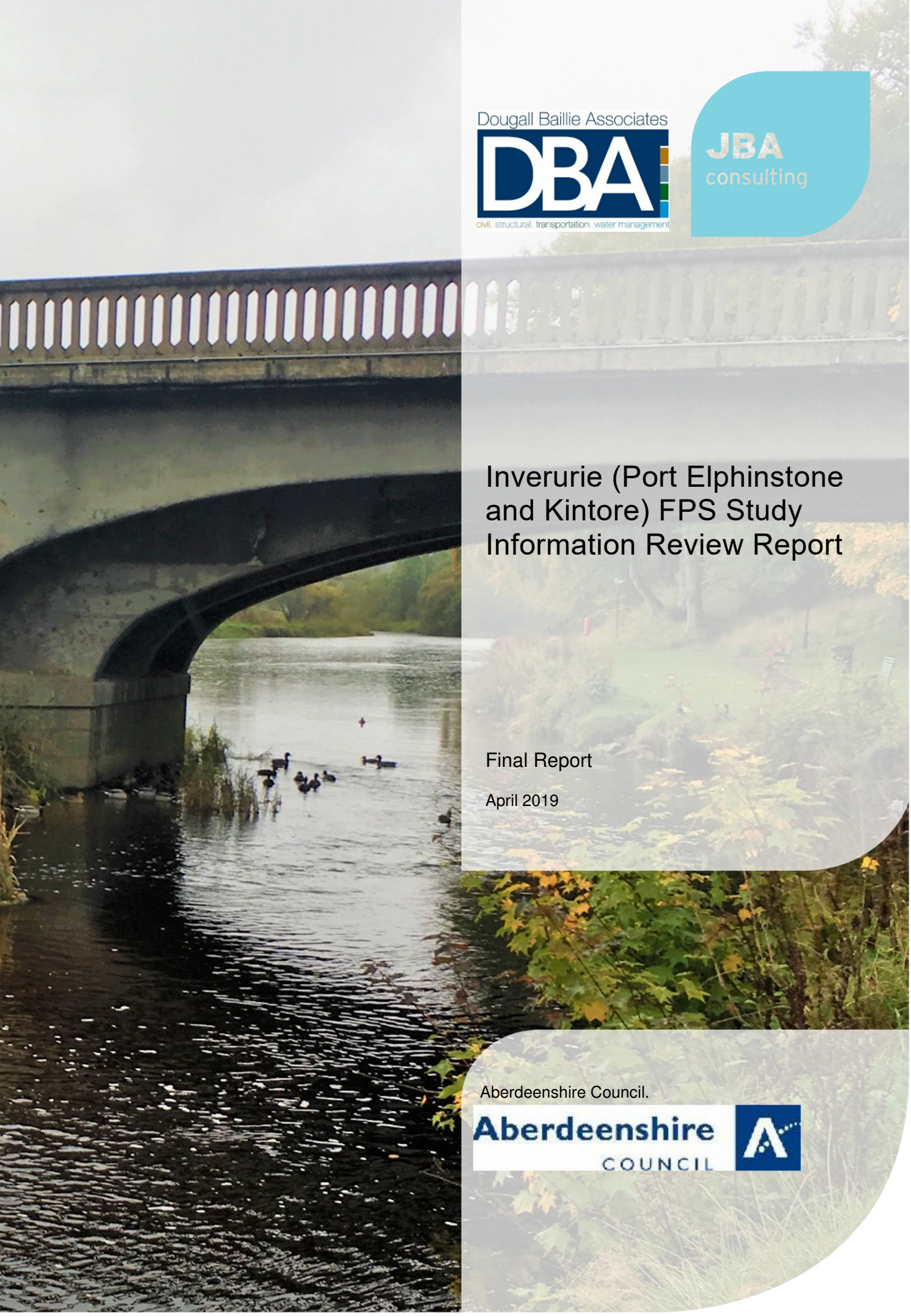

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Inverurie (Port Elphinstone and Kintore) FPS Study Information Review Report

Final Report

April 2019

Aberdeenshire Council.

Aberdeenshire COUNCIL

JBA Project Manager

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Revision History

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P01 / January 2018	-	Alistair Scotland and Lee Watson, Aberdeenshire Council
P03 / March 2018	Aberdeenshire Council comments addressed. Minor corrections.	Alistair Scotland and Lee Watson, Aberdeenshire Council
C01 / April 2019	Figure 1-8 amended. Published.	Alistair Scotland and Lee Watson, 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 Ballie's representative for the contract was Scott Macphail of Dougall Ballie and Aberdeenshire Council's representative for the contract was Alistair Scotland. Caroline Anderton, Alice Gent and Grace Thompson of JBA Consulting carried out this work.

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Director

Purpose

This document has been prepared as a Final Report for Dougall Baillie Associates. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

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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

2D	Two Dimensional (modelling)
AMAX	Annual Maximum
ARF	Areal Reduction Factor
BGS	British Geological Survey
CCTV	Closed Circuit Television
CEH	Centre for Ecology and Hydrology
CS	Cross Section
DDF	Depth Duration Frequency
DS	Downstream
DTM	Digital Terrain Model
EC	European Community
FEH	Flood Estimation Handbook
FRA	Flood Risk Assessment
GIS	Geographical Information System
HEC-RAS	Hydrologic Engineering Center – River Analysis System (developed by the US Army)
ID	Identifier
ISIS	Hydrology and hydraulic modelling software
LiDAR	Light Detection And Ranging
mAOD	metres Above Ordnance Datum
OS	Ordnance Survey
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SEPA	Scottish Environment Protection Agency
TBR	Tipping Bucket Raingauge
US	Upstream

1 Introduction

1.1 Study extent

Inverurie, located in Aberdeenshire, is a small town that lies north west of the confluence of the River Don and the River Urie. The A96 road passes through the town, making it part of the wider strategic growth area for the Garioch area and surroundings, offering major services and a retail centre. Port Elphinstone lies to the south of Inverurie and is bordered to the north and the east by the River Don; Port Elphinstone is downstream of the River Urie confluence. Port Elphinstone and Inverurie are separated by a bridge that spans the section of the River Don upstream of the confluence.

The headwaters of the River Don lie in the Cairngorms National Park near Inchrory at an elevation of 873.9 mAOD, flowing down to altitudes of 55 mAOD in Inverurie. The geology of the River Don catchment, as described by the British Geological Survey (BGS)[1], is mainly Dalradian metamorphics with large amounts of basic intrusives (such as Ordovician to Silurian igneous rock) and a small pocket of Old Red Sandstone (ORS). Thus, owing to its impermeable geology, the catchment has a rapid response to rainfall events. Land use is rural with some forestry and both pastoral and arable farming in the lower reaches. There are several tributaries on the Don - the key ones include the Tuach Burn and Loch Burn that run through Kintore, Burn Hervie and Roquharold Burn that flow into the River Don upstream of Port Elphinstone and the Strath Burn and Over Burn, which are mainly culverted under Inverurie.

The Aberdeenshire Canal[2] was opened in 1805 and ran from Aberdeen to Inverurie but was closed in 1854. Railway line has subsequently been laid along much of its course; however, remnants of the old canal can still be found at Port Elphinstone, where the terminus was located.

Inverurie, Port Elphinstone and Kintore are part of the North East Local Plan District (LPD). The flood risk management for this LPD is documented under the North-East Flood Risk Management Strategy (FRMS)[3] and the North East Local Flood Risk Management Plans (LFRMP)[4].

The areas of Port Elphinstone, Inverurie and Kintore lie within one of the Potentially Vulnerable Areas (PVA) in the North East LPD (PVA 06/13-Port Elphinstone and Kintore), with the A96 road and the Aberdeen to Inverness railway line passing through this 60 km^2 PVA (see Figure 1-1). The Inverurie flood protection study (incorporating Inverurie and Port Elphinstone) is ranked 57 of 168 nationally and 2 of 12 at the local authority level; the Kintore flood protection study is ranked 122 of 168 nationally and 8 of 12 locally. The Kintore study is to be undertaken as part of the next phase of studies in this region (Cycle 2). However, the Kintore catchment is sufficiently close to Inverurie and Port Elphinstone along the River Don and River Urie to warrant its inclusion in the modelling for this phase; extension of the model boundary downstream past Kintore will both allow for model calibration at a known point (the Parkhill gauging station) for this study, thus improving confidence in model outputs through Inverurie, and produce a model boundary that can be used when the Kintore study is undertaken at a later date. Inverurie and Port Elphinstone are most susceptible to fluvial flooding in the area surrounding the confluence of the River Don and the River Urie. The dominant flood mechanism in Kintore is fluvial flooding from the Loch Burn and Tuach Burn. The estimated Annual Average Damages (AAD) in the PVA caused by flooding is £510,000, with just over half being accounted for by fluvial flooding and the remaining caused by pluvial flooding. AAD for Inverurie, Port Elphinstone and Kintore are shown in Figure 1-2, Figure 1-3 and Figure 1-4 respectively. There are estimated to be 230 residential properties and 190 commercial properties at risk of flooding within the PVA, together with vast areas of agricultural land. Transport routes - in particular the B9170 road - are affected by pluvial flooding due to water backing up from the culverted section of the Strath Burn and due to blockage accumulating at the trash screen.

1 http://mapapps.bgs.ac.uk/geologyofbritain/home.html

2 https://en.wikipedia.org/wiki/Aberdeenshire_Canal

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

4 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]

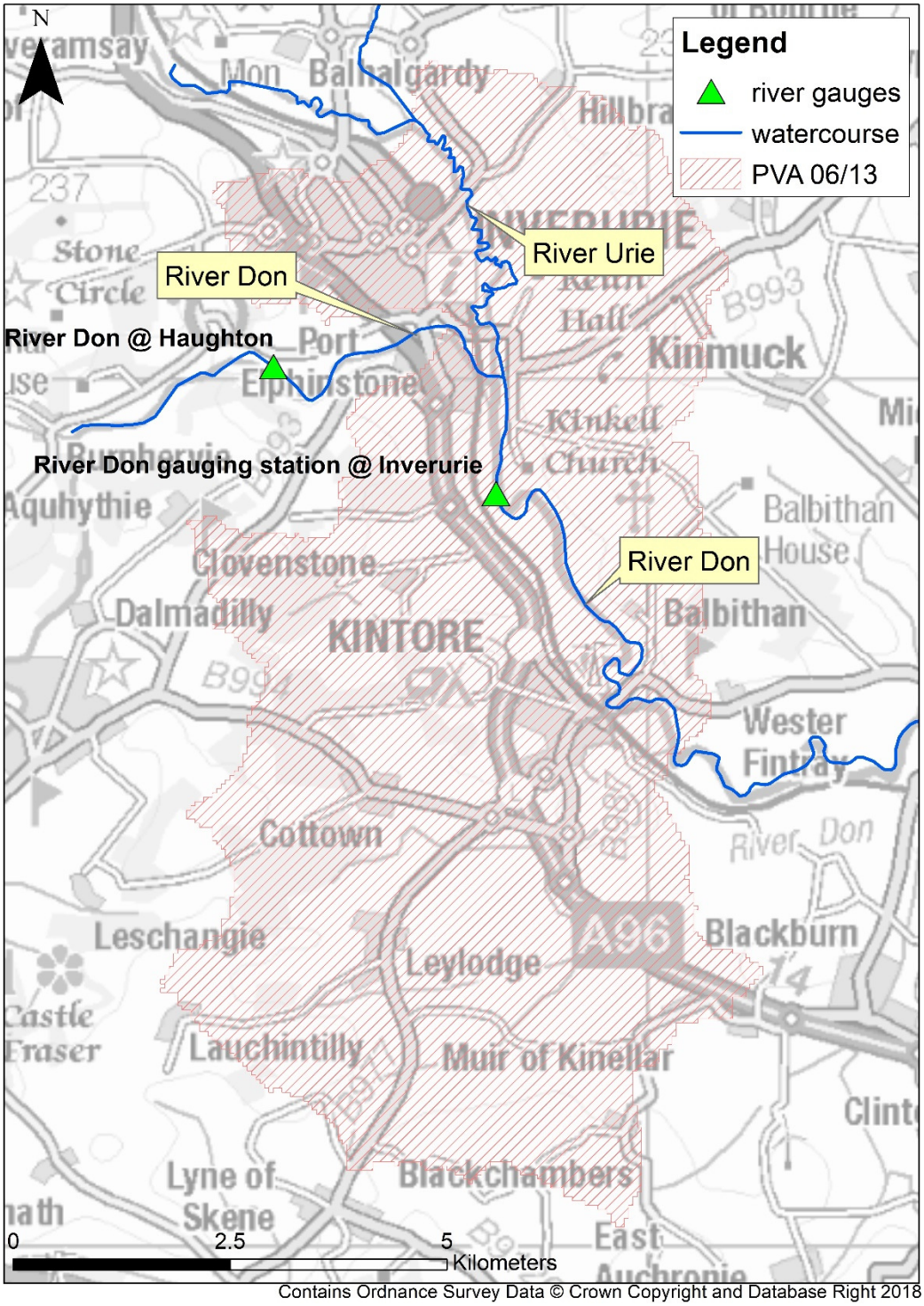


Figure 1-1: Location of PVA 06/13

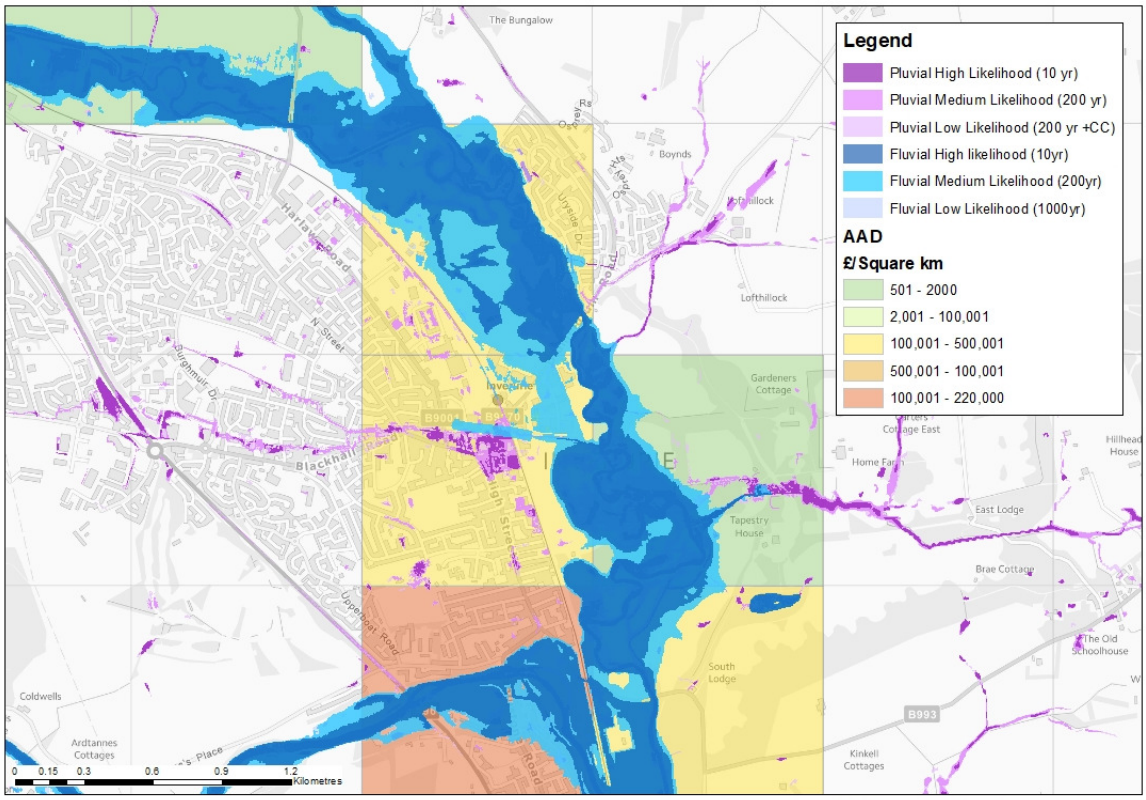


Figure 1-2: AAD for Inverurie shown in context of pluvial and fluvial flood extents

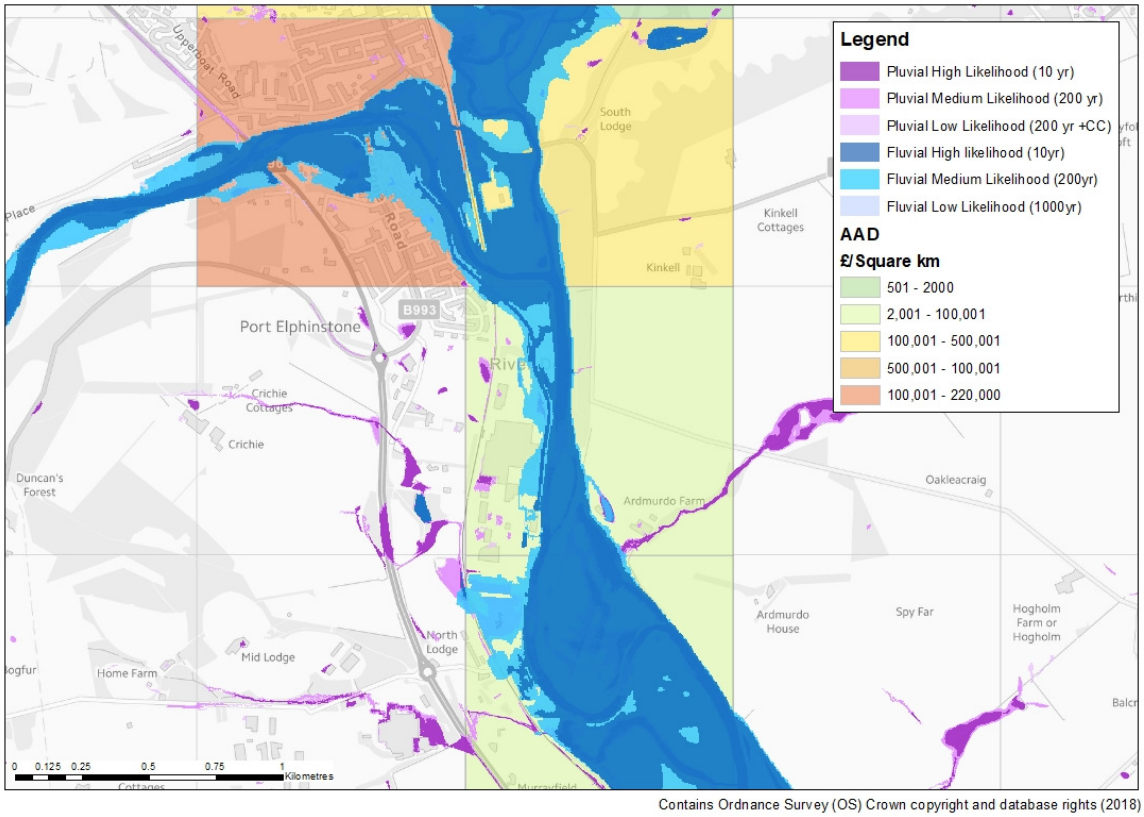


Figure 1-3: AAD for Port Elphinstone shown in context of pluvial and fluvial flood extents

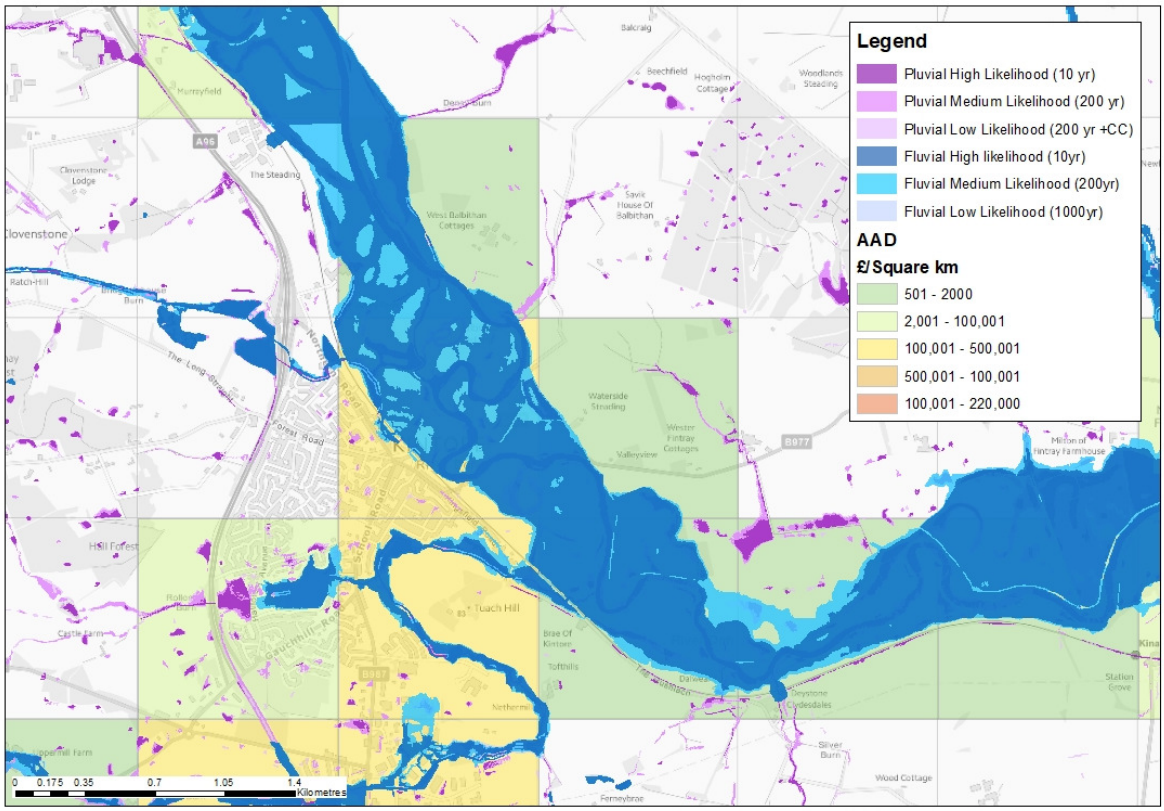


Figure 1-4: AAD for Kintore shown in context of pluvial and fluvial flood extents

There are no international or national landscape designations in Inverurie, Port Elphinstone or Kintore.

There are thirteen cultural sites within the PVA designated by Historic Environment Scotland that have been identified as being susceptible to flooding; these include Scheduled Monuments such as Broomend Henge and Keith Hall, which is classified as a Gardens and Designed Landscape site.

The LFRMP's key actions are:

- To reduce the physical risk, or disruption risk, related to areas of the A96 at risk of flooding: 23 locations on the A96 with a total length of 820 m for Inverurie and Kintore.
- To reduce risk from surface water flooding in Inverurie and Port Elphinstone as well as avoiding and reducing an overall increase in flood risk.

The study reaches of the River Urie and River Don at Inverurie, Port Elphinstone and Kintore are part of three sections of the watercourses identified in SEPA's River Basin Management Plan (RBMP)[5]:

- River Urie: Lochter Burn to Don (ID: 23282) - classified as 'Moderate' condition since the first classification in 2007 due to the quality of macrophytes (aquatic plants), which was rated as being of 'Moderate' quality, in contrast to the other categories that were assessed to be of 'High' or 'Good' quality.
- River Don: Alford to Inverurie (ID: 23293) - classified as 'Moderate' in 2016 after being downgraded from a ranking of 'Good' in 2007 and 2008 due to an increase in the reach acting as a barrier to fish migration.

5 SEPA RBMP website (2017) http://www.sepa.org.uk/data-visualisation/water-environment-hub/ [accessed 19/12/2017]

- River Don: Inverurie to Dyce (ID:23269) - classified as 'Good' in 2015 and 2016 following being classified as 'Moderate' from 2007 to 2014. In 2007 the hydromorphology of the reach was classified as 'Moderate' and from 2007 to 2015 the water quality was ranked as 'Moderate', as indicated by the nutrient enrichment and pollution status of phytobenthos (microscopic plants that exist attached to rocks or plants).

The River Don and River Urie are also designated salmonid waters[6] (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 Urie is gauged by SEPA at the Pitcaple gauging station and the River Don is gauged at Haughton and Inverurie (although the latter is a level only gauge). Records from recent storm events are noted below. The flows are based on values following a rating review of both gauges, which was conducted by JBA Consulting for a project commissioned by SEPA[7]. It is expected that, with changes in climate, extreme flood events will become more frequent and more intense.

Table 1-1: Gauge records from recent storm events

Gauge	November 2002 event		December 2015/January 2016 (Storm Frank)	
	Stage (m)	Flow (m^3/s)	Stage (m)	Flow (m^3/s)
Haughton	5.07*	273.93	5.50**	396.23
Pitcaple	2.64**	56.44*	2.88	63.88

* 2nd highest level on record

** Highest level on record

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

7 JBA Consulting. 2017. 2017s6610 - Haughton Rating Review Final Report v2.0 and 2017s6610 - Pitcaple Rating Review Final Report v2.0.

1.2 Inverurie proposed model extent

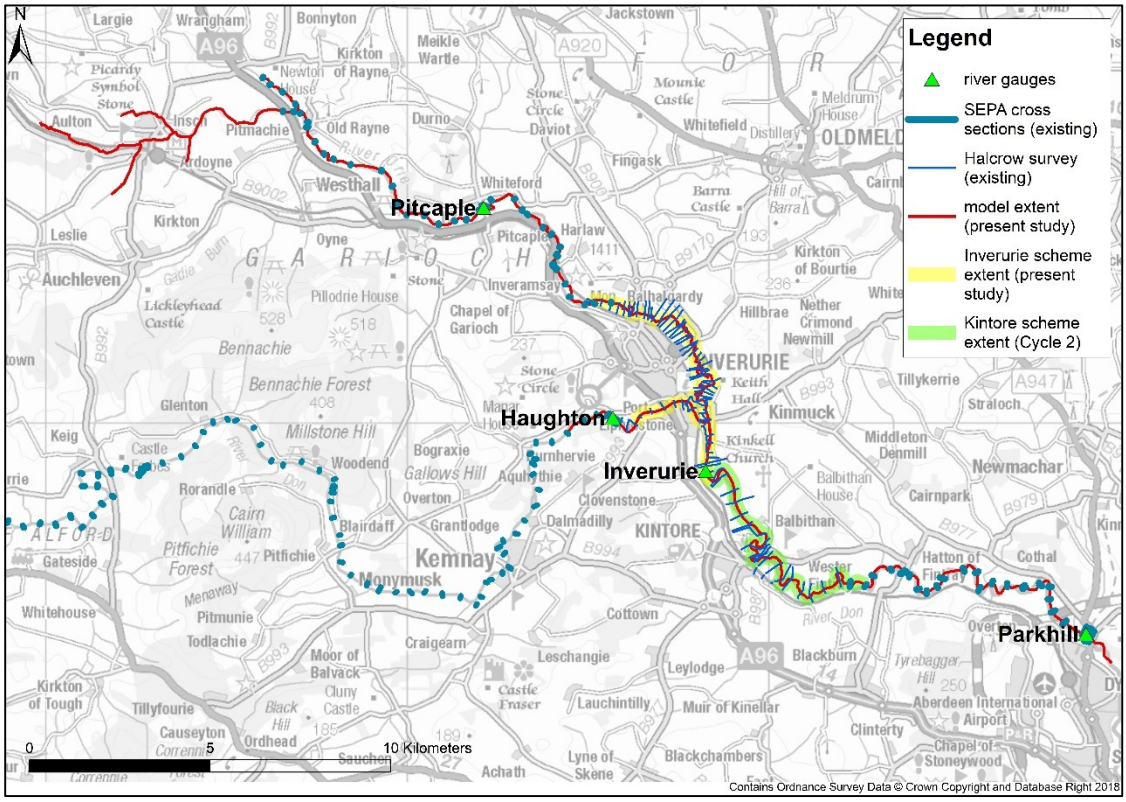


Figure 1-5: Existing survey and model/scheme extents for present study for Inverurie, Port Elphinstone and Kintore

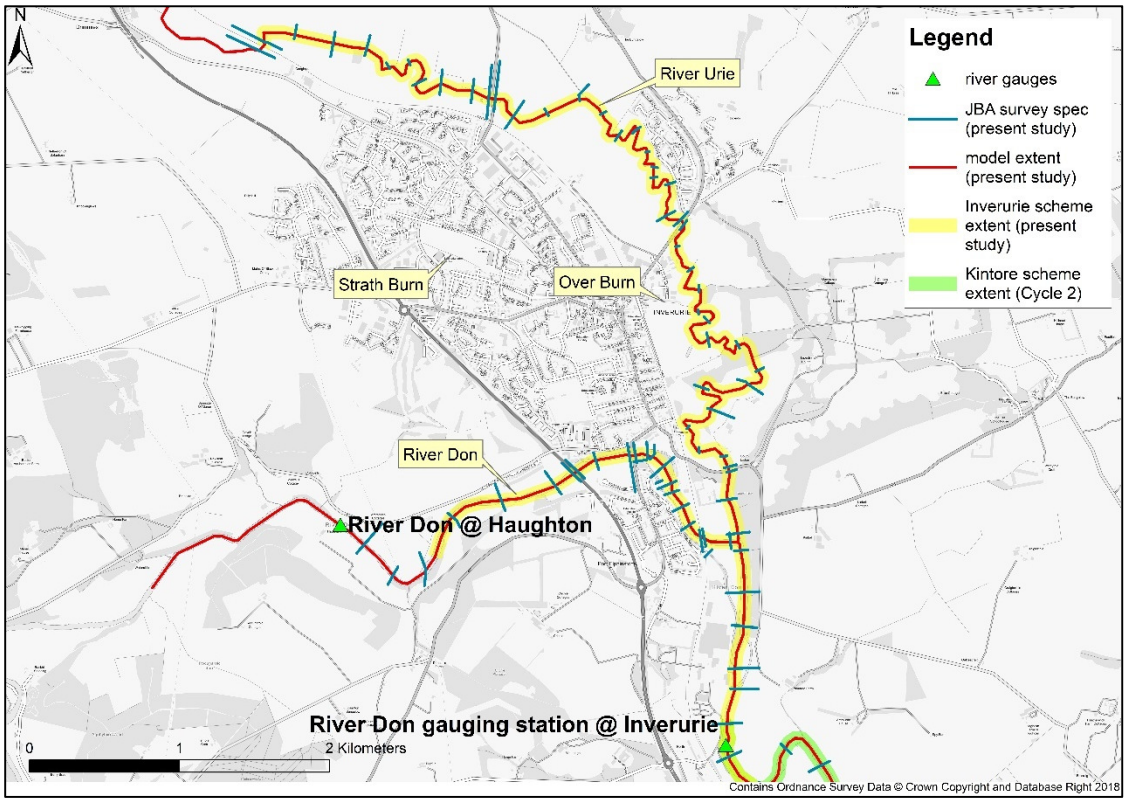


Figure 1-6: JBA Consulting survey spec for Inverurie and Port Elphinstone for present study

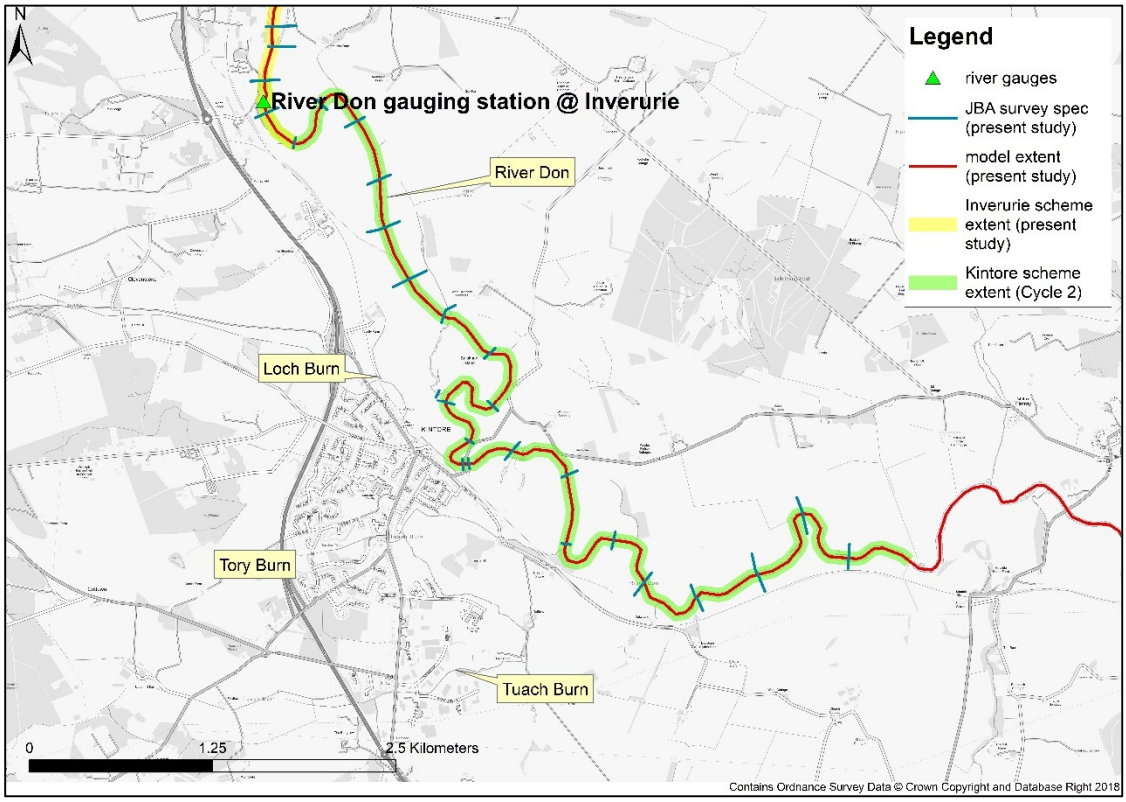


Figure 1-7: JBA Consulting survey spec for Kintore for present study

1.3 Historical flooding

A flood history review was carried out from data collected from the following: Aberdeenshire Council, Scottish Environmental Protection Agency (SEPA), Chronology of British Hydrological Events (CBHE), social media sources. The historical flood record for Inverurie, Port Elphinstone and Kintore is documented in the table below.

Table 1-2: Historical flood records for Inverurie, Port Elphinstone and Kintore

Date	Description	Source
1768 1828 1838 1872 1903 1905	Most agricultural crops damaged and extensive flooding to agricultural land after the River Don breached its banks.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [8]
1829	' …Several houses were flooded 4 or 5 feet deep, half the mill-house of Kemnay was swept away, and the wooden part of the machinery carried down to Inverurie and Kintore'	Muckle Spate, found online at: https://archive.org/stream/greatfloodsaugu00laudgoog#page/n250/mode/2up/search/Inverurie [assessed on 16.11.17]
1920	' Hundreds of Acres were inundated by the River Don bursting its banks; sheep, cattle and poultry perished.'	CBHE, found online at: < http://www.hydrology.org.uk/Chronology_of_British_Hydrological_Events.php> [accessed on 16.11.17]
1924	The Gas Burn flooded Blackhall Road in Inverurie.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk

8 North East Local Plan District- Local Flood Risk Management Plan 2016-2022. Found online at: https://www.aberdeenshire.gov.uk/media/17174/north-east-local-flood-risk-management-plan-2016-2022-web-version.pdf [accessed on 24/10/17]

		Management Plan [8]
1928 1948 1951	Flooding to agricultural land after the River Don breached its banks.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [8]
1995	Flooding to agricultural land from the Don breaching its banks. Flooding to Oldmeldrum Road and Souterford Road due to overtopping of the River Urie. Water levels of 4.74 m at Haughton gauging station.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [8]
2000	Extensive flooding to Inverurie, Port Elphinstone and Kintore. A range of flooding photos showing flood extents. Flood outlines of the October flood event which shows flooding from both the River Don and the Urie in eastern Inverurie, covering the agricultural floodplains. Further flooding to the agricultural land east of Kintore and south of Kemnay.	Photos and flood outlines supplied by SEPA and JBA Consulting UK.
2002	The Bridge of Don had the highest water level on record and flooding affected Canal Road. The Strath Burn caused flooding to central Inverurie due to culvert blockage from a trash screen. Flooding to Oldmeldrum Road and Souterford Road due to overtopping of the River Urie. Flooding in south east Kintore including Kingsfield Road after water backed up Tuach Burn from the River Don. Water levels backing up from the River Don caused flooding on Loch Burn in the eastern areas of Kintore affecting commercial property in the area between the two railway culverts and properties on Northern Road.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [8]
2002	Aerial flooding photos of the area.	Photos supplied by SEPA
2002	Flooding photos at Inverurie	Photos supplied by SEPA
2003	The flood barrier at Keithhall Road, Inverurie was breached and residential properties were flooded. The Strath Burn caused flooding to central Inverurie due to culvert blockage from a trash screen. Flooding in south east Kintore including Kingsfield Road after water backed up the Tuach Burn from the River Don.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan [8]
2004	The River Don caused flooding after breaching its banks. The Strath Burn caused flooding to central Inverurie due to culvert blockage from a trash screen.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[8]
2005	Water levels backing up from the River Don caused flooding on Loch Burn in the eastern areas of Kintore affecting commercial property in the area between the two railway culverts and properties on Northern Road.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[8]
2006	Flooding in south east Kintore including Kingsfield Road after water backed up in the Tuach Burn from the River Don.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[6]
2009	The River Don caused flooding after breaching its banks. The Strath Burn caused flooding to central Inverurie due to culvert blockage from a trash screen. Flooding to Oldmeldrum Road and Souterford Road due to the River Urie overtopping its banks. Flooding in south east Kintore including Kingsfield Road after water backed up the Tuach Burn from the River Don. Water levels backing up from the River Don caused flooding on Loch Burn in the eastern areas of Kintore affecting commercial property in the area between the two railway culverts and	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[8]

	properties on Northern Road.	
2010	The Strath Burn caused flooding to central Inverurie due to culvert blockage from a trash screen.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[8]
2016	56 properties damaged in Kintore and over 80 properties damaged in Inverurie. Emergency services were needed to rescue residents in Canal Road, Canal Crescent and Riverside Park which were inundated with several feet of water. The Port Elphinstone Bridge on Elphinstone Road was closed.	Aberdeenshire Council- North East Local Plan District: Local Flood Risk Management Plan[8.]
2016	Canal Road and Riverside Park flooded, with homes needing evacuating. Flooding of up to 4ft into one living room. The fire service rescued 50 people in Port Elphinstone.	The Press and Journal, found online at: < https://www.pressandjournal.co.uk/fp/news/aberdeenshire/799848/port-elphinstone-residents-tell-of-flooding/> [accessed on 16.11.17]
2016	'On Monday evening, residents in Canal Road in Inverurie were evacuated from their homes'……' Firefighters also rescued a woman who was trapped in her car by rising flood water in Inverurie…several householders in nearby Port Elphinstone were forced to leave their homes after water started coming through their floorboards'	BBC News, found online at: < http://www.bbc.co.uk/news/uk-scotland-35221823> [accessed on 16/11/17]
2016	'Dozens of homes were evacuated in Inverurie, Port Elphinstone and Ellon overnight as the swollen river sent flood waters racing down the streets'……' Gauge at Haughton measured the Don at 5.6 m - the highest level for 45 years. The level at the Parkhill gauge measured 4.84 m'.	The Sunday Post, found online at: < https://www.sundaypost.com/news/scottish-news/aberdeenshire-flooding-river-don-bursts-its-banks-with-homes-evacuated-in-inverurie-port-elphinstone-and-ellon/> [accessed on 16.11.17]
2016	Widespread flooding to Inverurie and Port Elphinstone. The highest water level on record at Haughton gauging station, 4.84 m	YouTube, found online at: https://www.youtube.com/watch?v=9HIZKrtV4p8 [accessed on 24/10/17]
2016	Flooding in Kintore. The highest water level on record at Haughton gauging station, 5.5 m.	YouTube, found online at: < https://www.youtube.com/watch?v=hOcRhiBT1YI> [accessed on 24/10/17]
2016	Flood photos from Aberdeenshire Council, See Appendix A	From Aberdeenshire Council, see Appendix A.

In summary, the key events in which Inverurie, Port Elphinstone or Kintore experienced flooding were as follows: 1829, 1924, 1995, 2002, 2003, 2004, 2005, 2006, 2009, 2010, 2015 and 2016. Key events are summarised below in Figure 1-8.

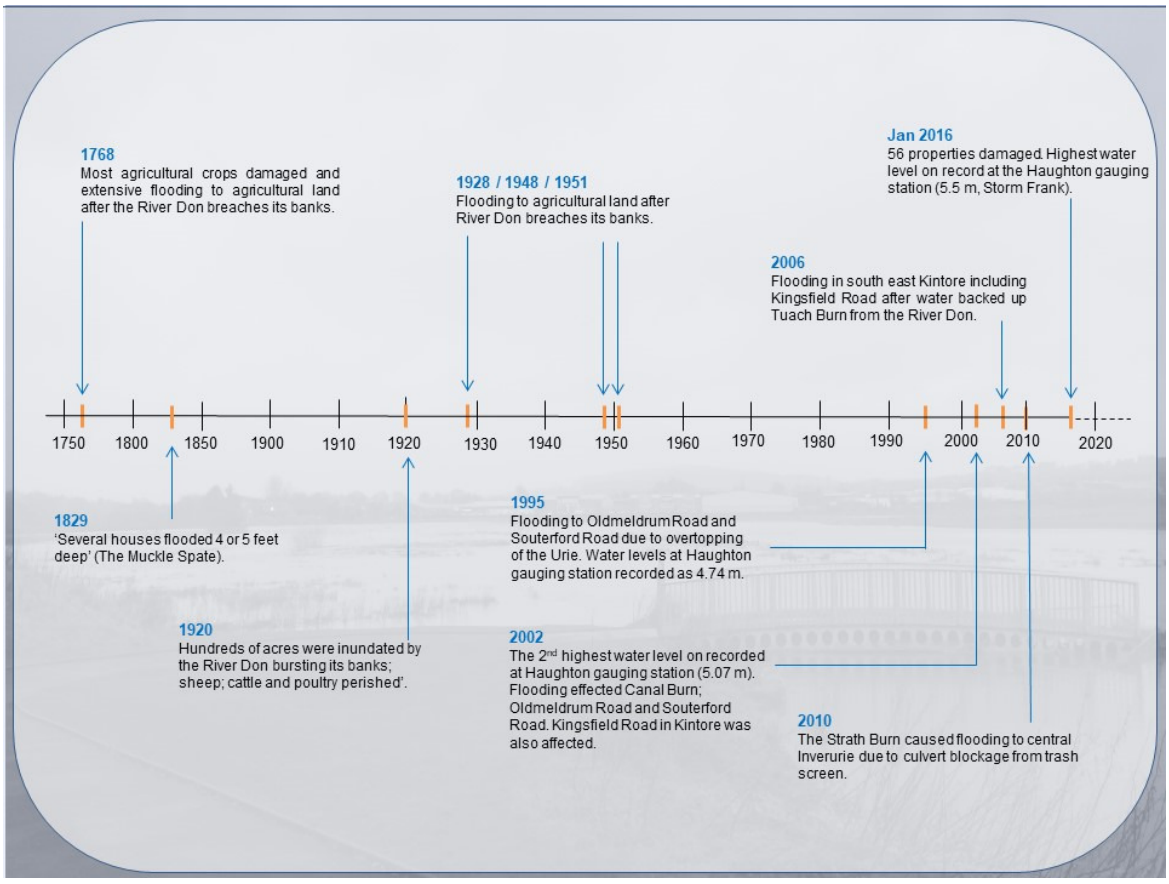


Figure 1-8: Key flood events in Inverurie, Port Elphinstone and Kintore (see Table 1-2 for sources)

1.4 Flood mechanisms

1.4.1 River Don fluvial flood mechanisms

In Inverurie and Port Elphinstone, out of bank flows from the River Don contribute to flooding of the B993, A96, Davidson Field, Riverside Park, St James Place and Canal View, as well as to surrounding river banks.

In Kintore, out of bank flows from the River Don contribute to inundation of the floodplains surrounding the Don to the east of Kintore and the streets of Bridge Road and The Rushlach. Due to high flows on the Don, water backs up in Tuach Burn and Tory Burn resulting in out of bank flows affecting the B987 road, Tumulus Way, Carmie Brae, Wyness Way and Hallforest Crescent.

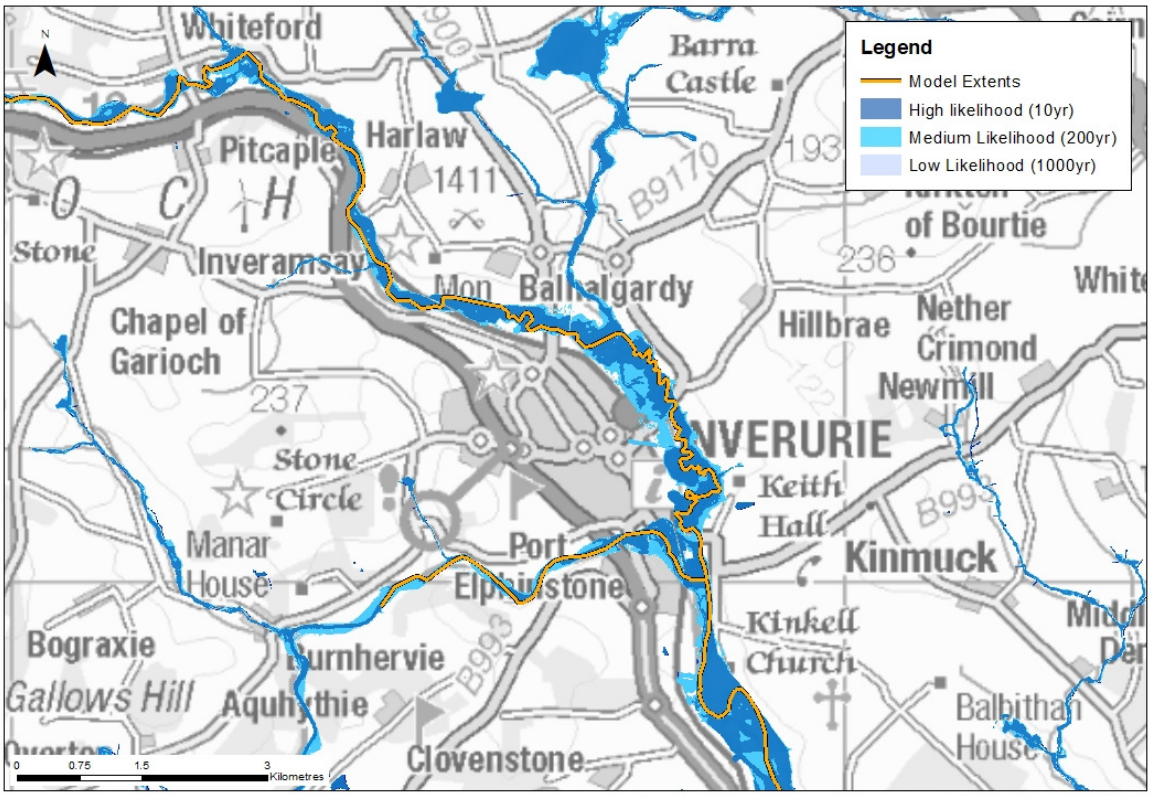


Figure 1-9: Fluvial flood outlines for the River Don and River Urie in Inverurie and Port Elphinstone

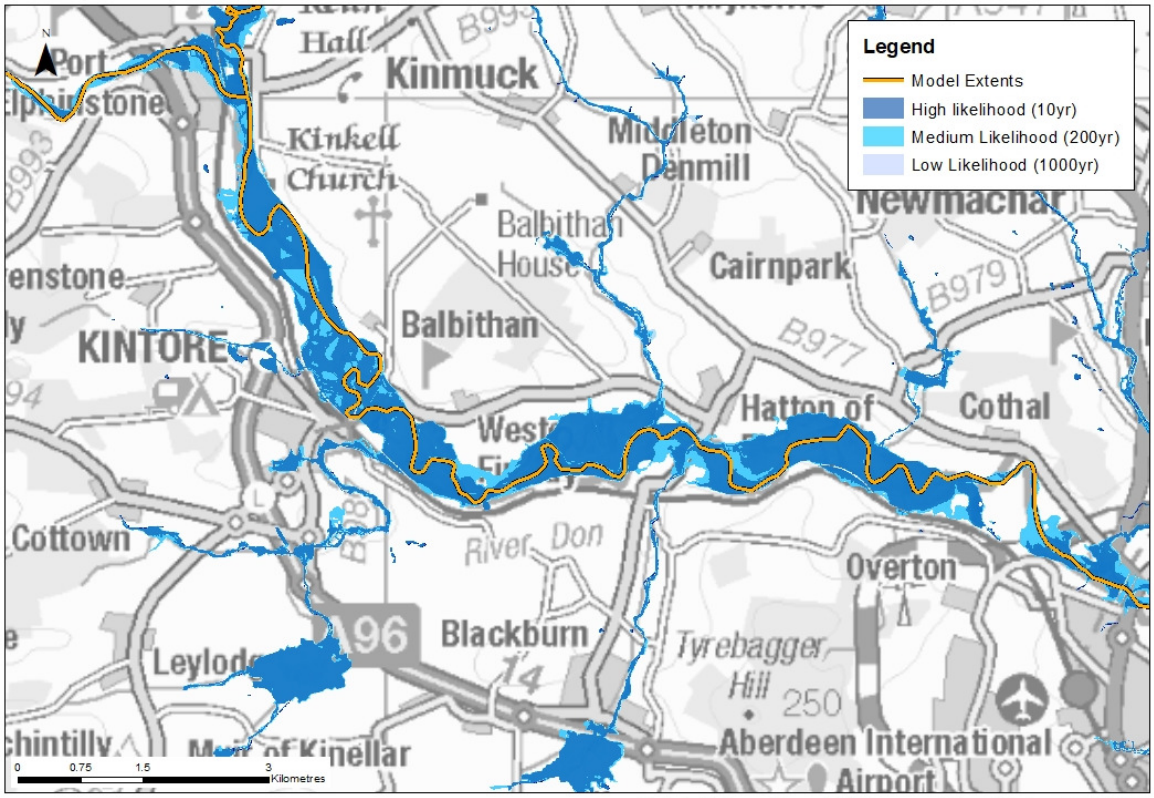
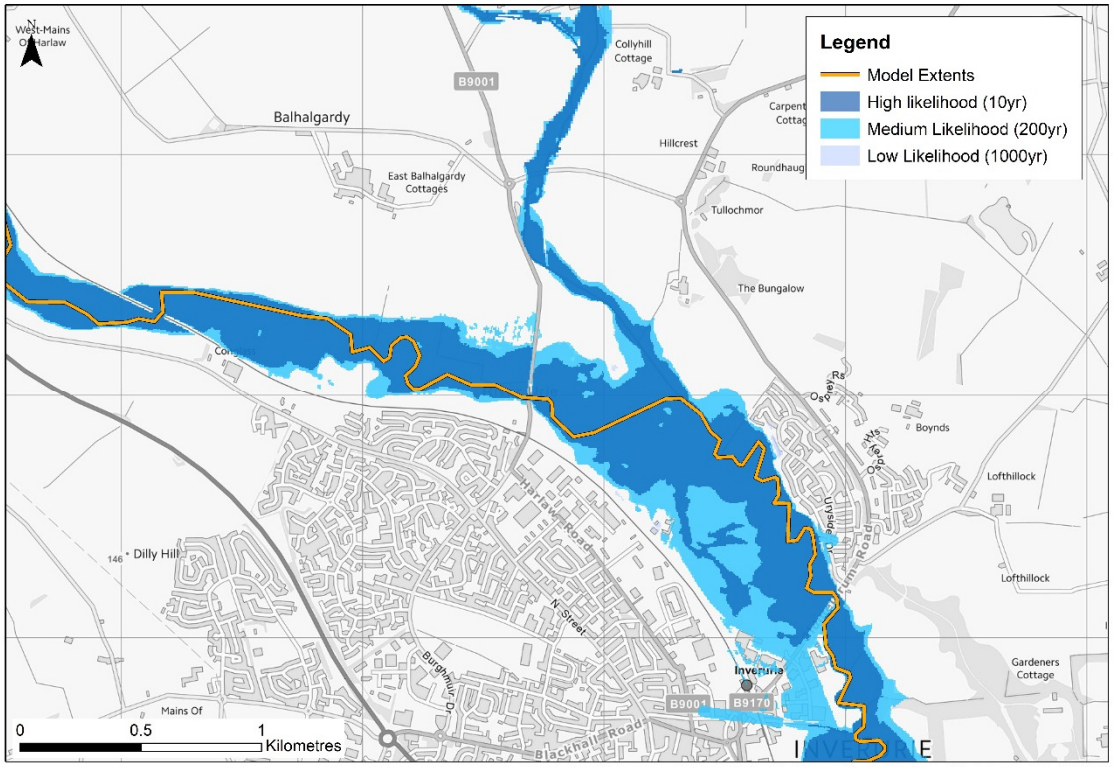


Figure 1-10: Fluvial flood extents from the Don in Kintore

1.4.2 River Urie fluvial flood mechanisms

In Inverurie, the primary flood mechanism from the Urie is overtopping of banks into the surrounding agricultural land and the south end of Oldmeldrum Road/the B9170. Out of bank flow pathways result in flooding to Souterford Ave, Souterford Drive, Old Port Road and Keithhall Road/the B993 (Figure 1-11).

In Port Elphinstone, out of bank flow pathways result in flood paths to the B993 road and surrounding agricultural land (Figure 1-12).



Contains Ordnance Survey Data © Crown Copyright and Database Right 2018

Figure 1-11: Fluvial flood extents from the Urie in Inverurie

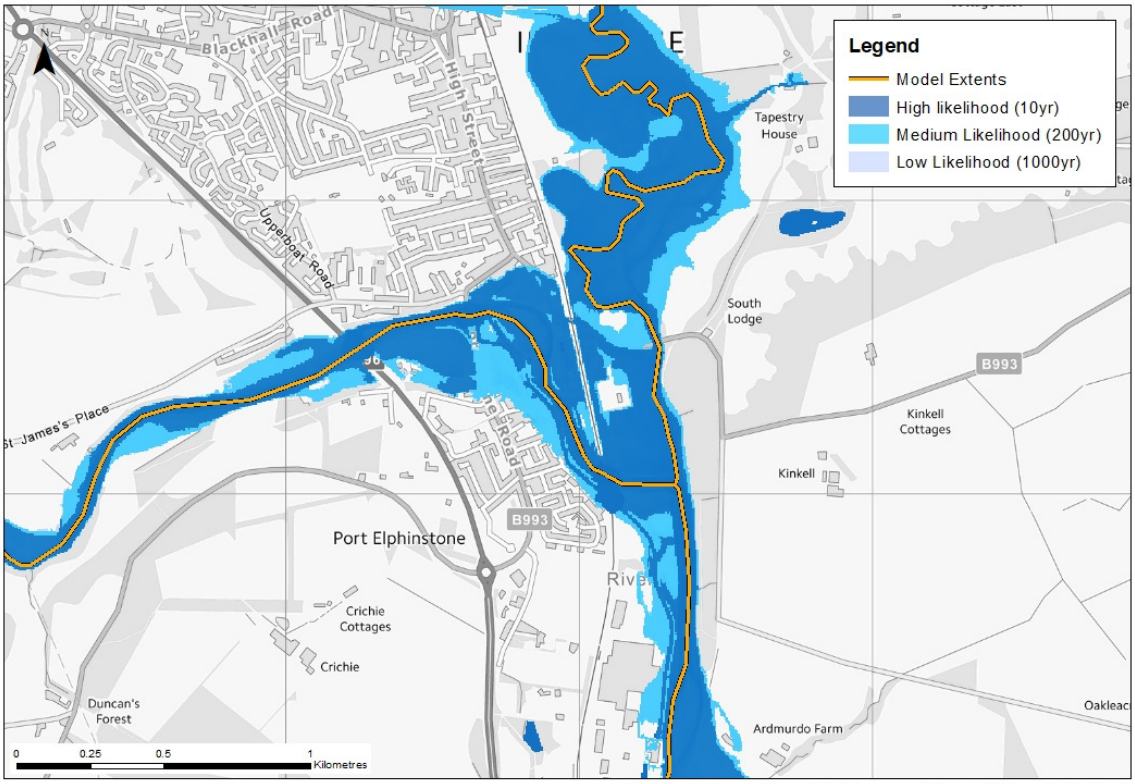


Figure 1-12: Fluvial flood extents in Port Elphinstone from the River Urie and River Don

1.4.3 Surface water flooding mechanisms

Flooding in Inverurie from surface water flow due to drainage incapacity during high flow events results in flood pathways through Inverurie town centre on West High Street, Station Road and Market Place, as well as surface flows along the B9170 and Blackhall Road.

In Kintore, surface water flooding mechanisms produce flow pathways resulting in water pooling behind the west side of the A96 road, south of Tory Burn near Wyness Way and south of East Park Road.

The extents of pluvial flooding are shown in Figure 1-13 and Figure 1-14.

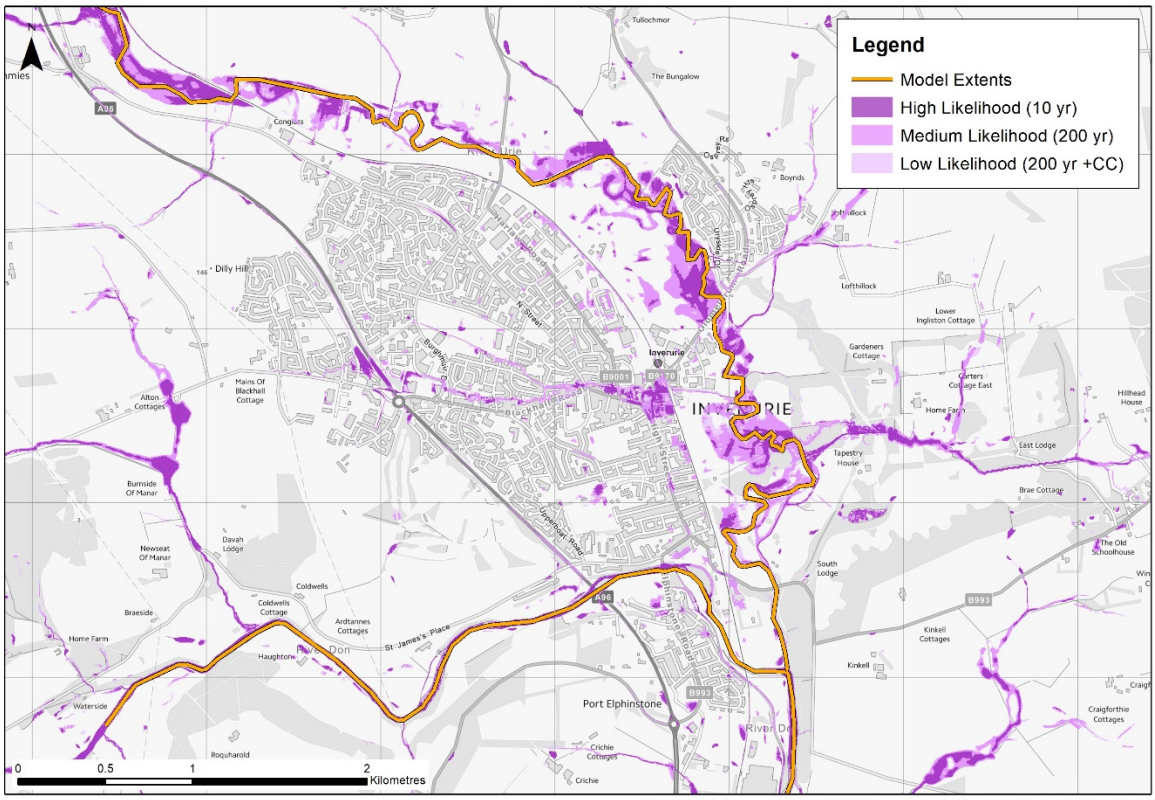


Figure 1-13: Surface water flood extents in Inverurie

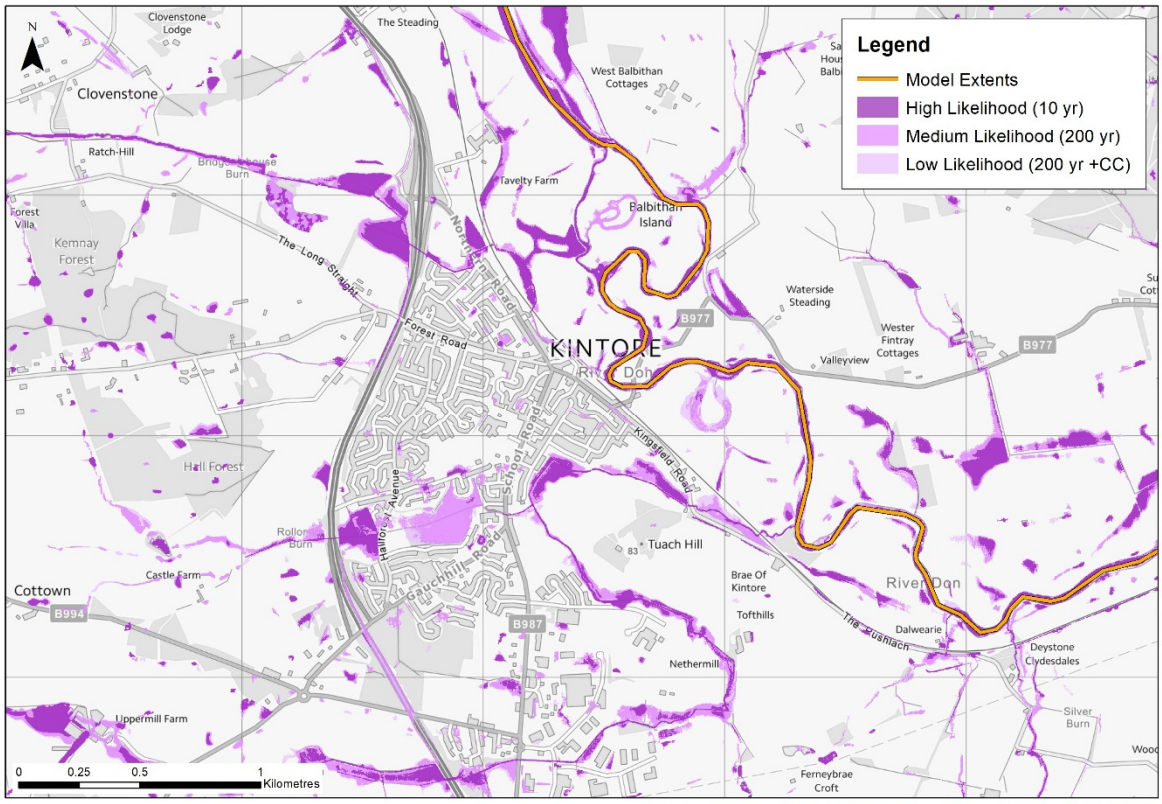


Figure 1-14: Surface water flood extents in Kintore

1.4.4 Coastal flood risk mechanisms

Inverurie, Port Elphinstone and Kintore are located more than 25 km from the mouth of the River Don, with typical catchment elevations exceeding 50 mAOD, and are therefore not susceptible to coastal flooding.

1.5 Watercourses

The following watercourses are included within the Aberdeenshire Council specification for assessment of flood risk in Inverurie, Port Elphinstone and Kintore.

Table 1-3: Summary of model and survey available

Watercourse	Modelled	Survey Data
River Don	Yes	Yes
River Urie	Yes	Yes

1.6 Current defences

1.6.1 Formal defences

There are currently two defence schemes in place in Inverurie to reduce flood risk; these are detailed in Table 1-4 and displayed in Figure 1-15.

Table 1-4: Flood defence schemes

Scheme	Date	Watercourse	Design Standard of Protection	Description
Inverurie (Strath Burn and Over Burn) Flood Prevention Scheme	1978	Strath Burn and Over Burn	30	Improvement and realignment of the Over Burn and Strath Burn culverts, installation of new culvert and works to the inlet.
Overburn Culvert, Inverurie Flood Prevention Scheme	2001	Over Burn	100	Operations include the installation of a new box culvert, using pre-cast reinforced concrete box culvert units between the corner of Constitution Street and Western Road and Burnbank at Port Road.

There is also a wall that has been constructed along the Strath Burn adjacent to the road of Maryfield West and Strathburn School.

There are no formal defences in Port Elphinstone or Kintore.

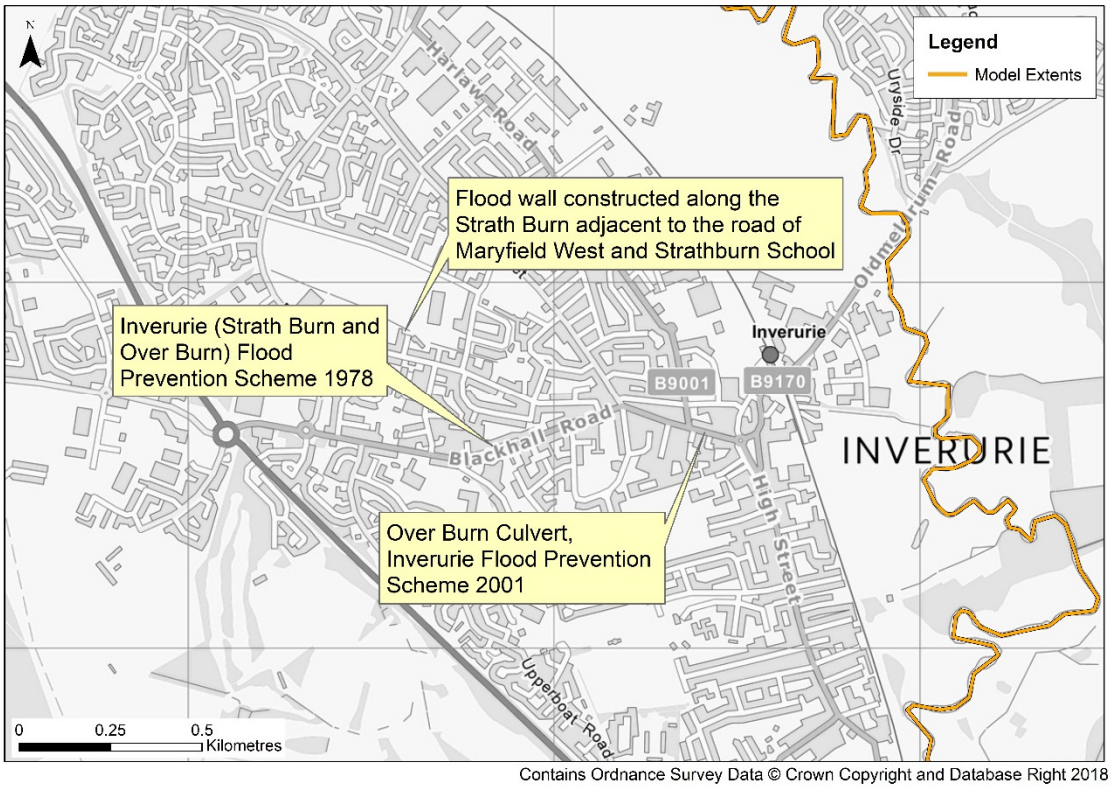


Figure 1-15: Flood defences in Inverurie

1.6.2 Informal defences

There is an informal flood defence in Inverurie: a flood defence bank and walls (referred to as the 'Scottish Water Embankment') have been constructed along the banks of the River Don on Keithhall Road, Inverurie. The bank is approximately 170 m in length and has a height of 6 m from the original bank level of 52.7 mAOD. There are also embankments around Davidson Field. At the time of the site visit for the present study, Scotframe were in the process of building flood defence walls in the vicinity of Souterford Bridge.

There are no informal defences in Port Elphinstone or Kintore.

2 Review of previous studies

A number of flood risk assessments (FRAs) and flood studies have previously been carried out in Inverurie, Port Elphinstone and Kintore and are summarised in Table 2-1 below. Potential sources of flooding are site specific but those applicable to the wider area are highlighted under Key Findings.

Table 2-1: Previous FRAs and flood studies and their key findings

Document Name	Author	Model Available?	Key Findings
2003 - Kintore Flood Attenuation Scheme	EnviroCentre	Yes	Purpose of the study is assessing flood attenuation in Kintore. • Model of the River Don and Tuach Burn. • Flows expected to peak in the Tuach Burn before in the Don. • Climate change to reduce the 1% AP (100 year) event to a 2.5% AP (40 year) event and then 1.6% AP (60-year) event by the 2080's.
2003 - Port Elphinstone Drainage Study	EnviroCentre	Yes - InfoWorks CS	Purpose of the study was to assess surface water drainage flow pathways. • The drainage study to model surface water flow pathways has shown: • Canal View and Canal Crescent are expected to be the first locations of flood inundation. • Climate change to reduce the 1% AP (100 year) event to a 2.5% AP (40 year) event to 1.6% AP (60-year) event by the 2080's. • The 50% AP (2 year) event is enough to cause flooding.
2003 - Inverurie Flood Study	Halcrow	Yes	Purpose of the study was to assess flood risk from the River Urie and the River Don. River Urie: • Flooding is predicted at the 50% AP (2 year) event. • The flood extent increases as the flows increase resulting in the 0.5% AP (200 year) event causing 550 m width of inundation. • Farmland is at the greatest risk comparative to residential housing. • Key properties at risk are in the area surrounding the confluence of the River Urie and River Don. River Don: • Farmland at greatest risk of inundation. • 1% AP (100 year) event and 0.5% AP (200 year) events predicted to cause widescale flooding to south Inverurie and Port Elphinstone. • Key flood locations are: Port Elphinstone Road; Canal Crescent and Canal Road; Kintore Golf club; Keithhall Road; and the old water treatment works.
2005 -	JBA	Yes	Purpose of the study was to assess the

Strath Burn Hydrological Assessment	Consulting		feasibility of upstream storage on the Strath Burn. • Modelling of the Strath Burn has shown that the 0.5% AP (200 year) event would cause flow greater than the channel and culvert capacities on the Strath Burn. • Key recommendation was the improvement of the trash screen at the entrance of the culvert system on Strath Burn.
2010 - Flood Risk Assessment for Oldmeldrum Road, Inverurie	JBA Consulting	Yes - HEC-RAS model and a 2D overland flow Rflow model.	Purpose of the study was a Flood Risk Assessment for Oldmeldrum Road, for a proposed residential development. • A hydrological model of the River Urie was constructed. • Souterford Bridge predicted to have no significant impact on predicted water levels at the site. The exception would be blockage which would likely cause road flooding and bridge overtopping. • Keithhall Bridge is predicted to have backwater effect, increasing water levels by 0.07 m. • 0.5% AP (200 year) event is defined as being within the 'functional floodplain' and any land raising or development would need to be linked to a storage provision.
2015 - Flood Risk Assessment for Oldmeldrum Road, Inverurie, updated	JBA Consulting	Yes - HEC-RAS an update of the 2010 model. JFlow surface modelling	Purpose of this study was an updated flood risk assessment for Oldmeldrum Road for a proposed development site. • A hydrological model of the River Urie was constructed. • For the 0.5% AP (200 year) event, modelling produced flood elevations of 54.41 mAOD and 54.93 mAOD on the Urie. • The surface water modelling predicted flooding on Oldmeldrum Road.
2015 - Inverurie Flood Study Update	Ch2m	Yes - the 2010 model, unaltered.	Purpose of the study is an update of the 2003 Inverurie flood study. • The water levels, when compared to 2003 and 2010 studies, have increased. • The average increase, since 2003, is 0.69 m on the Urie and 0.08 m on the River Don.

3 Hydrological review

A review of readily available archives will be undertaken 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 Don and Urie is already being undertaken as part of the Upper Don fluvial mapping project for SEPA. We will build on our experience of flood estimation in the Don catchments, where we have worked on the Inverurie storage assessment (Aberdeenshire Council) and Inverurie Flood Risk Assessment for a private developer and post flood surveys.

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: 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 will 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 return periods considered are presented in Table 3-1.

Table 3-1: Return periods and annual probability

Return Period	Annual probability
2	50%
5	20%
10	10%
30	3.33%
50	2%
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 Webservice; suitable OS mapping, geological and soil data will be used to update the descriptors, and all catchments will be digitised within ArcGIS.

Peak flows will be estimated using the most up-to-date FEH techniques. For all catchments, the FEH Statistical method and the Rainfall Runoff methods (including its Revitalised version, ReFH2 with FEH13 rainfall) will be used and the most appropriate method selected for use in the hydraulic model. In general, this will be the statistical method for large rural catchments and a Rainfall Runoff approach for smaller catchments.

The preferred methods for each watercourse are presented in Table 3-2.

Table 3-2: Preferred method for hydrology

Watercourse	Peak flow location	Preferred approach to FEH peak flows and hydrographs	Flow estimate locations
River Don	Haughton gauging station Inverurie Port Elphinstone Kintore Parkhill gauging station	FEH Statistical Single Site analysis With checks against FEH Statistical Enhanced Single Site analysis And/or FEH Statistical Pooled analysis Hydrograph synthesised from gauged data	US model boundary DS model boundary Haughton gauging station US and DS of the River Urie confluence Inverurie gauging station US and DS of the Bridgealehouse Burn at Kintore US and DS of Tuach Burn at Kintore Parkhill gauging station
River Urie	Pitcaple gauging station Inverurie	FEH Statistical Single Site analysis With checks against FEH Statistical Enhanced Single Site analysis FEH Statistical Pooled analysis Hydrograph synthesised from gauged data	US model boundary DS model boundary Pitcaple gauging station US and DS of all major tributaries

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 that is available through the review process and is longer than the period of the gauged record. JBA Consulting also has access to WINFAP v4, which allows for the incorporation of historical data within flood estimation. The primary gauging stations to be used are: the River Don at Haughton, with records dating from 1969; the River Don at Parkhill, with records dating from 1969; and the River Urie at Pitcaple, with records dating from 1984.

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 Consulting has an in-house tool for merging observed hydrographs). A similar approach is currently being undertaken in the Scottish Borders and this work has been reviewed and accepted by SEPA.

Within the hydraulic model, the fluvial inflow locations will be hydrographs derived from the observed data. Peak flow values at tributaries will be derived as follows.

- The growth curve for the main watercourse at the nearest gauging station (or at the downstream point of the model extent if the catchment is ungauged) 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 the client and SEPA.

A number of river and rain gauges are located within the catchment of the River Don to the Parkhill gauge. These are illustrated in Figure 3-1 and Figure 3-2, respectively.

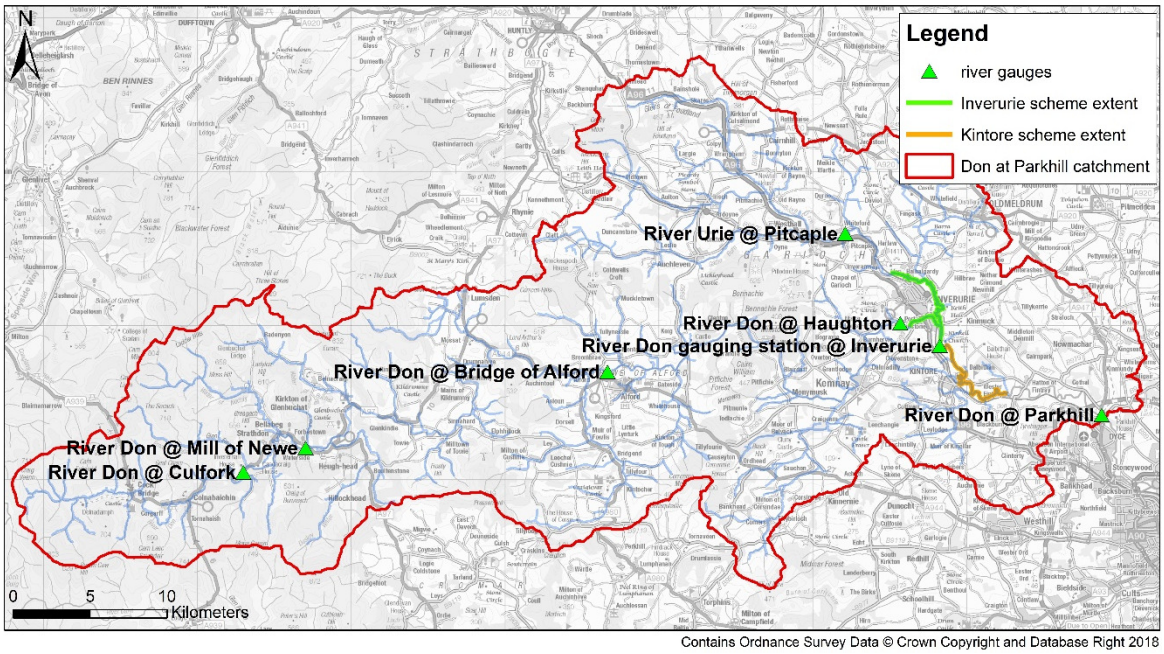


Figure 3-1: Locations of river gauges within the Don catchment to the Parkhill gauge

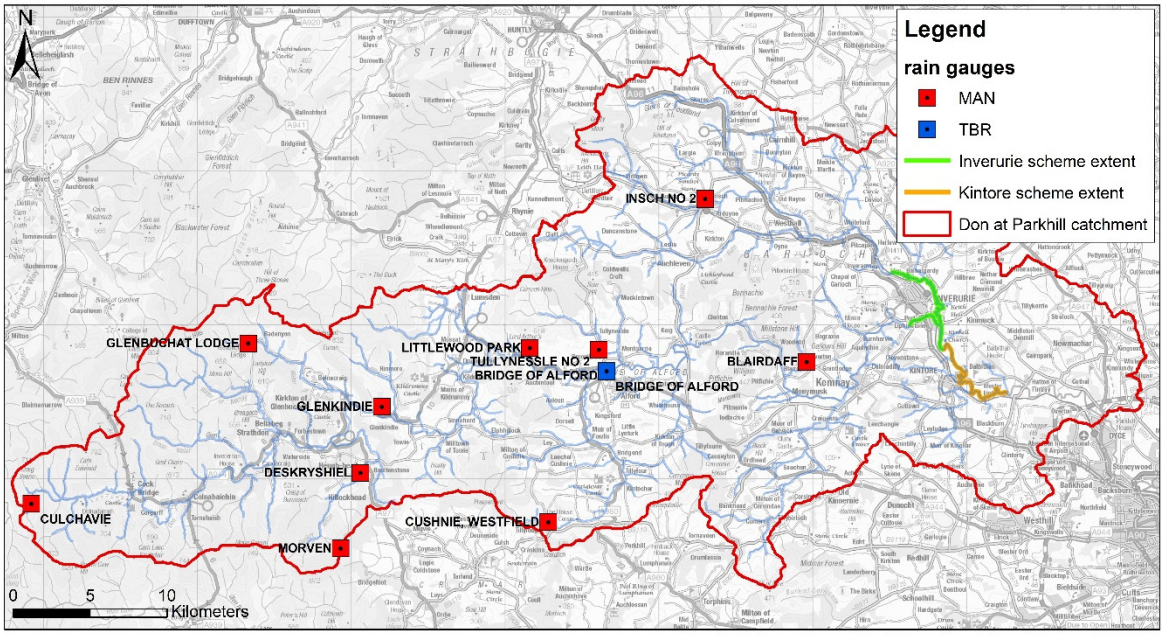


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Figure 3-2: Locations of manual (MAN) and tipping bucket (TBR) rain gauges within the Don catchment to the Parkhill gauge

4 Model summaries

4.1 River Don

The River Don was modelled by Halcrow Limited in 2003, using an ISIS Version 2.2 model. The model starts at Haughton Farm, continuing to the urban areas of Inverurie and downstream of Kintore with a total of 39 cross sections. Three bridges were included in the model.

4.2 Tuach Burn

The Tuach Burn, in Kintore, was modelled by EnviroCentre in 2003 using a hydrodynamic InfoWorks RS model. The model has 27 cross sections and extends from the upstream boundary in the field behind Kingsfield Road to the confluence point with the River Don. The Kingsfield Road Bridge and the Railway Bridge downstream are included in the model.

4.3 River Urie

The River Urie was modelled by Halcrow Limited in 2003, using an ISIS Version 2.2 model. The model starts where it meanders through a valley in the north east of Inverurie down to its confluence with the River Don. There were 40 cross sections used in the model and 3 bridges were included.

The River Urie was also modelled by JBA Consulting in 2010 using a HEC-RAS model, which had a reach length of 5143.2 m with average distance between cross sections of 184 m. No accounts were made for changes in floodplain storage or any potential changes in the channel geometry since 2003. The Souterford Bridge and the Keithhall Bridge were included in the hydraulic model.

An updated version of the 2010 HEC-RAS model, was developed by JBA Consulting in 2015, using an up to date AMAX data set. The Souterford Bridge and the Keithhall Road Bridge were modelled as bridges with the inclusion of expansion and contraction coefficients, as well as ineffective flow areas to represent the effects of the two structures on water levels in the Urie.

4.4 Strath Burn

The Strath Burn was modelled by JBA Consulting in 2005 in a HEC-RAS model and an InfoWorks CS model. The InfoWorks model included 26 cross sections and CCTV survey information, which was included in the model for the culvert. The HEC-RAS model (Version 3.1.2) included 26 cross sections and the survey of 2 bridges and a culvert.

4.5 Surface water flows

The surface water flows were modelled in Port Elphinstone in 2003 by EnviroCentre. Manholes across the area were modelled using twenty-five model nodes and the main outfall to the River Don.

Inverurie was modelled by JBA Consulting in 2015, using JFlow to assess the overland flow pathways across the catchment.

5 Survey implications

5.1 DTM

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

Dataset	Supplier
LiDAR Data	AC
NextMap Data	AC
NFM GIS dataset	SEPA
OS background mapping (Mastermap, 10km 25K)	AC

5.2 Cross sections

The project tender required pricing of 100 cross sections for the Inverurie, Port Elphinstone and Kintore study area based on Figure 3-2 in the ITT, which displayed 89 cross sections surveyed for the previous Inverurie study. These cross sections are to be used to develop new hydraulic models. Upon further examination of the model extent, fewer cross sections may be required for survey, although there may be a change to this number when the survey is undertaken in order to capture details of key features and structures that will be important when developing the hydraulic model.

Table 5-2: Cross section information

Element	Number prices as per ITT	Number of sections with Figures 3.1; 3.2 & 3.3	JBA specification
Inverurie, Port Elphinstone & Kintore cross sections	100	89	97
Inverurie, Port Elphinstone & Kintore thresholds	420	n/a	TBC

The number of threshold surveys priced in the tender totalled 420, but the exact number required will be determined later in the project after the hydraulic modelling has been undertaken. This will allow the modelled flood extents and depths to inform the locations where threshold surveys will be of most use in understanding flood risk and potential flood mitigation measures.

5.3 CCTV

CCTV surveys may be required for the culverts on the Strath Burn and Over Burn.

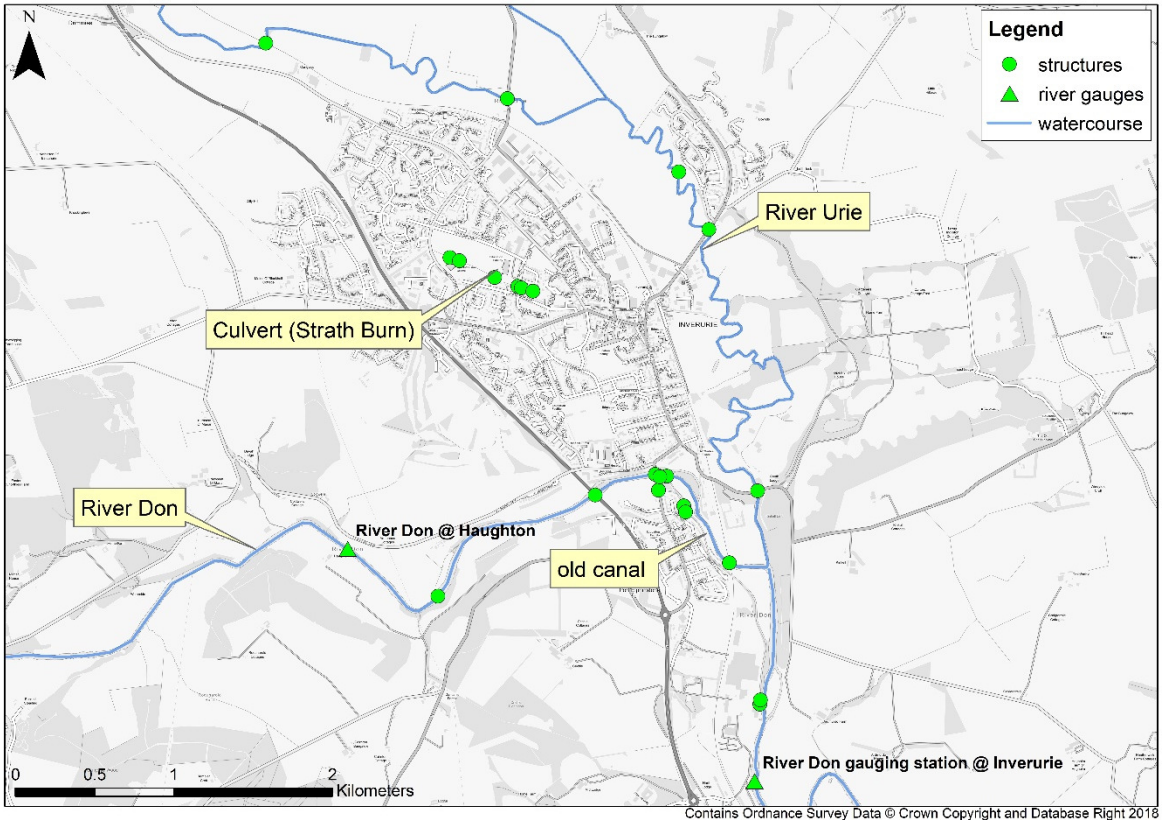

Figure 5-1: Locations of the structures in Inverurie and Port Elphinstone

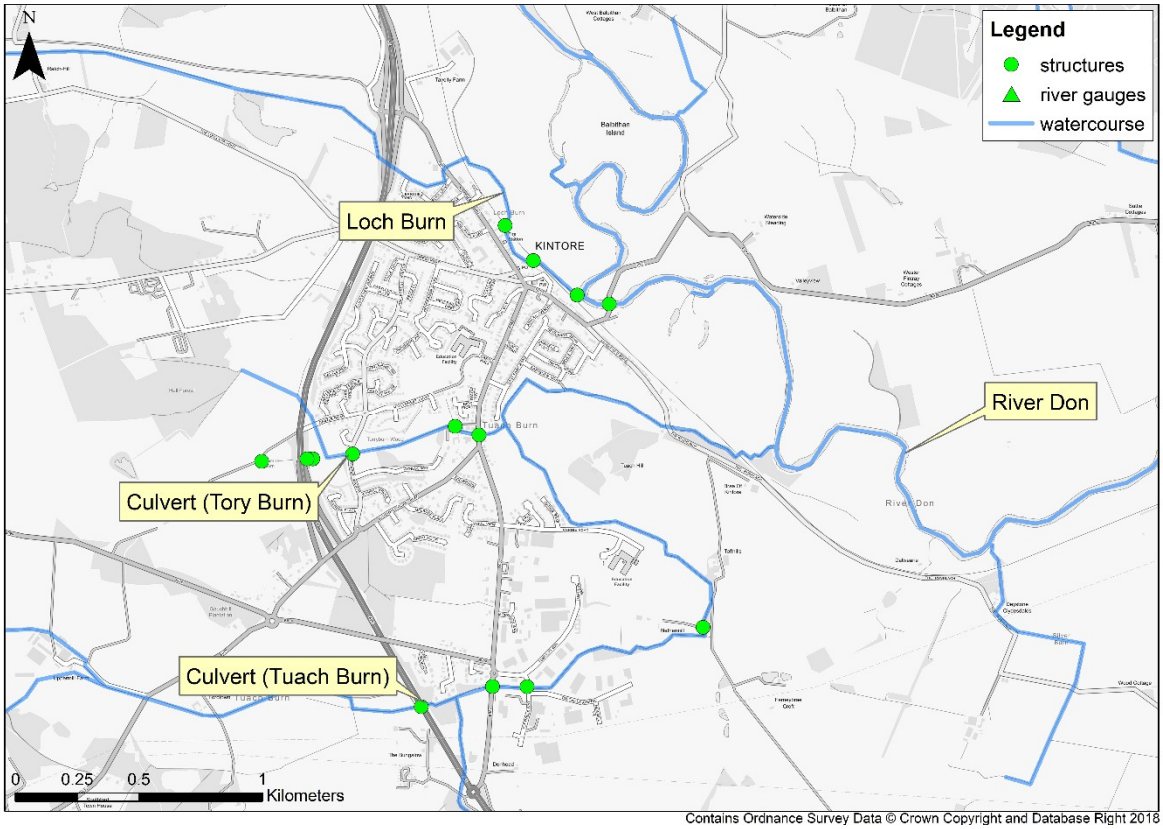

Figure 5-2: Locations of the structures in Kintore

6 Additional 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 as Priority	SEPA
Hydraulic Models	AC/SEPA
Council survey spec lines	AC

Appendices

A Historical flood photos 04/01/2016

A.1 Flooding at Inverurie, Port Elphinstone and Kintore.

View north behind canal, Port Elphinstone looking at Don @ 13:49

Behind canal view, Port Elphinstone @ 13:50

Behind canal view, Port Elphinstone @ 13:57

B993 Keithhall Road, adjacent to SW wastewater treatment works (WwTW) @ 14:06

Broom Inch bund @ 14:07

Adjacent to WwTW @ 14:07

Water flowing out of WwTW (video confirms) @ 14:09

Car stuck under Port Elphinstone Rail Bridge on B993 Keithhall Road (near WwTW) @ 14:10

Adjacent to WwTW @ 14:11

Breach of bund at Broom Inch @ 14:14

River Don at Broom Inch @ 14:15

Adjacent to Inverurie Precast, River Don upstream of Broom Inch (flood wall built by Precast to protect property) @14:15

B9001 at Lochter Burn (tributary of River Urie north of Inverurie) @ 14:30

View from B9001 @ 14:35

View from B9001 @ 14:36

B9001 Howford Bridge (north of Inverurie on the River Urie) @ 14:37

View from B9001 north of Inverurie looking south @ 14:40

Car stuck on B993 Keithhall Road under Port Elphinstone Rail Bridge @15:14

Basement of property on Canal View @ 15:30

Basement of property on Canal View @ 15:30

Rear of property on Canal View @ 15:35

Entrance to Canal View @ 15:49

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