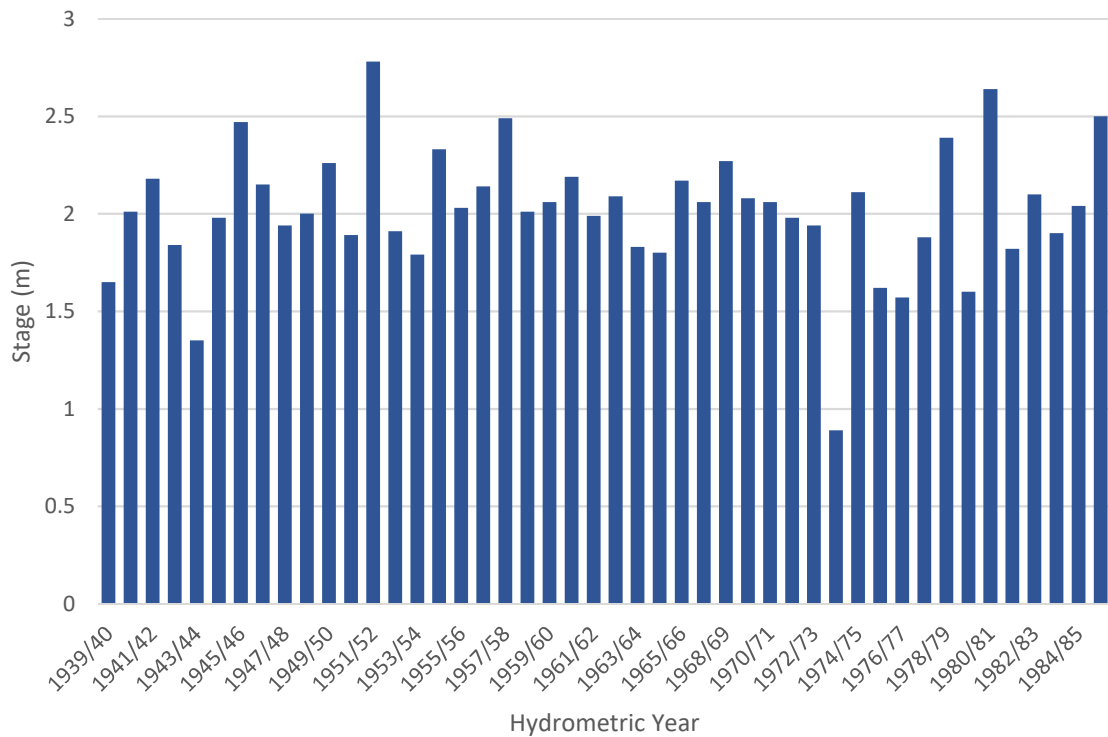


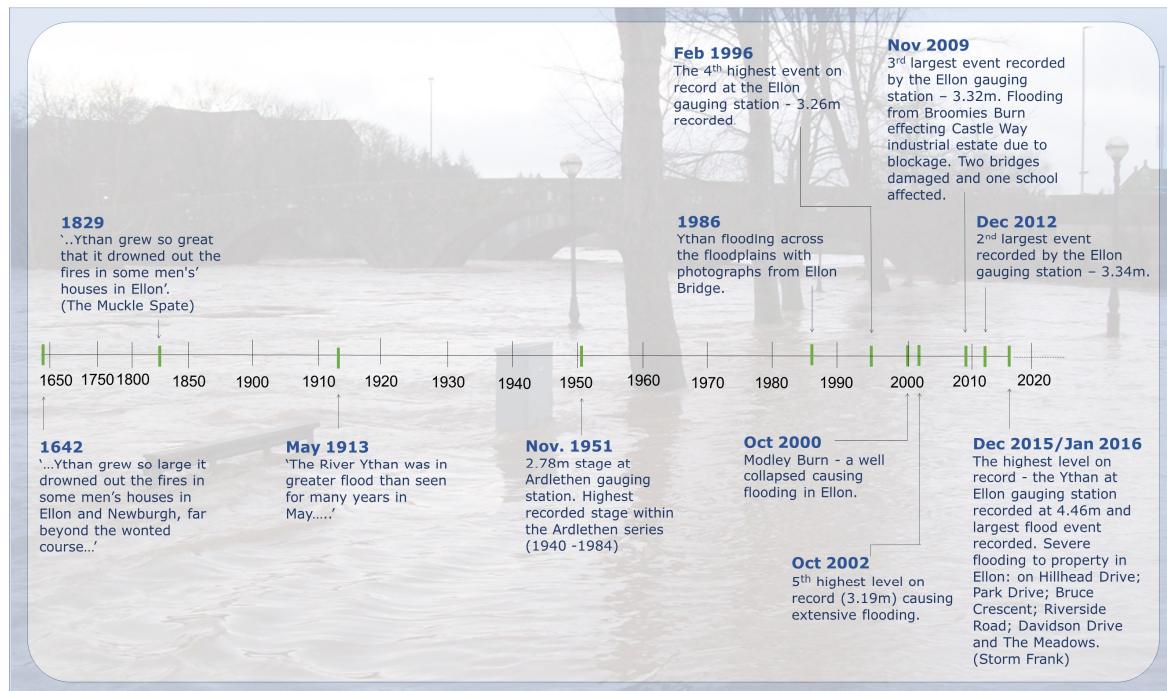


Table 1-3: River Ythan stage data from the Ardlethen and Ellon gauging stations for the fluvial flood events highlighted in Table 1-2

Hydrometric Year	Date	Stage (m)	Station (m <sup>3</sup> /s)	Rank at Station
1951/52	06-Nov-1951	2.780	Ardlethen	1
1994/95	12-Sep-1995	3.011	Ellon	7
1995/96	10-Feb-1996	3.256	Ellon	4
2002/03	23-Oct-2002	3.189	Ellon	5
2008/09	04-Sep-2009	2.784	Ellon	13
2015/16	08-Jan-2016	4.460	Ellon	1

In summary Ellon has experienced flooding in 1829, 1894, 1913, 1951, 1986, 1996, 2000, 2002, 2004, 2009, 2015 and 2016. Key events are summarised below in a timeline (Figure 1-4)

Figure 1-4: Key flood events in Ellon

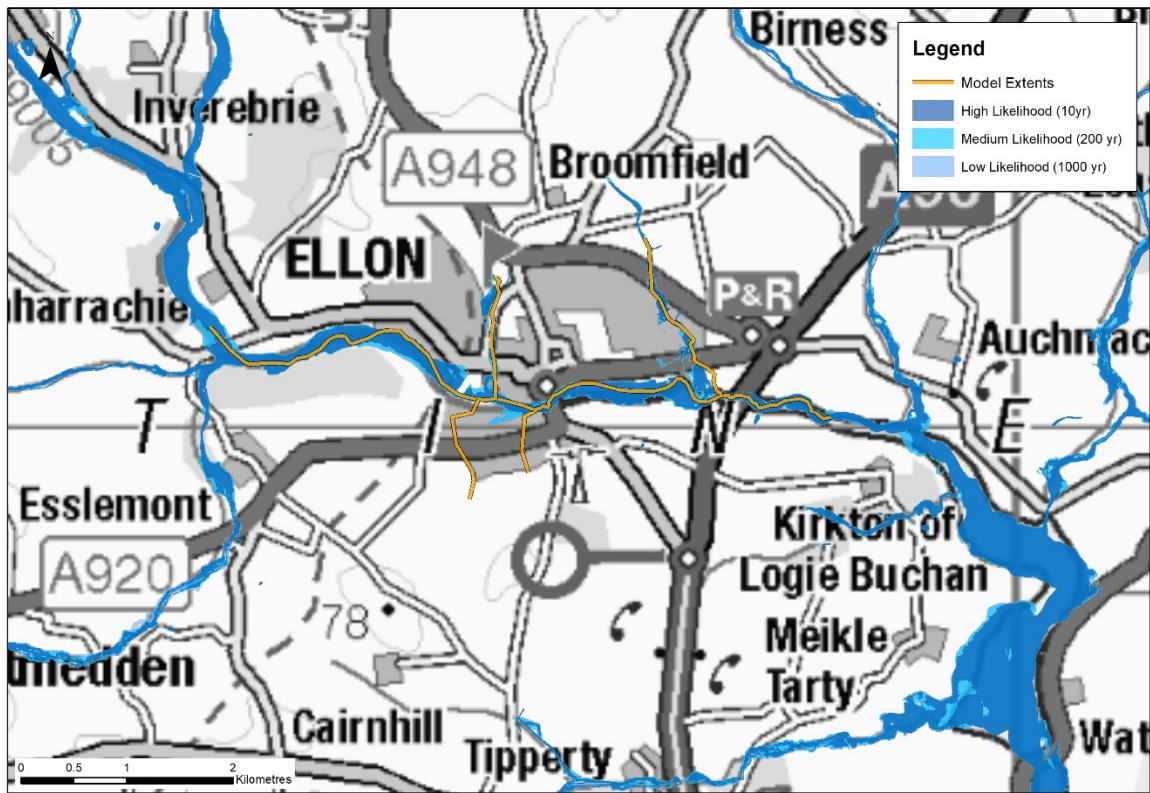


## 1.4 Flood Mechanisms

### 1.4.1 River Ythan Flood Mechanisms

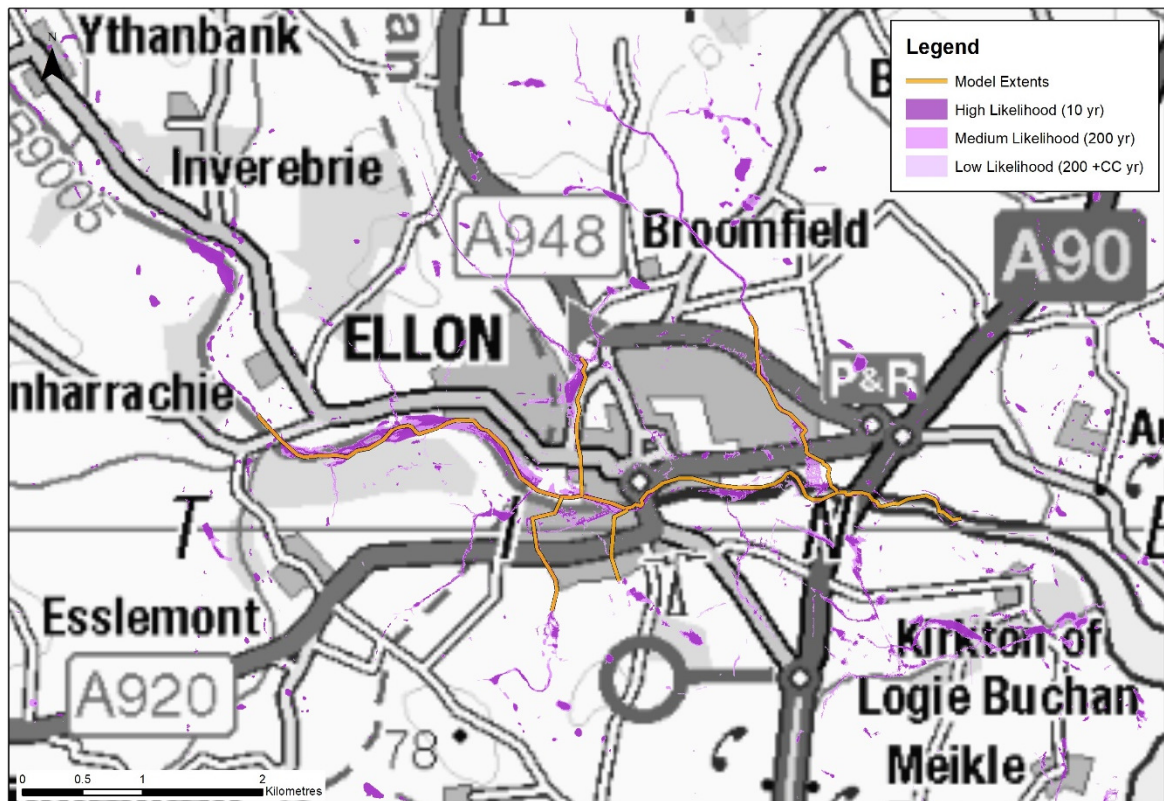
The key flood mechanism from the River Ythan to Ellon, is high flows resulting in overbank flows into agricultural land south of the River Ythan, in the upstream area of Ellon. Further flooding is characterised by overbank flows into the residential gardens in Snipe Street; Provost Cordiner Road; Bruce Crescent; and to the A920 road (Figure 1-8). Flooding from overbank flows north of the River Ythan occurs in The Meadows area of Ellon (Figure 1-9). Surface water flooding also makes up 25% of the contribution to flood risk in Ellon, characterised by major surface water flow pathways along Station Road; Hospital Road and East Castle Street.

Figure 1-5: SEPA fluvial flood map extent overview for Ellon with proposed model extents



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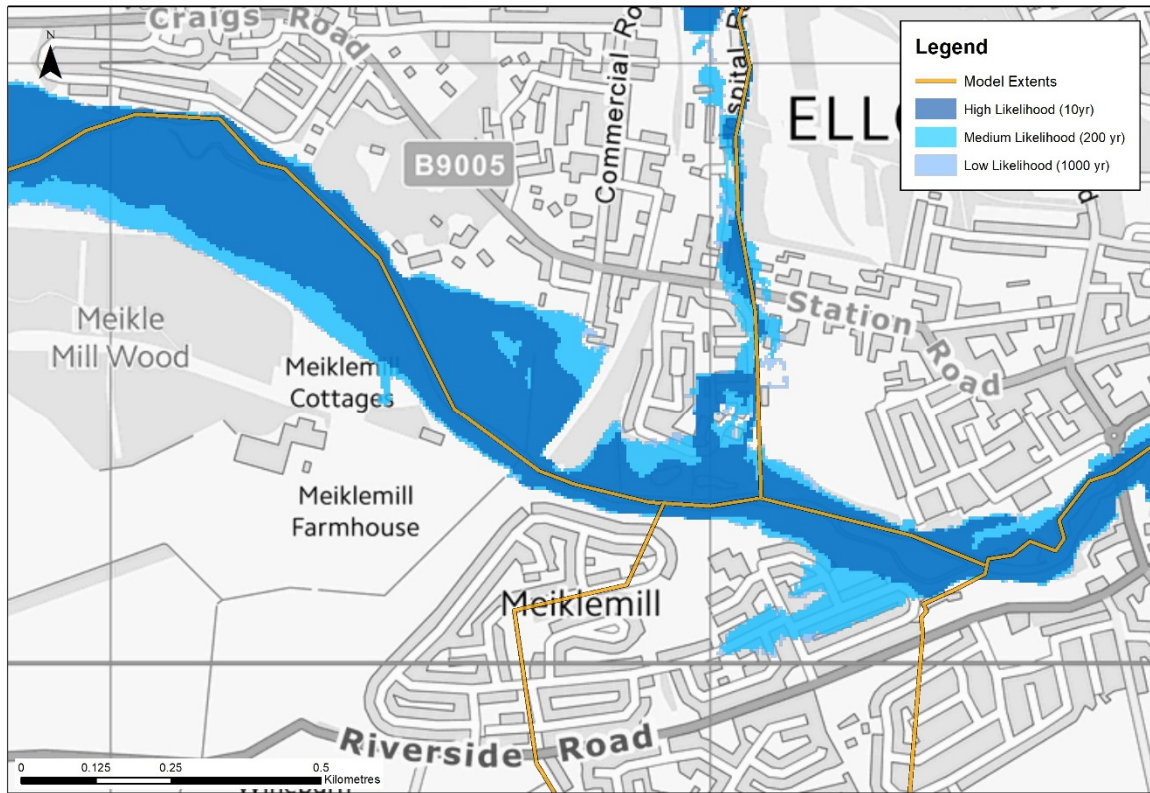
Figure 1-6: SEPA pluvial flood map extent overview for Ellon and proposed model extents



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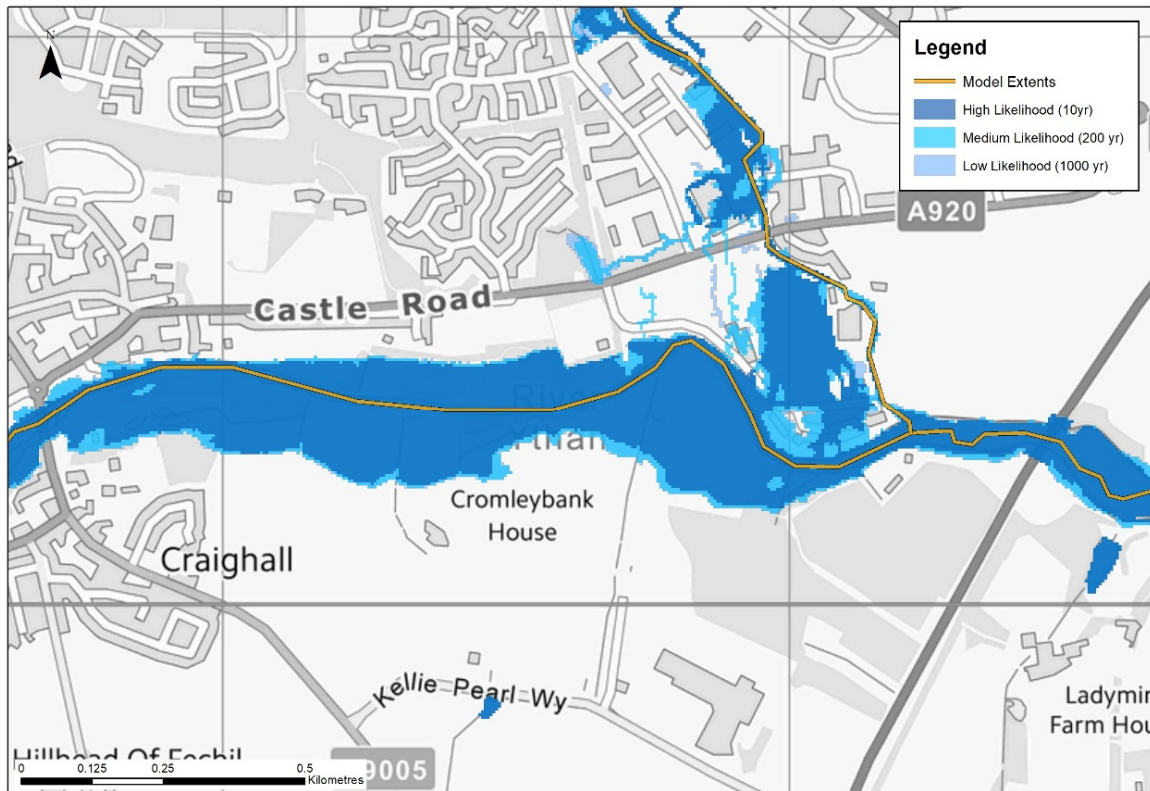


Figure 1-7: SEPA flood map extents for the River Ythan at the upstream extent of Ellon



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Figure 1-8: SEPA flood map extents for the River Ythan at the downstream extent of Ellon



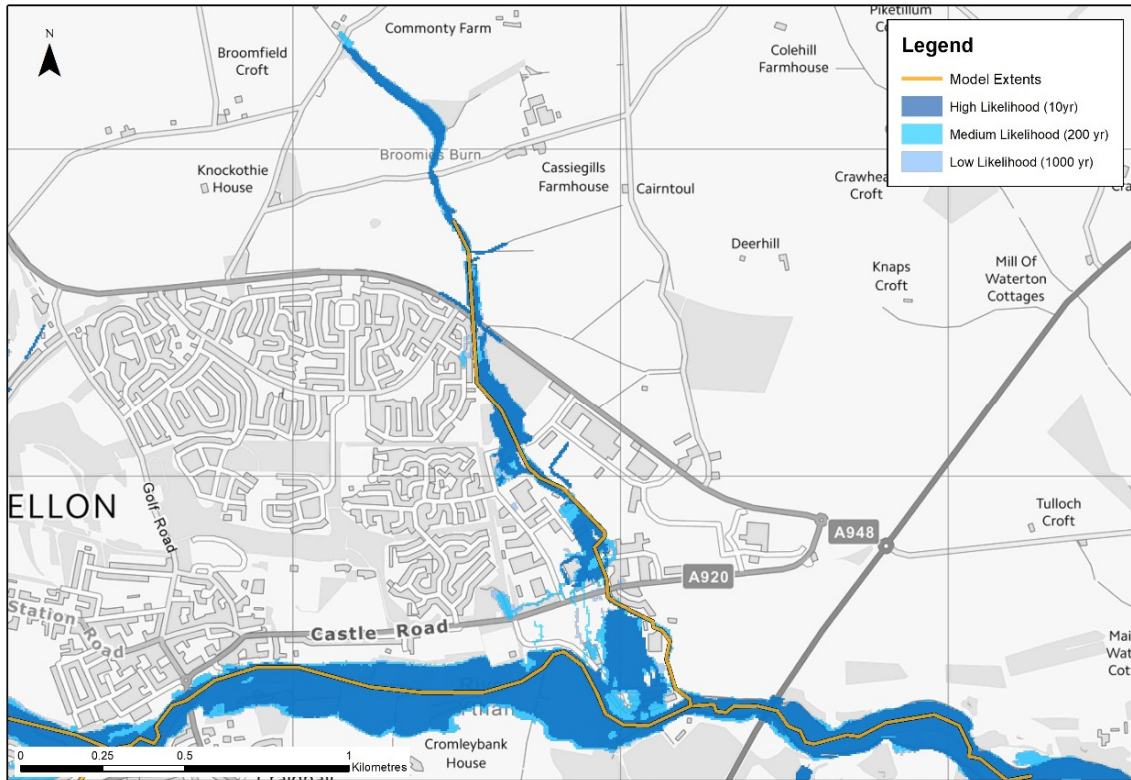
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### 1.4.2 Broomies Burn Flood Mechanisms

Flooding to Ellon from the Broomies Burn is suggested by the SEPA flood maps (Figure 1-9) to the Meadows area sports fields and to the Castle Way Industrial Estate. Historical flooding has occurred to Castle Way Industrial Estate area damaging two bridges, a school and two industrial units. The key mechanism is overbank flows from the burn.

Figure 1-9: SEPA flood map extents on the Broomies Burn

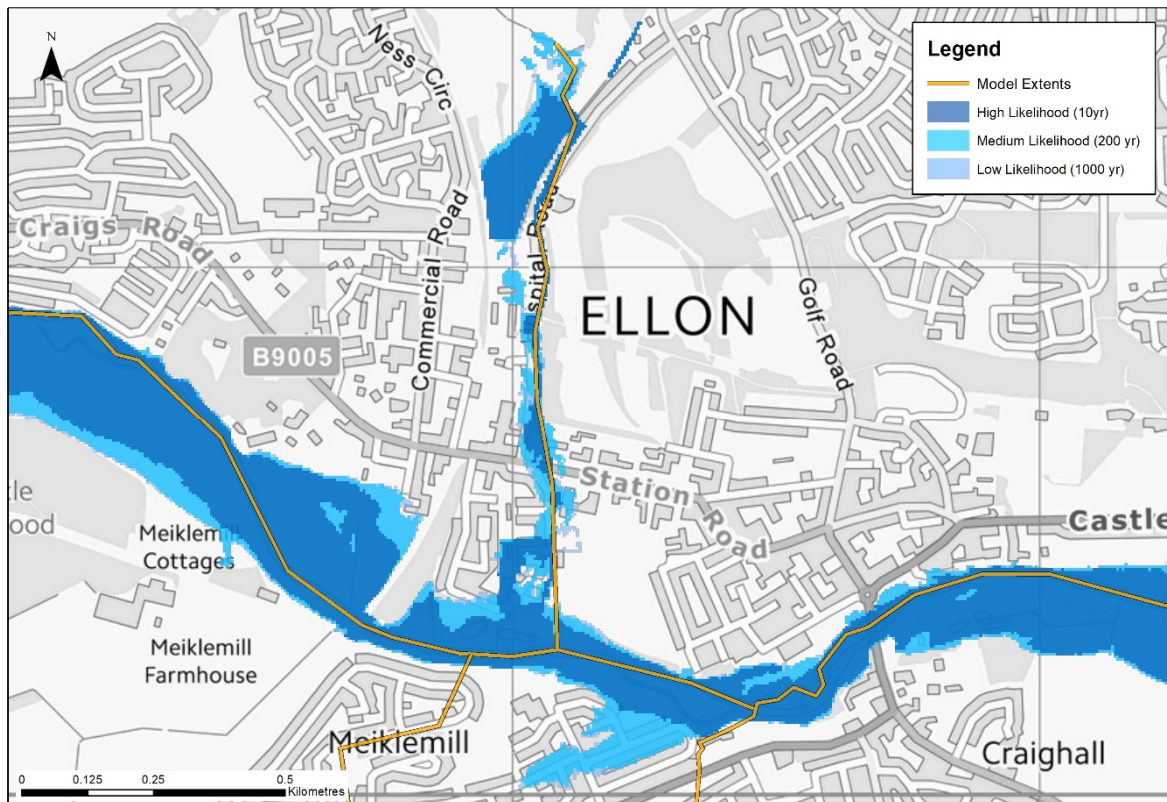


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### 1.4.3 Modley Burn Flood Mechanisms

Flooding to Ellon from the Modley Burn is suggested by the SEPA flood maps, see Figure 1-10, in McDonald Golf Club course pooling to the east of Hospital Road due to high, out of bank flows. Historical flooding from the Modley Burn was caused by a collapsed wall, downstream of Ellon primary school, blocking a culverted section of the Burn resulting in the water backing up and flooding residential basements.

Figure 1-10: SEPA estimated high risk flood extent on Modley Burn

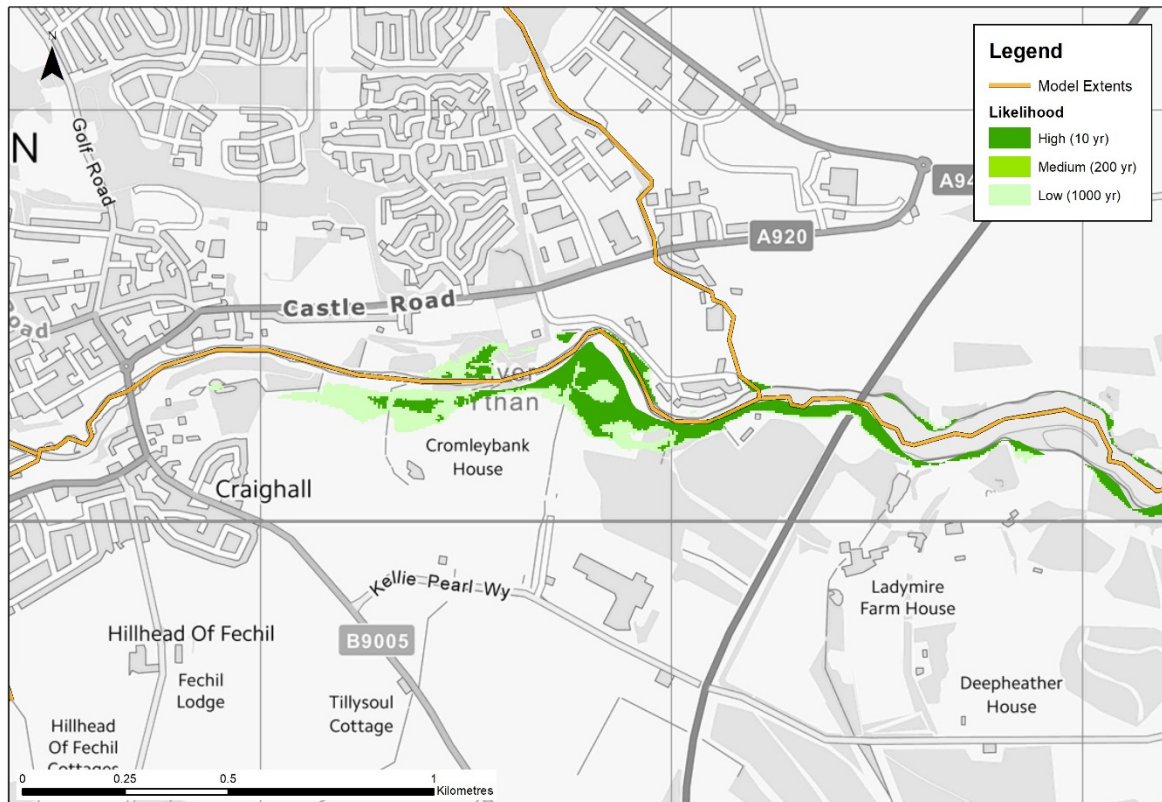


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#### 1.4.4 Coastal Flood risk mechanisms

Ellon is linked to the North Sea by the Ythan estuary downstream, making it at possible risk of coastal flooding during high tide events. The River Ythan is tidally influenced at Ellon, with the mean high water level and Normal Tidal Limit (NTL) located north east of the A90. Medium (200 year) to low (1000 year) coastal flood risk is indicated to extend upstream of the NTL to South Road Bridge, approximately 1.4 km further upstream. High risk (10 year) coastal flood extents are characterised by flooding near The Meadows, Castle Road and east Ellon (Figure 1-11).

Figure 1-11: SEPA estimated coastal flood extents at Ellon



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## 1.5 Watercourses

The following watercourses are included within the Aberdeenshire Council specification for assessment of flood risk in Ellon, see Table 1-4.

Table 1-4: Summary of model and survey available

Watercourse	Modelled	Survey data
River Ythan	Yes	Yes
Modley Burn	No	No
Broomies Burn	No	No
Meiklemill Burn	No	No

## 1.6 Current Defences

There are no formal flood defences on the River Ythan or its tributaries in Ellon.

### 1.6.1 Informal food defences

There are no informal flood defences on the River Ythan or its tributaries in Ellon.

## 2 Review of Previous Studies

Previous modelling studies carried out in Ellon are documented in Table 2-1 below. Potential sources of flooding are site specific but those applicable to the wider town are highlighted under key findings:

Table 2-1: Previous Flood Risk Assessments and flood studies and their key findings

Document name	Author	Model available	Key Findings
The Ythan at Ellon, Flood study report 2006	JBA Consulting	Yes	<p>Study to determine flood risk from the River Ythan, doesn't consider surface flows or the small burns.</p> <ul style="list-style-type: none"> <li>• Model from Bridge of Ardlethen to the A90 Road Bridge.</li> <li>• No blockage risk from bridges or culverts.</li> <li>• Assess and egress not compromised.</li> <li>• The downstream boundary is highly affected by the tide. Overbank flow commences at the 50% AP (2 year) event, however most properties lie above the 0.5% AP (200 year) flood extent.</li> <li>• Joint Probability analysis will be reassessed as part of this FPS.</li> </ul>
Cromleybank, Ellon Flood Risk Assessment	JBA Consulting	Yes, Infoworks RS model	<p>Study to assess flood risk to a housing development area in south east Ellon.</p> <ul style="list-style-type: none"> <li>• 0.5% AP (200 year) event modelled.</li> <li>• The River Ythan was modelled.</li> <li>• Model from Bridge of Ardlethen to the A90 Road Bridge.</li> <li>• Finished floor levels are proposed at 5.57 mAOD upstream and 5.04 mAOD in the downstream extent.</li> <li>• Access and egress not compromised.</li> <li>• Calibrated using data from SEPA's gauging station.</li> <li>• Flooding to Cromleybank area at 200 year return period.</li> <li>• Culvert incapacity a possible cause of local flooding.</li> </ul>
Crichie Burn, Fyvie - April 2006.	Halcrow		<p>Study to assess the flood levels, flood extents and properties affected from Crichie Burn, Fyvie.</p> <ul style="list-style-type: none"> <li>• 0.5% AP (200 year) event modelled.</li> <li>• Hydrological assessment of Crichie Burn</li> <li>• Climate change consideration was also included.</li> <li>• Study area from downstream of the Mill of Crichie down to the confluence of the Crichie Burn and the River Ythan.</li> <li>• Crichie Burn modelled in 1D using Infoworks from survey data of floodplain and watercourses.</li> <li>• 6 properties directly or indirectly affected by Crichie Burn for high return period events.</li> <li>• Blocked culvert and small culvert capacity cause of small local flooding issues.</li> </ul>



### 3 Hydrological Review

A review of readily available archives has been undertaken in Section 1.3 to develop the understanding of historical flood risk. Liaison with SEPA will be sought to ensure that up to date river flow data is being used, to discuss the estimation of flood flows used and to gain stakeholder and regulator 'buy in' at an early stage. Consideration to the pre and post January 2016 gaugings and rating information for the Ythan will be taken given the magnitude of the flood and likelihood of channel and therefore rating change. This study will build on our experience of flood estimation in the Ythan where we have worked on the Ellon Flood Study. SEPA have separately commissioned JBA to undertake a rating review of the Ythan at Ellon gauging station. This review will be undertaken prior to peak flow estimates on the Ythan being made in order to ensure that the best quality peak flow data is used in the analysis.

Previous studies, discussed in Section 2, have utilised the Flood Estimation Handbook (FEH) methodologies for estimates of design flows. Updates have since been made to the FEH methods and additional data are available, therefore, new estimates will be calculated using the most up to date FEH techniques including: the FEH Statistical method and the Rainfall-Runoff methods (including ReFH2 and FEH13 rainfall) will be used and the most appropriate method selected for use in the hydraulic model. In general, this is likely to be the Statistical method for large rural catchments and a Rainfall Runoff approach for smaller catchments. Where possible, historical flood data will also be incorporated for use in model calibration. The following return periods will be used:

Table 3-1: Return periods and Annual probability

Return Period	Annual probability
2	50%
5	20%
10	10%
30	3.33%
50	2%
75	1.33%
100	1%
200	0.5%
500	0.2%
1000	0.1%
30 +CC	3.33% +CC
200 +CC	0.5% +CC

The catchment parameters will be extracted from the FEH CD-ROM version 3 and reviewed against suitable OS mapping, geological and soil data. All catchments will be digitised within ArcGIS.

The preferred methods for each watercourse are as follows:

Table 3-2: Preferred method

Watercourse	Peak flow location	Preferred approach to FEH peak flows and hydrographs	Flow estimate locations
River Ythan	U/S Ellon	FEH Statistical Single Site analysis or FEH Statistical Enhanced Single Site analysis  Hydrograph synthesised from gauged data	Upstream boundary Ellon Gauging station Upstream and downstream of Modley Burn Upstream and downstream of Broomies Burn Downstream Boundary
Broomies Burn	River Ythan confluence	FEH Rainfall Runoff or REFH2 with FEH13;  REFH2 hydrographs	Upstream boundary Downstream boundary
Modley Burn	River Ythan confluence	FEH Rainfall Runoff or REFH2 with FEH13;  REFH2 hydrographs	Upstream boundary Downstream boundary
Meiklemill Burn	River Ythan confluence	FEH Rainfall Runoff or REFH2 with FEH13;  REFH2 hydrographs	Culvert Inlet

For the Statistical method, the following preferential hierarchy will be used: single site (SS) analysis (where a gauging station is present and where there is sufficient record length and quality at high flow, per SEPA preferences), enhanced single site (ESS) analysis (also where a gauging station is present or nearby) and pooling group (P) analysis ( ungauged catchment). In order to make the best use of local data, SS and ESS growth curves will, where appropriate, be transferred from local gauging stations to nearby locations. Where possible, the appropriateness of the resulting flood estimates will be considered in the context of any longer, ranked, flood history available through the review process and which is longer than the period of the gauged record. JBA also have access to WINFAP v4 which allows for the incorporation of historical data within flood estimation. The primary gauging station to be used is the Ythan at Ellon with records dating from 1983. This gauge replaced the Ythan at Ardlethen gauge which was in use from 1939 to 1982, but has since been discontinued. Analysis at both Ellon and Ardlethen (Figure 3-1) will be undertaken in order to provide better confidence in the flood estimates.

Data from the Mill of Keithfield river level station (Figure 3-1) will be used to help inform Time to Peak (Tp) for the Rainfall Runoff approach. The Tp value from Mill of Keithfield will then be used as a donor for the sites using the Rainfall Runoff approach. If flow data are also available, then, for ReFH2, the ReFH2 calibration facility will be used to calibrate ReFH2 to between 3 and 5 representative events recorded at the donor site (daily and 15 rainfall data and 15 min flow data will be required) and the ReFH2 parameters at the target site adjusted per FEH guidance. The final choice of Rainfall Runoff method (i.e. ReFH2 or FEH Rainfall Runoff) will be made on the basis of which method appears to be most representative of the catchment in question. Hydrographs for the smaller catchments will be derived using ReFH2 and scaled according to the final peak flow estimates from the preferred methods. Depth Duration Frequency (DDF) (which enables estimation of extreme rainfall at a particular location) and Areal Reduction Factor (ARF) parameters (which

relates point rainfall data across a catchment) will be derived from FEH13 rainfall data via the FEH Webservice.

Where a catchment wide critical duration is required, this will be calculated using the target point of the downstream end of the hydraulic model using the functionality within Flood Modeller and compared with estimates available based upon observed data (such as from the observed flood hydrographs and hyetographs; JBA's has an in-house tool for merging observed hydrographs).

Within the hydraulic model, the fluvial inflow locations will be represented by ReFH units. The peak flow will be overwritten with the information described in the preceding paragraphs and the same critical duration will be applied throughout the catchment. The ReFH unit is proposed in preference to the ReFH2 unit as it will increase model portability (e.g. to external organisations) by minimising licencing issues.

Where tributaries additional to those identified above need to be represented in the hydraulic model, these will also be represented by point ReFH units with peak flow values derived as follows:

- The growth curve for the main watercourse at the nearest gauging station will be assumed to be appropriate for all locations along the main watercourse.
- For consistency, the gauging station used as the donor site for QMED adjustment at that location will also be used as the donor site for QMED adjustment throughout.
- Catchment descriptors will be derived from the FEH CD-ROM upstream and downstream of each tributary.
- Area adjustments will be made for consistency with other analyses.
- At each location, QMED will be calculated from the adjusted catchment descriptors, the donor multiplier applied to QMED and the growth curve also applied. This will allow a consistent increase in flood flows from upstream to downstream.
- The lateral inflows themselves will be obtained by subtracting the peak flows from the reach immediately upstream of each tributary from the peak flows immediately downstream.
- The critical duration for the lateral inflows will be set to that of the model downstream extent as derived from Flood Modeller and checked against observed data.

Where possible, hydraulic modelling will be used to inform the suitability of the flood frequency estimates. Whereby the frequency of flooding established by the hydraulic modelling will be compared with the observed frequency available from the historical record and this information then used to best select the most appropriate method of flood flow estimation (e.g. FEH Statistical or Rainfall Runoff).

All hydrological analysis will be written up into an Interim Hydrology Report for review by both Aberdeenshire Council and SEPA.





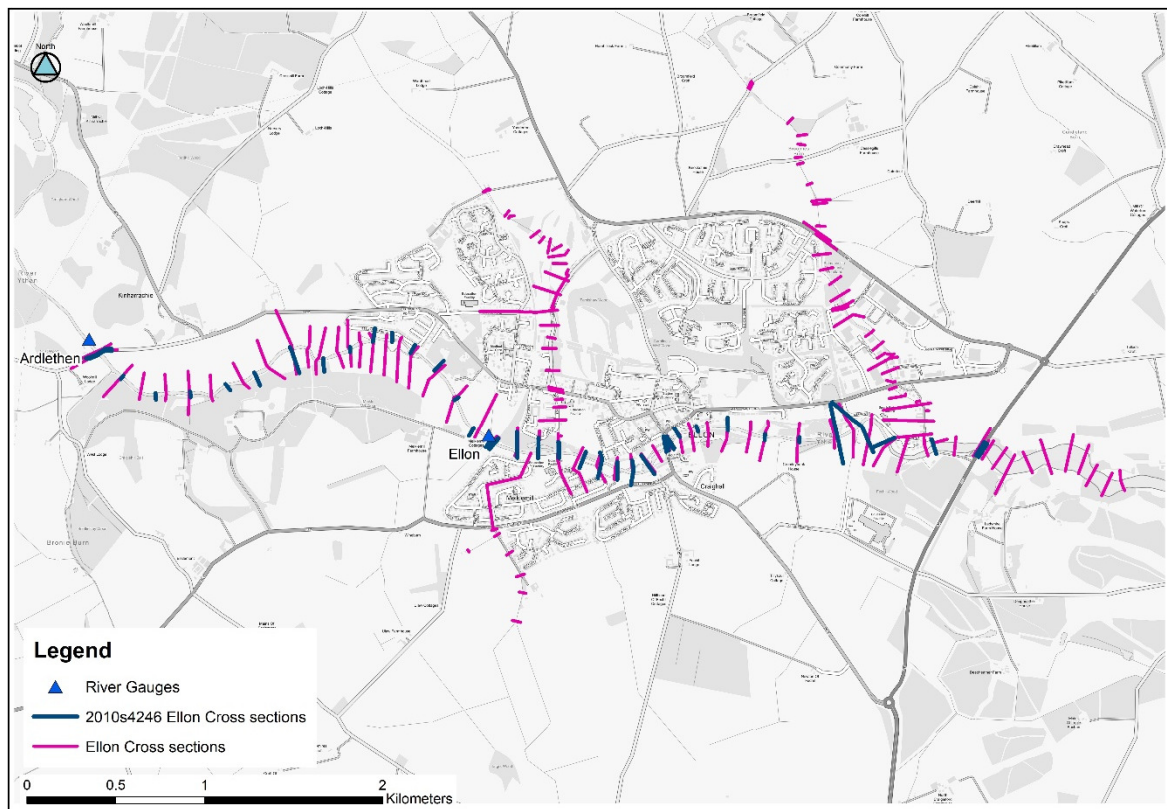
## 4 Model Summaries

### 4.1 River Ythan

The River Ythan has been modelled by JBA Consulting in 2010, using Infoworks RS software as a 1D unsteady model. The model is hydrodynamic, which simulates a full flood hydrograph allowing for accurate representation of storage and attenuation. The extent of the model is from the Ardlethen Road Bridge 1.7 km upstream of Ellon along a distance of 5.8 km to the A90 road bridge on the east side of the town. Cross-sections are placed every 100-200 m and there are 5 floodplain storage areas. Spill units link the floodplain storage areas to each other and the channel, allowing for out of bank flows and floodplain storage.

The location of the cross sections used in the 2010 model and those to be used in the present study are highlighted in Figure 4-1. It can be seen that the cross sections are in approximately similar locations but additional sections have been surveyed for this FPS and extend further downstream than that of 2010, in addition to survey of the tributaries.

Figure 4-1: 2010 model cross section comparison



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### 4.2 Modley Burn and Broomies Burn

Both the Modley Burn and Broomie's Burn have not previously been modelled. These will be added to the model for this FPS to identify and quantify flood risk from these burns.



## 5 Survey implications

### 5.1 DTM

Table 5-1: Details of the DTM data requested/supplied

Dataset	Supplier
LiDAR Data	AC
NextMap Data	SEPA (on behalf on AC)
NFM GIS dataset	SEPA
OS background mapping (MasterMap, 10K, 25K)	SEPA (on behalf of AC)

### 5.2 Cross sections

The ITT required pricing of 100 cross sections for the Ellon study area. JBA has developed a survey specification adapting the specification shown in Figure 3-1 of the ITT which displayed 130 cross sections. The revised JBA specification details 112 cross sections, so an additional 12 cross sections are recommended for survey in order to accurately capture key features and structures which can be used for this study, particularly for developing the hydraulic model.

Table 5-2: Details of the cross-section data

Element	Number priced as per ITT	Number of sections with figures 3.1,3.2 &3.3	JBA Specification
Ellon Cross sections	100	130	112
Ellon Thresholds	110	-	-

The number of threshold surveys priced in the tender totalled 110, but the exact number required will be determined later in the project after the hydraulic modelling has been undertaken. This is so that the modelled flood extents and depths can inform the locations where threshold surveys will be of most interest to understand flood risk.

### 5.3 CCTV

CCTV surveys would be required of the Culverts on Modley Burn; Hillhead Drive and the Meiklemill Burn. These CCTV surveys were not costed within JBA's proposal.

Figure 5-1: Location of the structures in Ellon

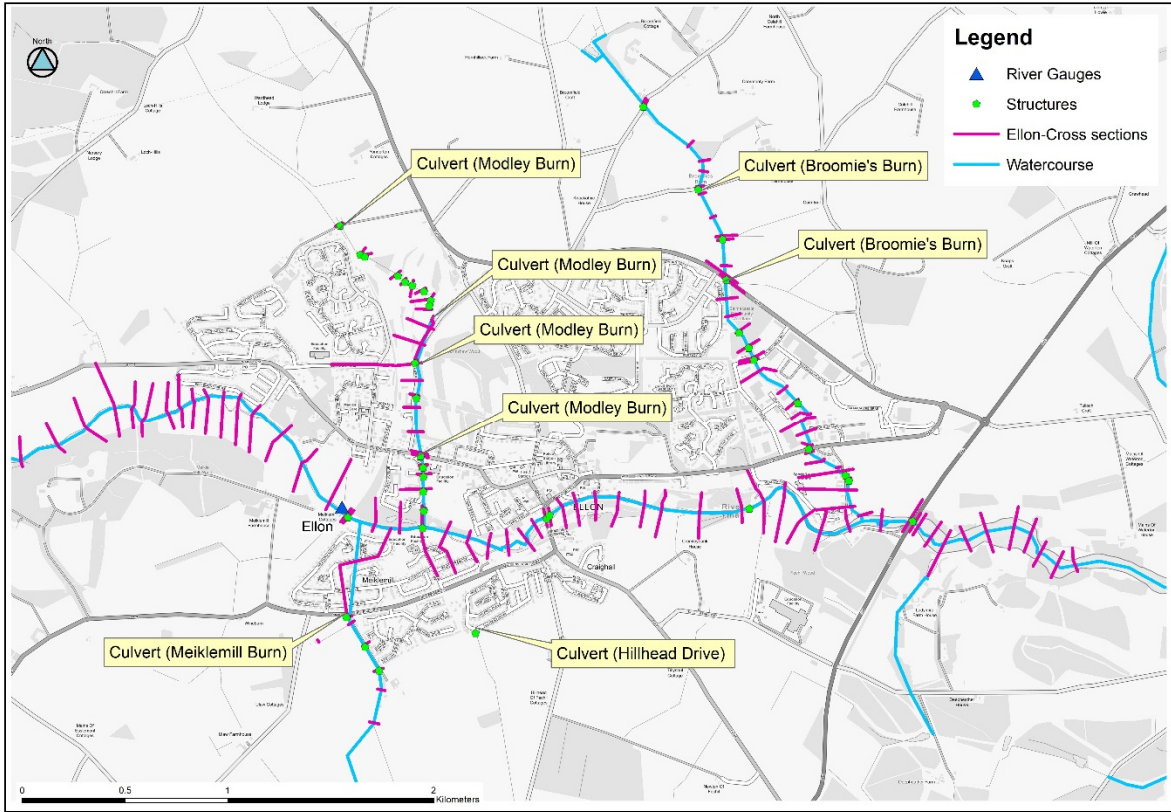
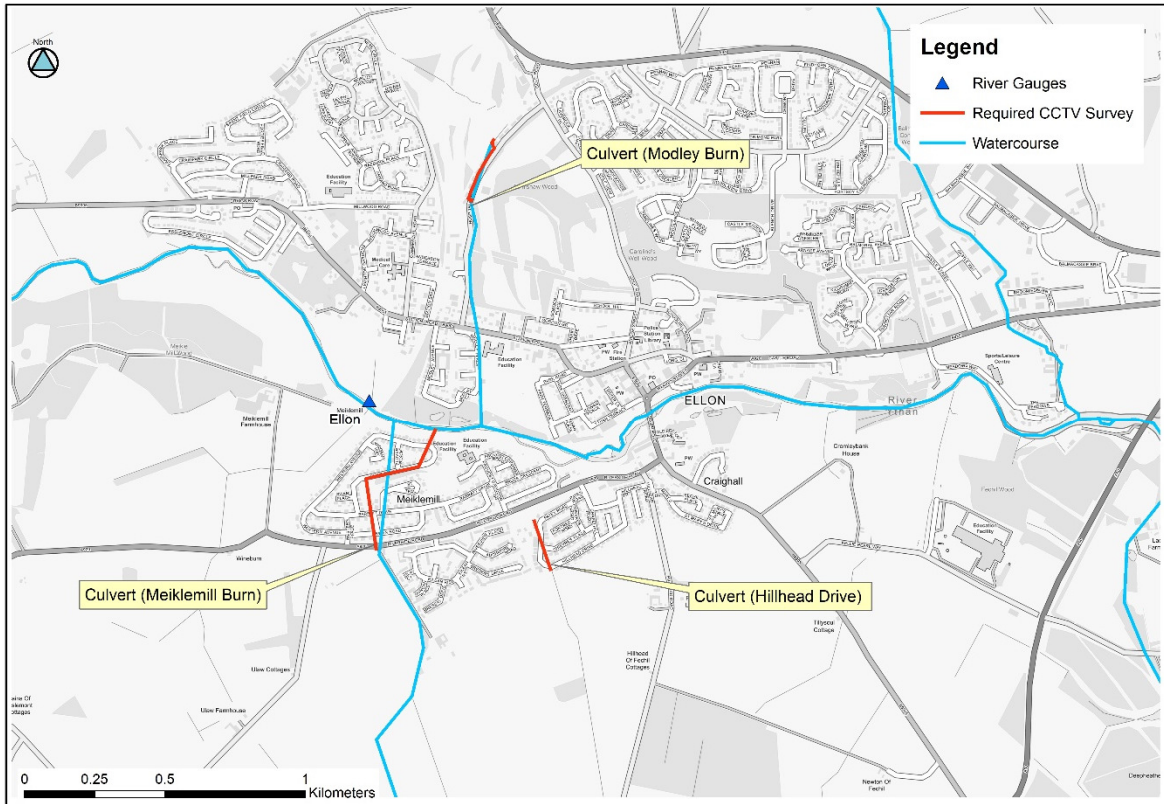


Figure 5-2: Location of the proposed CCTV culvert surveys



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## 6 Additional data requirements

Table 6-1: Additional data requested/supplied

Dataset	Source
River basin Management Planning datasets	SEPA
Morphology pressures datasets	SEPA
Scottish Digital Rivers Network	CEH
Receptor Dataset	SEPA
PRFA dataset	SEPA
Flood hazard mapping and model extents	SEPA/AC
Scottish Water Section 16 data	SW
Flood Event Database	SEPA
River-15min, Amax, Ratings-Ellon, Pitcaple, Parkhill, Alford	SEPA
Rainfall-TBR (Tipping Bucket Rainfall) as Priority	SEPA
Hydraulic Models (pluvial/surface water models)	AC/SEPA/SW
Council survey spec lines	AC

## Appendices

### A Aberdeenshire Council historical flooding photographs and pathways



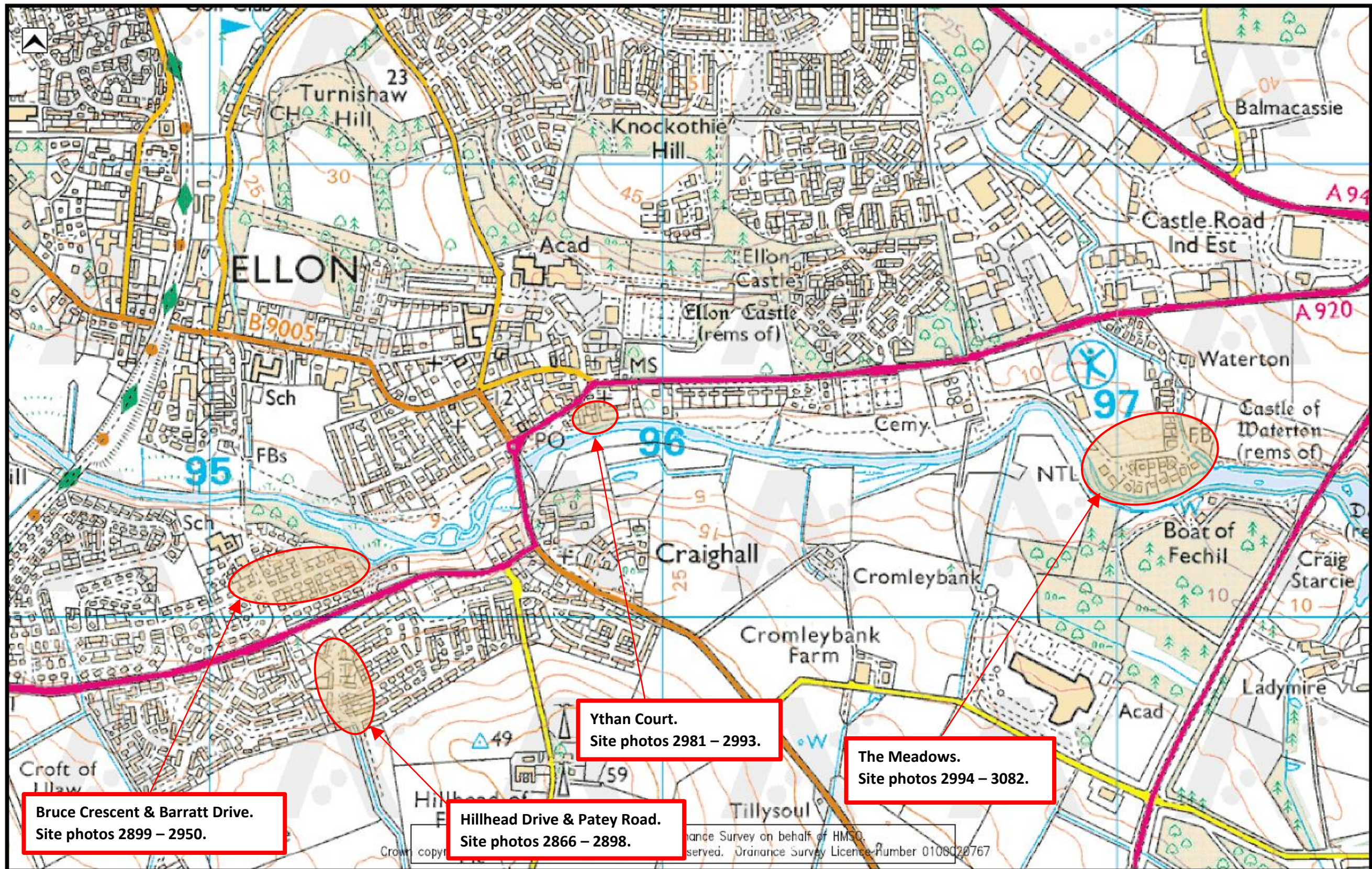


Figure 01: Plan of Ellon, with locations of 08/01/16 site inspections highlighted.



(1) Hillhead Drive



Burn waters  
overtopped on to  
Hillhead Drive on  
night of 07/01/16.

Photo 01: Burn at Hillhead Drive (taken 08/01/16)



Photo 04: Footpath opposite 34 Patey Road (taken 08/01/16)

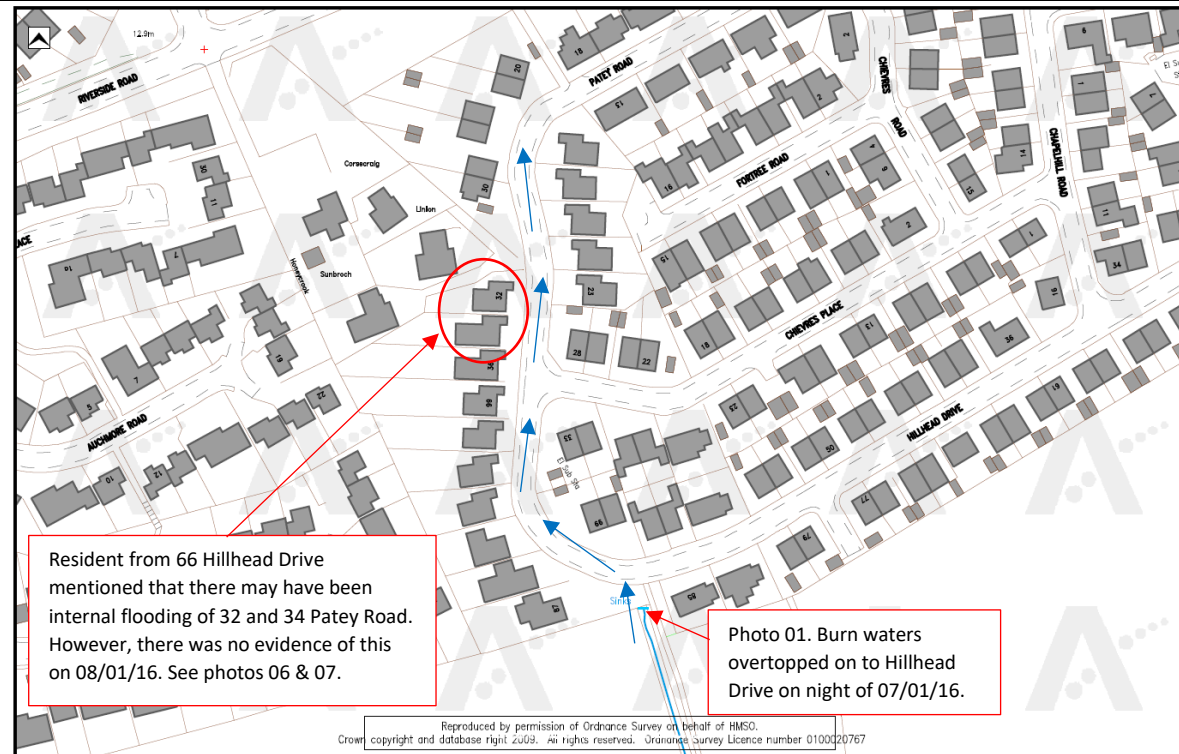


Photo 06: 34 Patey Road (taken 08/01/16)



Burn waters  
overtopped on to  
Hillhead Drive on  
night of 07/01/16.

Photo 02: Road opposite 87 Hillhead Drive (taken 08/01/16)



Resident from 66 Hillhead Drive  
mentioned that there may have been  
internal flooding of 32 and 34 Patey Road.  
However, there was no evidence of this  
on 08/01/16. See photos 06 & 07.

Photo 01. Burn waters  
overtopped on to Hillhead  
Drive on night of 07/01/16.

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Photo 07: 32 Patey Road (taken 08/01/16)



Photo 03: Road opposite 97 Hillhead Drive (taken 08/01/16)



Photo 05: Footpath opposite 32 Patey Road (taken 08/01/16)



Photo 08: Road opposite 30 Patey Road (taken 08/01/16)







(3) Market Street Car Park & Ythan Court



Photo 01: Market Street Car Park (taken 08/01/16)



Photo 04: Road to Ythan Court looking East (taken 08/01/16)



Photo 06: Birness, Ythan Court (taken 08/01/16)



Photo 02: Market Street Car Park (taken 08/01/16)

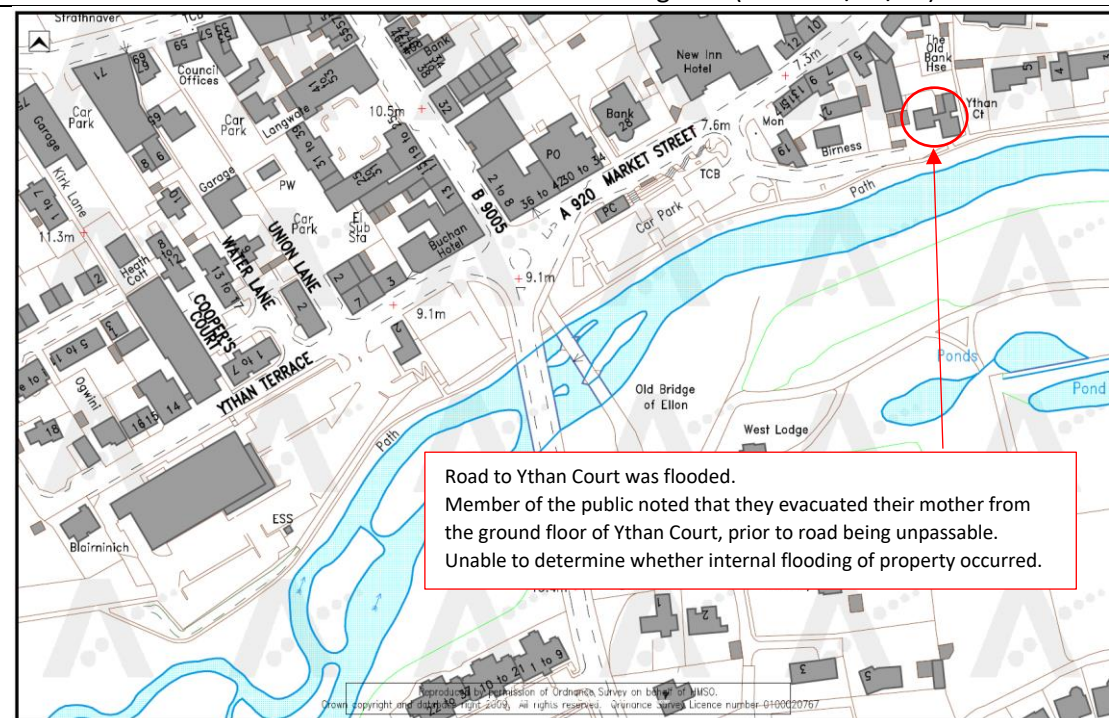


Photo 07: Ythan Court (taken 08/01/16)



Photo 03: Market Street Car Park, with debris line evident at base of steps to Market Street (taken 08/01/16)



Photo 05: Road to Ythan Court looking West (taken 08/01/16)



Photo 08: Ythan Court (taken 08/01/16)



(4) The Meadows



Photo 01: Road flooded adjacent to 01 The Meadows (taken 08/01/16)



Photo 04: 02 The Meadows (taken 08/01/16)

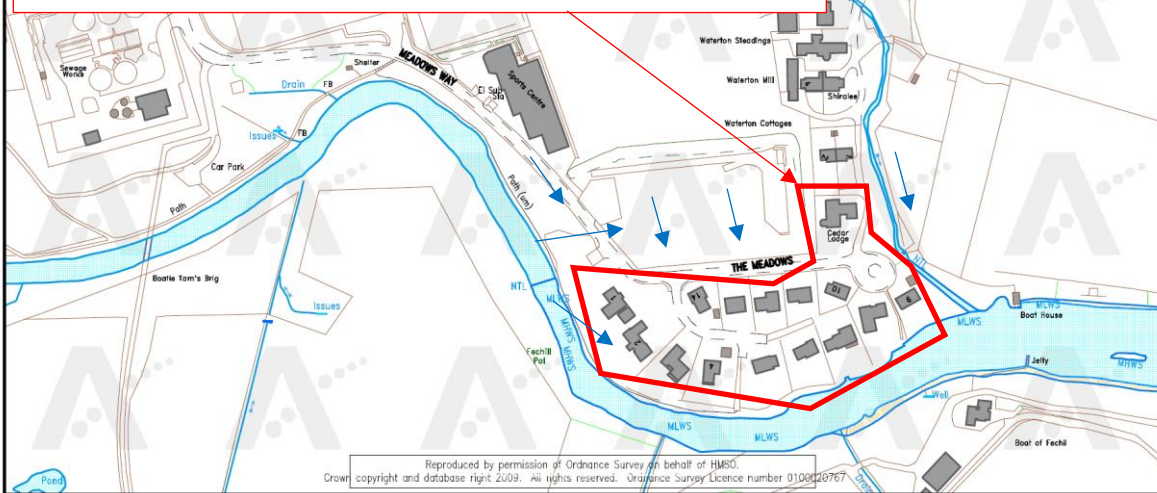


Photo 06: Waterton Cottages, with Broomies Burn on the right (taken 08/01/16)



Photo 02: Flood water being pumped into sports field by Fire Service (taken 08/01/16)

All properties at The Meadows, including Cedar Lodge, were evacuated on the night of 07/01/2016. Emergency Services evacuated residents by boat. Note for info that a number of residents were wheelchair bound. Significant number of properties suffered internal flooding. Residents of # 07, who were on site inspecting their property, noted that the significant factor was the volume of water flowing downhill from the sports field and burn, rather than the Ythan flooding from the rear of the properties.



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Photo 07: Road adjacent to Cedar Lodge, leading to 10 The Meadows (taken 08/01/16)



Photo 03: 01 The Meadows (taken 08/01/16)



Photo 05: 04 The Meadows (taken 08/01/16)



Photo 08: 11 The Meadows (taken 08/01/16)





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