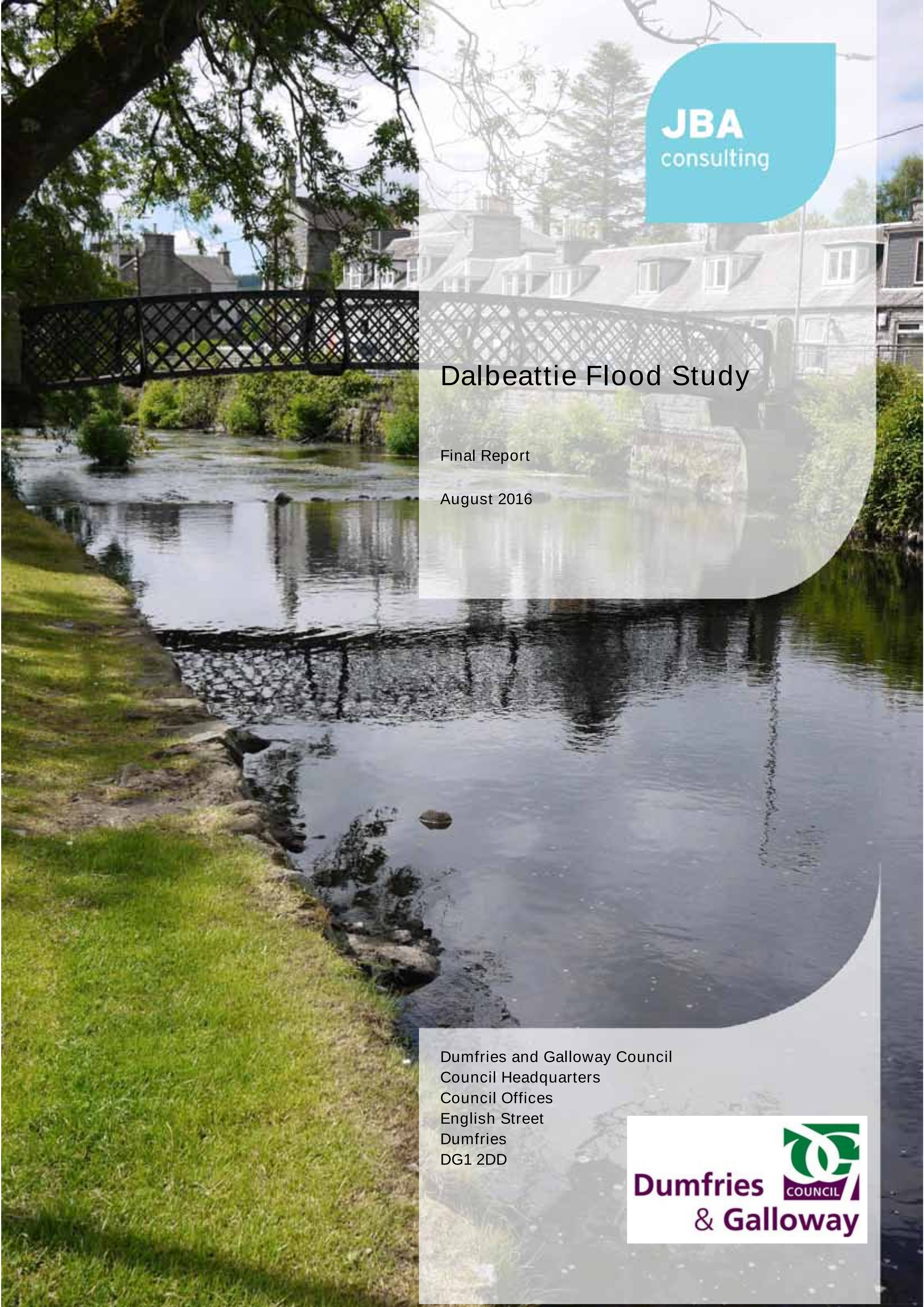

Dalbeattie Flood Study

Final Report

August 2016

Dumfries and Galloway Council
Council Headquarters
Council Offices
English Street
Dumfries
DG1 2DD

JBA Project Manager

Angus Pettit BSc MSc CEnv CSci MCIWEM C.WEM
Unit 2.1, Quantum Court
Research Avenue South
Heriot Watt Research Park
Riccarton
Edinburgh
EH14 4AP

Revision History

Revision Ref / Date Issued	Amendments	Issued to
V1.0 / 29 January 2016	-	Brian Templeton
V2.0/ 5 August 2016	Updates to text following comments from Council. Plans updated and enlarged.	Brian Templeton Ross Gibson

Contract

This report describes work commissioned by James McLeod, on behalf of Dumfries and Galloway Council, by a letter dated 10 June 2015. Dumfries and Galloway's representative for the contract was James Mcleod of Dumfries and Galloway Council. David Cameron, Robert Hooper, Jonathan Garrett, Barney Bedford and Angus Pettit of JBA Consulting carried out this work.

Prepared by .... David Cameron BSc PhD MCIWEM CWEM CSci

Senior Chartered Analyst

Prepared by .... Angus Pettit BSc MSc CEnv MCIWEM C.WEM CSci

Principal Analyst

Reviewed by .... David Bassett BSc MSc CEnv MCIWEM C.WEM

Director

Purpose

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JBA Consulting has no liability regarding the use of this report except to Dumfries and Galloway Council.

Acknowledgements

JBA wishes to thank SEPA for providing hydrometric information.

JBA would like to thank Brian Templeton for providing assistance and information to support the project.

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Executive Summary

Reason for works

In response to Dalbeattie's long flood history the Dalbeattie and District Flood Prevention Scheme was implemented in the early 1981. This included flood defences in Dalbeattie and Kirkgunzeon which had the primary aim of mitigating river flooding of these towns from the Dalbeattie Burn, Kirkgunzeon Lane and Drumjohn Burn.

Analysis of flood incidents in Dalbeattie, annual maximum flows and rainfall data suggests that whilst Dalbeattie has witnessed a number of flood issues in the recent past, none of these have been as a result of direct overtopping of the defences.

The flood defence assets are generally in a good condition, but are in need of some basic maintenance and inspection.

An assessment to review the condition and standard of defences and to update previous studies was commissioned by Dumfries and Galloway Council.

Hydrology

Flood flow estimates for design purposes have been undertaken using standard FEH methodologies. A range of design flows have been provided using the preferred FEH Statistical Method.

Whilst the flow estimates are carried out using standard methodologies, without any gauging of the watercourses the design flow estimates should be treated with caution. Tests have been undertaken on the BFI value used. An adjustment of this parameter is not deemed necessary but could increase flood flows significantly. The impact of this on flood mapping is discussed within the main report.

Any flood defence improvements or significant capital spent would benefit from some flow gauging over a period of time to improve the flow estimates.

Risk

The flood defences have a good standard of protection and in many areas are providing a 200 year standard of protection. Uncertainty in the hydrology for this ungauged catchment should be noted in reference to this standard of protection.

The majority of flood risk relates to the Edingham Burn. This area was not included as part of the FPS and is at risk from floods in excess of the 5 year flood (i.e. at risk at the 10 year flood). Many properties in this Edingham Burn area are have floor levels that are raised above ground levels reducing the impact of the flooding to properties.

Freeboard on many flood defences is suitable. However for assets at Colliston Park (Asset 7) and at the bowling green (Asset 17) the level of freeboard is insufficient at the 200 year standard of protection and would be impacted under current climate change scenarios. Asset 7 is also in poor condition and would benefit from being raised and improved.

Approximately 16 properties are at risk from the 200 year return period flood with 51 at risk when climate change estimates are taken into account.

Flood mitigation options

Overall the FPS assets are in good to fair condition but could benefit from minor upgrades, more regular inspection and maintenance of some elements. However, there are a number of short term or small scale measures that could benefit the town of Dalbeattie from future flooding. These are summarised in the main report.

A full long list and short list of options has been considered. The following options have been considered further in the option and economic appraisal:

- Do Minimum
- Option 1 - Property Level Protection
- Option 2 - 200 year SOP for Edingham Burn
- Option 3 - 200 year SOP with an allowance for climate change for Edingham Burn and the rest of Dalbeattie.

Flood risk to the Kirkgunzeon village is minimal as the flood defences present offer a good standard of protection.

Expected benefits

Flood damages for the Do Minimum and Do Something options have been assessed using standard FHRC Multi-Coloured Manual approaches. Flood damages avoided for each option are given below:

- Option 1 (PLP) - £1,112k
- Option 2 (Defence to 200 yr standard on Edingham Burn) - £1,112k
- Option 3 (Defence to Dalbeattie and Edingham Burn with climate change included) - £1,335

Investment appraisal

A summary of the flood damage results for the proposed options are provided in the Table below along with the calculated costs for each option. All options assessed are economically viable with benefit-cost ratios greater than 2 for all options.

Summary of benefit-cost calculation (£k)

	Do Minimum	Option 1	Option 2	Do Minimum with climate change	Option 3
Total PV costs (£k)	-	179	331	-	424
Total PV costs + Optimism bias (£k)	-	286	530	-	678
PV damage (£k)	1,322	210	210	1,609	274
PV damage avoided (£k)	-	1,112	1,112	-	1,335
Benefit-cost ratio	-	3.5	2.1	-	2.0
Incremental BCR	-	-	0.5	-	1.5

Recommendations

A number of short term quick wins and longer term flood mitigation measures have been recommended. The PLP option has the highest benefit-cost ratio although the two structural options are both cost effective with BCRs greater than 2.

Option 1 is therefore preferred but all of the options assessed could be developed in the longer term. The use of Option 1 as a short term method, perhaps progressed using the Council's subsidy scheme would be beneficial.

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Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
ALTBAR	Mean catchment altitude (m above sea level)
AMAX	Annual Maximum
BFI	Base Flow Index
BFIHOST	Base Flow Index estimated from soil type
C1	Benchmarking system using GPS
CAR	Controlled Activity Regulations (2010)
CCTV	Closed Circuit Television
DPLBAR	Index describing catchment size and drainage path configuration
DS	Downstream
DTM	Digital Terrain Model
EN	English Nature
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FPEXT	FEH index describing floodplain extent
FPS	Flood Protection Scheme
FRA	Flood Risk Assessment
GIS	Geographical Information System
HEC-RAS	Hydrologic Engineering Center – River Analysis System
ISIS	Hydrology and hydraulic modelling software
LiDAR	Light Detection And Ranging
mAOD	metres Above Ordnance Datum
NGR	National Grid Reference
OS	Ordnance Survey
OS NGR	Ordnance Survey National Grid Reference
PVc	Present Value Cost
QMED	Median Annual Flood (with return period 2 years)
SAAR	Standard Average Annual Rainfall (mm)
SEPA	Scottish Environment Protection Agency
SFRA	Strategic Flood Risk Assessment
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff estimated from soil type
Tp	Time to Peak

TUFLOW	Two-dimensional Unsteady FLOW (a hydraulic model)
URBEXT	FEH index of fractional urban extent
US	Upstream

1 Introduction and site description

1.1 Background

This flood study was commissioned by Dumfries and Galloway Council in October 2014 in order to gain a greater understanding of the flood mechanisms and improve upon SEPA's Flood Risk Management maps in Dalbeattie and provide an appraisal of options to reduce flood risk.

The council commissioned a Strategic Flood Risk Assessment (SFRA) for Dumfries and Galloway in 2007. This study ranked Dalbeattie 5th in a list of priority areas for further investigation into flood risk based on the number of properties potentially at risk of flooding. The assessment was based on 5 categories; economics, social, environmental, planning and frequency of flood risk for all towns within the council area.

In 2015, as part of the Flood Risk Management (Scotland) Act 2009, SEPA has completed a review of flood risk in the Dalbeattie area as part of the Solway Local Plan District. Within this it identified the Potentially Vulnerable Area (PVA) (reference 14/19). Based on SEPA's Flood Risk Management Strategy and current SEPA mapping, Dalbeattie has 220 residential properties and 60 non-residential properties at risk and an estimated £600,000 of Annual Average Damages (AAD).

In response to ongoing and proactive flood management for Dalbeattie and the proposals associated with the FRMS, this flood study was commissioned to improve on past flood mapping and to re-appraise the flood defence scheme.

1.2 Report objectives and approach

The aim of the study will enable Dumfries and Galloway Council to make an informed decision with regard to the current and future level of flood risk from the Dalbeattie Burn and the Kirkgunzeon Lane in Dalbeattie and Kirkgunzeon. The study will produce flood maps for different return periods, outline flood mitigation options and assess the economic viability of the preferred flood mitigation option.

Hydraulic analysis and inundation mapping has been carried out both with and without hydraulic structures for the following return periods (Annual Probability (AP)):

- 1:2 (50% AP)
- 1:10 (10% AP)
- 1:25 (4% AP)
- 1:50 (2% AP)
- 1:100 (1% AP)
- 1:200 (0.5% AP)
- 1:200 + Climate Change (0.5% AP considering climate change)
- 1:1000 (0.1% AP)

Outline designs have been proposed to achieve a:

a. 0.5% AP with an allowance for climate change level of protection
b. Quick wins to immediately mitigate river flood risk.

1.3 Extent of study area and description

There are three main areas of interest as part of the original FPS and as part of this study:

- Dalbeattie town
- Kirkgunzeon
- Culvert to the north of Dalbeattie on Edingham Burn

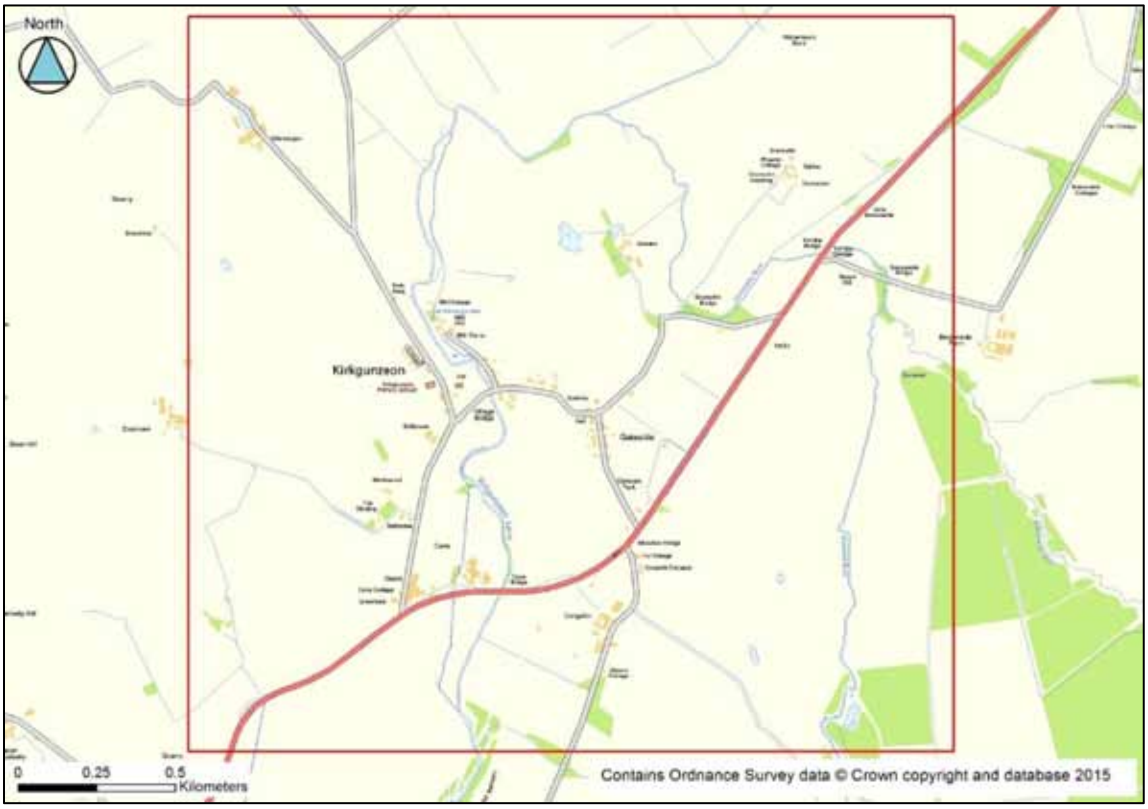
Dalbeattie is located approximately 20km SW of Dumfries and the neighbouring village of Kirkgunzeon sits 14km SW of Dumfries. The Dalbeattie Burn runs through the centre of Dalbeattie. Figure 1-1 shows the two main areas of interest in Dalbeattie and on the Edingham Burn.

Figure 1-1: Dalbeattie (1) and Edingham Burn (2) study areas

Kirkgunzeon lies to the east and west of the Kirkgunzeon Lane watercourse and the Drumjohn Burn runs to the northeast. Figure 1-2 shows the main areas of interest in Kirkgunzeon.

The study area for flood mapping extends along both banks of the Kirkgunzeon Lane watercourse. In addition, the Edingham Burn is included in the analysis to cover the urban reach of this watercourse within Dalbeattie.

Figure 1-2: Kirkgunzeon study area (3) including Drumjohn Burn



1.4 Catchment description

The watercourse most relevant to the Dalbeattie FPS is the Kirgunzeon Lane (also known as the Dalbeattie Burn). The Kirgunzeon Lane flows in an approximately southerly direction and has a catchment area of 96 km^2 at Dalbeattie. The catchment land use is typically grazing with some forestry. The area of the catchment at Dalbeattie is underlain by sedimentary bedrock (wacke) with superficial deposits of alluvium and till[1].

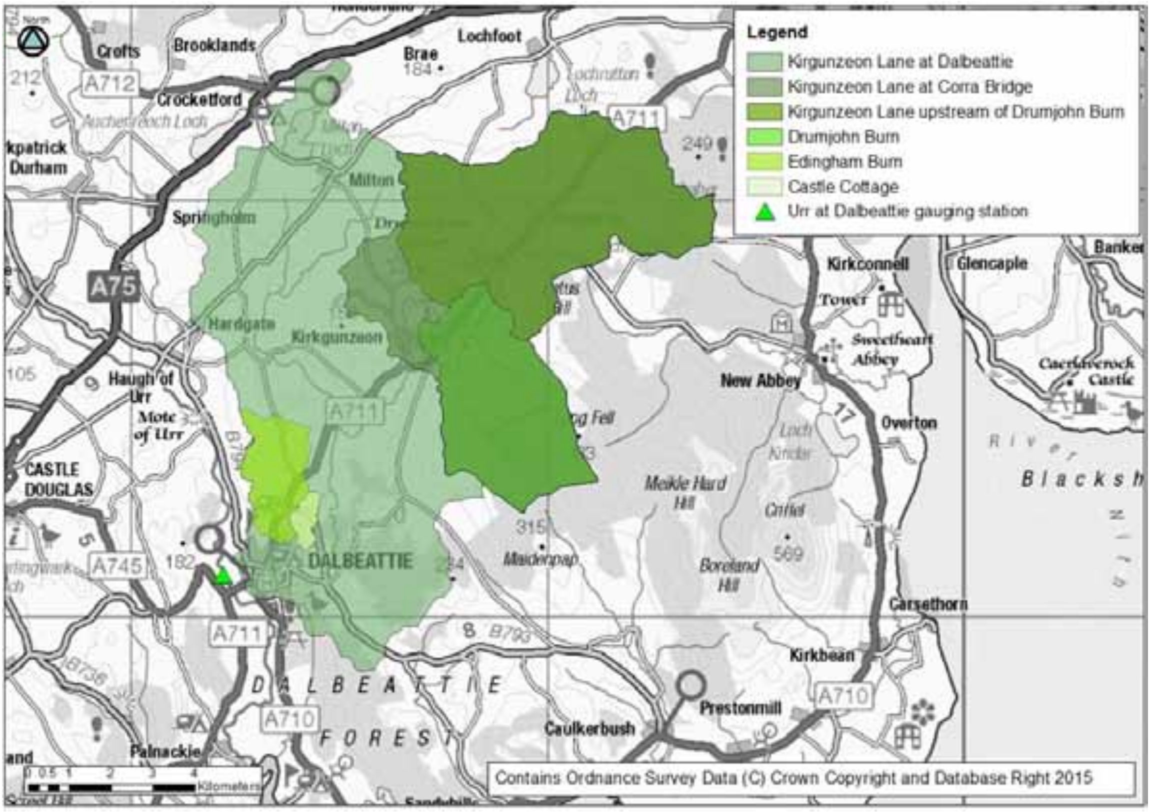
The Kirgunzeon Lane ultimately flows into the Urr Water immediately downstream of Dalbeattie and discharges into the Solway Firth about 10 km downstream. The lower reach of the Kirgunzeon Lane at Dalbeattie is within the tidal limit. Several subcatchments of the Kirgunzeon Lane are also of relevance for this flood protection study. These include: the Drumjohn Burn upstream of the confluence with the Kirkgunzeon Lane and the Edingham Burn and the tributary of the Edingham Burn at Castle Cottage.

All of these watercourses are ungauged. The nearest SEPA gauging station (number 80001) is located on the Urr Water catchment (Figure 1-3), less than 1 km west of Dalbeattie. This gauging station has been in operation since 1963 and is included within the HiFlows-UK dataset and is listed as being suitable for both QMED estimation and inclusion in pooling groups[2] and was used in much of the flood estimation approach described in subsequent sections.

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

[2] http://nrfa.ceh.ac.uk/data/station/peakflow/79004

Figure 1-3: Kirkgunzeon Lane catchment



1.5 Return Period and Probability

For flood frequency analysis, the probability of an event occurring is expressed as a return period. The return period on the annual maximum scale, T, is defined as the average interval between years containing one or more floods exceeding a flow Q(T). In the Flood Estimation Handbook (FEH), the flood with return period T is referred to as the T-year flood.

A useful term closely linked to return period is the annual probability, AP, which is the probability of a flood greater than Q(T) occurring in any year. This is simply the inverse of T:

$$AP = 1/T$$

For example, there is a 1 in 100 chance of a flood exceeding the 100-year flood in any one year. A full list of typical return periods and APs used for flood management is shown in the table below.

Table 1-1: Return period and equivalent annual probability

Return Period	Annual Probability [AP] (%)
2 year	50
5 year	20
10 year	10
25 year	4
30 year	3.33
50 year	2
75 year	1.33
100 year	1
200 year	0.5
500 year	0.2
1000 year	0.1

It is very important to realise that a flood with a return period of T years has a finite probability of occurring during any period of duration less than T years. The probability p that a T year flood will occur at least once in an N year period is given by the “risk equation”:

$$P = 1 - (1 - 1/T)^N$$

This equation indicates that over a ten year period (such as the 10 years since the last flood), the probability of a 100 year flood occurring is 10%. This increases to 34% for a 25 year flood occurring in a 10 year period.

2 Existing flood defence measures

2.1 Background

In 1981 a Flood Protection Scheme (FPS) was installed in Dalbeattie and Kirkgunzeon which had the primary aim of mitigating river flooding of these towns from the Dalbeattie Burn, Kirkgunzeon Lane and Drumjohn Burn.

The scheme was split into three areas which comprised the following:

- Drumjohn Burn upstream of Drumjohn Bridge: aiming to alleviate flooding on the A711 and in the caravan park at Mossfoot Bridge.
- Kirkgunzeon Lane at Corra Bridge: aiming to protect property and the road at Corra from the Kirkgunzeon Lane.
- Dalbeattie area: aiming to protect the town of Dalbeattie.
    - o There was also a small culvert added or improved in the old railway embankment to the north of Dalbeattie on Edingham Burn.

A figure of the assets constructed in the scheme are compiled in Figure 2-1 and Figure 2-2 (also provided as an A3 plan in the Figures Section). An asset condition summary report is provided in Appendix B.

Figure 2-1: Asset locations and asset reference number in Dalbeattie

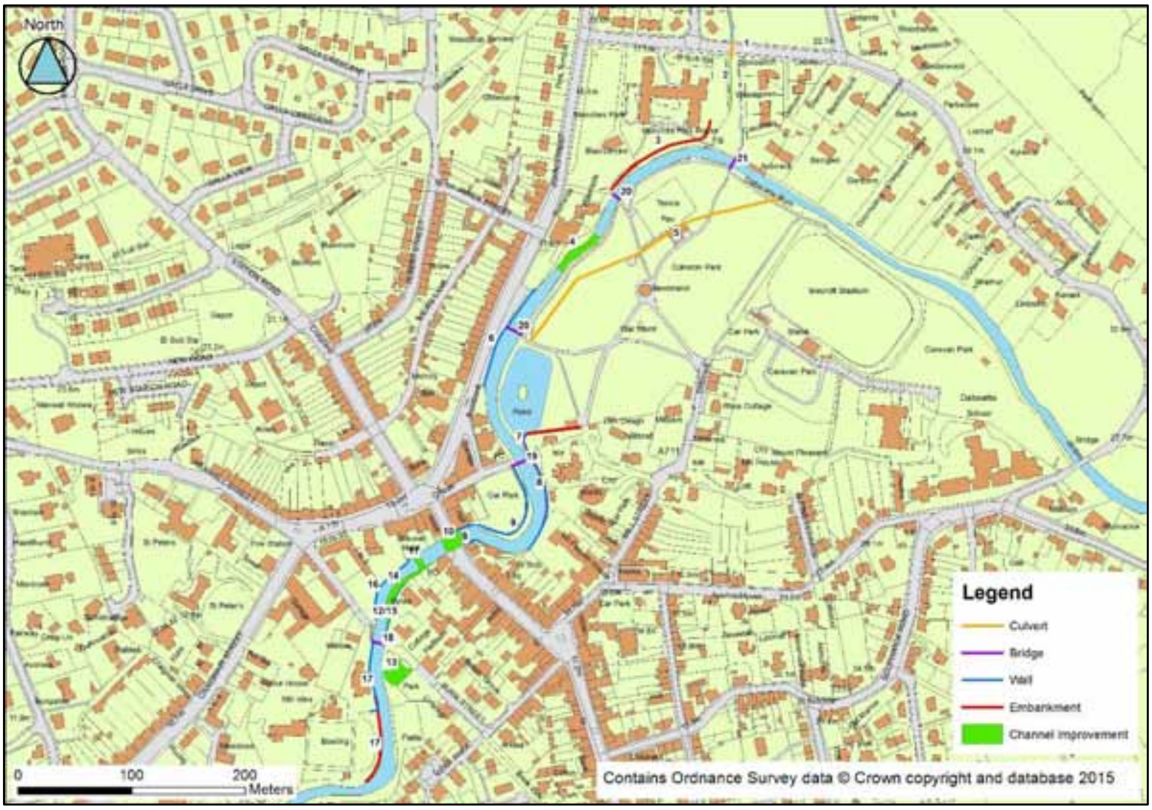
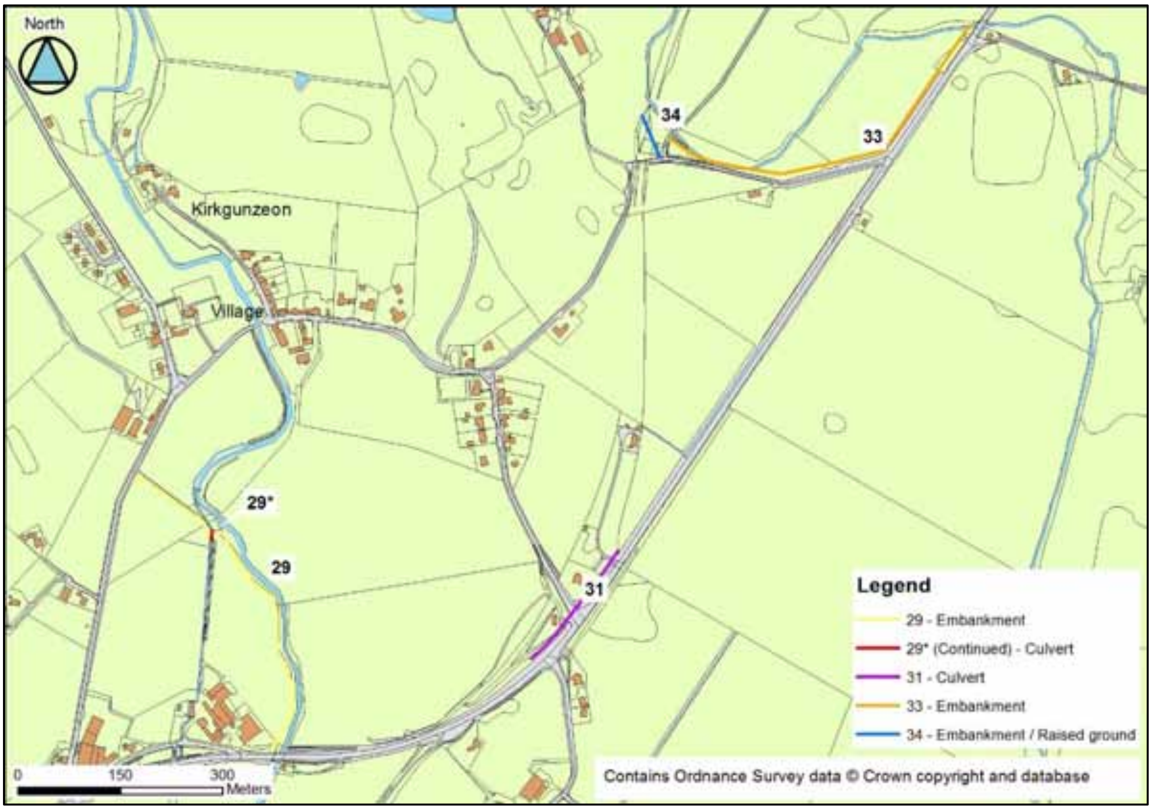


Figure 2-2: Asset locations and asset reference number in Kirkgunzeon



2.2 Current condition

Dumfries and Galloway Council's requested JBA to carry out a condition assessment of the existing flood defences which form the 1981 FPS in terms of structural condition, overall effectiveness and suggested improvements. This condition assessment included inspection of the culverts which form part of the FPS.

Angus Pettit (Principal Flood Analyst) of JBA Consulting carried out the assessment of FPS infrastructure during walk overs on the 22 June 2015 and 20 October 2015 based on visual observations. No testing of the infrastructure took place.

A detailed condition assessment of the defences is provided in Appendix B. The condition assessment included flood defence structures as part of the FPS as well as other walls, which although not part of the FPS, may influence flood flows.

2.2.1 Current standard of defences

The current condition grade of each flood defence asset was determined using the Environment Agency Condition Assessment Manual. Results for each asset are provided in Table 2-1. The condition of the assets is generally good to fair (average Grade 2-3), with one graded 4 (poor). Further structural inspection and maintenance of these assets is recommended to ensure that they are fit for purpose.

Table 2-1: Asset condition summary

Study Area	Asset numbers	Condition grade	Poor condition assets
Dalbeattie area	1-27	80% Grade 2 15% Grade 3	Asset No. 7 (Embankment) - Grade 4 (Poor)
Edingham Burn	1	100% Grade 2	-
Kirkgunzeon	29-34	100% Grade 3	-

2.3 Recommendations

The flood defence assets are generally in a good condition, but are in need of some basic maintenance and inspection. A full list of quick wins is proposed in Section 9.5. Some reach wide maintenance measures and recommendations are made below:

- There are many unflapped outfalls present along the Dalbeattie Burn. These should be checked for presence and condition, any missing should be installed and an inspection and maintenance regime set up to ensure the long term maintenance of these outfllalls.
- The presence of Water Hemlock-dropwort is prevalent in some reaches of the Kirkgunzeon Lane in Dalbeattie and the Edingham Burn. Management or monitoring of this recommended to ensure good channel conveyance is maintained.
- Some channel reaches are overgrown and in need of maintenance. Some reaches were removed of vegetation as part of the FPS works.
- Some culverts are blocked with sediment. This should be removed.

3 Current condition of culverts

The culverts were inspected internally via a CCTV survey carried out by Underground Inspection Services 7 September 2015. A full survey report has been supplied to Dumfries and Galloway Council, with a summary of the condition of the culverts below. Table 3-1 provides a summary of the inspections undertaken. Figures 3-1 to 3-2 show the location of the culverts (also provided as an A3 plan in the Figures section of the report).

Table 3-1: CCTV culvert inspection data

Category	Comments
Date of inspection(s)	CCTV Survey - 07 September 2015
Inspector(s)	Underground Inspection Services
Nature of culverts	CCTV footage was taken along 8 distinct culverts. Full details are provided in the CCTV report and in the summary below.
Location of culverts	The culverts are listed in the table below and shown in Figure 3-2 and Figure 3-3.
Nature of inspection(s)	The inspections were walkover surveys and visual inspection of the culvert inlets and outlets. A full CCTV survey was undertaken by UIS. No jetting or directional drilling was undertaken to clear debris or blockages.
Comments from Residents	No comments were received from residents regarding any of the culverts.
Associated reports	UIS CCTV Survey Report (J36714), 17-09-2015

Culvert ref.	Location	Survey complete?
1	Dalbeattie - west bank	Yes
2	Dalbeattie - Barhill Road	Yes
3	Dalbeattie - Dalbeattie High School	Yes
4	Dalbeattie - west bank	Yes
5	Dalbeattie - east bank	Partial - restricted access
6	Dalbeattie - east bank	Partial - abandoned due to debris
7	Kirkgunzeon - A711	Yes
8	Dalbeattie - east bank	No. Poor access. Unable to find culvert.
9	Dalbeattie - Colliston Park	Pipe surcharged at upstream end.
10	Edingham Burn - Old railway culvert	No - 60% blocked with sediment

Figure 3-1: Culvert locations and survey for culverts 1-6, 8, 9

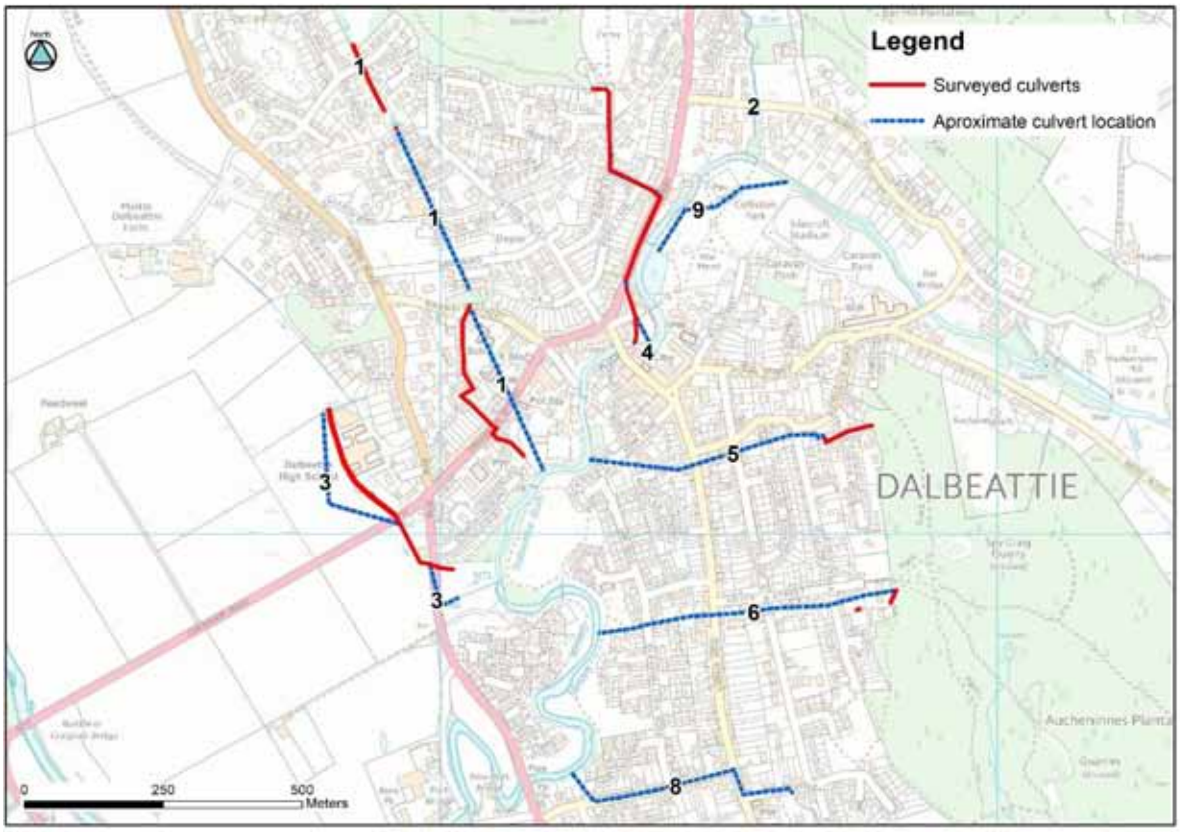


Figure 3-2: Culvert location and survey for culvert 7

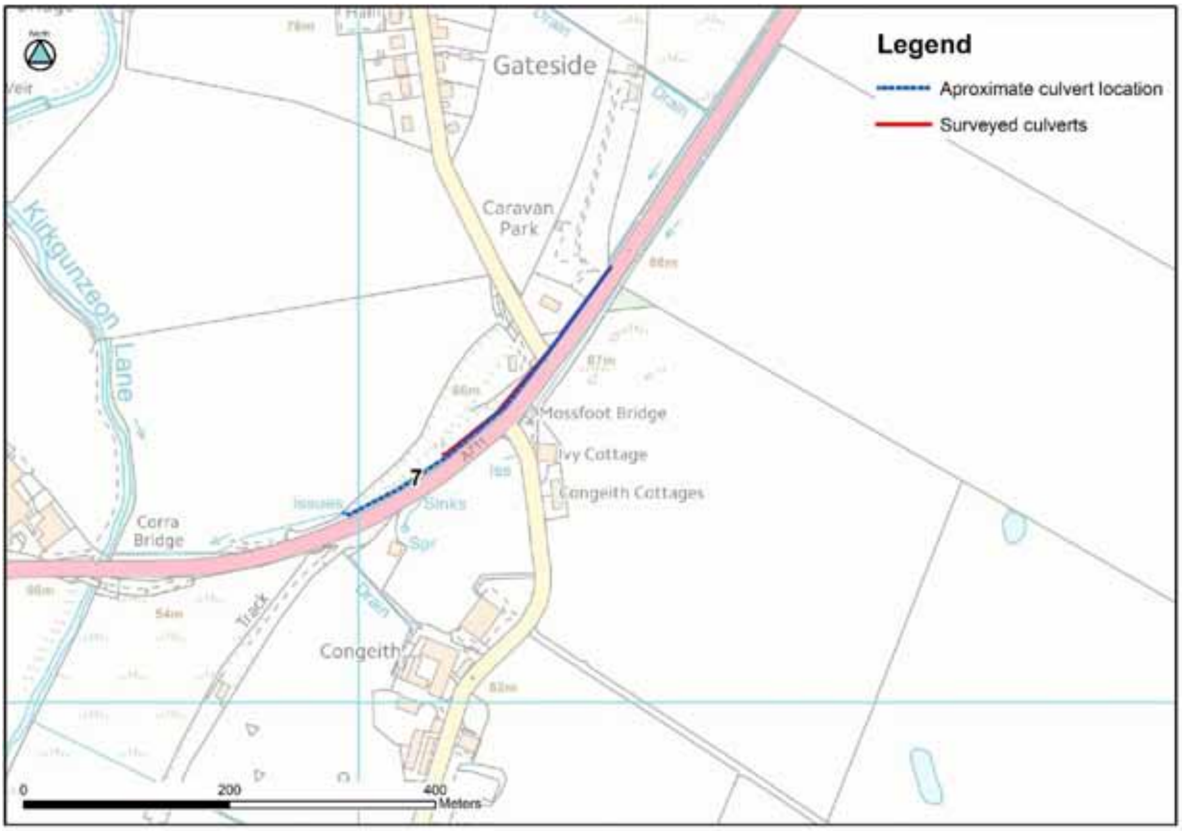
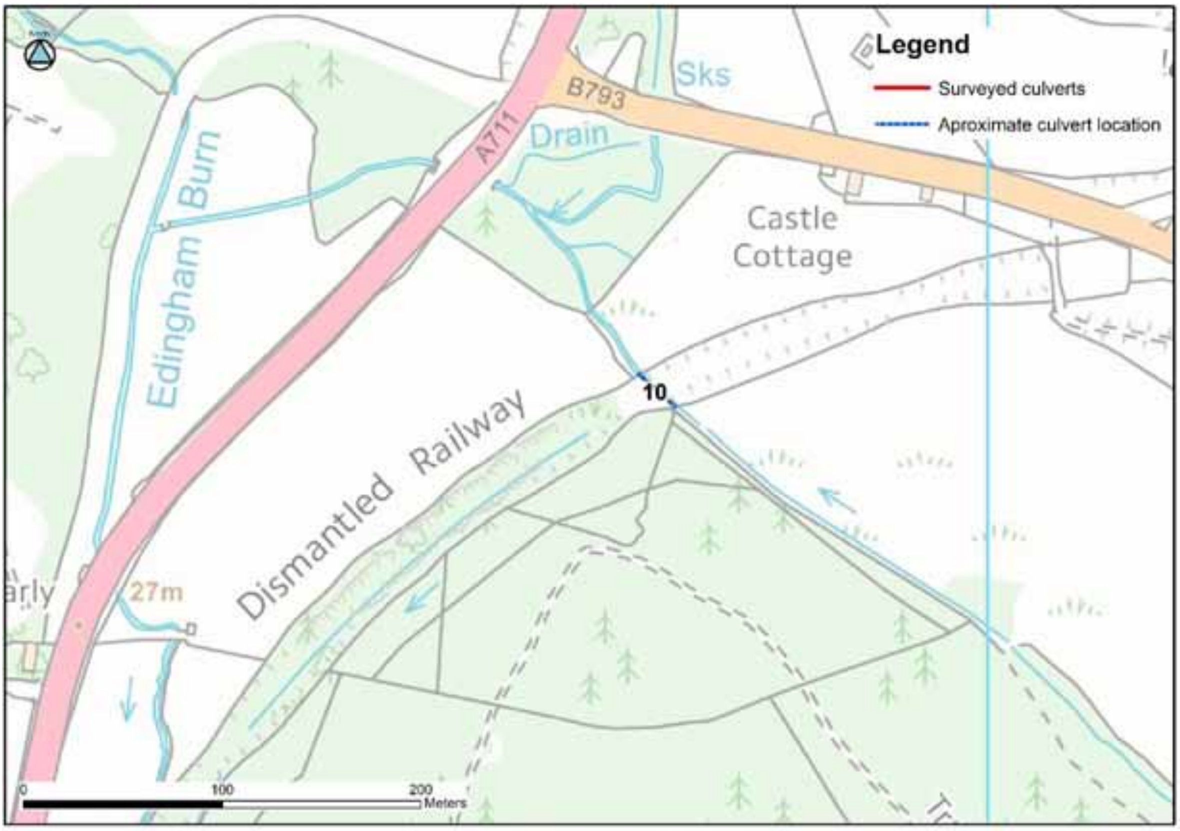


Figure 3-3: Culvert location and survey for culvert 10



3.1 Impact of condition on fluvial flood risk

Culverts play an important role in conveying surface water from street level to the nearest suitable watercourse. When the culverts become choked with debris, such as culvert 1 and 3, they can no longer carry out their intended purpose. Likewise where flap valves (installed on the culvert outlets to prevent flood flows in the channel flowing back up the culvert and surge charging at street level) are seized in an open position they no longer perform their function. The culvert outlet inverts are positioned close to normal water elevations in the channel. By maintaining correctly operating flap valves it will also help to keep the culvert free of debris that may get washed into the culvert during higher than normal flows.

3.2 Recommendations

It is clear from the CCTV footage that the culverts are in need of regular maintenance. Major blockages should be removed as a priority. Where culverts are damaged or cracked regular inspections should be carried out to monitor crack progression and ingress of material from the breaks. If it is deemed necessary the damaged culverts should be repaired or replaced. Pipe slip-lining or pipe "bursting" techniques could be considered.

Some of the outlets have flap valves. Some of these were not found during the survey. A full review of all flap valves is required to locate missing outfalls, check the condition and presence of flap valves and the repair and maintenance schedule implemented to ensure that where appropriate high water levels are not transmitted through the flood protection.

Culvert recommendation summary:

- Remove blockages
- Monitor pipe condition
- Repair, fit or replace flap valves
- Establish regular inspection and cleaning maintenance schedule

4 Flood History

4.1 Introduction

In response to Dalbeattie's long flood history the Dalbeattie and District Flood Prevention Scheme was implemented in the early 1980's which protected property in the vicinity of Drumjohn Bridge, Corra and the some of the area of Dalbeattie by the Dalbeattie Burn. A flood record supplied by Dumfries and Galloway Council as well as an internet search shows that Dalbeattie is also effected by surface water runoff and ground water and is summarised below.

4.2 Historic flooding

Table 4-1: Historic flood events/evidence

Comment	Scale of flood	Year of flood	Source
Comparable to the 1815 flood.	Regional	February 1780	The Times (London, England),Thursday, Oct 05, 1815; pg. 4; Issue 9644
Extensive flood but on a lesser scale to the 1815 flood.	Regional	15-16 November 1807	The Times (London, England),Thursday, Oct 05, 1815; pg. 4; Issue 9644
Three days of torrential rain and high winds caused flooding across Dumfries. The area between the River Nith to New Abbey to New Galloway was the worst affected. The River Nith was said to be out of bank for 20 miles along its length. At New Abbey a bridge which had "stood the buffetings of winter storms for centuries" was washed away. A newly constructed bridge in New Galloway was also washed away as well as several bridges in Moffat area.	Regional	September 1815	The Times (London, England),Thursday, Oct 05, 1815; pg. 4; Issue 9644
At Dalbeattie the excessive rainfall resulted in considerable flooding.	Dalbeattie	3 March 1910	Scotsman Publications
Good deal of flooding in Dalbeattie. Along the valley of the Urr and in other districts a considerable quantity of land lies under water.	Catchment	19 December 1911	Scotsman Publications
All the meadows between Dalbeattie and Southwick through which the Kirkgunzeon Lane runs were in flood on Saturday afternoon.	Catchment	8 February 1915	The Scotsman
Dalbeattie experienced a very severe flood. It damaged people's property and caused a lot of inconvenience.	Dalbeattie	31 October 1977	BBC History
Flooding reported in Dalbeattie	Dalbeattie	10 October 2000	The Mirror
Houses flooded in Dalbeattie -	Dalbeattie /	11 October 2008	The Times

River Nith burst its banks for second times in 3 days. A75, A711 and A714 road closures.	regional		
Two inched of rain fell in 12 hours, Kirgunzeon Lane burst its banks. Roads washed away, Carsphairn flooded, village shops and cottages. A713 in Carsphairn, A762 closed at Dalry and A712 closed at ken Bridge. Colliston Park in Dalbeattie inundated. Fire brigade had to pump water out of a house in Galla Avenue.	Dalbeattie / regional	31 December 2013	The Daily Record
Recorded flood incidents from Dumfries and Galloway Council. Source and frequency discussed further below.	Dalbeattie	From 2002 to 2015	Dumfries and Galloway Council

4.3 Analysis of D&G flood records

A flood data archive was supplied to JBA Consulting by Dumfries and Galloway Council. The records begin in 2002 and continue to present day. 68 counts of flooding have been recorded by the council in Dalbeattie since their official recordings began in February 2002. This data was analysed by flood type. Surface water and pluvial flood events were grouped together. "Other Drainage" accounts for nearly half of the recorded events.

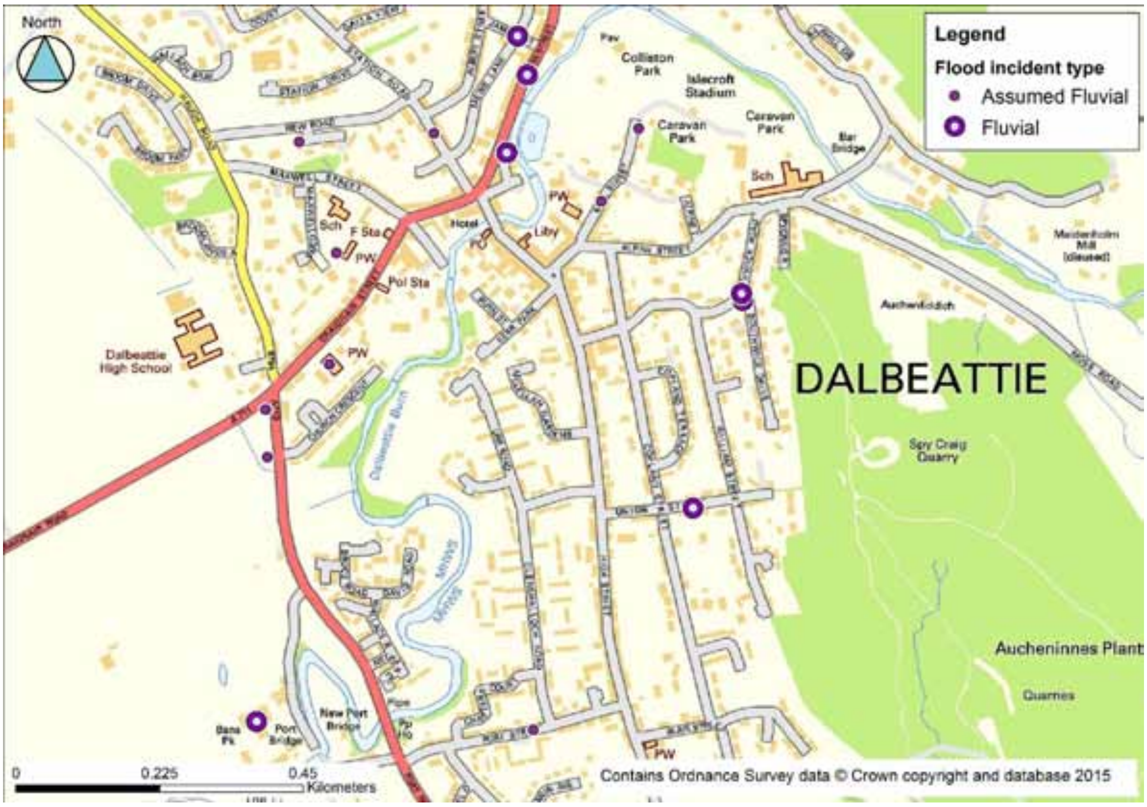
Table 4-2: Recent Dalbeattie flood records by flood source

Flood type	Number of recorded events
Fluvial	8 (+13 assumed fluvial)
Pluvial	8
Surface water	5
Groundwater	1
Sewer	2
Other Drainage or artificial structure	31

4.3.1 Fluvial flooding

There are 8 fluvial flood records. Flooding from Dalbeattie Burn has effected Burnbank Cottage' basement, John Street and ETB Technology. There are 2 recorded instances from Rounall Woods Burn which effected Southwick Road suggesting a fluvial flood risk from the hillsides that drain towards the river through the town. Figure 4-1 shows where the recorded fluvial flood incidents have occurred.

Figure 4-1: Location of 'fluvial' flood events in Dalbeattie (2002-2015)



Most of the 'Assumed Fluvial' records are not located near to the Kirkgunzeon Lane and are more likely to be related to minor culvert or surface water issues rather than flooding from the watercourse itself.

9 of the 21 counts of fluvial flooding correspond to the annual maximum flows in the Urr Water for the year of the flood - a good proxy for peak flows on the Kirkgunzeon Lane. Two of the events located along John Street correspond to peak flows on the Urr for the years 2003 and 2005. Two further records in the downstream industrial estate relate to the peak flow event of 2009.

Table 4-3: Peak flows on the

Fluvial flood event	Flow (m^3/s)	AMAX date
30/11/2003	132.4	29/11/2003
08/01/2005	93.9	08/01/2005
20/11/2009	151.8	19/11/2009

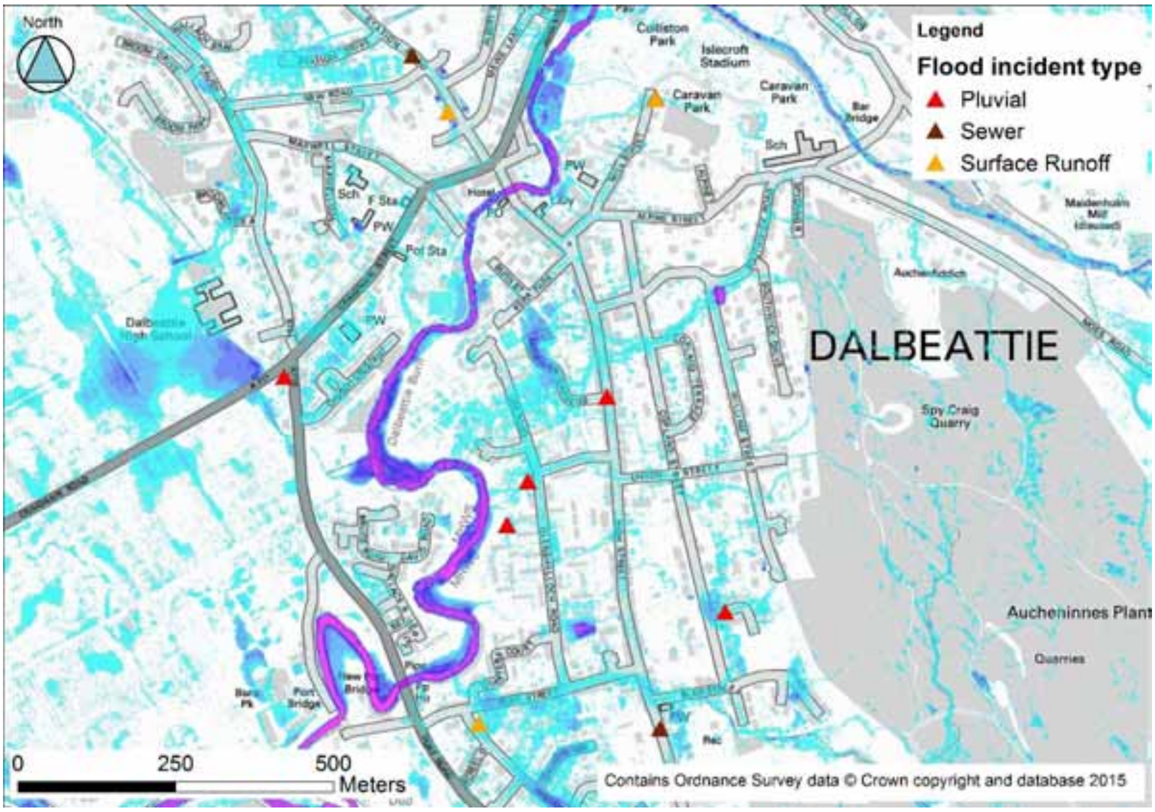
4.3.2 Surface water or Pluvial flooding

Of the 13 recorded instances of pluvial flooding, 6 occurred on either the 9 and 17 August 2004. Flood incidents have been recorded at:

- Tollbar Cottage,
- Along the A711 and High Street
- Back Knowe Crescent
- Munched View
- Boolers Cottage
- Property 4, 11 and 13 on Station Road
- Kerr Cottage
- Garden of 19 Urr Road, 2 Millbrookdown Mill, 22 Glenshalloch Road

Two further flood incidents attributed to "Sewer" (sewers noted as having been over capacity or blocked) also occurred in August 2004 suggesting that this event was significant and lead to flooding problems within the urban area of Dalbeattie. Figure 2-2 shows the location of the 13 flood incidents within Dalbeattie superimposed on the 200 year 3 hour storm event (See Section 8.1.1 for methodology).

Figure 4-2: Pluvial flood incidents



Analysis of the SEPA raingauge in Dalbeattie for the 17 August 2004 which accounts for many of the recorded pluvial events shows a very intense burst of rainfall over a 1 hour and 15 minute period. Approximately 38 mm of rain fell in this period. This high rainfall intensity event has a return period of approximately 84 years.

4.3.3 Ground water

A single incident of ground water flooding has been recorded. The incident occurred on the 7 February 2003 at 1 St James Street.

4.4 Conclusion

Analysis of flood incidents in Dalbeattie, annual maximum flows and rainfall data shows that the town of Dalbeattie has witnessed a number of flood issues in the recent past. Evidence of fluvial flooding is limited and would suggest that no direct overtopping of flood defences has occurred since 2002 (or indeed since the construction of the flood defences). Records of fluvial flooding incidents reflect possible drainage issues or seepage rather than overtopping of defences.

Many of the records suggest other non-river flood problems as a result of direct rainfall over the town, runoff from the woodland to the east of the town and general drainage and sewer capacity problems in isolated locations within the town.

Whilst this report focuses on the river defences and fluvial flood risks, an integrated approach which takes into account all sources of flooding may be beneficial to provide a comprehensive flood solution.

5 Flood Estimation

5.1 Flood frequency estimation using FEH

In order to provide a comprehensive input to the hydraulic model, flow estimates were required for the Kirgunzeon Lane at several locations (Dalbeattie, Corra Bridge, and upstream of the Drumjohn Burn confluence) together with the Drumjohn Burn, Edingham Burn and the tributary of the Edingham Burn at Castle Cottage.

Important inputs into a flood risk assessment are the analysis of historic floods (where data are available), and estimation of flood flows for a range of annual probabilities or 'design' events. Flood estimates for catchments of this size and type are undertaken using the Flood Estimation Handbook (FEH). The FEH offers three methods for analysing design flood flows: the Statistical, the Rainfall Runoff, and hybrid methods. The Statistical method combines estimation of the median annual maximum flood (QMED) at the subject site with a growth curve, derived from one of three methods; (a) a pooling group of gauged catchments that are considered hydrologically similar to the subject site, (b) through single site analysis of a nearby gauge, or (c) a combination of the two through the use of enhanced single site. The Rainfall Runoff method combines design rainfall with a unit hydrograph derived for the subject site (the Rainfall Runoff method has recently been updated as ReFH2[3]). Hybrid methods involve a combination of the two. Both the Statistical and Rainfall Runoff procedures require the derivation of catchment descriptors. For this study these were initially abstracted digitally using the FEH CD ROM v3.

Adjustments were then made to catchment area (using OS background mapping) and URBEXT (using the national growth model through the year of study, 2015, per FEH Volume 5). The FEH CD-ROM BFIHOST values appeared reasonable in comparison to the available geological information[4].

With respect to choice of approach for estimating flood flows, the catchments are largely rural with a small influence of attenuating features such as lochs. Given the availability of the Urr Water at Dalbeattie as a potential donor site from a similar nearby catchment, the Statistical method was therefore assumed to be the most reasonable approach for estimating flood flows for all of the watercourses except for the watercourse at Castle Cottage, which has a very small catchment area (0.65 km^2, (Table 5-2). The FEH Rainfall Runoff method was therefore deemed to be the most appropriate approach for this catchment. A 20% climate change allowance upon the 0.5% AP (200 year) event was applied in each case, per SEPA guidance[5]. Further details of the flow estimates are included in Appendix A.

[3] Wallingford Hydro Solutions (WHS) The Revitalised Flood Hydrograph, ReFH2: Technical Guidance. 2015

[4] http://mapapps.bgs.ac.uk/geologyofbritain/home.html

[5] SEPA – Technical Flood Risk Guidance for Stakeholders, Version 9.1, June 2015

Table 5-1: Catchment descriptors

Catchment Descriptor	Urr at Dalbeattie Gauging Station (80001)	Kirgunzeon Lane at Dalbeattie	Kirgunzeon Lane at Corra Bridge	Kirgunzeon Lane upstream of Drumjohn Burn	Drumjohn Burn	Edingham Burn	Castle Cottage
AREA (km^2)	197.07	96.01 adjusted (94.99 FEH CD-ROM)	41.09 adjusted (40.69 FEH CD-ROM)	23.76 adjusted (23.52 FEH CD-ROM)	13.02 adjusted (12.81 FEH CD-ROM)	4.41 adjusted (4.43 FEH CD-ROM)	0.651 adjusted (0.650 FEH CD-ROM)
ALTBAR (m above sea level)	155	104	128	118	160	55	44
BFIHOST	0.376	0.476	0.481	0.544	0.358	0.414	0.36
DPLBAR (km)	20.25	13.73	7.37	5.27	4.10	2.33	0.71
FARL	0.963	0.951	0.951	0.917	1.000	0.944	1
FPEXT	0.0714	0.1057	0.0724	0.0672	0.0667	0.053	0.0575
SAAR (mm)	1341	1258	1303	1284	1361	1144	1152
SAAR4170 (mm)	1352	1308	1356	1317	1441	1192	1185
SPRHOST (%)	48.39	41.31	40.8	35.97	49.4	48.81	48.53
URBEXT1990	0.0004	0.0060 adjusted (0.0056 FEH CD-ROM)	0.0006 adjusted and FEH CD-ROM	0.0002 adjusted and FEH CD-ROM	0.0000 adjusted and FEH CD-ROM	0.0030 adjusted (0.0028 FEH CD-ROM)	0.0000 adjusted and FEH CD-ROM
URBEXT2000	0.0016	0.0074 adjusted (0.0072 FEH CD-ROM)	0.0007 adjusted and FEH CD-ROM	0.0012 adjusted and FEH CD-ROM	0.0000 adjusted and FEH CD-ROM	0.0088 adjusted (0.0085 FEH CD-ROM)	0.0000 adjusted and FEH CD-ROM

Table 5-2: Design peak flows[6]

Annual Probability (AP)	**Return** period (years)	Kirgunzeon Lane at Dalbeattie (m^3/s)	Kirgunzeon Lane at Corra Bridge (m^3/s)	Kirgunzeon Lane upstream of Drumjohn Burn (m^3/s)	Drumjohn Burn (m^3/s)	Edingham Burn (m^3/s)	Castle Cottage (m^3/s)
50	2	35.9	17.8	8.0	11.6	2.6	0.8
20	5	45.0	22.4	10.0	14.5	3.6	1.1
10	10	51.6	25.6	11.5	16.7	4.3	1.4
4	25	61.0	29.9	13.6	19.7	5.5	1.6
3.33	30	63.0	31.3	14.0	20.3	5.7	1.7
2	50	69.0	34.2	15.3	22.3	6.5	2.1
1.33	75	74.1	36.8	16.5	23.9	7.2	2.3
1	100	77.9	38.7	17.3	25.2	7.7	2.5
0.5	200	88.1	43.7	19.6	28.4	9.1	2.9
0.5 + 20% CC	200 + 20% CC	105.7	52.5	23.5	34.1	10.9	3.5
0.2	500	103.6	51.4	23.0	33.4	11.3	3.6
0.1	1000	117.2	58.1	26.1	37.8	13.4	4.3

6 All flows calculated using the FEH Statistical method except for Castle Cottage where the FEH Rainfall Runoff method was used because of the small catchment size (<1 km^2).

5.1.1 Comparison between BFI adjusted flows

Tests have been undertaken on the BFI value used. An adjustment of this parameter is not deemed necessary but could increase flood flows significantly. The impact of this on flood mapping is shown in Table 5-3 below. The difference in flow at the 200 year flood is 53m³/s or 60% higher. This is a significant increase. For example, if the BFI adjusted flows are used, a 200 year flood flow would be equivalent to a 10-25 year flood.

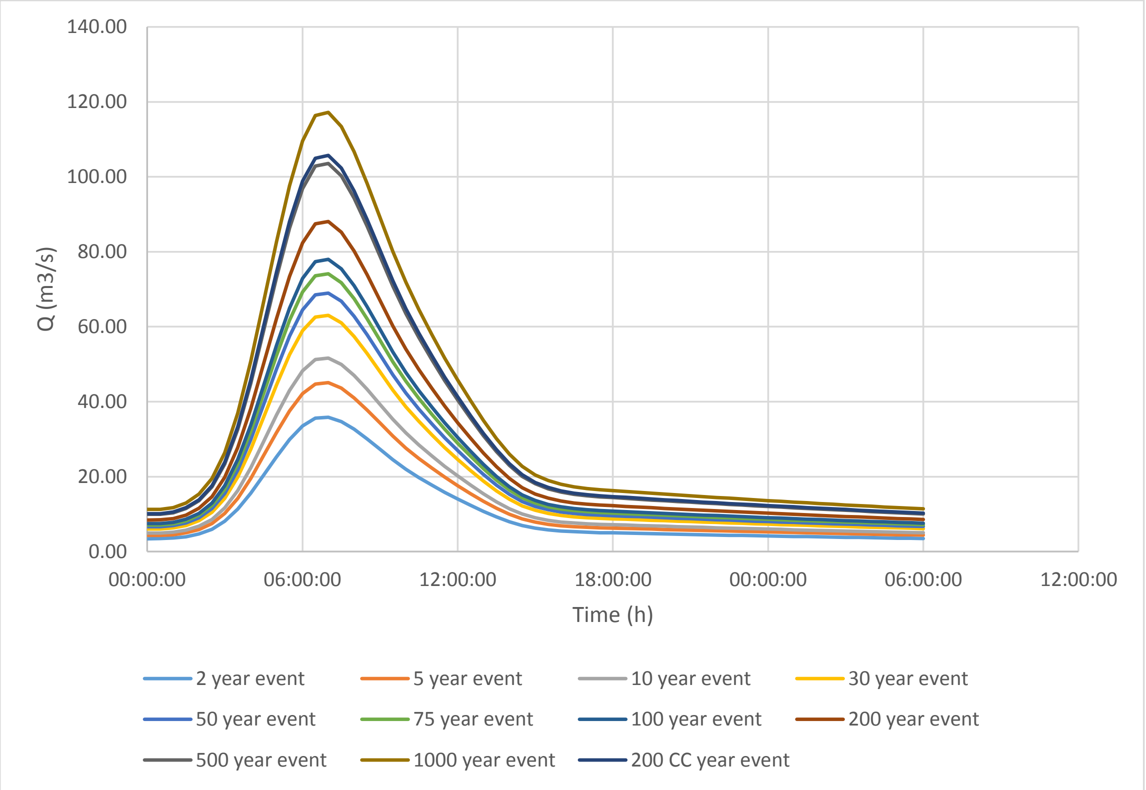
Table 5-3: Comparison of design peak flows with and without the adjustment of BFI

Annual Probability (AP)	Return period (years)	Kirkgunzeon Lane at tidal limit (m³/s) Unadjusted BFI	Kirkgunzeon Lane at tidal limit (m³/s) Adjusted BFI	Difference (m³/s)
50	2	35.9	57.3	21.5
20	5	45.0	72.0	27.0
10	10	51.6	82.5	30.9
4	25	61.0	97.5	36.5
3.33	30	63.0	100.7	37.7
2	50	69.0	110.3	41.3
1.33	75	74.1	118.4	44.4
1	100	77.9	124.6	46.7
0.5	200	88.1	140.8	52.7
0.5 + 20% CC	200 + 20% CC	105.7	165.6	62.0
0.2	500	103.6	187.3	70.1
0.1	1000	117.2	169.0	63.3

5.2 Design hydrographs

Design hydrographs for each watercourse were required for input to the hydraulic model. As the watercourses are ungauged, ReFH2 was used to generate design hydrographs. The magnitudes of the hydrographs were then scaled using peak flow to match the FEH Statistical estimates. Figure 5-1 provides an example series of hydrographs developed for the Kirkgunzeon Lane at Dalbeattie.

Figure 5-1: Scaled ReFH2 hydrographs for the Kirkgunzeon Lane at Dalbeattie



5.3 Summary of hydrology

The above chapter can be summarised as follows:

- Flood flow estimates for design purposes have been undertaken using standard FEH methodologies.
- A range of design flows have been provided using the preferred FEH Statistical Method.
- Whilst the flow estimates are carried out using standard methodologies, without any gauging of the watercourses the design flow estimates should be treated with caution.
- Tests have been undertaken on the BFI value used. An adjustment of this parameter is not deemed necessary but could increase flood flows significantly. The impact of this on flood mapping is discussed.
- Any flood defence improvements or significant capital spent would benefit from some flow gauging over a period of time to improve the flow estimates.
- A standard 20 % for climate change has been used in the assessment.

6 Hydraulic Model

6.1 Introduction

This section of the report presents the models used in this study, along with justification of the decisions made during model development.

6.2 Model Overview

Two separate models have been developed for the study watercourse:

- Kirkgunzeon Lane covering Dalbeattie where the watercourse is known as Dalbeattie Burn, which includes part of the tributary Edingham Burn.
- Kirkgunzeon Lane covering Kirkgunzeon and part of the tributary Drumjohn Burn.

Both areas have been represented with linked 1D-2D hydraulic models. This study involves assessing the standard of protection offered by the FPS and the impact of changes to the FPS. Linked modelling offers the capability of looking at channel and floodplain water levels and flows and their interactions, as well as ease of manipulation of FPS components for options modelling. The linked 1D-2D approach was therefore deemed the most suitable and efficient for this study. The models are constructed with the ISIS-TUFLOW software which is industry standard for this type of modelling and offers a wide range of modelling outputs. This software was chosen to achieve a high quality hydraulic model capable of outputting various deliverables to meet the study requirements.

6.3 Topographic Datasets

6.3.1 Survey data

A survey conducted by Atlantic Geomatics Ltd in 2005 for the Scottish Flood Defence Asset Database (SFDAD) project provided the majority of information for the model build. As part of this study, JBA Consulting carried out additional survey of river cross sections and structures on the Kirkgunzeon Lane in Dalbeattie on 14 July 2015 and a further survey for the Kirkgunzeon Lane in Kirkgunzeon. This data forms the basis of the 1D hydraulic models in ISIS where available.

Further cross section data for Edingham Burn was taken from survey data from a flood risk assessment (FRA) for Barhill Road undertaken by JBA in 2012. The existing HEC-RAS model was used for information where structure data remained incomplete. The survey conducted in Kirkgunzeon did not cover the whole of the modelled reach. The section between approximately Drumjohn Bridge and Kirkgunzeon Parish Church has no recent surveyed cross section information. This includes a weir at the confluence of Drumjohn Burn and Kirkgunzeon Lane. Bridge structures included in the models are shown in Table 6-1 to Table 6-3 below.

Table 6-1: Bridges on the Kirkgunzeon Lane in Dalbeattie

Structure	Photograph	Details
Bar Bridge, Moss Road		Downstream face OS NGR: NX 83876 61405 FPS Operation: N/A Model Node: DALB01_2715
Colliston Park footbridge, near Munches Park House		Upstream face OS NGR: NX 83568 61669 FPS Operation: 21 Model Node: DALB01_2293
Colliston Park footbridge, at St John's Road		Upstream on left bank, looking downstream towards right bank OS NGR: NX 83466 61640 Model Node: DALB01_2176
Colliston Park footbridge at John Street		Upstream of footbridge from left bank looking towards right bank and John Street OS NGR: NX 83377 61522 Model Node: DALB01_2026
Water Street footbridge		Upstream face OS NGR: NX 83383 61405 FPS Operation: 19 Model Node: DALB01_1898

Structure	Photograph	Details
High Street road bridge		Upstream face of bridge from right bank OS NGR: NX 83330 61320 FPS Operation: 10 Model Node: DALB01_1762
Maxwell Street footbridge		Upstream of bridge from right bank OS NGR: NX 83256 61246 Model Node: DALB01_1633
Footbridge at Church Crescent and Urr Road		Looking to right bank from left OS NGR: NX 83168 61084 FPS Operation: N/A Model Node: DALB01_1400
Footbridge at David Road and Birch Grove		Upstream face from left bank OS NGR: NX 83218 60898 FPS Operation: N/A Model Node: DALB01_1059
Newport Bridge road bridge (A710)		Upstream face from right bank OS NGR: NX 83152 60554 Model Node: DALB01_0493

Structure	Photograph	Details
Road bridge near Biggar's Mill Business Park		Upstream face from left bank OS NGR: NX 83052 60499 Model Node: DALB01_0093

Table 6-2: Bridges on the Edingham Burn, Dalbeattie

Structure	Photograph	Location
Barhill Road culvert		Upstream face OS NGR: NX 83566 61771 FPS Operation: N/A Model Node: EDIN01_0103
Footbridge at confluence with Kirkgunzeon Lane, near Munches Park House		Upstream face OS NGR: NX 83549 61684 FPS Operation: N/A Model Node: EDIN01_0007

Table 6-3: Bridges on Kirkgunzeon Lane and Drumjohn Burn in Kirkgunzeon

Structure	Photograph	Location
Drumjohn Burn		
Toll Bar Bridge, A711 road bridge		Upstream face OS NGR: NX 87775 67201 Model Node: KIRK02_0702

Structure	Photograph	Location
Drumjohn Bridge, farm access bridge		Downstream face OS NGR: NX 87325 67045 Model Node: KIRK02_0133
Kirkgunzeon Lane		
Kirkgunzeon Village Bridge		Looking upstream from right bank OS NGR: NX 86706 66759 Model Node: KIRK01_0879
Metal footbridge upstream of Corra Castle		Upstream face. OS NGR: NX 86628 66521 Model Node: KIRK01_0553
Corra Bridge, A711 road bridge		Looking downstream from right bank. OS NGR: NX 86723 66132 Model Node: KIRK01_0109
Old road bridge at Corra Bridge		Looking downstream from A711 Corra Bridge. OS NGR: NX 86741 66117 Model Node: KIRK01_0092

JBA Consulting carried out a top of bank survey, to find the crest level of all embankments within the study reach, on both the Dalbeattie Burn and Kirkgunzeon Lane. Building threshold elevation data was also collected in order to carry out a damage assessment.

6.3.2 Other data

Filtered DTM data has been used to create the model grid. A 1m resolution LiDAR DTM dataset was provided by the Dumfries and Galloway Council.

Ordnance Survey MasterMap data has been used to define land use categories for applying Manning's n roughness values to the 2D domain.

6.4 Model Setup

This section gives details of the coverage of the two models developed for this study, and outlines the components of the 1D and 2D domains.

6.4.1 Linking

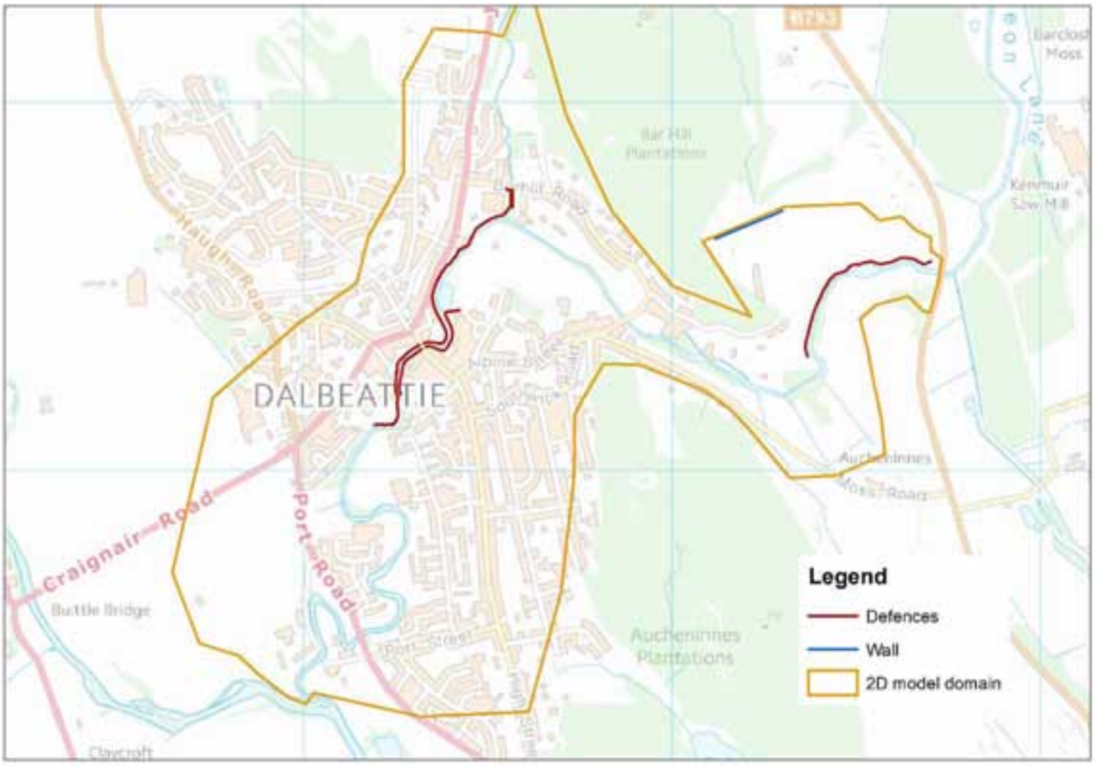
A uniform approach was used to link the 1D model to the 2D domain. TUFLOW 'HX' links were used to create a dynamic link based on modelled water levels. Elevations are enforced along these links, using Z lines to ensure that the model grid represents the bank levels in the 1D-2D interface cell. The Z lines use top of bank survey where available. Outside the surveyed area, levels are interpolated between ISIS cross sections.

6.4.2 Extents

Dalbeattie model

The Dalbeattie model consists of a 1D reach on the Dalbeattie Burn and one on part of the Edingham Burn through Dalbeattie, plus a single 2D domain which covers the floodplain in the study area (Figure 6-1). On the Kirkgunzeon Lane/Dalbeattie Burn watercourse, the model extends from the B793 upstream of Dalbeattie, NGR 284725 561533, through the built-up area of Dalbeattie to the confluence with the Urr Water, downstream of the A710 near Biggar's Mill Business Park, NGR 283022 560382. The Edingham Burn is included from the dismantled railway near Nursery Cottage/Rounall Avenue, NGR 283551 562172, to the confluence with the Dalbeattie Burn downstream of Barhill Road near Munches Park House, NGR 283550 561685. The 2D domain covers both banks of the modelled watercourses for the entire modelled reach, including the area behind the flood defences. It has a grid of cell size 4m, and has its origin at NGR 282982 560256. Base elevation data in the 2D model grid are interpolated from the LIDAR DTM, which has a resolution of $1m^2$. An artificial wall has been put in place on the northern edge of the domain close to Bar Hill to prevent water exiting the 2D domain in this location (see model assumptions section for more details).

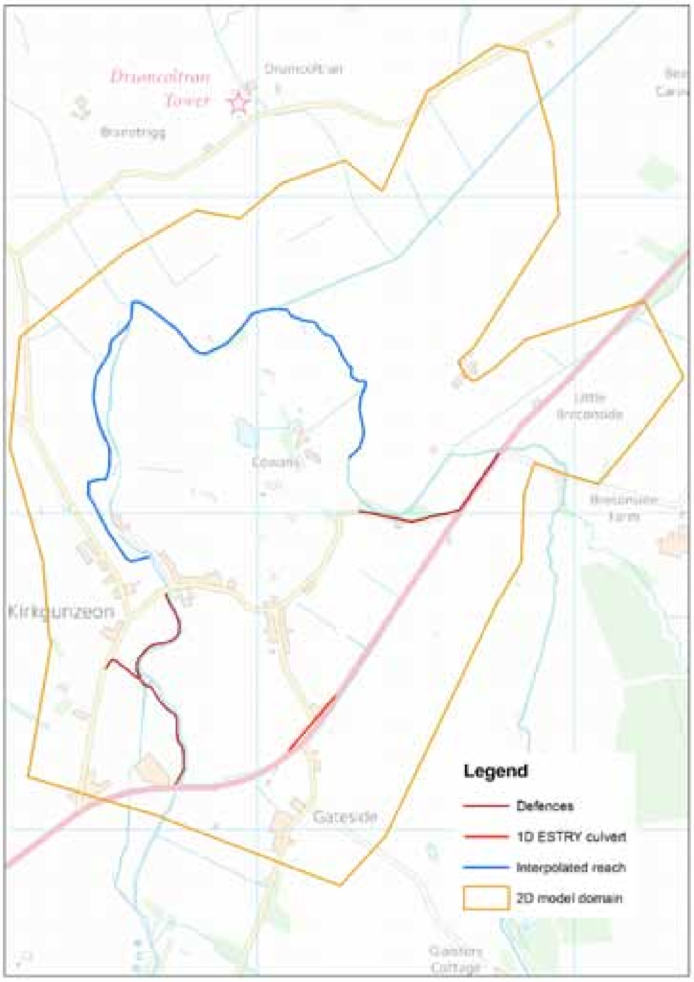
Figure 6-1: Dalbeattie model schematic



Kirkgunzeon model

The Kirkgunzeon model also consists of a single 1D reach of the channel, embedded in a single 2D domain which covers the floodplain through the modelled reach. The extent of this model is shown in Figure 6-2. The modelled reach extends from just upstream of the A711 at Toll Bar Bridge, NGR 287774 567203, to just downstream of Corra Bridge, NGR 286741 566129. The upstream 1.41km of the modelled reach is Drumjohn Burn. NGR 287062 567649 marks the confluence of Drumjohn Burn and Kirkgunzeon Lane. Downstream of this point the modelled watercourse is the Kirkgunzeon Lane. The 2D domain is comprised of a grid of 4m cell size covering both banks of the watercourse along the modelled reach. A culvert alongside the A711 in the vicinity of Mossband Caravan Park, is also included in a TUFLOW 1D component, to allow representation of any interactions of floodwater with this culvert (see Figure 6-2). Base elevation data in the 2D model grid are interpolated from the LIDAR DTM, which has a resolution of $1m^2$.

Figure 6-2: Kirkgunzeon model schematic



6.4.3 Boundaries

Upstream boundaries to the model consist of inflows into the 1D domain at the upstream end of the modelled watercourses. The 2D model upstream boundaries on each watercourse are located at a natural break in the topography as much as possible. In the Kirkgunzeon model the 2D upstream boundary has been located a short distance upstream of surveyed cross section data so as not to influence floodplain flow patterns in the vicinity of Toll Bar Bridge, A711. Downstream boundaries are Normal Depth boundaries at the downstream limit in the 1D and 2D domains. The boundaries and related hydrology applied to each model are discussed here. Tidal boundaries have been modelled separately as a sensitivity test.

1D domain

The inflows to the ISIS models are flow-time (QT) boundaries at the upstream limit of each modelled watercourse. The design hydrograph from ReFH2 is applied through these boundaries, adjusted to the FEH statistical peak. In the Dalbeattie model there are inflows to the upstream of Edingham Burn and the Kirkgunzeon Lane/Dalbeattie Burn. In the Kirkgunzeon model there is an inflow at the upstream end of the Drumjohn Burn. This has a minimum flow set to improve model stability. Another inflow accounts for the Kirkgunzeon Lane flow at the confluence with the Drumjohn Burn. This inflow is however applied further downstream than the confluence, this is due to the presence of interpolated sections.

At the 1D downstream limits of the study watercourses, the models calculate water depth using the flow input and river bed slope. In hydraulic modelling this type of boundary is known as a Normal Depth boundary. The Edingham Burn watercourse links directly to the Dalbeattie Burn.

2D domain

At the downstream end of the 2D domains, head-flow (HQ) boundaries have been applied across the floodplain. These are normal depth boundaries based on slope of the floodplain. There is one of these boundaries on both the left and right banks at the downstream limit of each model.

6.4.4 Roughness

Channel (1D domain)

In the 1D model of the Dalbeattie Burn through Dalbeattie, both the channel and the overbank areas have been split into three categories of roughness. Observations on site, such as presence of water crowfoot and steep reaches over bedrock, were used to inform the location of different categories. Manning's n values corresponding to these categories are shown in Table 6-4 below.

Table 6-4: Dalbeattie Burn model roughness values

Category	Manning's n	Model nodes applied to
Channel		
General	0.040	DALB01_3895-2026 DALB01_1848-1750 DALB01_1615-1400
Steep	0.050	DALB01_1948-1898 DALB01_1684-1633
Slack	0.038	DALB01_1400-0000
Overbank areas		
Grass	0.051	DALB01_3895-3391 Left Bank DALB01_2336-1898 DALB01_1549-0000
Trees	0.077	DALB01_3305-2352
Paved	0.055	Right Bank DALB01_3232-3090 DALB01_1799-1582 Right Bank DALB01_2336-1948

River cross section profile varies along the Dalbeattie Burn depending on location. In the upper half of the model the floodplain is more rural, with open land in the most upstream section then Colliston Park at the more upstream end of Dalbeattie. The watercourse then passes through a section which is heavily urbanised on both banks through the centre of Dalbeattie, before passing into an area with some green space on the banks downstream towards the downstream modelled limit.

Roughness values in the 1D Kirkgunzeon model are uniform along the whole modelled reach. A Manning's 'n' value of 0.040 is applied in the channel, and 0.049 is applied for the overbank portions. The majority of the modelled reach is rural, with just a short section more urban through the village of Kirkgunzeon.

Floodplain (2D domain)

Floodplain areas were divided into polygons of similar landuse and surface, based on the Ordnance Survey MasterMap dataset. Manning's 'n' roughness values were then assigned to each land use category and applied to the 2D model domain. The values used are presented in the following table, along with a description and the TUFLOW material code which was used to apply each value.

Table 6-5: Manning's n roughness values used for 2D modelling

Material Code	Manning's n	Description
1	0.500	Buildings
2	0.070	Trees
3	0.060	Rough grass
4	0.040	General surfaces/Natural surfaces
5	0.030	Inland Water
6	0.025	Manmade surfaces, roads, manmade paths

6.4.5 2D domain features

Buildings

Buildings are modelled in the active domain of the model, using a high roughness level rather than excluding from the modelled domain. Building footprints were taken from OS Mastermap. All buildings have a Manning's n roughness value of 0.5 applied to the grid cells within their footprint.

Ground Modifications

Several modifications to the base ground model grid have been applied in both the Dalbeattie Burn and Kirkgunzeon Lane models.

- The bank elevations have been reinforced in the 2D model domain. TUFLOW Z lines have been used to apply the defence crest elevation values from the bank top survey. This is a more direct method than interpolating grid values from the DTM and is therefore more accurate.
- In some places patches have been used to raise bridge deck elevations where the LIDAR filtering has removed these. This has been done using the TUFLOW zsh polygons where bridge decks are included in the 2D domain.
- Some zsh polygons have also been applied in places to smooth irregularities in the ground model where anomalies exist (thought to be due to LIDAR filtering).

In the Dalbeattie Burn model, an artificial wall has been stamped onto the ground model grid between two high points in the area of Bar Hill on the right bank floodplain. This was done to block a possible flow path into the neighbouring Edingham Burn valley. Survey data is not available for the whole watercourse in this valley and this area is beyond the scope of this study, so the decision was made to eliminate this flow path. Should this area be of interest for further studies the possible interactions between the two valleys should be considered.

6.5 Model calibration and validation

There are several ways in which a hydraulic model can be calibrated. The most reliable method is using flow and or level data from within the study catchment. An alternative is to validate predicted model flood extents with historic flooding events, which can be particularly effective if an estimate of return period can be achieved. However, there are no flow or level gauging stations on the study watercourse, and there have been no flooding events on the watercourse since the flood protection scheme (FPS) was installed. It is therefore very difficult to calibrate model results. Sensibility checks have been carried out, to validate predicted model flood extents and flood mechanisms on the ground.

Test simulations were run to assess the impact on model extents of BFI values used in the hydrological estimates. Knowledge of the catchment suggests that the hydrological estimates with BFI unadjusted provide a more realistic pattern of flooding in this catchment.

6.6 Assumptions and uncertainties

The nature of hydraulic modelling means that assumptions are generally made about parameters and components of the models, as not all details can always be accommodated or incorporated. This is a standard approach widely accepted across the industry. In general the modelling assumes that

- values of parameters set in the models are representative of conditions on the ground (e.g. roughness, inflows)
- 1D cross sections provide a reasonable representation of the channel geometry
- the LIDAR DTM accurately reflects the floodplain terrain

In addition to these general assumptions, further specific assumptions have been applied to the modelling for this study.

Survey data was not available for a large section of the Kirkgunzeon Lane upstream of Kirkgunzeon village or for a weir at the Kirkgunzeon Lane-Drumjohn Burn confluence. Data was incomplete for a weir in Dalbeattie near Maidenholm Forge Mill and a weir downstream of Kirkgunzeon village bridge. Interpolated cross sections have been used to represent the missing section of the channel near Kirkgunzeon, which assumes the cross sections upstream and downstream are representative of this missing reach. The weir upstream of Kirkgunzeon is not included in the model and drop in bed over the weirs in Dalbeattie and Kirkgunzeon village have been estimated from site observations. These modelling decisions may affect the reliability of modelled water levels locally.

Mill lades within the study reaches have not been modelled directly.

Base ground levels have been modified in some small areas to smooth out anomalies found within the grid, thought to be due to the filtering of the LIDAR data. This also applies at some bridge decks which are modelled in the 2D domain.

The external wall of a demolished building in Dalbeattie has been included in the defences layer. This assumes the wall is in good condition and would act as a defence.

During model development it was found that it may be possible for some flow to pass from the right bank floodplain of the Dalbeattie Burn near Bar Hill into the neighbouring valley containing Edingham Burn. Survey data is not available for a large proportion of the watercourses in that valley, and this area is beyond the scope of the current study. The possible flow route in this area has therefore been artificially blocked for the purposes of the modelling for this study. Should the Bar Hill area be of interest, flow interactions between the two valleys should be investigated. This is discussed further in Section 7.2.1.

The inflow representing the Kirkgunzeon Lane watercourse to the confluence with the Drumjohn Burn has been applied to the model further downstream than the confluence location. This was due to the use of interpolated cross sections in the unsurveyed reach. This may mean that flows in the area between the confluence and Kirkgunzeon Parish Church are underestimated, however flows through Kirkgunzeon village will be as estimated for this location. As this area is rural with small numbers of properties the impact is likely to be small.

The upstream limit of the Kirkgunzeon Lane watercourse near Toll Bar Bridge (A711) has been extended further upstream than available survey data to remove the impact of the upstream boundary proximity on floodplain flooding patterns here. This applies to a short distance of the model in an area of few properties.

It should be noted that the modelled watercourse upstream of the Kirkgunzeon Lane and Drumjohn Burn confluence is Drumjohn Burn. Model node labels here begin KIRK. The Kirkgunzeon Lane watercourse has not been modelled in the 1D domain upstream of this confluence as survey data was not available here. Further survey of this reach would allow inclusion in the model 1D domain and would improve confidence in floodplain flooding patterns in this area. As there are few properties here this approach was deemed suitable for this study.

Recommendations

Recording of river levels and rainfall within the catchment would help to reduce uncertainty in hydrological estimates used, and aid model calibration which would improve confidence in predicted modelled water levels. Without this recorded data the standard of protection analysis is reliant on the estimated return periods from the hydrological analysis.

Acquisition of further survey data for river cross sections and structures on the study watercourses in some areas would improve the model representation of the study reaches and reduce uncertainty in predicted water levels in various locations. Most notably on the Kirkgunzeon Lane between Drumjohn Bridge farm access bridge and Kirkgunzeon village Parish Church.

The models developed here are deemed appropriate to fulfil the aims of this study with the data available. They could be improved if further data should become available in the future. The representation of the model structures and 2D domain are valid up to the 1000-year flow.

6.7 Modelled Scenarios

6.7.1 Design Runs

The design runs form the baseline modelling for this study, representing the current situation assuming defences are in place. This model scenario was run for a range of return periods from 2-year to 1000-year design events, including an allowance for climate change on the 200-year return period event. These simulations were carried out for both the Dalbeattie and Kirkgunzeon models.

6.7.2 Freeboard

Both models have been run in a 'No Freeboard' scenario. This represents the defences along the study reach without an allowance for freeboard. Surveyed defence crest levels have been lowered by 0.30m everywhere. This scenario has been run for the full range of return periods as in the design runs.

6.7.3 Blockage

A blockage scenario has been run for both models, the Dalbeattie Burn in Dalbeattie and the Kirkgunzeon Lane in Kirkgunzeon. This represents a 20% reduction in area at all of the bridge structures along the modelled reach simultaneously. Blockage has been simulated by reducing the soffit level of the bridges. This scenario was run for the 200-year return period event and the 200-year plus an allowance for climate change.

6.7.4 Tidal downstream boundary

This model scenario applies to the Dalbeattie Burn model, Dalbeattie only. The downstream boundaries in both the 1D and 2D domains were changed from normal depth boundaries to constant level boundaries. These level boundaries apply the extreme sea level estimate for the 200-year return period at the study area (T200), which is 6.4272mAOD. This was run for the 200-year return period event only.

7 Model results

7.1 Introduction

Flood mapping has been undertaken and is based on the 1D-2D modelling using the unadjusted BFI hydrological estimates. Model results are provided in a number of formats:

- The flood levels in mAOD at each cross section for each return period are contained in Appendix E.
- The model results have been displayed graphically as flood maps in Appendix D.

Discussion on the performance of the flood defences is provided in Section 5.

7.1.1 Discussion on BFI

A separate flood modelling was undertaken using hydrological estimates based on the unadjusted BFI values (utilising values in the BFI map of Scotland) as a separate test on the 200 year return period. This is discussed further in the Sections below.

7.2 Flood map results

Flood maps were produced by combining the 1D and 2D results. The 2D maximum flood depths were produced in TUFLOW however as the channel and adjacent banks were modelled as 1D the results do not show any water in the watercourse channel. The 200 year flood map is provided for Dalbeattie in Figure 7-1 below and for Kirkgunzeon in Figure 7-2 (also provided as an A3 plan in the Figures section of the report). These maps have also been created as 0.25m flood depth contours.

Figure 7-1: Flood depth map for the 200 year (0.5%) modelled flood event in Dalbeattie

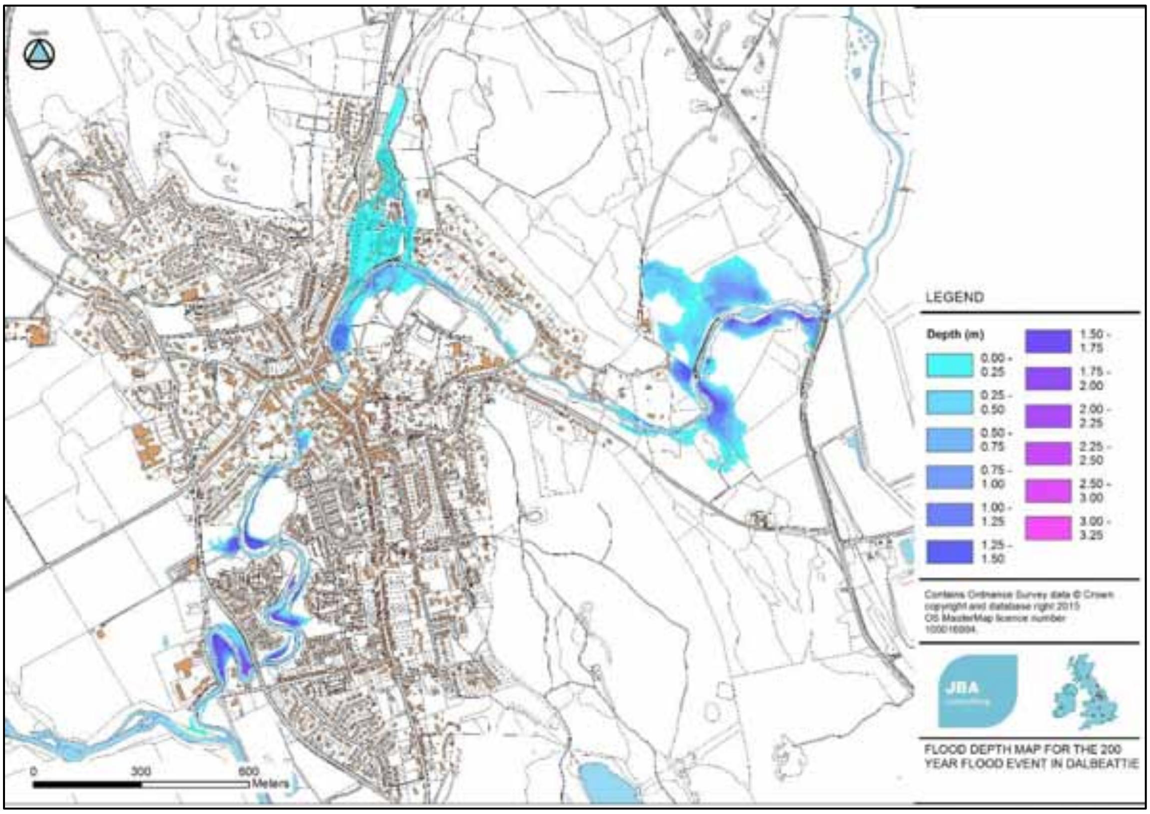
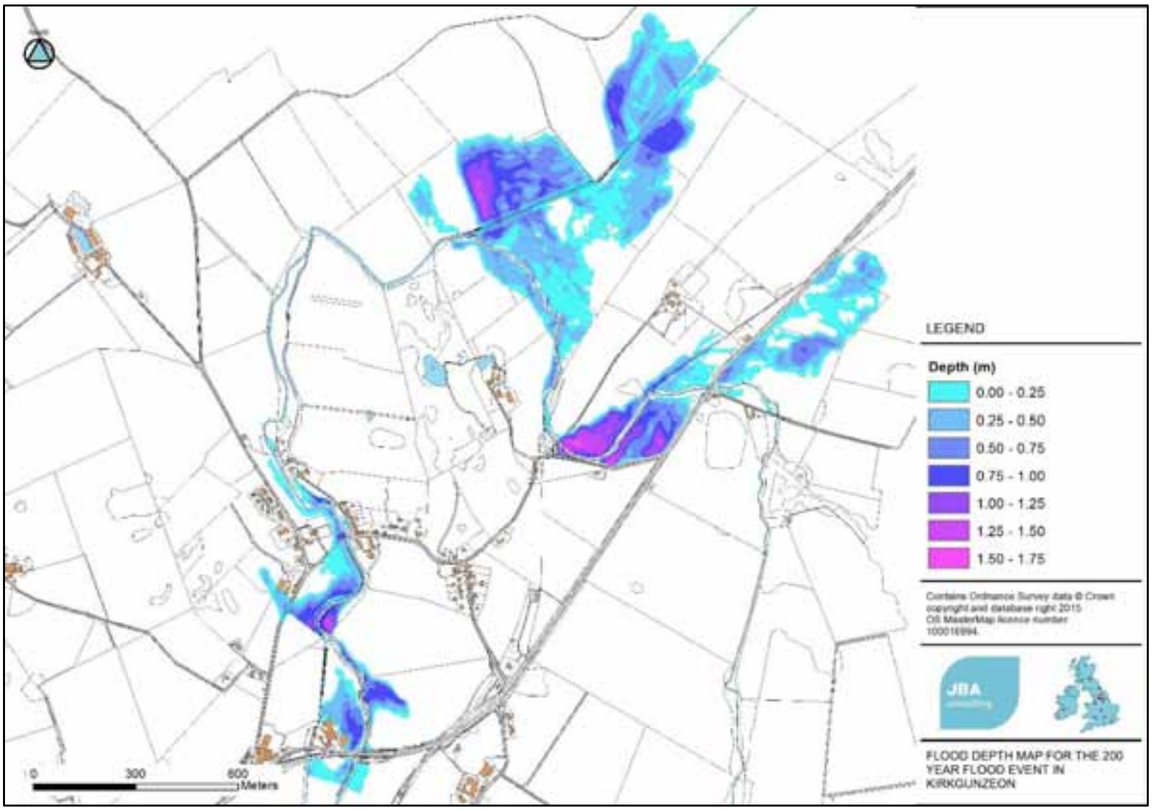


Figure 7-2: Flood depth map for the 200 year (0.5%) modelled flood event in Kirkgunzeon



7.2.1 Risk of flow route from Maidenholm reach to Edingham Burn

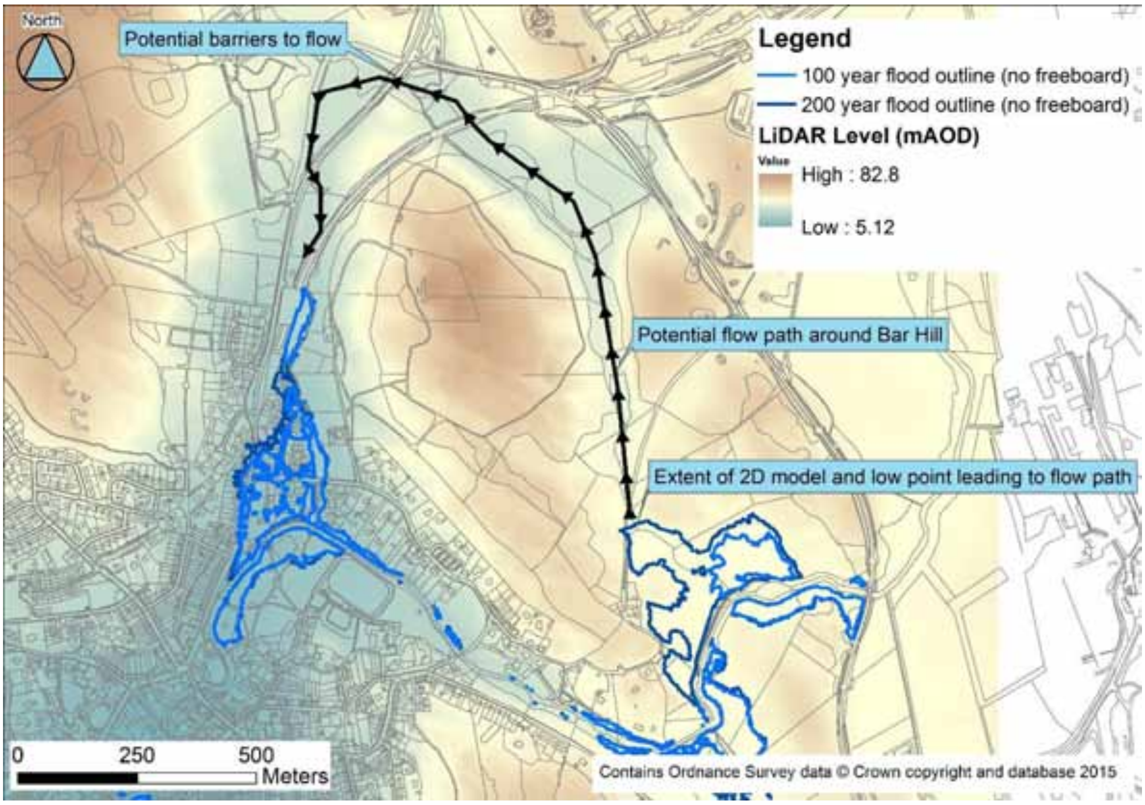
During the modelling of the Dalbeattie reach, a potential flow path was discovered from behind the Maidenholm embankment (right bank) around the east and north side of Bar Hill before joining the Edingham Burn. The modelling undertaken suggests that this could be a flood route once the Maidenholm embankment overtops and the floodplain fills to the point at which the flow path could initiate. The flow path is shown in Figure 7-3 below.

Whilst this flow route has not been modelled, it is estimated from the modelling undertaken that it could start at the 200 year flood (the 100 year flood is predicted to partially fill the Maidenholm floodplain but not to a level where the flow path can start). Based on the LiDAR information, it is estimated that levels in the floodplain would need to rise to a level of approximately 40mAOD before the flow path can initiate.

This flow path would be constrained by a number of barriers including the:

1. The old railway embankment. This has been modelled (see Appendix C) and has a capacity of $3.6m^3/s$. It is also currently 50% blocked by sediment.
2. The A711 road embankment. The condition and type of culvert through this embankment is unknown.
3. Natural floodplain attenuation.

Figure 7-3: Flow path around Bar Hill



This has some important implications for the appraisal of options on the Dalbeattie and Edingham Burns:

1. At extreme floods (200 year flood or greater) there may be some loss of flow in the reach from Maidenholm to the confluence with the Edingham Burn. This is currently not taken into consideration in the existing model and is therefore conservative.
2. At extreme floods (200 year flood or greater) there is a risk that the Edingham Burn flows could increase as a result of the flow path around the north of Bar Hill. This increase in flows would be constrained by differences in the timing of the peak flow, natural floodplain attenuation and potential attenuation behind old railway and road embankments, but is a risk that would need to be considered as part of any detailed appraisal.

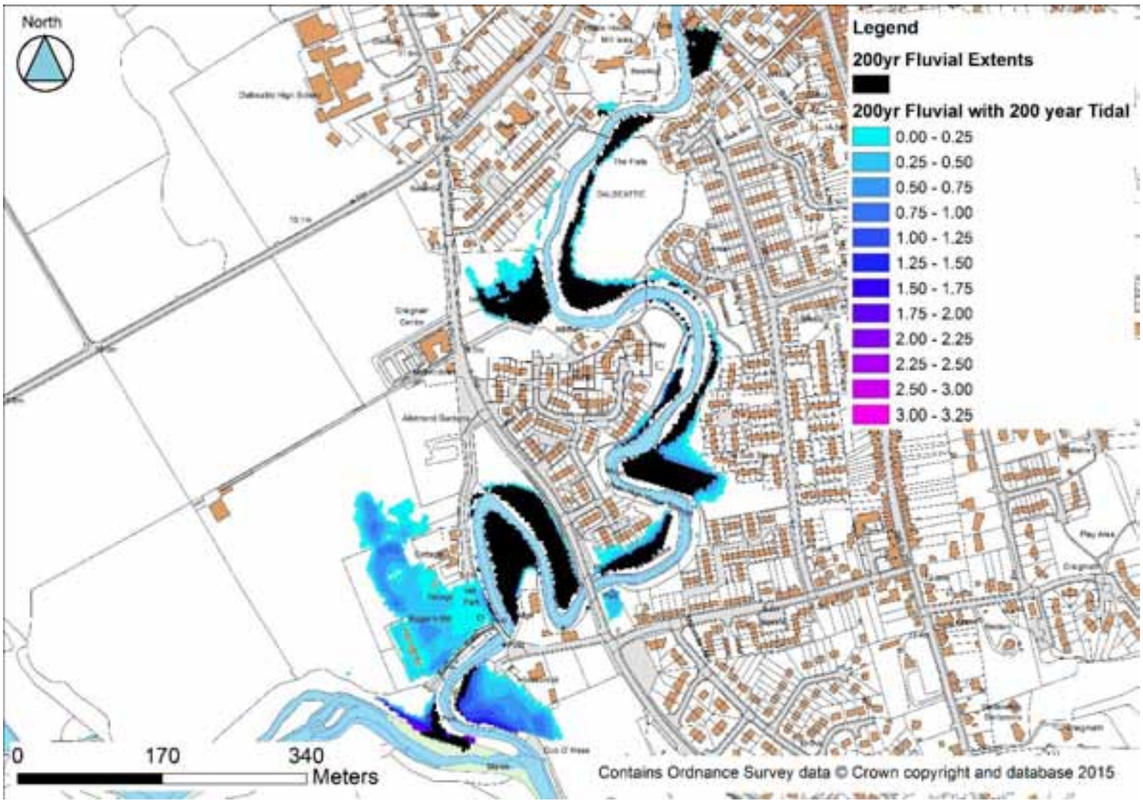
It is unclear why the Maidenholm embankment was added as part of the Dalbeattie FPS, other than perhaps to provide some additional protection to agricultural land. It is now clear that this may have been predicted as part of the original design work.

7.3 Tidal risk

The impact of coastal flood risk to the lower reaches of Dalbeattie has been assess by running the model with a constant extreme tidal still water level as the downstream boundary. The model has been run with the 200 year river flow and a conservative 200 year tidal flow as well. Whilst this combination is unrealistic due to the probability of a 200 year flow and tide occurring at the same time, it is a useful check for the purposes of this assessment and to inform the decision making process.

The difference between the purely 200 year and the combined event is shown in Figure 7-4 (also provided as an A3 plan in the Figures section of the report). Whilst the impact of high tidal levels at the downstream reach extents as far upstream as Maxwell Street/Beech Grove, the impact on flood levels and flood extents is relatively minor. The impact is most noticeable in the reach downstream of the road bridge near Biggar's Mill Business Park and in the business park itself.

Figure 7-4: Tidal flood risk



7.4 Freeboard modelling

The modelling undertaken has been repeated with the flood defences lowered by 300mm (flood defences are mainly walls through the main reach through Dalbeattie). This is to adjust the defence crest levels to the original design levels and to consider uncertainties in the original design.

Flood risk in Dalbeattie is increased at the 200 year flood suggesting that there is minimal (less than 300mm) freeboard from the modelled water levels to the flood defence elevations for some assets. This is most noticeable for the embankment in Colliston Park (Asset 7) and at the embankment surrounding the bowling green (Asset 17) (see Figure 7-5)

Flood risk with the freeboard adjustment in Kirkgunzeon and Drumjohn is not affected suggesting that there is a suitable freeboard for these embankments.

Figure 7-5: Comparison of modelled flood extent with and without 300mm freeboard adjustment

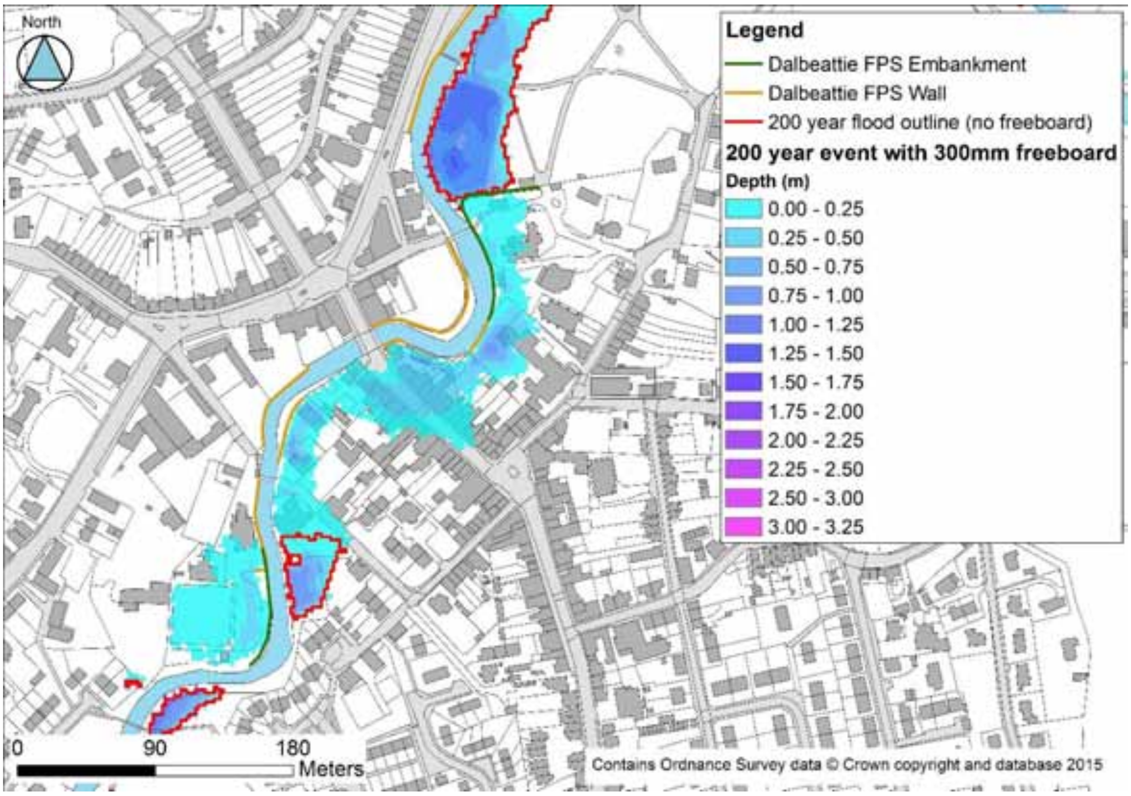


Figure 7-6: Comparison of modelled flood extent with and without 300mm freeboard adjustment

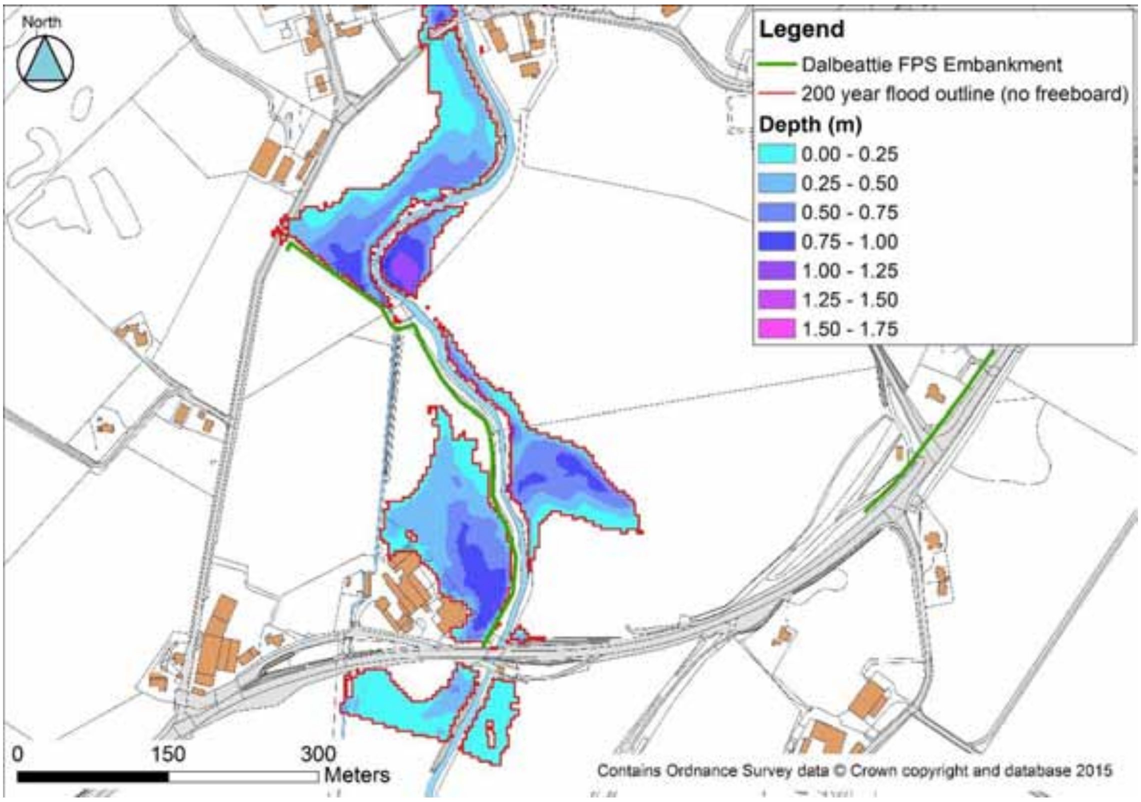
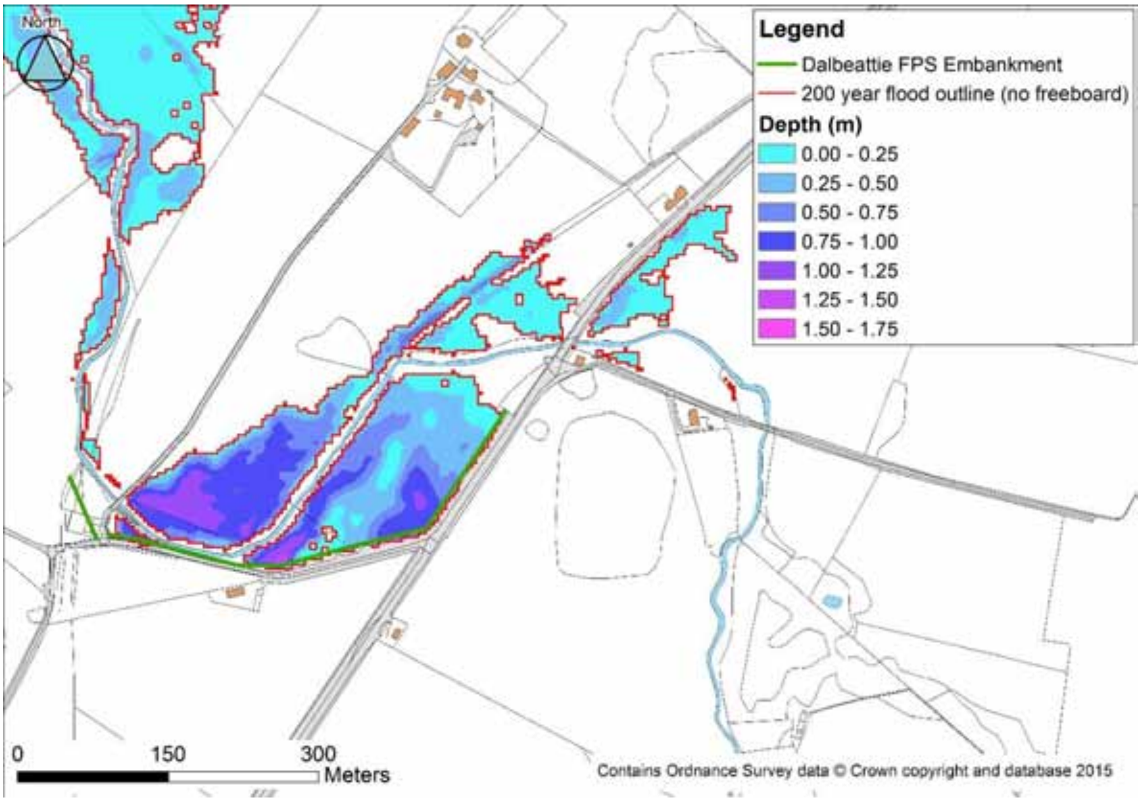


Figure 7-7: Comparison of modelled flood extent with and without 300mm freeboard adjustment



7.5 Bridge capacity review

Hydraulic structures are important considerations in flood modelling as their presence generally constricts the cross section of the watercourse. They are often liable to blockage by large debris carried by the flood flows and hence are often the point where the watercourse exits the channel.

The structures in this reach generally have a good standard of protection, able to convey the 200 year flow without water levels surcharging the bridge soffits (as shown in Table 7-1).

Table 7-1: Bridge capacity

Bridge	Watercourse	Lowest soffit level (mAOD)	Return period at which soffit is reached
B793	Kirkgunzeon Lane	41.90	>1000
Bar Bridge	Kirkgunzeon Lane	25.45	>1000
Upstream Colliston park footbridge	Kirkgunzeon Lane	15.87	>1000
Mid Colliston Park footridge	Kirkgunzeon Lane	15.24	>1000
Downstream Colliston Park footridge	Kirkgunzeon Lane	13.15	>1000
Water street footbridge	Kirkgunzeon Lane	12.69	>1000
High street road bridge	Kirkgunzeon Lane	11.37	>1000
Maxwell Street footbridge	Kirkgunzeon Lane	10.34	>1000
Footbridge	Kirkgunzeon Lane	7.62	200
Footbridge	Kirkgunzeon Lane	7.46	>1000
A710 Port Road	Kirkgunzeon Lane	7.07	>1000

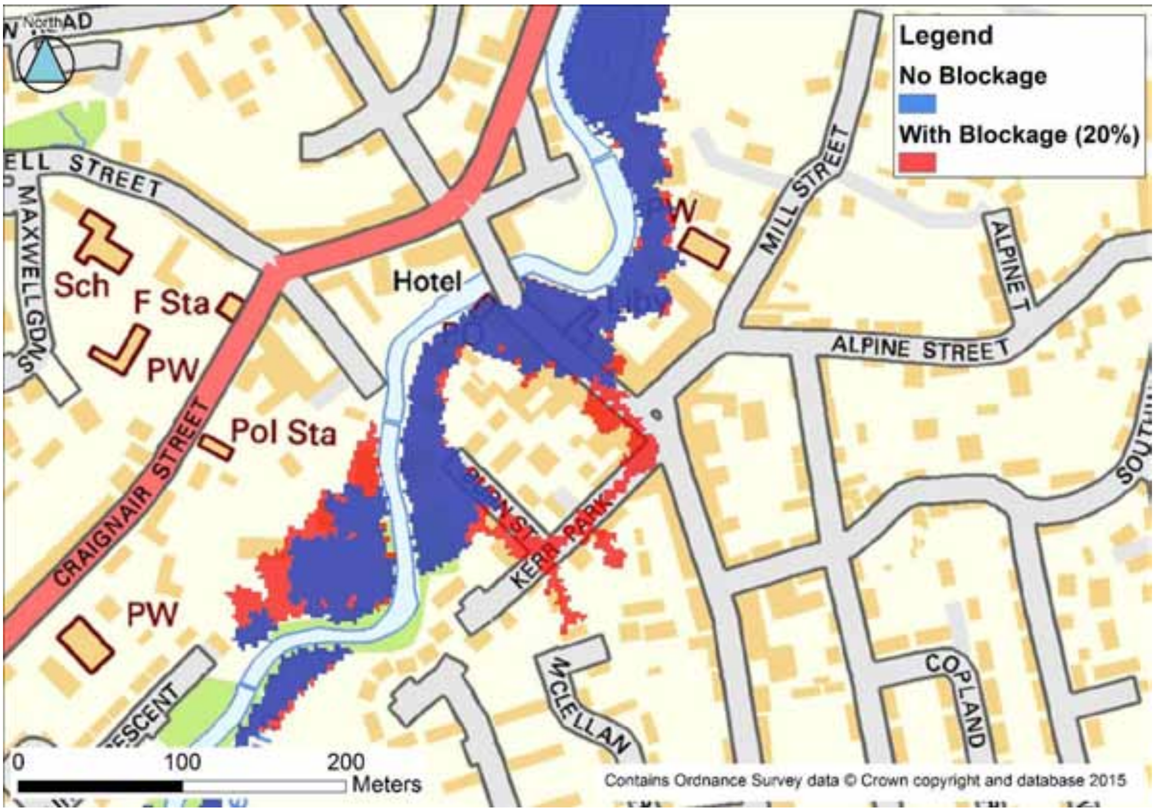
Biggers Mill Business Park Arch Bridge	Kirkgunzeon Lane	6.80	>1000
Barhill Road Culvert	Edingham Burn	16.44	<2
A711 Drumjohn Bridge	Drumjohn Burn	69.29	>1000
Drumjohn farm access bridge	Kirkgunzeon Lane	67.04	10
Kirkgunzeon village Bridge	Kirkgunzeon Lane	57.94	>1000
A711 Kirkgunzeon Lane bridge and old road bridge	Kirkgunzeon Lane	53.86	>1000
Old stone arch bridge	Kirkgunzeon Lane	55.03	>1000

7.5.1 Bridge blockage analysis

As blockage of bridges during floods can significantly reduce the opening area of the structures and increase the afflux across the bridge, a test in the modelling was undertaken to block the structures. As all structures in the reach are single span open structures, the probability of blockage is limited, however this is still a risk of a tree, for example, blocking on the upstream face of the bridges.

As such, the soffit of each bridge was lowered to reduce the opening area of the bridge by 20%. The results in terms of the modelled flood extent did not vary during blockage runs due to the already high bridge capacity along the modelled watercourses. There is very little difference between the baseline and blockage runs at the 200 year flood. With the inclusion of climate change a small change in flood outline is observed in Dalbeattie as shown in Figure 7-8.

Figure 7-8: Comparison between blockage and baseline run in Dalbeattie



7.5.2 Flood mapping deliverables

The following flood maps listed and described in Table 7-2 have been produced and are contained in Appendix F. These have been supplied digitally to Dumfries and Galloway Council in MapInfo and AutoCAD format.

Table 7-2: Summary of model results

Name	Description
Dalbeattie runs:	
2 Year Event.pdf	Dalbeattie - 2 year flow on the Kirkgunzeon Lane and Edingham Burn
10 Year Event.pdf	Dalbeattie - 10 year flow on the Kirkgunzeon Lane and Edingham Burn
25 Year Event.pdf	Dalbeattie - 25 year flow on the Kirkgunzeon Lane and Edingham Burn
50 Year Event.pdf	Dalbeattie - 50 year flow on the Kirkgunzeon Lane and Edingham Burn
100 Year Event.pdf	Kirkgunzeon - 100 year flow on the Kirkgunzeon Lane and Edingham Burn
200 Year Event.pdf	Kirkgunzeon - 200 year flow on the Kirkgunzeon Lane and Edingham Burn
1000 Year Event.pdf	Kirkgunzeon - 1000 year flow on the Kirkgunzeon Lane and Edingham Burn
200 Year +CC.pdf	Kirkgunzeon - 200 year flow with an allowance for climate change on the Kirkgunzeon Lane and Edingham Burn
200 Year +CC Adjusted.pdf	Kirkgunzeon - 200 year flow with an allowance for climate change and including Base Flow Index on the Kirkgunzeon Lane and Edingham Burn
Kirkgunzeon runs:	
2 Year Event.pdf	Kirkgunzeon - 2 year flow on the Kirkgunzeon Lane and Drumjohn Burn
10 Year Event.pdf	Kirkgunzeon - 10 year flow on the Kirkgunzeon Lane and Drumjohn Burn
25 Year Event.pdf	Kirkgunzeon - 25 year flow on the Kirkgunzeon Lane and Drumjohn Burn
50 Year Event.pdf	Kirkgunzeon - 50 year flow on the Kirkgunzeon Lane and Drumjohn Burn
100 Year Event.pdf	Kirkgunzeon - 100 year flow on the Kirkgunzeon Lane and Drumjohn Burn
200 Year Event.pdf	Kirkgunzeon - 200 year flow on the Kirkgunzeon Lane and Drumjohn Burn
1000 Year Event.pdf	Kirkgunzeon - 1000 year flow on the Kirkgunzeon Lane and Drumjohn Burn
200 Year +CC.pdf	Kirkgunzeon - 200 year flow with an allowance for climate change on the Kirkgunzeon Lane and Drumjohn Burn
200 Year +CC Adjusted.pdf	Kirkgunzeon - 200 year flow with an allowance for climate change and including Base Flow Index on the Kirkgunzeon Lane and Drumjohn Burn
Options runs:	
Freeboard modelling	The above flows were replicated with lowered defences to allow for 300mm freeboard
Blockage modelling	Blockages were modelled in Kirkgunzeon and Dalbeattie for the 200 year and 200 year with an allowance for climate change flows.

7.6 Properties at risk

All properties potentially at risk were identified and threshold surveys were undertaken to determine the flood risk to each property. Modelled flood levels were compared against these property threshold levels to determine the number of properties at risk from flooding from the relevant watercourses. The properties where threshold level surveys were undertaken are shown on Figure 7-9 and Figure 7-10.

Figure 7-9: Surveyed threshold levels in Dalbeattie

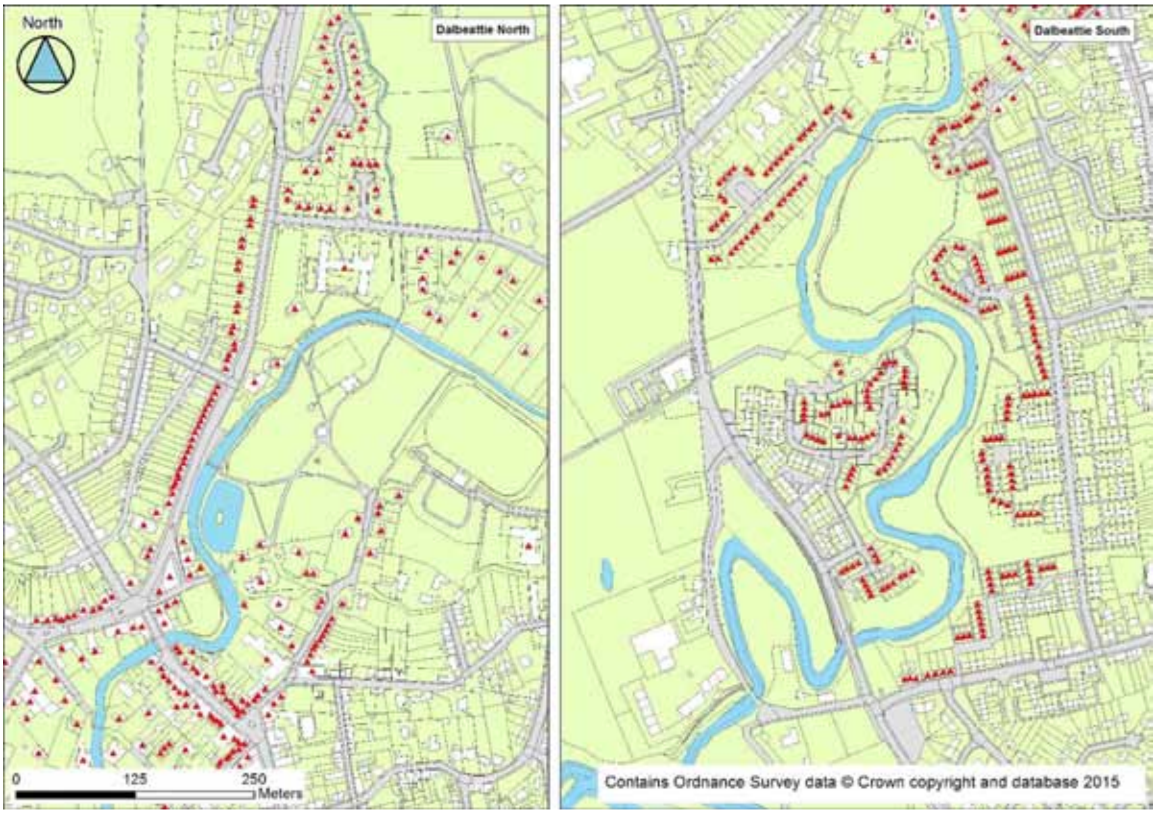
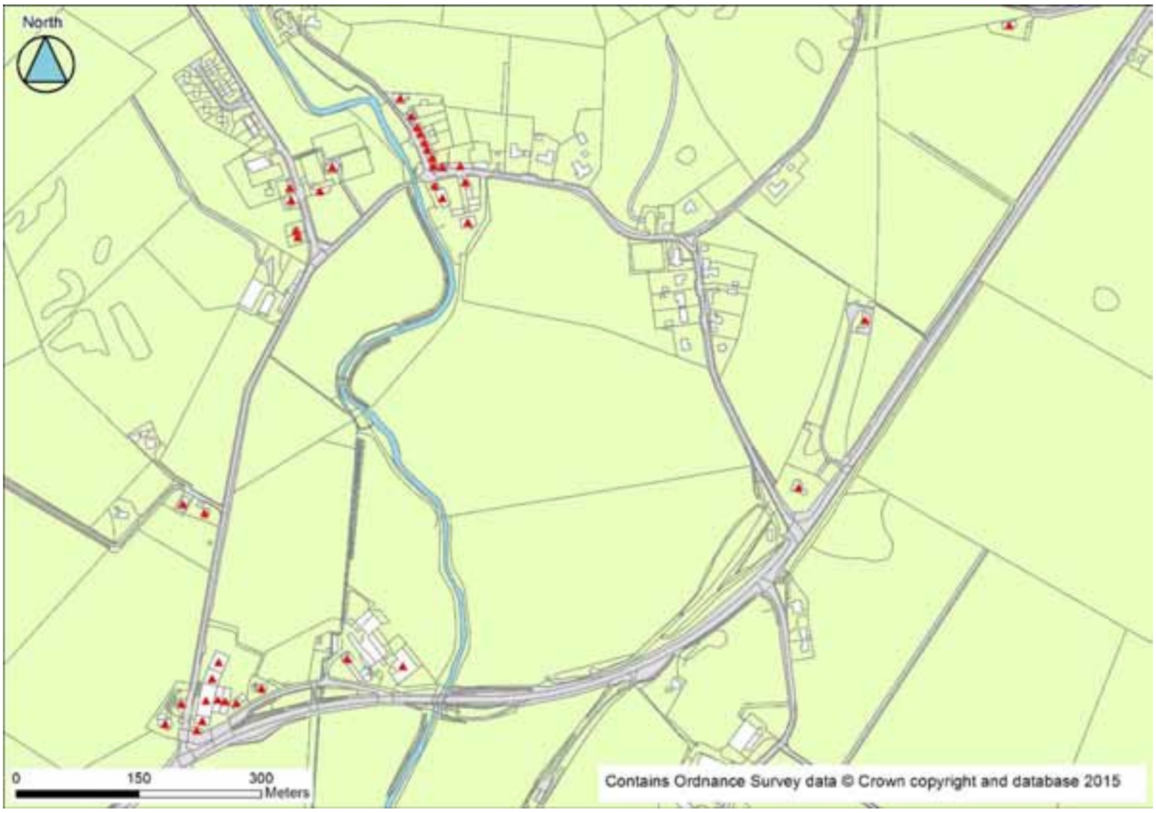


Figure 7-10: Surveyed threshold levels in Kirkgunzeon



7.6.1 Properties at risk from the Kirkgunzeon Lane in Dalbeattie

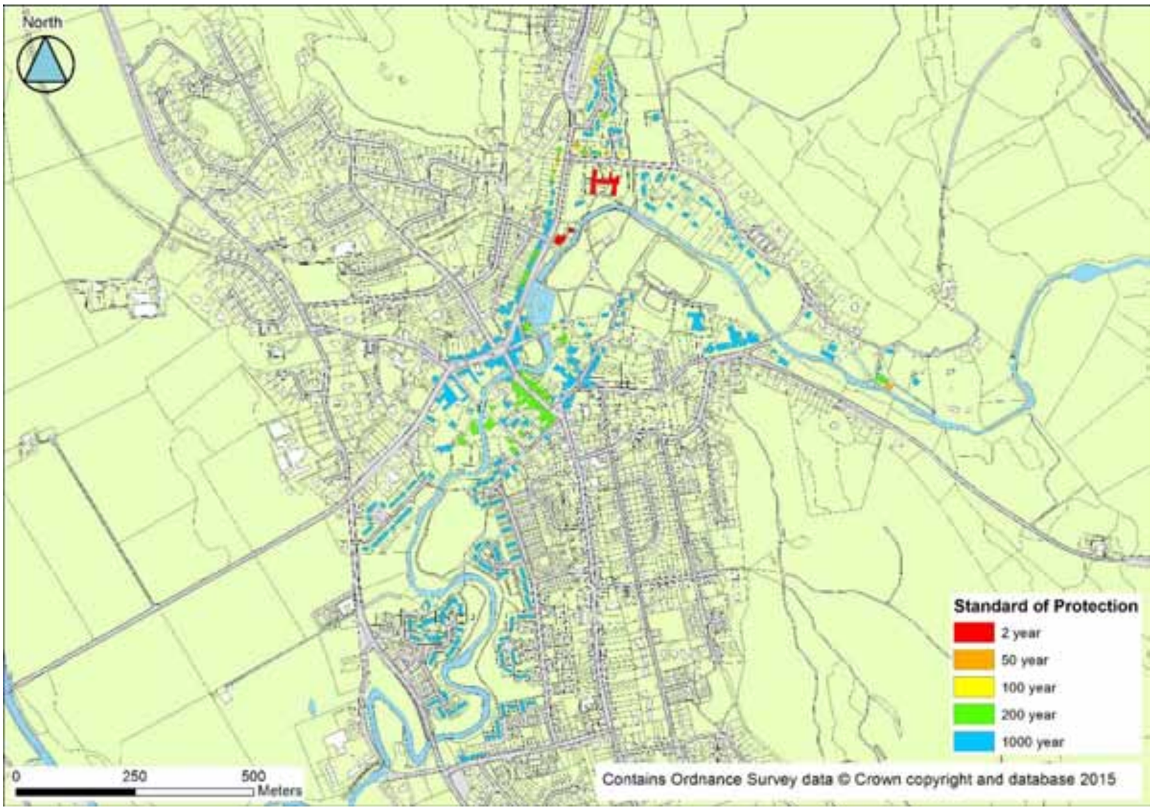
A summary of the properties flooded is provided in Table 7-3, and a plan of the standard of protection for each property is shown in Figures 7-11 to 7-13 (also provided as an A3 plan in the Figures section of the report). A full database of properties at risk and the modelled depth of flooding is provided in Appendix F.

Table 7-3: Summary of properties at risk from the Dalbeattie Burn

	2	10	25	50	100	200	200cc	1000
Properties flooded above TL	0	2	2	2	2	4	28	41
Properties flooded (includes below floor level to -0.3m)	0	3	3	3	9	16	51	88
Average flood depth (above threshold)	0	0.07	0.15	0.19	0.15	0.32	0.20	0.26
Maximum flood depth (above threshold)	0	0.10	0.19	0.24	0.27	0.64	0.71	0.75

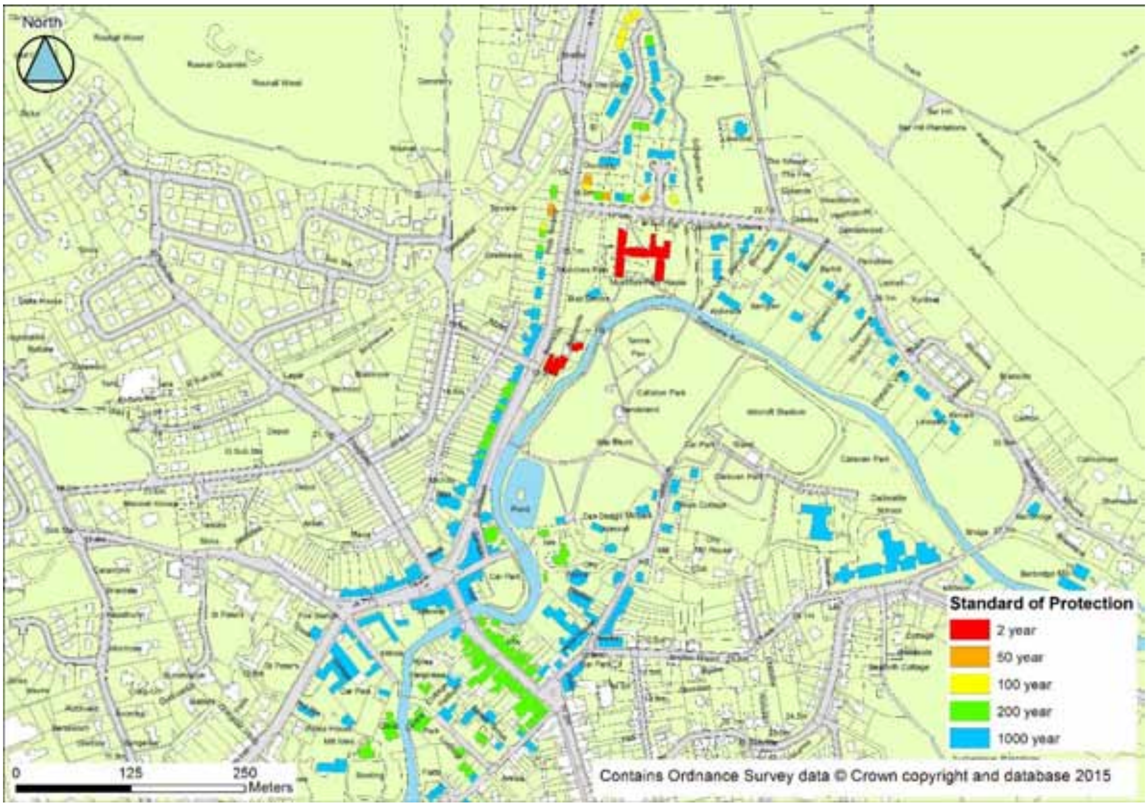
Analysis of properties flooded in the table above are given for those above the property threshold and those below the threshold (in the solum between ground and floor level). Not all property types will flood below the floor level (as this depends on construction type and age), but it is useful to include as it will still cause flood damages (drying and clean-up costs). Furthermore, the use of PLP measures can minimise these type of flooding relatively easily.

Figure 7-11: Properties at risk and standard of protection



Note. A 100 year SOP suggests that the properties would not flood at the 100 year flood, but would be at risk from a 200 year flood.

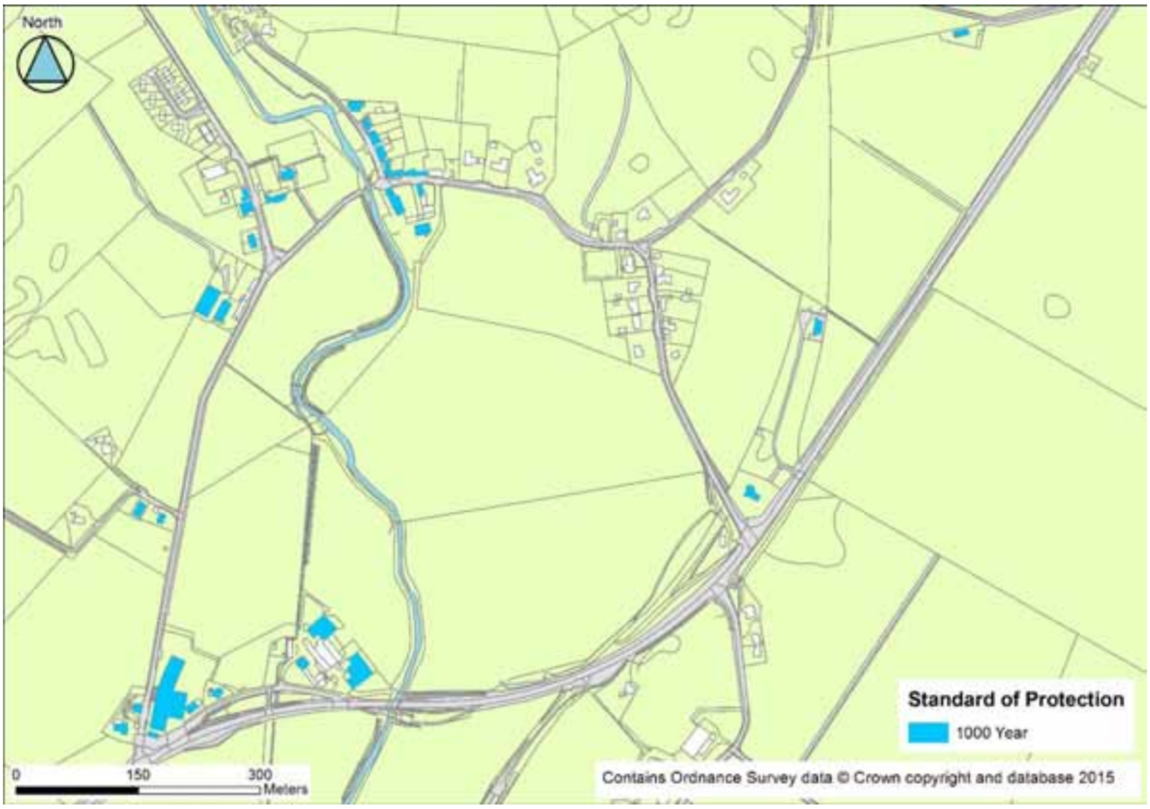
Figure 7-12: Properties at risk and standard of protection, at a larger scale



7.6.2 Properties at risk from the Kirkgunzeon Lane and Drumjohn Burn (upstream reach)

Whilst modelled flood waters reach the outer extents of a number of properties in this study area the flood waters do not reach sufficient elevation to exceed threshold levels (including below floor level -0.3m) in any properties in the model domain. This suggests that all properties in the Kirkgunzeon study area have a 1000 year standard of protection. Overall the risk is extremely low.

Figure 7-13: Properties at risk and standard of protection in Kirkgunzeon



7.7 Effectiveness of FPS

The defence elevations have been compared against the modelled water levels to determine the current standard of protection for those defences along the three main watercourses. This analysis is shown in Figures 7-14 to 7-22.

The analysis compares flood levels against the defence levels. For comparison, the defence levels are shown assuming a reduction in levels by 300mm to take into account freeboard. This is provided for information and to gauge the relative uncertainty in the standard of protection.

7.7.1 Upstream Kirkgunzeon Lane in Dalbeattie

The analysis of the modelled water levels against the surveyed defence crest levels suggests that the right bank flood defences have a good standard of protection in the region of a 100 year event, with allowance for a full 300mm freeboard.

The left bank has a consistently good standard of protection, in the region of the 200 year flood event with an allowance for climate change. The embankment consisting FPS Operation 7, which extends across the base of Colliston Park, perpendicular to the main channel, is likely to be the main concern in this reach whilst it does maintain a standard of protection for the 200 year flood event without freeboard allowance or the 10 year event if a 300mm freeboard is allowed for.

Figure 7-14: Defence height vs. water surface elevation on the Kirkgunzeon Lane in Dalbeattie, upstream of High Street Bridge - Right bank

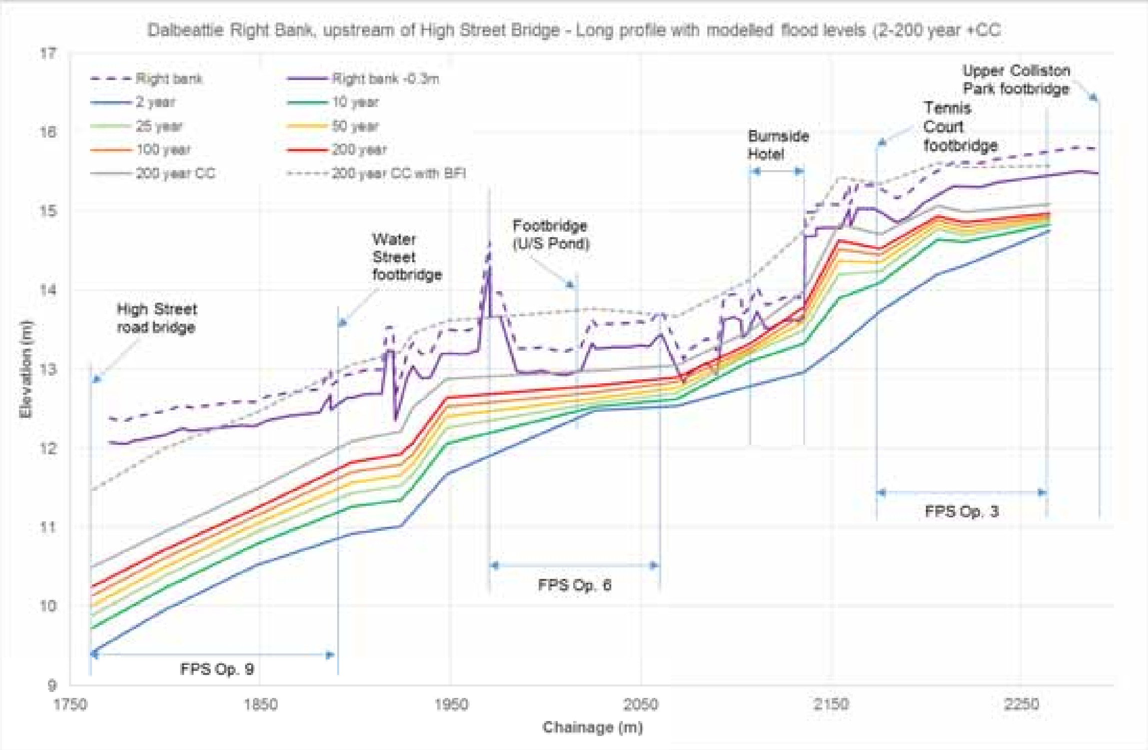
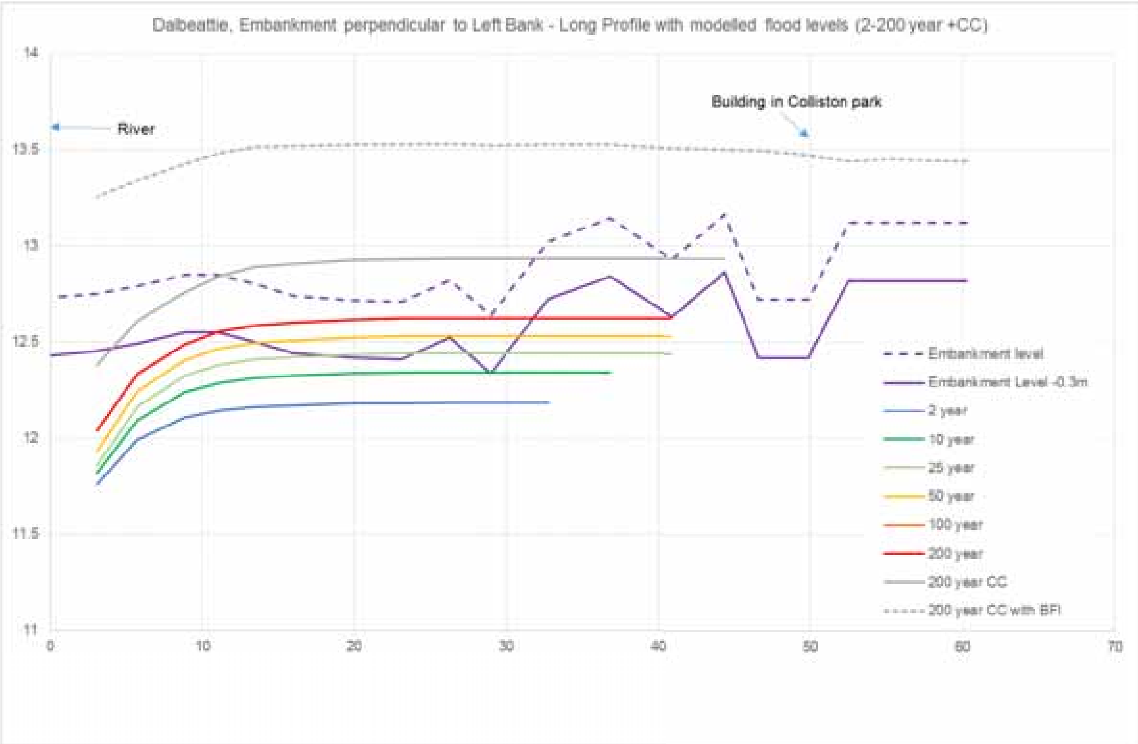


Figure 7-15: Defence height vs. water surface elevation on the Kirkgunzeon Lane in Dalbeattie, upstream of High Street Bridge - Left bank

Figure 7-16: Defence height vs. water surface elevation at FPS Operation 7 on the Kirkgunzeon Lane in Dalbeattie, downstream of pond in Colliston Park - Perpendicular to Left bank



7.7.2 Downstream Kirkgunzeon Lane in Dalbeattie

The modelled flood waters up to the 200 year event with an allowance for climate change are maintained in bank for the majority of the reach downstream of the High Street Bridge in Dalbeattie for both right and left banks. The standard of protection is lower, in the region of the 100 year flood, for the section of the reach on the right bank which is immediately downstream of the FPS Op. 17 embankment. The flood mapping results attained during this study suggest modest amounts of flooding from overtopping in this area even given the 200 year flood with allowance for climate change.

Figure 7-17: Defence height vs. water surface elevation on the Kirkgunzeon Lane in Dalbeattie, downstream of High Street Bridge - Right bank

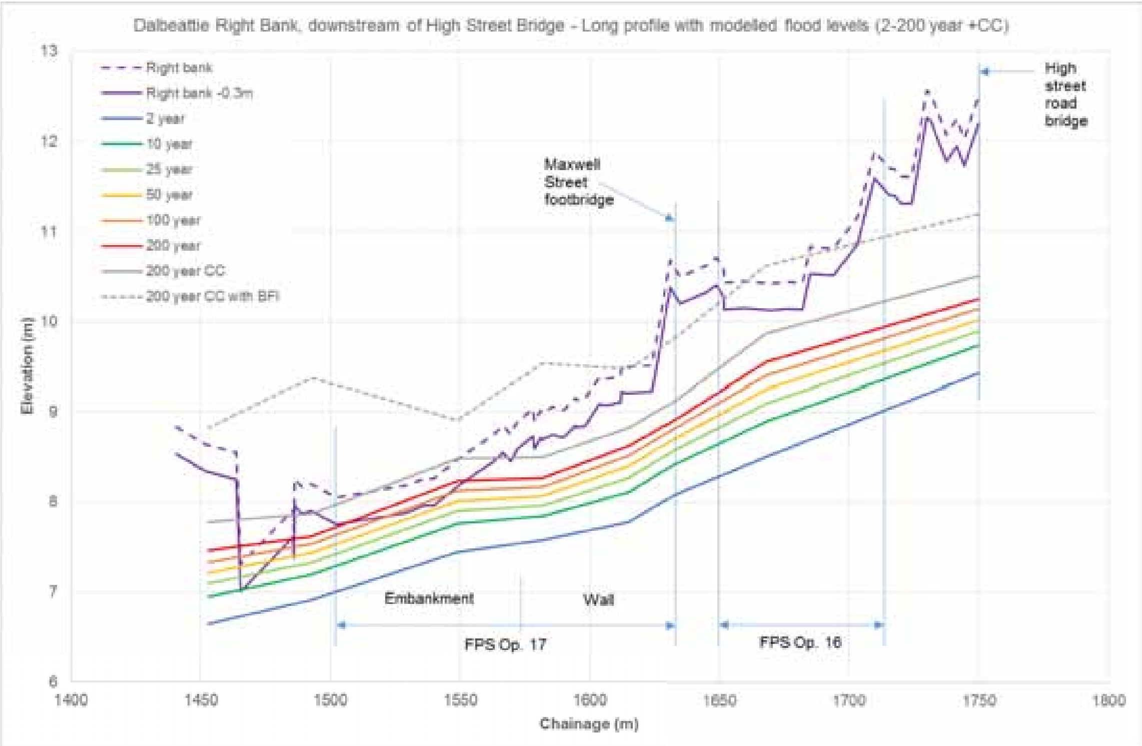
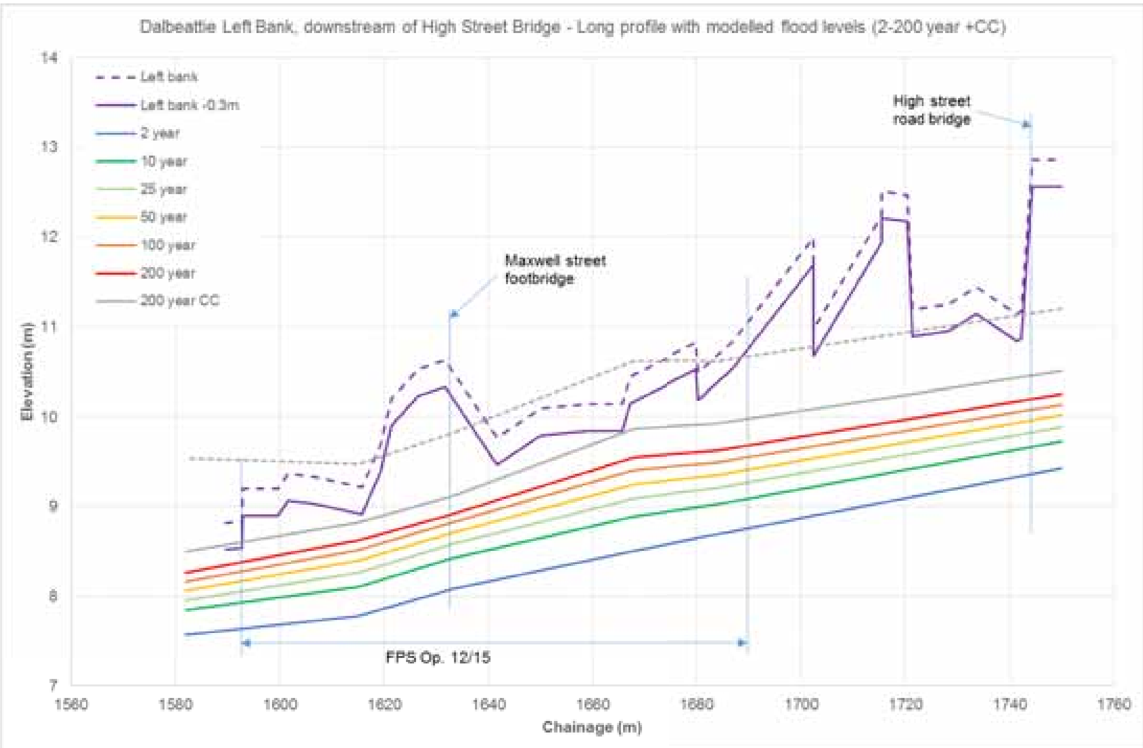


Figure 7-18: Defence height vs. water surface elevation on the Kirkgunzeon Lane in Dalbeattie, downstream of High Street Bridge - Left bank



7.7.3 Edingham Burn

Comparing the modelled water levels against the surveyed defence crest levels suggests that the right bank flood defences on the Edingham Burn have a good standard of protection in the region of the 200 year flood with allowance for climate change and adjusted using the Base Flow Index. This standard of protection does not include a full 300mm freeboard which, if allowed for, reduces the standard of protection to a flood event with a recurrence of approximately 25 years.

Figure 7-19: Defence height vs. water surface elevation on the Edingham Burn in Dalbeattie - Right bank

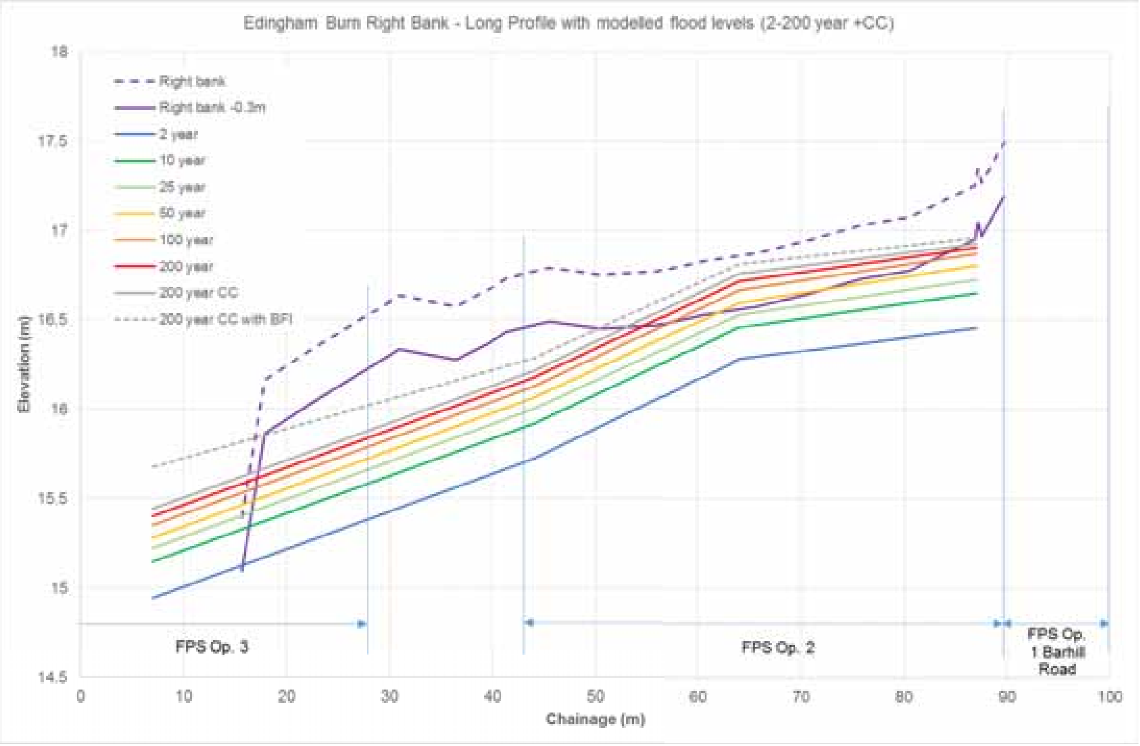
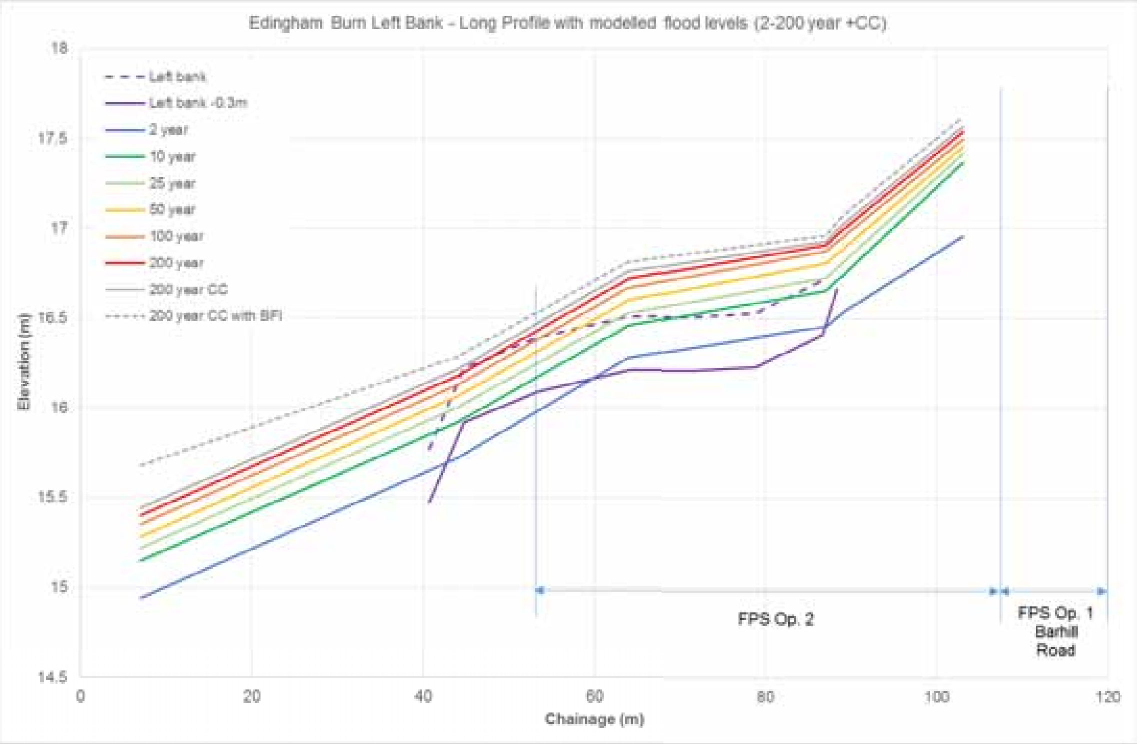


Figure 7-20: Defence height vs. water surface elevation on the Edingham Burn in Dalbeattie - Left bank



The results for the left bank suggest a poorer standard of protection from a modelled 10 year event at the lowest and a 200 year event at the greatest. The flood mapping shows flood water overtopping the banks in this region but not causing significant property flooding compared to the upper Edingham Burn reach which was not surveyed.

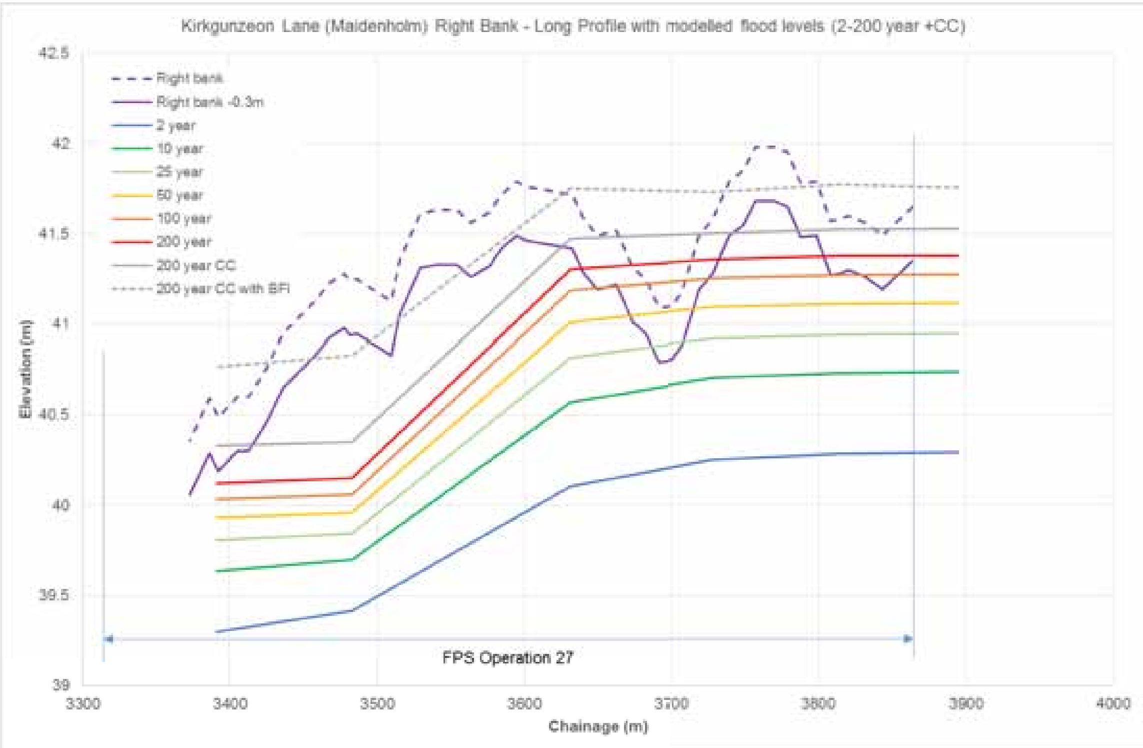
In the model runs the lower Edingham Burn left bank shows water levels below threshold around properties adjacent to the Burn. Given additional protection to the upper Edingham Burn right bank, threshold levels could be approached with increased water levels forced by water remaining in bank.

7.7.4 Maidenholm

Analysis of the modelled water levels along the Maidenholm reach of the Kirkgunzeon Lane suggests that surveyed crests have a general standard of protection in the region of the modelled 200 year flood with an allowance for climate change.

A short section of the reach proximate to Duncan's Pool (a widening of the channel) brings the overall standard of protection down to approximately 50 years (without a full 300mm freeboard allowance). This is in agreement with the flood mapping carried out which shows the 100 year flood overtopping FPS Op. 27 embankment in this location and causing agricultural land to flood.

Figure 7-21: Defence height vs. water surface elevation on the Kirkgunzeon Lane in Maidenholm - Right bank

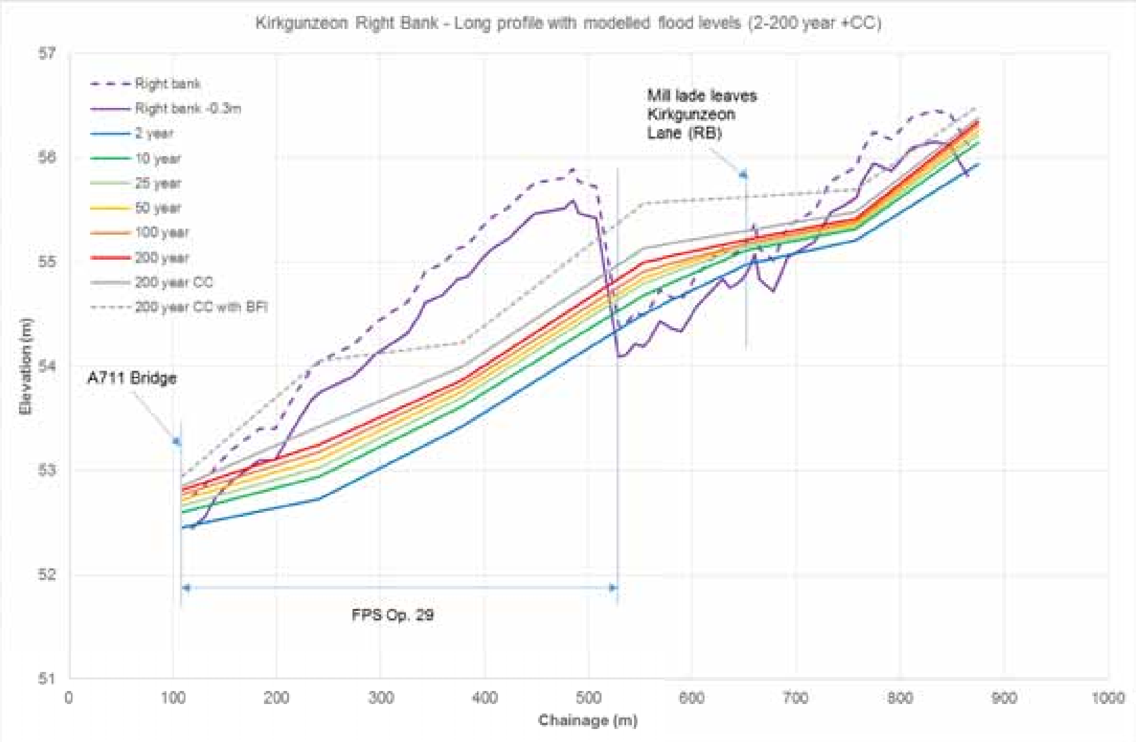


7.7.5 Kirkgunzeon

The surveyed defence crest levels for the right bank in Kirkgunzeon suggest a standard of protection of below 2 years in places, particularly upstream of the disused Mill lade. This is to be expected as this is not part of the flood defences and is a natural flood bank.

The section downstream of the Mill lade, protected by asset 29 has a higher standard of protection in the region of the 200 year flood with an allowance for climate change and inclusion of the Base Flow Index but the standard of protection decreases dramatically downstream, close to the A711 bridge. This is only likely to make agricultural land at risk of inundation. No crest levels were surveyed for the left bank in Kirkgunzeon as there are no flood defences.

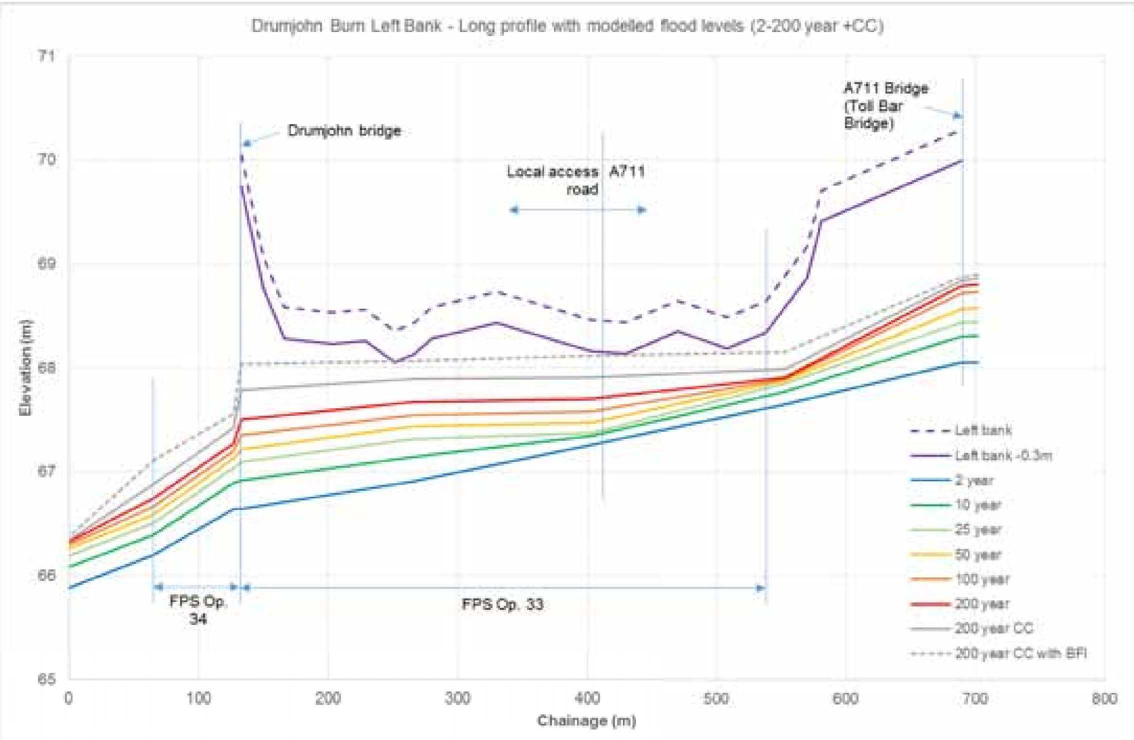
Figure 7-22: Defence height vs. water surface elevation on the Kirkgunzeon Lane in Kirkgunzeon - Right bank



7.7.6 Drumjohn Burn

The defended reach at Drumjohn protected by asset 33 has a very good standard of protection in the region of the 200 year flood with an allowance for climate change.

Figure 7-23: Defence height vs. water surface elevation on the Drumjohn Burn northeast of Kirkgunzeon - Left bank



7.8 Summary of flood risk

The flood risk to Dalbeattie and Kirkgunzeon can be summarised as follows:

- The flood defences have a good standard of protection and in many areas are providing a 200 year standard of protection. Uncertainty in the hydrology for this ungauged catchment should be noted in reference to this standard of protection.
- The majority of flood risk relates to the Edingham Burn. This area was not included as part of the FPS and is at risk from floods in excess of the 5 year flood (i.e. at risk at the 10 year flood).
- Many properties in this Edingham Burn area are have floor levels that are raised above ground levels reducing the impact of the flooding to properties.
- There is no direct overland flow path back to the Kirkgunzeon Lane for flows that are out of bank on the Edingham Burn (due to the flood defence embankments along the Kirkgunzeon Lane). This increases the flood depths locally along John Street.
- Freeboard on many flood defences is suitable. However for some assets at Colliston Park (Asset 7) and at the bowling green (Asset 17) the level of freeboard is insufficient at the 200 year standard of protection. Asset 7 is also in poor condition and would benefit from being raised and improved.
- The impact of climate change exposes the same structures as above to flood risk.
- The modelling has identified a potential flow path from the Maidenholm reach to the north and around Bar Hill and into the Edingham Burn catchment. This is a risk that would only occur at the 200 year flood flow, but should be investigated further.
- Flood risk in the Kirkgunzeon reach is minimal with the embankments present in good condition and with a good standard of protection. Kirkhouse farm buildings in Kirkgunzeon would ideally be protected, as would Corra farm but the type of buildings at risk may well not necessitate immediate action relative to the care home and hotel in Dalbeattie.

8 Urban and surface water flood risk

SEPA's Flood Risk Management Maps show limited surface water flood risks in Dalbeattie. This surface water mapping was carried out using SEPA's national surface water mapping that has not been carried out to the same methodology or detail as the regional mapping undertaken by JBA Consulting. As a result surface water mapping has been re-assessed for this study using the available DTM and the SEPA regional mapping methodology.

SEPA's surface water flood maps were developed by JBA Consulting using JFlow, JBA's in-house 2D modelling software package. JBA has undertaken the same methodology to assess the surface water flood risk to Dalbeattie to help inform flood risk and risk under defended scenarios.

8.1.1 Methodology

JFlow for surface water mapping works on the basis of applying a rainfall event across the entire study area. The chosen rainfall event was the 200 year, 3 hour storm duration. The rainfall event was calculated based on the FEH CD v3 using a point located in Dalbeattie to give appropriate catchment descriptors and rainfall rate. To be conservative the summer profile was chosen as this has a shorter time to peak and is applicable to the urban area of Dalbeattie.

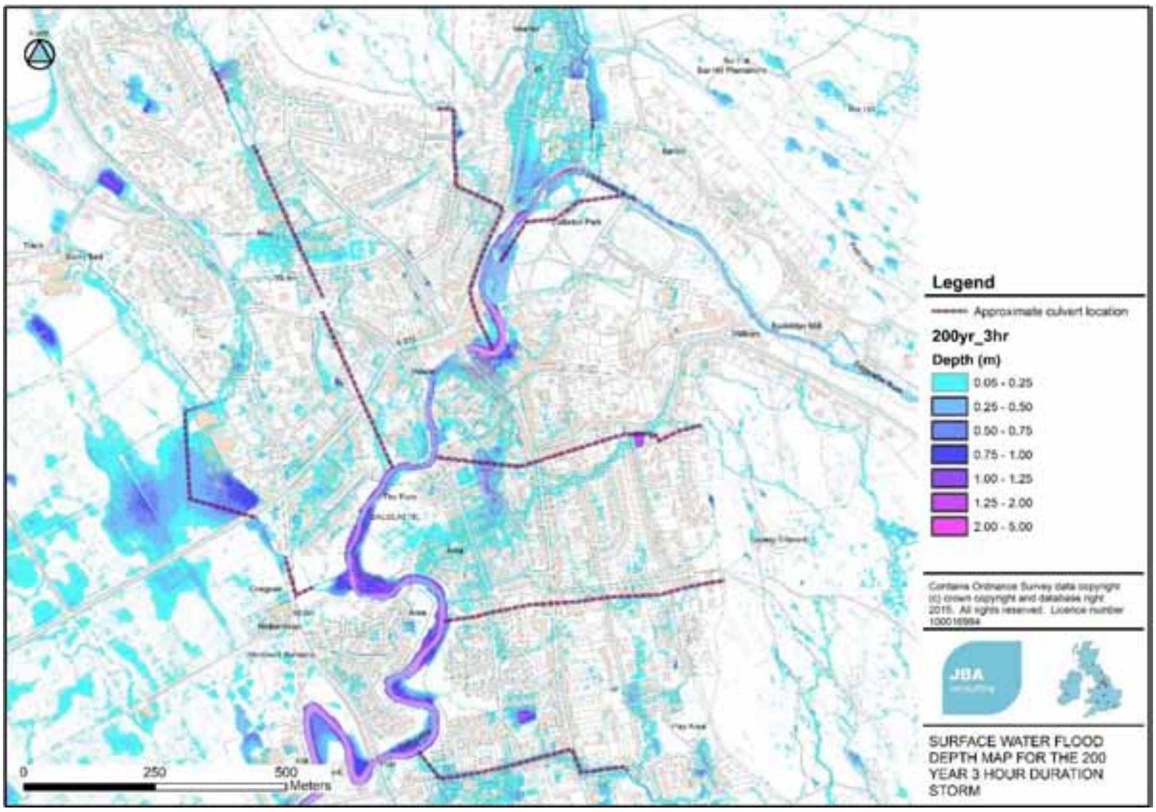
The model was run on a 1m resolution to match the available DTM data. Maximum flood depth and velocities were derived automatically from the 2D modelling. As this type of surface water modelling applies rainfall to every cell, the flood depths derived from the 2D modelling are clipped at a predefined depth (otherwise all cells would be shown as being flooded). The depth typically used is 0.05m.

The mapping is useful to review the flow paths and ponding areas, however it will not necessarily correctly identify all flow paths as the resolution will not pick up key features such as walls, buildings, surface water drainage and kerbs.

8.1.2 Results

The surface water flood map results are shown in Figure 8-1 (also provided as an A3 plan in the Figures section of the report). The results suggest that there is localised ponding in Dalbeattie to depths that could cause a flood risk to properties located close to the Kirkgunzeon Lane.

Figure 8-1: 200 year surface water flood risk for Dalbeattie including the CCTV surveyed culverts



The areas of the model which show greatest surface water flood depths do not closely match with those where pluvial flood events have been recorded, suggesting further detail may be required in the model to determine flow paths controlled by topography on a smaller scale than provided by the LiDAR data used.

The location of culverts correspond to the location of low points and ponding shown in Figure 8-1. In addition, there are a number of flow paths within the town itself and outside the fluvial flood outlines that could cause additional flood risk to the town.

This information is provided to inform future maintenance and operational purposes. No flood mitigation options are considered to deal with the surface water flood risks as part of this report, although the recommendations made in Section 3.2 should be considered.

9 Options for flood mitigation

9.1 Relevant legislation

Local Authorities are responsible for flood management under the Flood Risk Management (Scotland) Act 2009. Under this legislation, Local Authorities have discretionary powers to undertake activities to mitigate against flooding.

9.1.1 Relevant Guidance

Guidance for flood risk management in Scotland is provided within the following documents:

- Flood Risk Management (Scotland) Act 2009: Sustainable Flood Risk Management - Principles of Appraisal: A Policy Statement
- Flood Risk Management (Scotland) Act 2009: Delivering Sustainable Flood Risk Management

Specific guidance on project appraisal is provided in the Scottish Government Flood Protection Scheme - Guidance for Local Authorities document. Only Chapters 5 and 6 of this document are currently available. Chapter 5 which covers the project appraisal guidance (assessment of economic, environmental and social impacts) was updated in February 2012.

Further guidance on Local Authority functions under the Act is available in the Flood Risk Management (Scotland) Act 2009 - Local Authority Functions Under Part 4 Guidance document[7].

9.2 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 flood (1 in 200 year). This standard is the level of protection required for most types of residential and commercial/industrial development as defined by 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%, 1% annual probability and if appropriate a lesser level. The guidance also states that options should be tested against a “1% exceedance probability plus allowances for climate change to be included in all appraisals”.

Based on the above guidance the aim of the scheme will be to assess options up to the 0.5% AP (200 year) flood if possible, but to test lower return period events if required. Each option has been assessed to achieve a:

1. 0.5% AP with an allowance for climate change level of protection
2. 0.5% AP level of protection

9.3 Long list of options

The following table provides an overview of potential flood alleviation options that could benefit Dalbeattie and the upstream area of Kirkgunzeon. Overall the analysis of the flood risk suggests that the main town of Dalbeattie and the village of Kirkgunzeon are well protected from river flooding by the existing flood defences. As a result, limited mitigation measures are required other than continued inspection, maintenance, flood warning, community awareness/self help and emergency planning.

The most significant risk is from the Edingham Burn where limited flood mitigation works were applied as part of the original FPS. In this location, additional measures would be beneficial to reduce the flood risk.

[7] The Scottish Government, Flood Risk Management (Scotland) Act 2009 - Local Authority Functions Under Part 4 Guidance, July 2015: http://www.gov.scot/publications/2015/07/7909/0

Those that are considered to be most viable have been assessed further in Section 6.

Table 9-1: Available flood alleviation options for Dalbeattie

Category	Measure / Action	Discussion
Avoid	Relocation	Relocation is not a widely used method of flood mitigation in the UK partly due to the fact that the HM Treasury's economic appraisal methodology limits flood damages to the market value of the property. *Decision: Unlikely to be economically or socially viable at this stage. Option not progressed further.*
Prepare	Flood warning	Flood warning is not currently available for Dalbeattie other than as a regional flood alert from SEPA. Provision of flood warning in this catchment with sufficient lead time would be challenging and limited without some gauging of the river flows. Discussions with SEPA suggest that they are planning to extend coverage of flood warning for this catchment in the future In the longer term, we would recommend that discussions are held with SEPA to install river flow gauges within the catchment to start collecting the necessary information to support future flood warning and forecasting. This will also have secondary benefits of improving the long term hydrology estimates and any property level protection offered by the Council. *Decision: Viable option that should be assessed further through discussions between SEPA and D&G Council*
	Resistance	Flood resistance measures help mitigate floodwater from entering a building using a variety of techniques and products. Resistance measures such as airbrick covers and door guards are not currently provided by the Dumfries and Galloway subsidy scheme but the inclusion of Dalbeattie in this scheme, particularly for two large commercial properties has the potential to reduce the risk of damages considerably. This is discussed further in the section below. *Decision: Viable option that should be assessed further.*
	Resilience (retrofit)	Flood resilience measures reduce the consequence of flooding and accept that flooding into a property can occur, but can be managed and cleaned rapidly after a flood with minimal disruption and temporary accommodation. These measures are usually only viable if they are undertaken after a flood event and as part of the repair process. *Decision: Unlikely to be economically viable at this stage. Option not progressed further.*
Protect	Natural Flood Management	Natural flood management options have been considered in a separate report. Natural flood management options should focus on the catchment rather than single sites such as Dalbeattie. In the wider catchment there is some potential for floodplain storage and increasing channel sinuosity to lower channel water levels, however many good practices are already being employed by land owners and land managers. *Decision: To be considered alongside other options rather than alone.*
	Demountable defences	Demountable defences are linked to the availability of adequate flood warning and are typically used where direct defences are impractical, uneconomic or environmentally / aesthetically unacceptable. Temporary or demountable defences in Dalbeattie will unlikely

Category	Measure / Action	Discussion
		to be technically or practically suitable due to the long length of defences required, the short lead time and large staff numbers required to install. *Decision: Unlikely to be a practical option. Option not progressed further.*
	Direct defences	Direct defences are unlikely to be of use for the majority of the study area however the properties alongside and downstream of the Edingham Burn could benefit from the installation of defences to alleviate a large proportion of the modelled flooding in this area. *Decision: Viable option that should be assessed further.*
	Upstream storage	Upstream storage would have multiple benefits for flood risk throughout the catchment. However, there are many technical, environmental and economic constraints associated with damming the watercourse. As the standard of protection in the town is relatively good this option has not been considered as the costs would exceed the damages avoided by any scheme. *Decision: Unlikely to be a practical or cost-effective option unless combined with a Natural Flood Management scheme.*
	Channel modification	Channel modification as an independent option is unlikely to provide the benefits of flood protection. The options for channel widening are extremely limited and constrained by existing bridge crossings, existing defences and riparian ownership boundaries. *Decision: Unlikely to be a practical option. Option not progressed further.*
	Diversion	There is no scope for channel diversion around the town of Dalbeattie. *Decision: Unlikely to be a practical option. Option not progressed further.*
	Bridge adjustments	The current standard of protection for the bridges on the modelled watercourses is good, thus any adjustment to these is unlikely to reduce the flood risk further. *Decision: Unlikely to significantly reduce flood risk. Option not progressed further.*

9.4 Options in relation to SEPA Flood Risk Management Strategies

The Act places responsibilities on various authorities including SEPA, Scottish Water and Local Authorities to work collaboratively to responsibly and sustainably seek to reduce flood risk from all sources. The Scottish Environment Protection Agency (SEPA) and 14 lead local authorities are jointly consulting on the future direction and delivery of flood risk management in Scotland. Together, they are focusing on where the flooding impacts are greatest and where the benefits of investment can be maximised.

SEPA have recently published their Flood Risk Management Strategies (FRMS) in association with local authorities. These provide prioritised actions for flood mitigation in each PVA to allow the careful reduction of risk in a holistic way at a catchment level. This report achieves one of the actions identified by the FRMS and provides a more detailed assessment of the risks and options for mitigation than the SEPA strategy. The recommendations of this report will need to be fed into the wider SEPA Strategy and Local Flood Risk Management Plans.

9.5 Recommendations and quick wins

Overall the FPS assets are in good to fair condition but could benefit from minor upgrades, more regular inspection and maintenance of some elements.

There may be a number of short term or small scale measures that could benefit the town of Dalbeattie from future flooding. A number of different types of measures or short term 'quick wins' have been identified that cover a range of aspects from maintenance to small scale works. These are summarised in Table 9-2 and referenced geographically in Figure 9-1 and Figure 9-2 (also provided as an A3 plan in the Figures section of the report).

Figure 9-1: Location reference plan for recommendations and quick wins identified in Table 9-2.

Figure 9-2: Location reference plan for recommendations and quick wins identified in Table 9-2.

Table 9-2: Short term recommendations and quick wins

Ref.	FPS asset ref.	Problem	Action	Evidence
1	-	Regular water gates along channel increase potential of blockage	Consider removal or replacement with electric water gates to reduce risk of blockage. Consider telemetry or inspection to mitigate risk of blockage	
2	2, 9	Consider vegetation management	Manage vegetation to maintain conveyance	

Ref.	FPS asset ref.	Problem	Action	Evidence
3	3	Erosion of concrete sill on right bank adjacent to Munches Park	Monitor erosion	
4	5	Screen is not in line with current design standards, potential for blockage	Replace screen with one which meets current design standards	
5	-	Unflapped outfalls present along the Dalbeattie Burn	Check condition/presence and add/replace flap valves if necessary	Multiple outfalls present
6	-	Potential flow route onto John Street given 200 year + climate change flood event	Consider raising garden wall alongside burn and/or using outer perimeter garden wall as flood defence wall in longer-term	
7	7	Flood defence wall/embankment not fit for purpose	Consider repair or upgrade to embankment	
8	12, 15	Leylanddii growth between sections of flood defence wall	Monitor tree growth and structural impacts on defence wall	

Ref.	FPS asset ref.	Problem	Action	Evidence
9	14	Channel overgrown	Periodic maintenance of vegetation within channel	
10	17	Inconsistent defence level	Consider extending defence line behind bowling green	
11	26	Culvert barrels are approximately 50% blocked with sediment	Sediment management	
12	27	Vegetation growth on river side	Maintain embankment and monitor vegetation growth	
13	29	New pipe (unflapped) through culvert. Informal rock outfall added	Investigate pipe and fit flap valve. Consider removal or construction of headwall and flapvalve.	
13a	29	Risk of bypassing of flood embankment	Fit sluice gate on to inlet of pipe through culvert to prevent excessive flows bypassing embankment.	

Ref.	FPS asset ref.	Problem	Action	Evidence
14	30	Flap is stuck open by debris and bed material	Maintain flap valve, clear channel downstream, set up regular inspection regime	
15	-	Raised embankment by local landowners using dredged material - potential for impact on flood levels	Monitor dredging and embankment raising. Consider discussion with SEPA regarding CAR licence.	
16	-	Channel widening by local landowners	Monitor for possible channel instabilities and erosion. Consider discussion with SEPA regarding CAR licence.	
17	31	Channel overgrown and loose material on right bank has potential to block culvert	Channel maintenance and removal of loose material	
18	31	Screen could become overgrown	Review maintenance and access regime for screen	

Ref.	FPS asset ref.	Problem	Action	Evidence
19	33	Embankments could become overgrown	Maintain embankments	
20	33	Embankment access point lower than general crest level	Monitor level change at access point	
21	-	Screen on downstream face of bridge does not allow removal of blockages during flood events	Move screen to upstream face	
22	-	Watergate beneath A711 road bridge is in middle of bridge - poor access	Consider removal or moving watergate to somewhere with improved access	

10 Short list of options

The selected short list of options have been assessed in more detail and included within the economic appraisal. Further details on each are provided below.

10.1 Do Nothing

The Do Nothing represents the 'walk away' scenario, cease all maintenance and repairs to existing defence and watercourse activities. This represents a scenario with no intervention in the natural processes. The 'Do Nothing' option is used within the appraisal as a baseline and a means of calculating the whole scheme benefits of the 'Do Something' option.

The Do Nothing option is not technically a viable option in Dalbeattie due to the presence of existing defence assets that the Council has a duty to maintain. Furthermore, the Council also has a duty to assess bodies of water and schedule works of clearance and repair if these would substantially reduce risk of flooding under the Flood Risk Management (Scotland) Act 2009.

10.2 Do Minimum

The 'Do Minimum' option represents the current situation with ongoing maintenance of the watercourse, channel banks and defence assets. This assumes that no blockage (other than permanent fixtures) are present on any structure.

10.3 Option 1 - property level protection

Property Level Protection (PLP) is flood resistance and resilience measures however it generally takes the form of demountable door guards and air brick covers. Dumfries and Galloway employs a subsidy scheme that would be used to implement this option. Under this scheme, residents can purchase PLP products from the Council at a subsidised rate.

Figure 10-1: Examples of PLP (automatic airbrick and door guard)

PLP products are generally considered reliable up to a depth of 0.6m due to structural integrity of buildings. Therefore, to assess the feasibility of PLP the number of properties at risk from direct flooding and those that could benefit from installation of PLP products are displayed in Table 10-1. The table below shows that for the 200 year flood, 16 properties could benefit from PLP, although one has a flood depth that exceeds the standard 0.6m depth (although only marginally at 0.64m). Careful selection of products may be needed for this property, and in the very least a survey of the property would be required.

The table also shows that many properties would only require very margin low cost options to protect against inundation as many are predicted to flood below the threshold only. In these instances automatic air-bricks alone may be appropriate to protect the homes (garages and outbuildings may require additional protection however). This is particularly the case for the 200 year flood where 12 properties could be protected for by relatively low cost measures.

As the standard of protection to residential properties is high (50 year SOP), the implementation of PLP would need to be combined with education for homeowners, regular trial runs and exercises to ensure that the community can manage and respond adequately to flood events. This would be a challenge over the long term for this site where flood risk is relatively low.

The two properties modelled to be at risk at lower return periods are the Burnside Hotel and the Munches Park House (a care home). Specialist surveys and advise may be required to provide property level protection for these two larger properties.

Table 10-1: Number of properties at risk and protected

Scenario	10 year	25 year	50 year	100 year	200 year	200 year CC	1000 year
Properties at risk (above floor level)	2	2	2	3	4	28	41
Properties at risk (below floor level)	3	3	3	9	16	51	88
No. properties at risk with PLP assuming a 0.6m limit	0	0	0	0	1	1	3
The property counts represent both residential and commercial properties and include all properties flooded above the surveyed floor level and to a depth 300mm below the floor level (sub floor or solum flooding).							

Furthermore, specific flood warning and forecasting would be required on the catchment to provide the necessary lead time for the community to react to flood warnings. If this cannot be implemented (indeed, there are challenges to providing adequate lead times on a small catchment), an automatic approach to PLP may be preferable. Automatic PLP products aim to be passive and do not require homeowner intervention prior to a flood. The downside of these products is that they are more expensive and may not be available via the Dumfries and Galloway subsidy scheme.

Outcome: Until flood forecasting can be provided an automatic PLP approach is preferred. Benefits and costs of this option to be assessed.

10.3.1 Lower cost PLP option

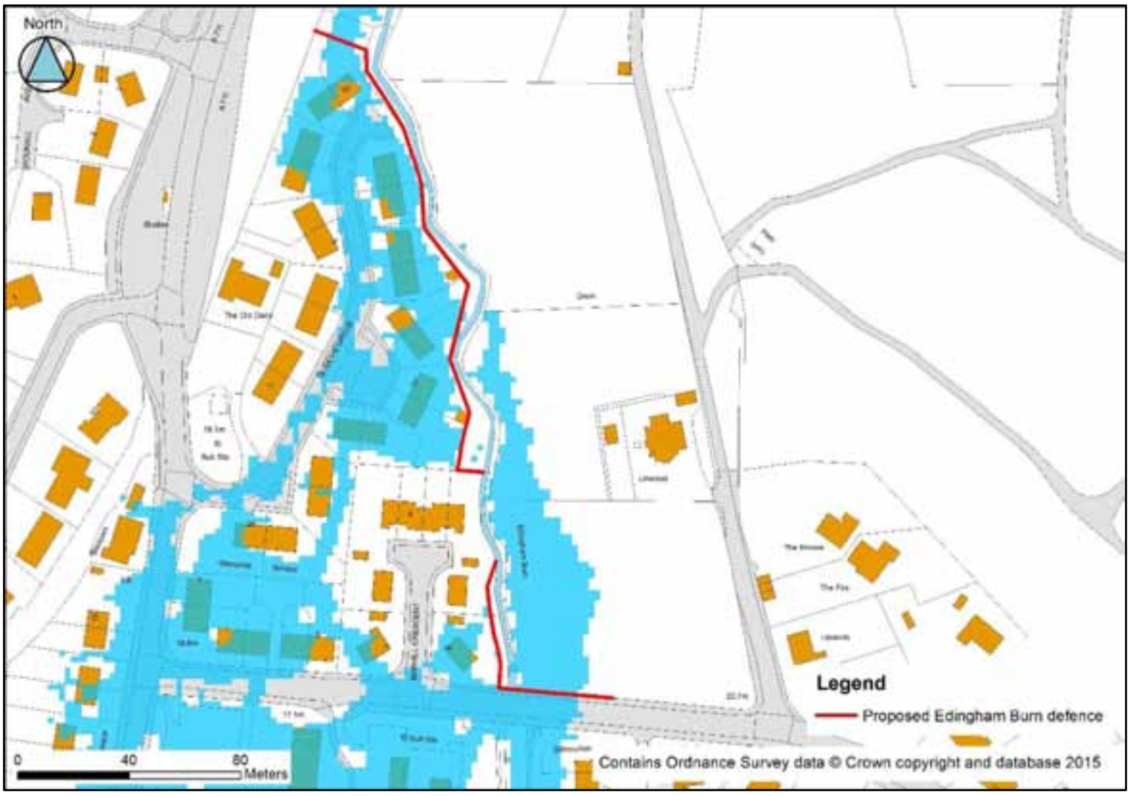
The above approach is the preferred recommendation for implementation of PLP in Scotland based on Scottish Government guidance. However it does not take into account the Council's current subsidy scheme for PLP products. The use of this scheme could achieve many of the flood benefits stated above at a lower cost. However, the approaches provided are generally manual approaches that require installation prior to a flood. Such an approach therefore would require some form of flood warning, although this could be provided by the Council in the absence of any SEPA gauging and catchment flood warnings.

10.4 Option 2 - Raised flood defences along Edingham Burn to provide a 1 in 200 year standard of protection

The majority of the flood risk emanates from the Edingham Burn reach which is not protected by any flood defences in the upper urban reach. All of the properties at risk at the 200 year flood are at risk from the Edingham Burn. This is the same for the 200 year flood with an allowance for climate change, although some additional out of bank flows are predicted for this event (but no additonal properties).

Based on the modelling undertaken, direct defences could be constructed to the right bank of the Edingham Burn in the form of a sub-1.2m stone or concrete wall. A wall would be the preferred option here to avoid encroachment into gardens by embankments, although some form of channel realignment/widening could also be used to reduce the land take on the right bank. Figure 10-2 shows the indicative location of the new walls that would need to be constructed along the right bank of the Edingham Burn.

Figure 10-2: Proposed defence location along Edingham Burn to protect a large area of northern Dalbeattie



It should be noted that the above analysis assumes no additional flows from the Kirkgunzeon Lane and the bypass route around Bar Hill (see Section 7.2.1). Further analysis is required of this risk at detailed design stage. However, we would recommend that either a secondary embankment is built to prevent this flow path or the additional flows are considered as part of the design or within the freeboard allowance.

10.5 Option 3 - Option 2 plus improvements to Asset 7 and Asset 17

A potential flow route has been identified over the wall/embankment in Colliston Park at the upper end of Asset 7 (see Appendix B) on the left bank of the river. The wall currently has a standard of protection of 200 years, with extremely limited freeboard.

Repair and raising of this wall is priority to protect properties directly downstream of Colliston Park in Dalbeattie for events in excess of the 200 year flood and to incorporate climate change. The proposed changes would entail raising the wall by up to 0.6m to provide a standard of protection of 200 years with an allowance for climate change.

Current defences have been found to be incomplete around the bowling green in Dalbeattie, downstream of Asset 17 (right bank). This area has a 200 year standard of protection based on the existing flood defences. With an allowance for climate change, the area is predicted to be at risk with flood depths in the order of up to 0.4m, however the bowling green and the clinic to the north both have floor levels above the predicted flood levels.

Technically, flood risk to the properties is therefore minimal, although there would be clean up and repair costs associated with the car park and the bowling green. This however is unlikely to justify an increase in the flood defence height to provide a 200 year standard of protection with an allowance for climate change.

If this area was to be protected a new wall would be recommended to increase the height of the current embankment and to extend the embankment downstream to limit flows leaving the channel. A wall of up to 0.5m height would provide a standard of protection of 200 years with an allowance for climate change.

To summarise, in order to provide a 200 year standard to Dalbeattie with an allowance for climate change the following works would be required:

- Flood defences on the Edingham Burn as per Option 2.
- Raised wall/embankment at Colliston Park.

10.6 Summary of options assessed

Based on the long list and short list appraisal of options assessed above we recommend that the following options are considered further in the economic appraisal:

- Do Minimum.
- Option 1 - Property Level Protection.
- Option 2 - 200 year SOP for Edingham Burn.
- Option 3 - 200 year SOP with an allowance for climate change for Edingham Burn and the rest of Dalbeattie.

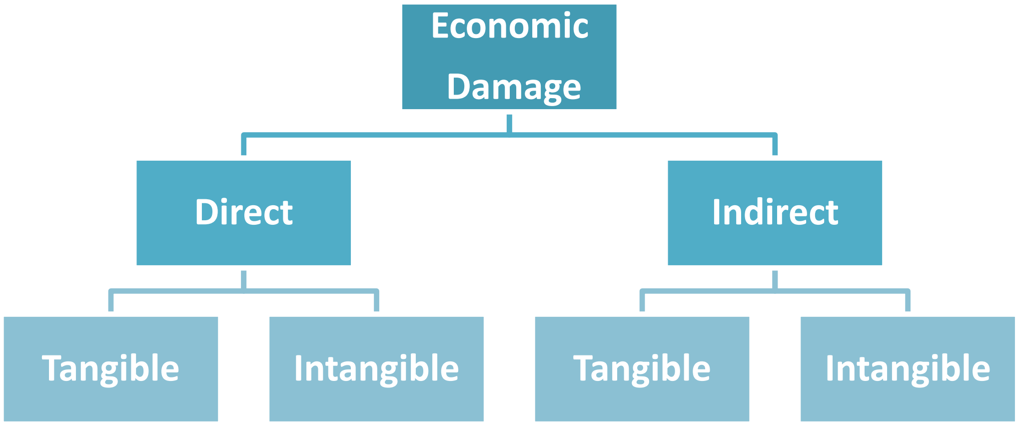
It should be noted that whilst the flood defence at Maidenholm has a lower standard of protection than the preferred 200 year flood, this defence only protects agricultural land as is not considered in need of improvement (notwithstanding the risk of bypassing of flows around Bar Hill).

Flood risk to the Kirkgunzeon village is minimal as the flood defences present offer a good standard of protection. The Kirkhouse farm buildings in Kirkgunzeon would ideally be protected as would Corra farm but the type of buildings at risk may well not necessitate immediate action as they have a good standard of protection and may be relatively resilient to flooding.

11 Damage methodology

Flood damage assessment can include direct, indirect, tangible and intangible aspects of flooding, as shown in the Figure 7-1. Direct damages are the most significant in monetary terms, although the MCM and additional research provide additional methodologies, recommendations and estimates to account for the indirect and intangible aspects of flood damage.

Figure 11-1: Aspects of flood damage



Flood damage estimates have been derived for the following items:

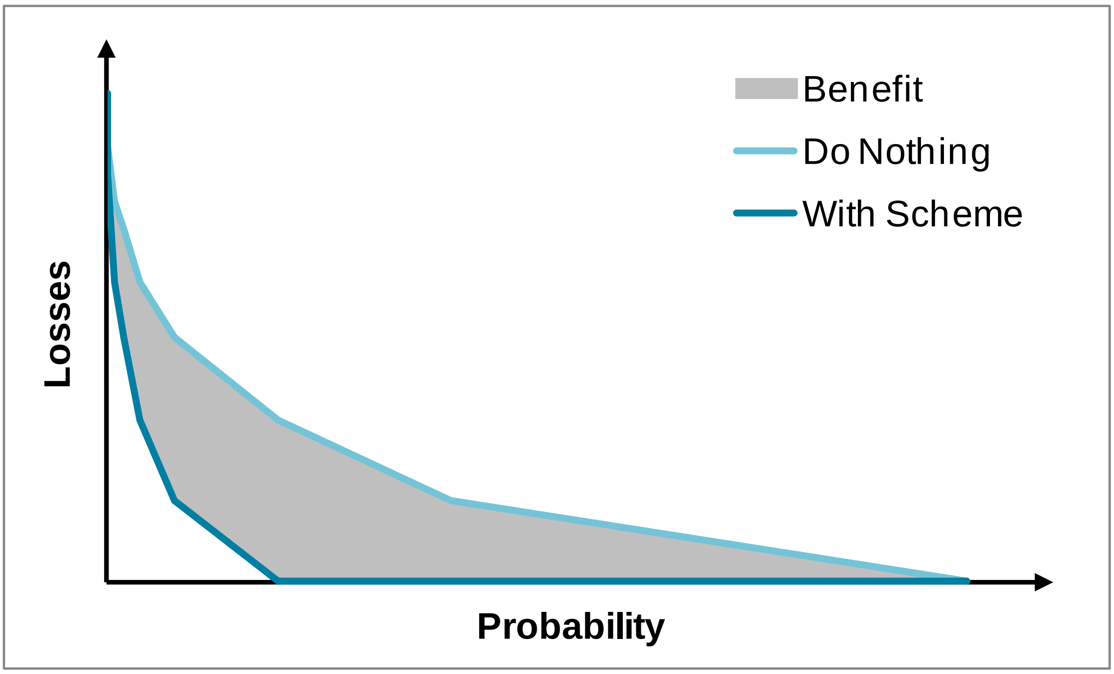
1. Direct damages to residential properties;
2. Direct damages to commercial and industrial properties;
3. Indirect damages (emergency services);
4. Intangible damages associated with the impact of flooding;
5. Damage to vehicles;
6. Emergency evacuation and temporary accommodation costs.

The following assumptions and additional data were used to improve and provide the necessary information to supplement the above datasets.

11.1 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 7-2. 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 then 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 11-2: 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.

11.1.1 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 building floor's area) flood damage estimates have been calculated and are presented in Table 8-2.

The following assumptions, presented in the Table 8-1, were used to generate direct flood damage estimates.

Table 11-1: 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 2013 MCM codes applied.	Best available data used.
Upper floor flats	Upper floor flats have been	Whilst homeowners may be

Aspect	Values used	Justification
	removed from the flood damage estimates.	affected it is assumed that no direct flood damages are applicable.
MCM damage type	MCM 2013 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 2013 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.
Socio-economic equity	Distributional Impacts (DI) impacts derived from the 2001 census show no significant difference in "DE" social grades compared to the national average.	As per Treasury Green Book recommendations, analysis of DI is not deemed to be necessary and has been excluded.
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.

11.1.2 Property data set

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

11.1.3 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 Dalbeattie were obtained from the Scottish Assessors Association website[8]. Equivalent yield varies regionally and temporarily, but is recommended to be a value of 10-12.5 for flood defence purposes[9]. A value of 12.5 was used.

However the resulting property valuations were judged as been undervalued. An alternative approach was used where by 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.

11.1.4 Updating of Damage Values

The MCM data used is based on January 2015 values and therefore do not need to be brought up to date to compare the costs and benefits.

[8] www.saa.gov.uk
[9] Environment Agency (2009). Flood and Coastal Erosion Risk Management - Appraisal Guidance.

11.1.5 Socio-economic equity

Work on the impacts of flooding on individuals has shown that flooding may affect people according to aspects such as their income. The rationale being that a loss will matter more to a person on low income compared to someone with a high income. Current advice from the Scottish Government, based on advice from the Treasury Green Book recommends that Distributional Impacts (DI) analysis should be undertaken if it is 'necessary and practical'. Analysis has been carried out with and without the influence of Distributional Impacts.

Assessing whether it is necessary is based on the mix of social grades and levels of income within the appraised area. Analysis of the 2001 Census data for Dalbeattie indicates that there are a high proportion of lower social group households. Table 11-2 illustrates this proportion and indicates that 31% of people in Dalbeattie are in the 'DE' social grade. This is more than the Scottish average but very similar to the average for Dumfries and Galloway, thus the analysis of DI is deemed not to be necessary.

Table 11-2: Proportion of social grades within Dalbeattie

Location	AB	C1	C2	DE
Dalbeattie	11%	25%	33%	31%
Dumfries & Galloway	14%	25%	32%	30%
Scotland	19%	31%	24%	26%
Difference	-3%	0%	7%	5%
The total number of people represents those aged 16+ for which a grade can be applied.				

The above analysis suggests that if comparing Dalbeattie with another area requiring funding, the socio-economic aspects of flooding should not be considered as a pound spent at Dalbeattie is unlikely to have a greater benefit than that spent at an alternative location with a lower social impact.

We recommend that distributional impacts are not considered at this stage and the recommended scaling of the total damages by the social grade weighting factors provided in Table 7-4 is not undertaken.

Table 11-3: Total weighted factors by social grade group

Class	AB	C1	C2	DE
Weighting	0.74	1.12	1.22	1.64
Factors are provided in Chapter 5 (section 4.1.22) of the Scottish Government's Flood Prevention Scheme guidance document.				

11.2 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.

11.3 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.

11.3.1 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 (2013)[10] 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.

11.3.2 Vehicle losses

Chapter 4, Section 4.5.7 of the MCM (2013) recommends that the average loss associated with vehicle damage during flood events should be determined using a value of £3,600 per property flooding to a depth greater than 0.35m. This value has been applied to all properties flooding to a depth greater than 0.35m within Dalbeattie for each return period flood event assessed and the AAD and PVd calculated as normal.

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

12 Summary of total flood damages

12.1 Properties at risk

The total number of properties inundated for the Do Minimum Scenario has been assessed are provided in Table 12-1.

Table 12-1: Number of properties flooded within appraisal area for the Do Minimum Scenario

	2 year	10 year	25 year	50 year	100 year	200 year	200 CC year	1000 year
Residential	0	0	0	0	1	2	11	14
Non-residential	0	2	2	2	2	2	17	27
Total	0	2	2	2	3	4	28	41

12.2 Do Minimum event damages

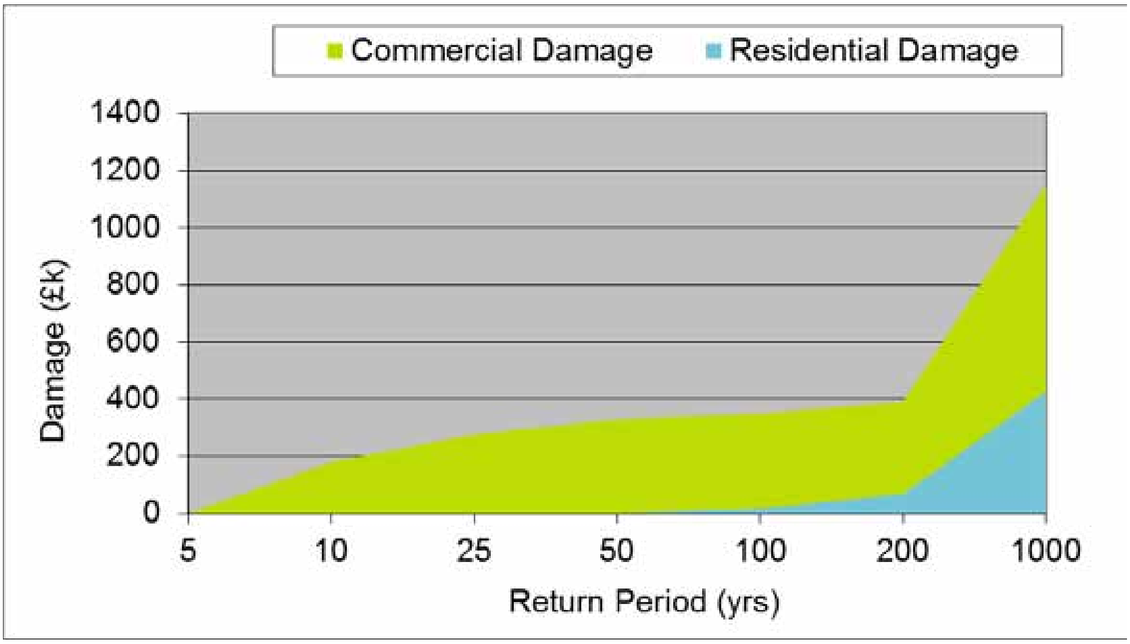
Event damages have been calculated for a range of return periods. JBA's damage calculation spreadsheets provide event damages based on MCM depth damage curves. Full results are provided in Appendix H. The event damage for each option is provided in Table 9-2. These represent the total potential flood damages based on the modelled flood levels for Dalbeattie for the current existing case. Damages include all direct and indirect property flood damages.

Table 12-2: Total property flood damage for each scenario (£) (prior to capping)

	10 year	25 year	50 year	100 year	200 year	1000 year
Residential	2	2	2	17	67	427
Non-residential	179	277	329	349	390	1150
Total	181	278	331	366	457	1577

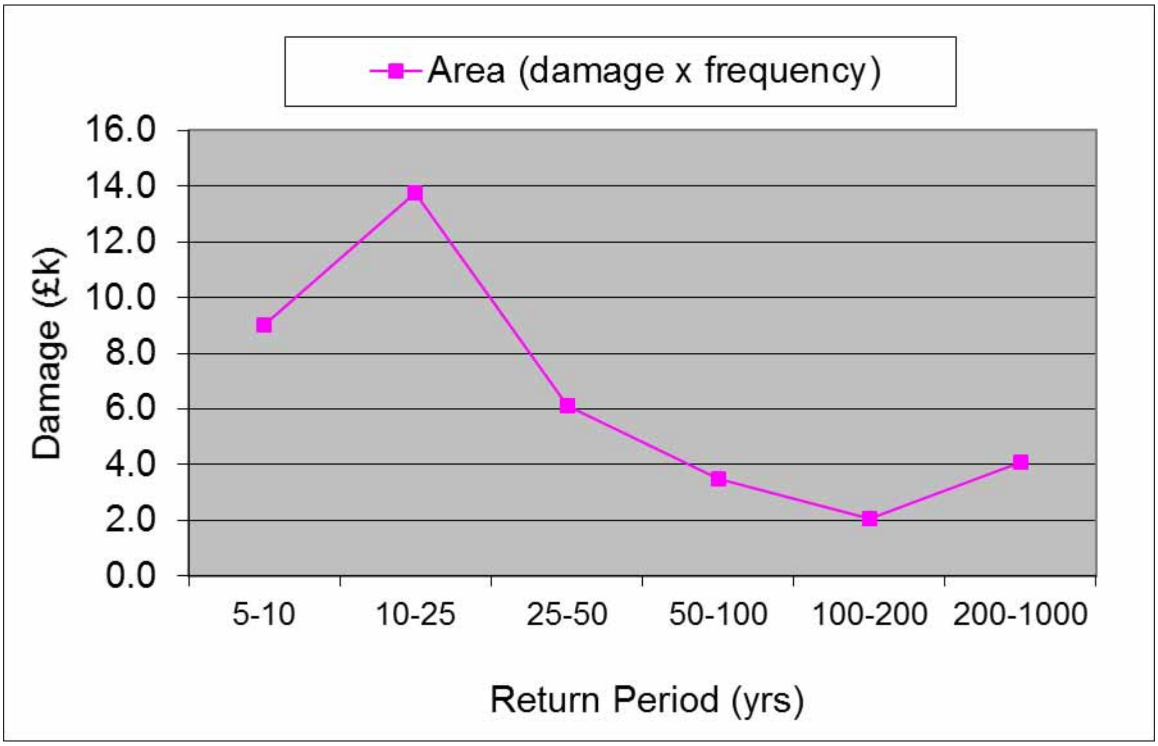
The above damages are used to calculate Annual Average Damages (AAD). Plotting the damages against the frequency of flooding (annual probabilities) allows us to determine the AAD as the area beneath the curve (Figure 12-1). This figure shows that flood damages are relatively small for the lower to medium flood events, but rises significantly once the flood defences are exceeded.

Figure 12-1: Loss probability curve for the Do Minimum baseline



Typically, the majority of the benefits arise from the reduction in losses from the more frequent events. The interval benefits for Dalbeattie are presented in Figure 12-2. This shows that the much of flood damages occur at the more frequent flood events - those properties at risk from the Edingham Burn.

Figure 12-2: Interval benefits for the Do Minimum baseline



12.2.1 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 10 properties with highest flood damages from all sources have been listed in Table 12-3 below.

This illustrates that the highest flood damages are generated from predominantly 2 commercial properties accounting for approximately 90% of the total damages. Further discussion with these property owners may be useful to determine if they have been flooded in the past from the Edingham Burn. A lack of evidence of flooding may suggest that the flood mapping is overestimating the risk to these properties or that surface water drainage not considered by the 2D modelling is alleviating some of the flood risk in this overland flow path.

Table 12-3: Top 10 highest damage contributors for the Do Minimum Scenario

Rank	Property address	PVd (£k)	Percentage of total PVd
1	Munches Park House, Barhill Road, Dalbeattie. DG5 4JB	655.4	55%
2	Burnside Hotel, John Street, Dalbeattie. DG5 4JJ	411.1	34%
3	Waterside, John Street, Dalbeattie. DG5 4JJ	23.2	2%
4	56-60 High Street, Dalbeattie. DG5 4AA	7.4	1%
5	Ferguslea, Burn Street, Dalbeattie. DG5 4AE	6.1	1%
6	15A High Street, Dalbeattie. DG5 4AD	6.1	1%
7	Miromar, 9 Queen's Grove, Dalbeattie. DG5 4JG	5.9	0%

8	32 High Street, Dalbeattie. DG5 4AA	5.2	0%
9	Dalbeattie and District Day Centre, Burn Street, Dalbeattie. DG5 4AE	5.0	0%
10	24 High Street, Dalbeattie. DG5 4AA	4.0	0%

12.2.2 Summary of Do Minimum Indirect and intangible damages

The indirect and intangible damages have been estimated for the Do Minimum option based on the methodology outlined in the Chapter 11. A summary of the proportion of total damages by each damage component is provided in Figure 9-3 and in Table 12-4.

Figure 12-3: Total PV damages for the Do Nothing by damage component (£k)

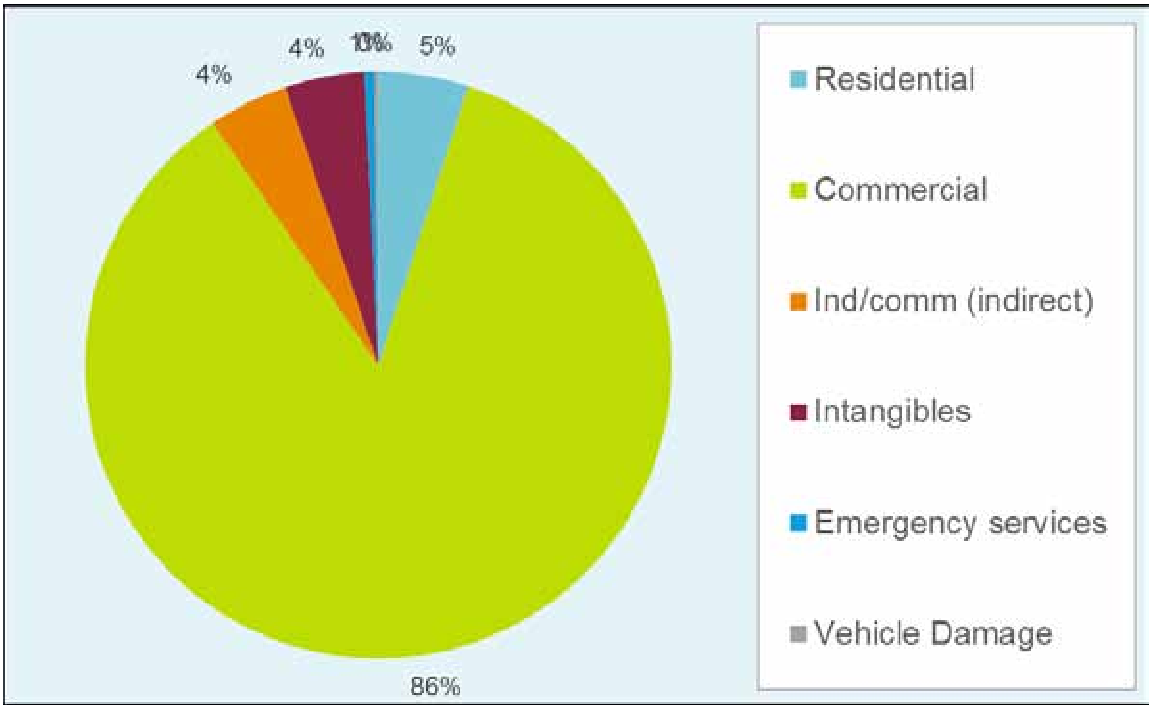


Table 12-4: Do Minimum flood damage (£k)

Scenario	Property AAD	Property PVd	Indirect PVd	Intangible PVd	Total PVd
Flood damages	40.1	1,196	68	58	1,322

12.3 Option 1 - Property Level Protection Damages

Analysis of the property level protection option has been assessed by reducing flood damages for those properties at risk (most are predicted to flood to depths less than 0.6m, with a maximum of 0.64m). The total flood damages for each modelled return period is presented in Table 12-5. One property is excluded from the scheme as it is outwith the Edingham flood risk zone (at Forgewood).

Table 12-5: Comparison of Do Minimum and PLP properties at risk and direct property damages (£k)

Scenario	10 year	25 year	50 year	100 year	200 year	1000 year
Do Minimum - properties at risk	3	3	3	9	16	88
PLP Option - properties at risk	0	0	0	1	1	88
Do Minimum - flood damages	181	278	331	366	457	1,577

Scenario	10 year	25 year	50 year	100 year	200 year	1000 year
PLP Option - flood damages	0	0	0	2	2	1,577

Total AAD and PVd for the PLP option is presented in Table 12-6. The use of PLP reduces the AAD significantly compared to the Do Minimum baseline assuming all properties at risk from the 200 year return period have PLP installed.

Table 12-6: Summary of flood damages for direct defence option (£k)

Scenario	Residential AAD	Residential PVd	Indirect PVd	Intangible PVd	Total PVd
Do Minimum	40.1	1,196	68	58	1,322
Option 1 - PLP (200yr)	6.9	154	30	26	210

It is assumed that the damages avoided by the PLP option are reduced by 10% to allow for the risk of failure of the measures during flood events (operator or product failure). This reduces the damages avoided from £1,112k to £1,001k. A small reduction is applied as the assumption is that automatic measures would be used in Dalbeattie.

12.4 Option 2 - Raised defences - Edingham Burn in Dalbeattie

Analysis of the raised defence option has been assessed by assuming zero flood damages for each return period assessed up to and including the design flood. Flood damages for above design events are assumed to be the same as the Do Minimum option. The total flood damages for each modelled return period are not shown as they are exactly the same as those shown in Table 12-5.

Total AAD and PVd for the PLP option is presented in Table 12-7. The use of PLP approximately halves the AAD compared to the Do Minimum baseline assuming all properties at risk from the 500 year return period have PLP installed. However, using PLP alone may be acceptable as it only provides a 10 year standard of protection to the community with some properties still at risk at the 25 year return period and above.

Table 12-7: Summary of flood damages for direct defence option (£k)

Scenario	Residential AAD	Residential PVd	Indirect PVd	Intangible PVd	Total PVd
Do Minimum	40.1	1,196	68	58	1,322
Option 2	6.9	154	30	26	210

12.5 Option 3 - 200 year SOP in Dalbeattie with climate change

Analysis of the raised defence option has been assessed by assuming zero flood damages for each return period assessed up to and including the design flood. Flood damages for above design events are assumed to be the same as the Do Minimum option. The total flood damages for each modelled return period are not shown as they are exactly the same as those shown in Table 12-5.

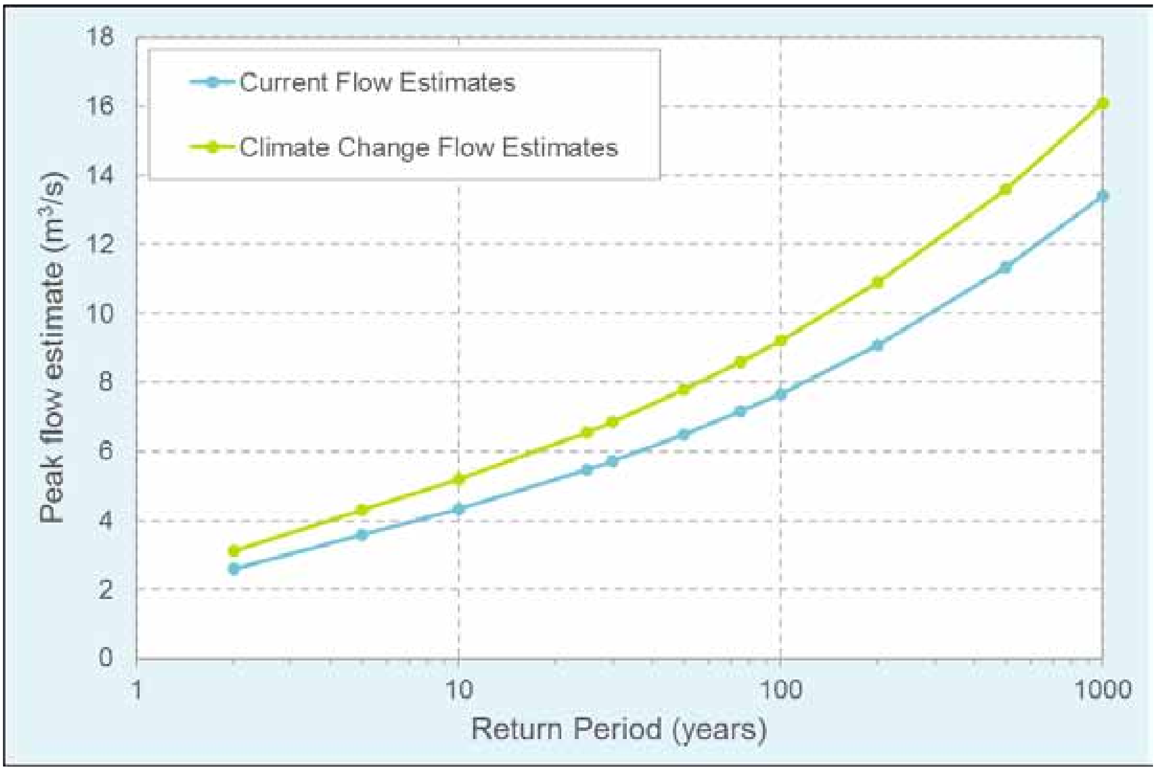
A key difference for Option 3 is that the scheme would be designed to incorporate an increase in flood damages due to climate change. Under this option flood damages and the benefits of protecting against the anticipated increases in flood flows with climate change needs to be taken into consideration. This is assessed further in the sections below.

12.5.1 Impact of climate change

The impact of climate change over the life of a scheme was undertaken to see if the impact of a 20% increase in flood flows by 2080 for all return periods assessed would significantly increase the flood damages and thus the benefits of protecting the scheme to a 200 year standard with an allowance for climate change. The assumption is that over the life of the scheme, and assuming that the design included the allowance for increasing flows, the economic benefits would increase over the scheme life.

This has been assessed by estimating what a specific return period today would be by 2080 assuming a 20% uplift in flows for all return periods. An example of this process is shown graphically in Figure 12-4. The chart shows that, for example, a 200 year flood today will be equivalent to 100 year flood in 2080. The severity of the flood will be the same but it will be occurring more regularly on average.

Figure 12-4: Difference in flows under the climate change scenario



12.5.2 Methodology

Guidance on incorporating climate change[11] into benefit-cost assessments recommends that for each option, climate change allowances on flood flows at future time steps are applied over the evaluation period. The economic loss results are summed using agreed discount factors to determine the whole life benefits.

The impact of climate change on the scheme has been assessed by calculating the present day and the 2080 average annual benefits for the Do Minimum and each option. 2080 AAD have been calculated by changing the annual probability for each flood return period assessed, using Figure 12-4 as a guide.

Thus the annual average damages have been derived at years 2015 and 2080. The results for each intervening period have been linearly interpolated and discounted to obtain the total present value damage over the 100 year appraisal period.

12.5.3 Results

Total AADs for the two periods assessed are provided below, along with the resultant whole life present value estimates and damages avoided for each option assuming climate change can be built into the designs.

[11] Defra/EA, 2003. UK Climate Impacts Programme 2002. Climate change scenarios: Implementation for Flood and Coastal Defence Users. R&D Technical Report W5B-029/TR.

Table 12-8: Impact of climate change on Do Minimum scenario (£k)

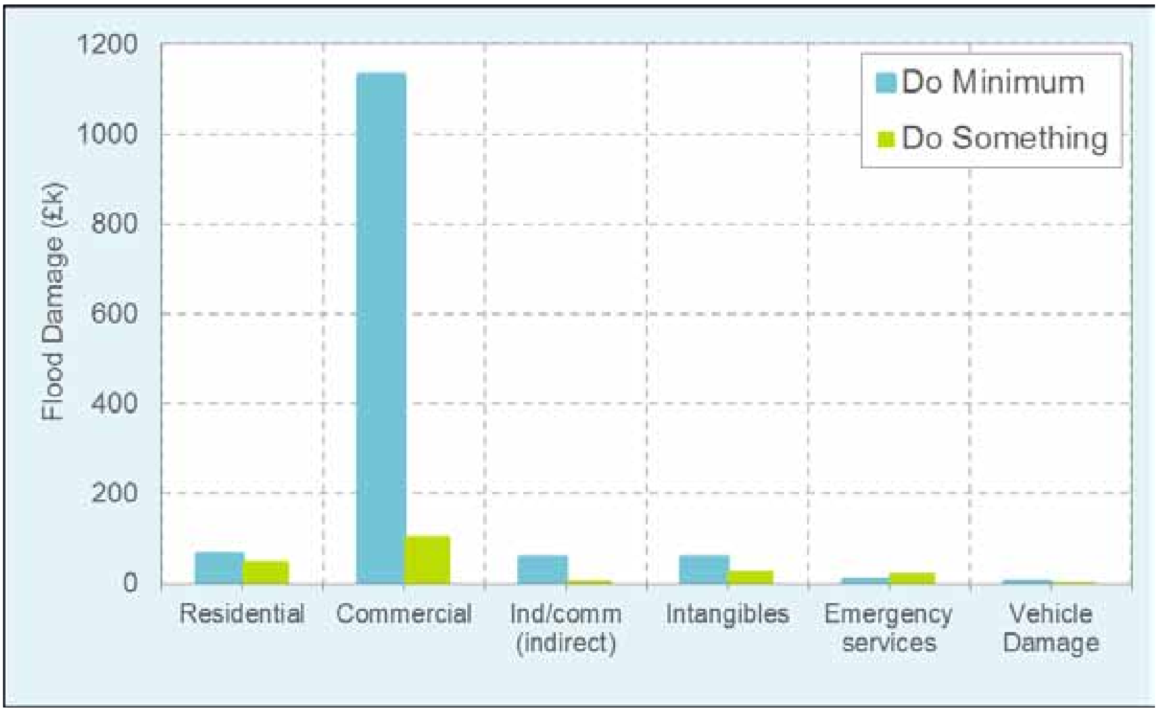
	AAD damages (£k) 2015	AAD damages (£k) 2080	AAD damages (£k) 2114	PV total damage (£k)	PV damages avoided (£k)
Do Minimum	44.4	68.8	68.8	1,609	-
Option 3	7.1	12.5	12.5	274	1,335

Based on these assumptions, the total Do Minimum flood damages are estimated to increase from £1,322 at the present day to £1,609k by 2080. Damages for Option 3 would be £1,335.

12.6 Summary of flood damages

A summary of the damage reductions for each option assessed by damage category is provided in Figure 12-5 below. This shows the significance of the non-residential properties in terms of total flood damages and how the options proposed will reduce this. In reality, as the majority of flood damages are generated from just 2 properties, the protection of these properties could significantly reduce the total flood damages, although wider disruption would remain.

Figure 12-5: Total PV damages for each option assessed broken down by damage component (£k)



13 Cost estimates

13.1 Price Base Date

The price base date is January 2015. Cost calculations have therefore been updated to the same date in order to compare the benefits and costs on an equal basis. The costs and benefits have been discounted over the 100 year life of the scheme to determine present values.

13.2 Whole life cost estimates

The outputs from SEPA's 'Costing of Flood Risk Management Measures'[12] project were used for the purpose of this assessment. This project was undertaken by JBA and provided a range of cost summary reports for use by SEPA in their Flood Risk Management Strategies. The data provides a range of costs for a portfolio of flood defence measures and is ideally suited to strategic level studies.

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, therefore these costs are unlikely.

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 2016).
4. Enabling costs are assumed to be complete in year 0.

13.3 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.

13.4 Option 1 - Property Level Protection costs

PLP can be a cost effective option for small to moderate flood events or where shallow flooding is observed. This is the case in Dalbeattie from the Edingham Burn where the majority of flood depths is predicted to be less than 0.6m. Furthermore, two properties have a lower standard of protection and contribute to the majority of the flood damages. Targeting these two properties would alleviate a large proportion of the damages across Dalbeattie, but may have higher than usual costs associated with PLP due to the non-standard nature of the properties (non-residential).

[12] SEPA, 2013. Costing of Flood Risk Management Measures (F4006): Category 13 - Fluvial Defence Measures

Table 13-1: Properties needing PLP (£/m)

Type	10 yr	25 yr	50 yr	100 yr	200 yr
Properties flooded below threshold level	1	1	1	6	12
Properties flooded above threshold level	2	2	2	3	4

The determination of PLP costs for all properties including the Munches Park House care home and Burnside Hotel, is difficult given the large number of windows and doors which would require protection. A bespoke solution would likely be required for each and would likely incur considerably higher costs than would be expected under usual PLP costs estimations. As an example, a PLP scheme for a similarly sized building to Munches Park House, operating as a Medical Centre, incurred capital costs of £107,000. Similar costs could therefore be expected for Munches Park House.

Offsetting this high cost is the relatively low cost associated with providing PLP to properties that are predicted to flood, but not above the floor level of the property (sub floor level flooding only). In these instances relatively minor measures are required - predominantly automatic airbricks. For this reason, much lower costs have been assumed (£2,000 per property).

Costs for other property types are based on the Scottish Government report on the 'Benefits of PLP' and provided in Table 13-1 below. We have assumed the following whole life costs for each property type.

Table 13-2: Cost per property by flood depth and property type

Property type	Cost for sub floor level flooding	Cost for above threshold flooding
Detached	£2,000	£18,606
Flat	£2,000	£12,925
Semi	£2,000	£17,817
Terrace	£2,000	£12,749
Office	£3,000	£27,274
Shop	£3,000	£24,206
Hotel	£4,000	£18,606
Care Home	£4,000	£100,000

Total costs for Option 1 to provide a 200 year standard are estimated to be:

- Whole life costs - £179,000

13.5 Option 2 and 3 - Raised defences

Costs for these 2 Options assume that to provide protection low walls would be needed on top of the current top of banks. In some instances it will be necessary to create a new embankment, install walls along a currently undefended reach or to increase the height or replace walls already in place.

The total length of defence where modelled 0.5% AP flood levels currently exceed the elevation of the current defences is 180m for Option 2 (to provide a 200 year SOP on the Edingham Burn) and 240m for Option 3 (to provide a 200 year SOP with climate change on the Edingham Burn and the rest of Dalbeattie). Defence increases have been calculated to ensure sufficient freeboard throughout the reach.

The direct defence costs have been based on values provided in SEPA's Cost of Flood Risk Management Measures Report[12]. The cost estimates account for all costs associated with the project over its expected life. Tables of the costs for new walls, raising current walls and sheet piled walls are compiled below in Table 13-3 to Table 13-4.

Table 13-3: Wall cost per metre (£/m)

Length (m)	< 1.2m	1.2 - 2.1 m	2.1 - 5.3m	> 5.3m
Average	1,419	2,905	3,577	1,1168
Minimum	7,75	1,144	1,950	3,505
Maximum	1,624	4,591	4,615	13,105

Table 13-4: Wall raising cost per metre (£/m)

Length (m)	< 1.2m	1.2 - 2.1 m
Average	1,029	2,177
Minimum	7,75	1,073
Maximum	1,378	2,390

The maximum costs have been assumed since the risk is unclear at this stage whilst the style and placement of the defences selected likely minimises any potential risk. Risks could emerge from multiple landowners being involved, limited working space, the proximity to unknown services and mixed access meaning that the river itself may be required for access in places.

The defences which require additional protection of current assets and those that are wholly new are summarised in Table 13-5 and Table 13-6 below. The height of defences were calculated as an average for each length. The average height of each length of defence was calculated based on flood levels plus 0.3m freeboard and based on current flood levels and ground levels. It is assumed that Asset 04, the sheet piled wall, is not to current design standards and will need to be replaced in full rather than simply raised. For the calculation of PVc Asset 04 was replaced at the same time as the other capital costs occurred.

Table 13-5: Unit and total estimated defence costs - 200 year event

Location	Defence type	Typical defence height (m)	Lengt h (m)	Unit cost	Total cost
Option 2 - Edingham Burn	New wall	<1.2m	180	£1,624	£292,320
Option 3 - Edingham Burn and Dalbeattie	Wall raising	<1.2m	60	£1,378	£82,680

In addition to the above the following additional costs are assumed:

- Enabling costs of 15% have been assumed
- Annual maintenance costs of up to £0.85/m/annum

Total cash and present value (PV) costs are provided for the two options assessed in Table 13-6.

Table 13-6: Cash costs and total whole life (PVc) costs for Option 2 and Option 3 (£k)

Element	Option 2 - 200 year return period	Option 3 - 200 Year return period with climate change
Enabling cost	44	61
Capital cost	292	375
O&M cost	15	20
Total PVc	£331	£424

13.6 Cost summary

A summary of costs with optimism bias applied is presented in Table 13-7 below.

Table 13-7: Option cost summary with optimism bias (£k)

Option	200 year	200 year with climate change
Option 1 - PLP	£179	-
Option 2 - New defences along Edingham Burn to provide a 200 year SOP	£331	-
Option 3 - New defences along Edingham Burn and raised defences in Colliston Park to provide a 200 year SOP with climate change	-	£424

14 Benefit-cost analysis

14.1 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 Scottish Government 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 these it is necessary to assess the damages that are likely to occur under both the Do Nothing and Do Something scenarios. The benefits of any particular Do Something option can then be calculated by deducting the Do Something damages from the Do Nothing damages.

14.2 Guidance and standard data

The principles of benefit-cost ratio calculations are summarised as follows:

- Derive the damages associated with do-nothing;
- Derive the damages associated with each scheme option;
- Derive the benefits (damages avoided) associated with each option;
- Derive the costs for each option; and
- Derive the benefit-cost ratios for each option.

14.3 Benefit-cost results

A summary of the flood damage results for the proposed PLP option are provided in Table 14-1. All options assessed are economically viable with benefit-cost ratios greater than 2 for all options.

Table 14-1: Summary of benefit-cost calculation (£k)

	Do Minimum	Option 1	Option 2	Do Minimum with climate change	Option 3
Total PV costs (£k)	-	179	331	-	424
Total PV costs + Optimism bias (£k)	-	286	530	-	678
PV damage (£k)	1,322	210	210	1,609	274
PV damage avoided (£k)	-	1,112	1,112	-	1,335
Benefit-cost ratio	-	3.5	2.1	-	2.0
Incremental BCR	-	-	0.5	-	1.5

14.3.1 Economic preferred option

The option with the largest benefit cost ratio is Option 1 - the PLP option with a BCR of 3.5. However, this does not take into account any additional costs associated with necessary flood warning that would be beneficial for PLP for the Edingham and Kirkgunzeon Lane catchments.

The two structural options are both cost effective with BCRs greater than 2. The Incremental benefit-cost ratio (IBCR) attempts to determine if the extra cost of moving from the least cost option to the more expensive option is outweighed by the extra benefit. In the case of moving from Option 1 to Option 2 the IBCR is less than 1 suggesting that it is not worth moving from Option 1 to Option 2. The IBCR of moving from Option 2 to Option 3 is 1.5 suggesting that it would be worthwhile.

Option 1 is therefore preferred but all of the options assessed could be developed in the longer term. The use of Option 1 as a short term method, perhaps progressed using the Council's subsidy scheme would be beneficial.

15 Conclusion and Recommendations

This report presents the results of a detailed flood risk appraisal of Dalbeattie and the upstream community of Kirkgunzeon from the Kirkgunzeon Lane. These areas are protected by a Flood Prevention Scheme constructed in 1981. Direct overtopping of the flood defences have not been witnessed since construction, however there have been a number of flood events from other sources within the town.

A detailed hydrological assessment of the Kirkgunzeon Lane and Edingham Burn has been undertaken to derive flow inputs into a hydraulic model of the rivers through Dalbeattie and Kirkgunzeon. Whilst the flow estimates are carried out using standard FEH methodologies, without any gauging of the watercourses the design flow estimates should be treated with caution.

Previous survey used for the SFDAD study in 2005 was used and complimented with additional survey undertaken by JBA. This was used to build a 1D model and a linked 1D/2D TuFLOW flood model. Flood mapping has been undertaken and is based on the 1D-2D modelling and the underlying topographical data. Flood maps were prepared for each event and include the 2, 10, 25, 50, 100, 200, 200 plus climate change, and 1000 year return periods. The flood mapping is an improvement on available national datasets from SEPA and should be used by the Council for planning considerations.

The model results estimate that 16 properties would be affected during a 200 year flood; the majority of which are residential with two key commercial properties: a care home and hotel. These properties are at risk from the Edingham Burn. Annual average flood damages are estimated to be £40,100 with a Present Value damage in the region of £1.3 million.

15.1 Hydrometry and warning recommendations

Any flood defence improvements or significant capital spent would benefit from some flow gauging over a period of time to improve the flow estimates. This would also support future flood warning and forecasting on the catchment by providing the necessary evidence to calibrate flood warning models.

15.2 Asset maintenance recommendations

Asset inspections have suggested that the defences would benefit from additional inspections and maintenance of the watercourse and defences. In particular, many outfalls are present which need to be inspected and flap valves fitted. Some of the smaller watercourses could benefit from intermittent vegetation and sediment management.

As part of this assessment CCTV of key culverts was undertaken within Dalbeattie. This found that some culverts were blocked and in need of clearance. Major blockages should be removed as a priority. We recommend monitoring of the condition is undertaken more frequently and a repair and inspection and cleaning maintenance schedule is established.

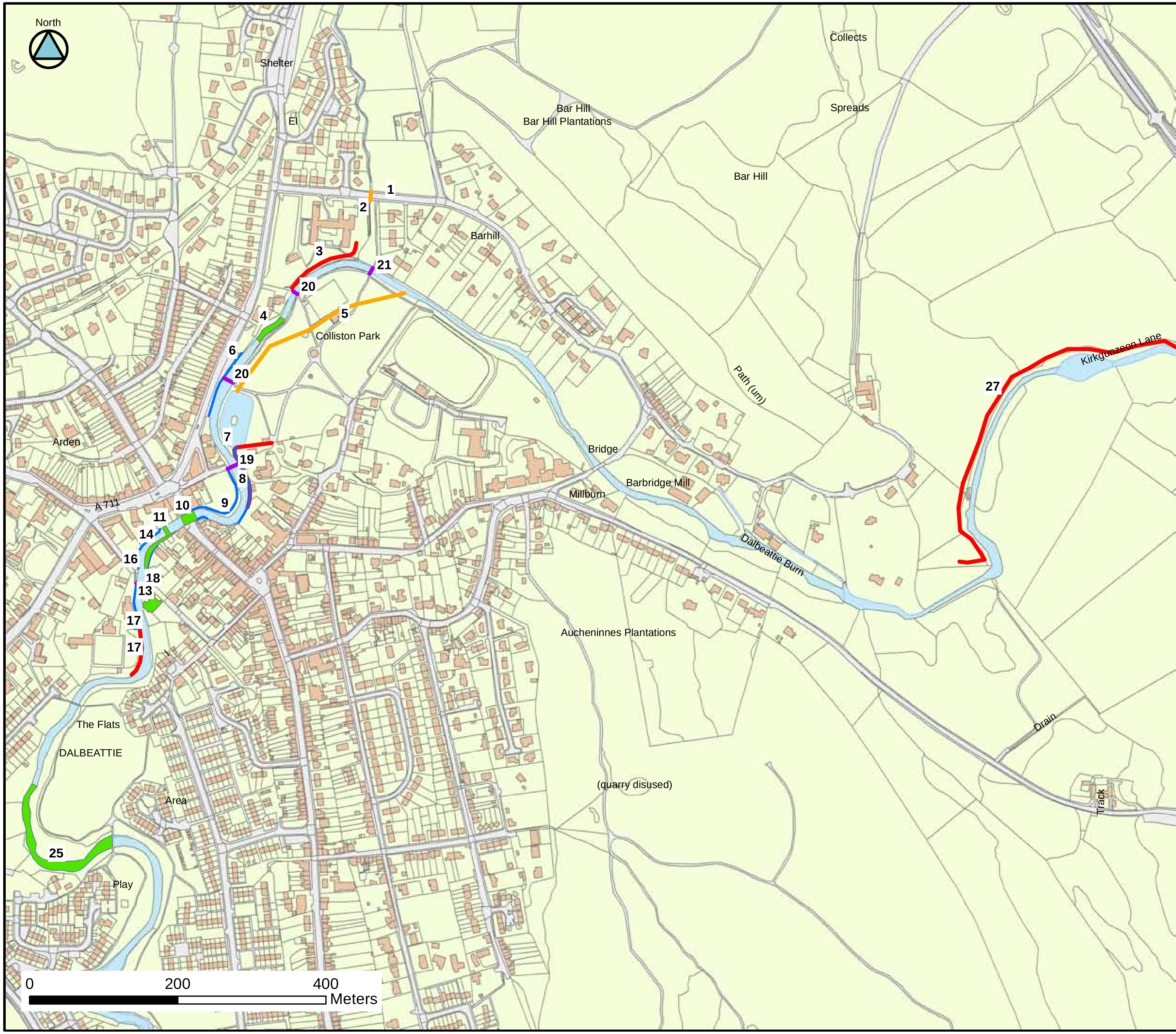
Condition survey of the flood defence assets shows that these are in a good condition. The wall/embankment on the edge of Colliston Park (Asset 7) is in poor condition and modelling suggests that this is the asset that would be exceeded (overtopped) first during a significant flood (in excess of a 200 year flood). It is recommended that remedial work is undertaken to locally raise this defence.

15.3 Options appraisal

A number of flood mitigation options have been considered including; property level protection and new direct defences on the Edingham Burn. A number of short term quick wins and longer term flood mitigation measures have been recommended.

All options assessed are economically viable with benefit-cost ratios greater than 2 for all options. The PLP option has the highest benefit-cost ratio although the two structural options are both cost effective with BCRs greater than 2. Option 1 is therefore preferred but all of the options assessed could be developed in the longer term. The use of Option 1 as a short term method, perhaps progressed using the Council's subsidy scheme would be beneficial.

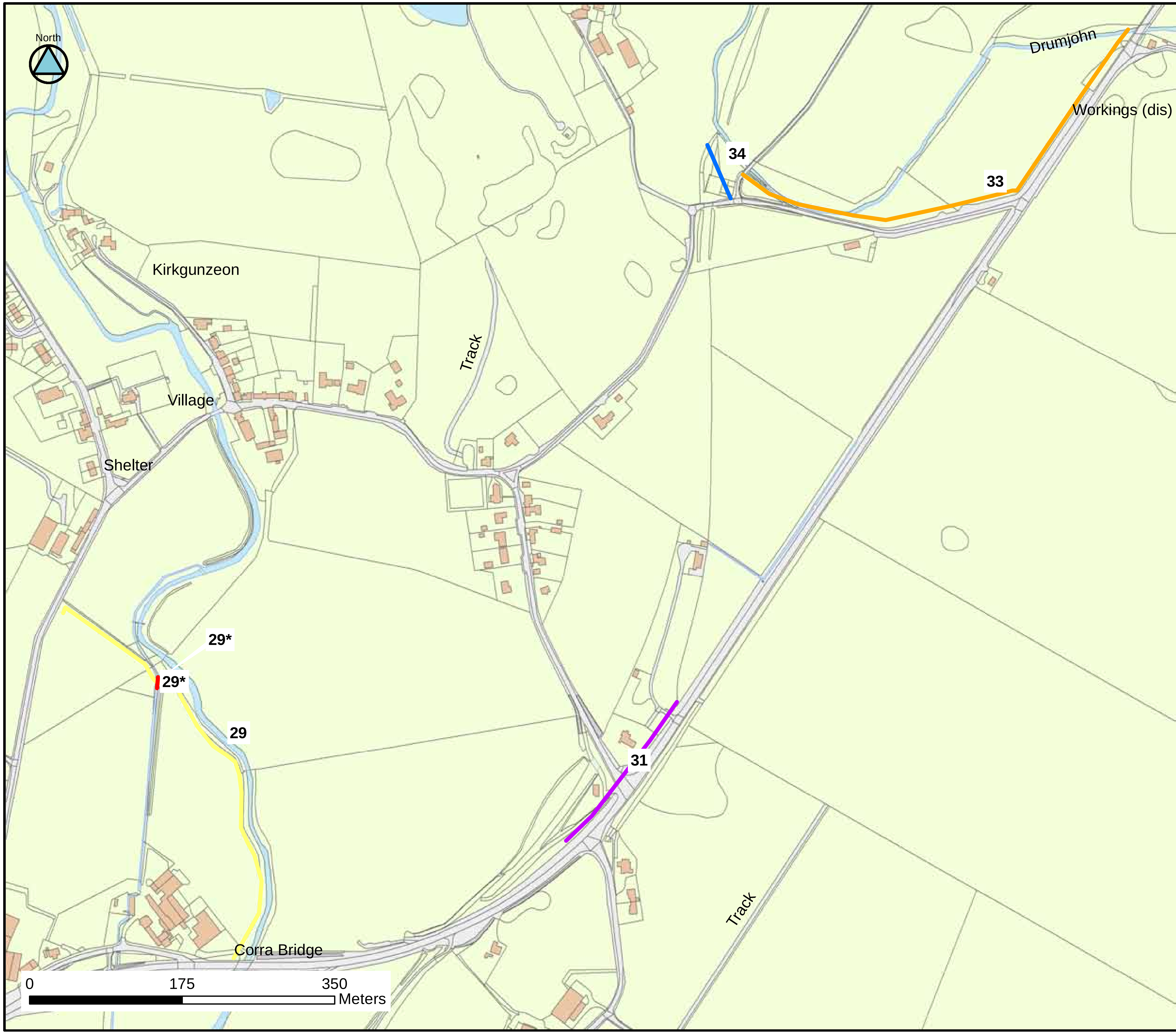
Figures Section



LEGEND

- Culvert
- Bridge
- Wall
- Embankment
- Channel Improvement

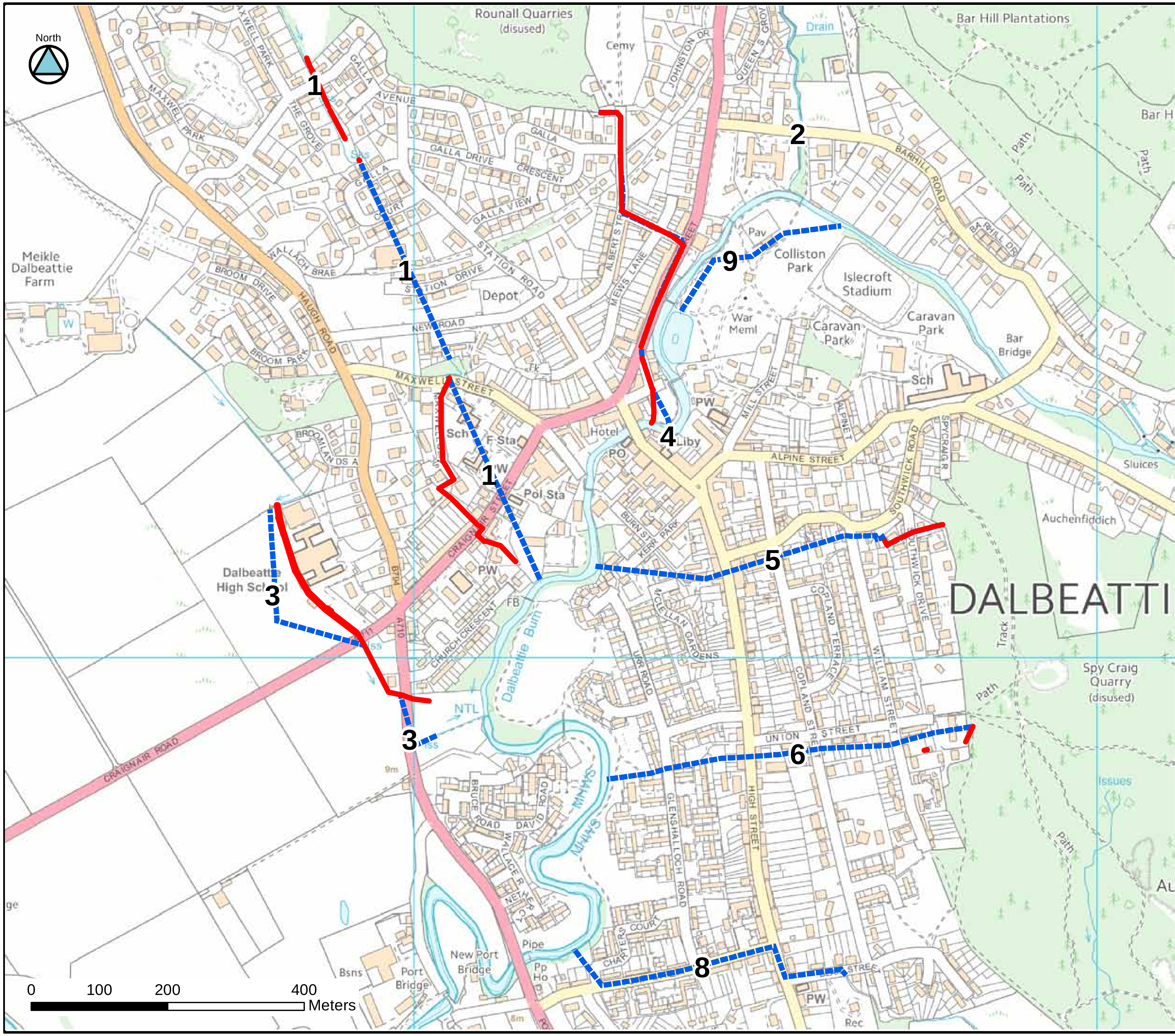
ASSET LOCATIONS AND ASSET REFERENCE NUMBERS FOR DALBEATTIE



LEGEND

- 29 - Embankment
- 29* (Continued) - Culvert
- 31 - Culvert
- 33 - Embankment
- 34 - Embankment / Raised ground

ASSET LOCATIONS AND ASSET REFERENCE NUMBERS FOR KIRKGUNZEON



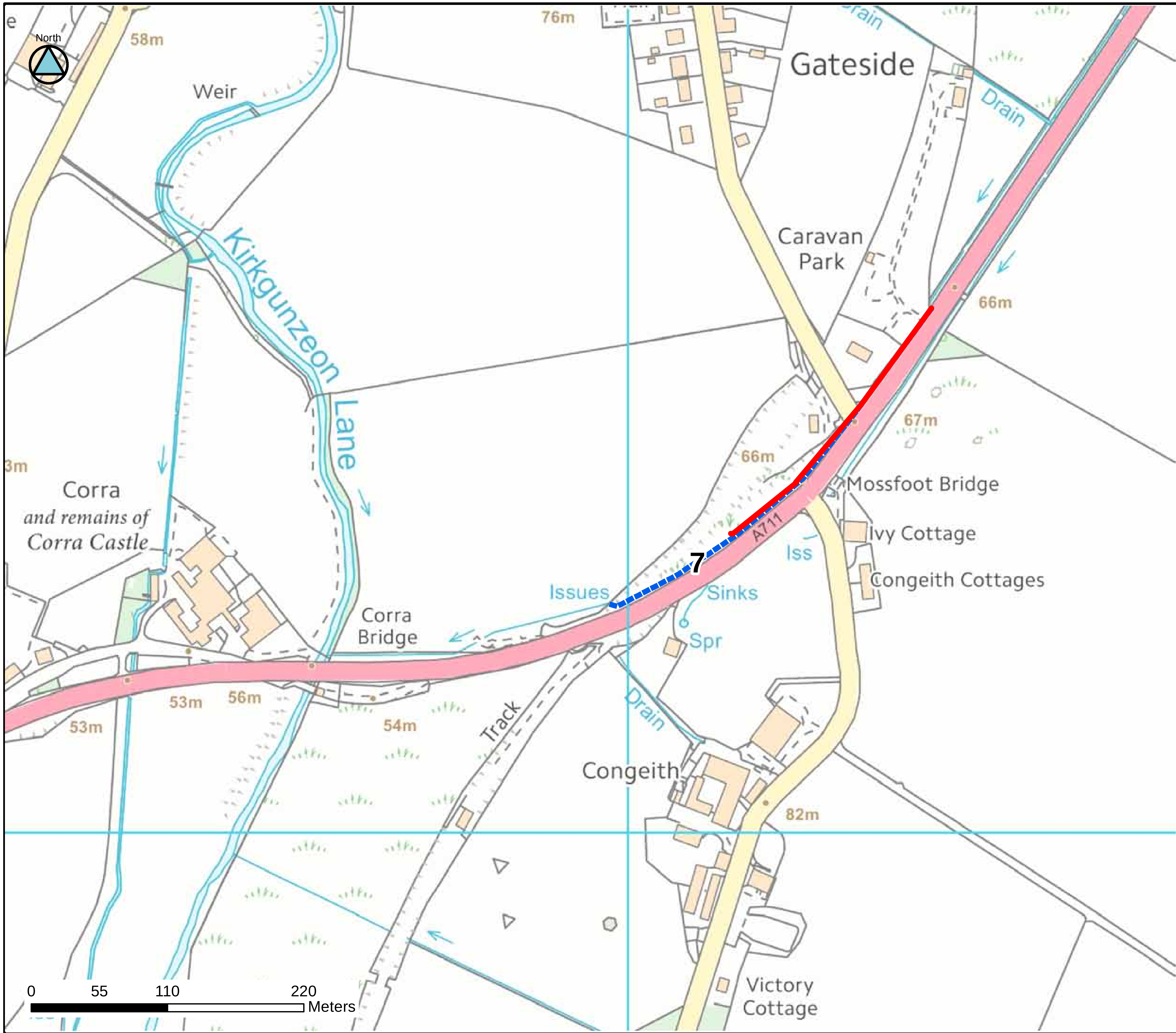
LEGEND

Surveyed culverts

Aproximate culvert location

JBA consulting

CULVERT LOCATIONS AND SURVEY FOR CULVERT 10



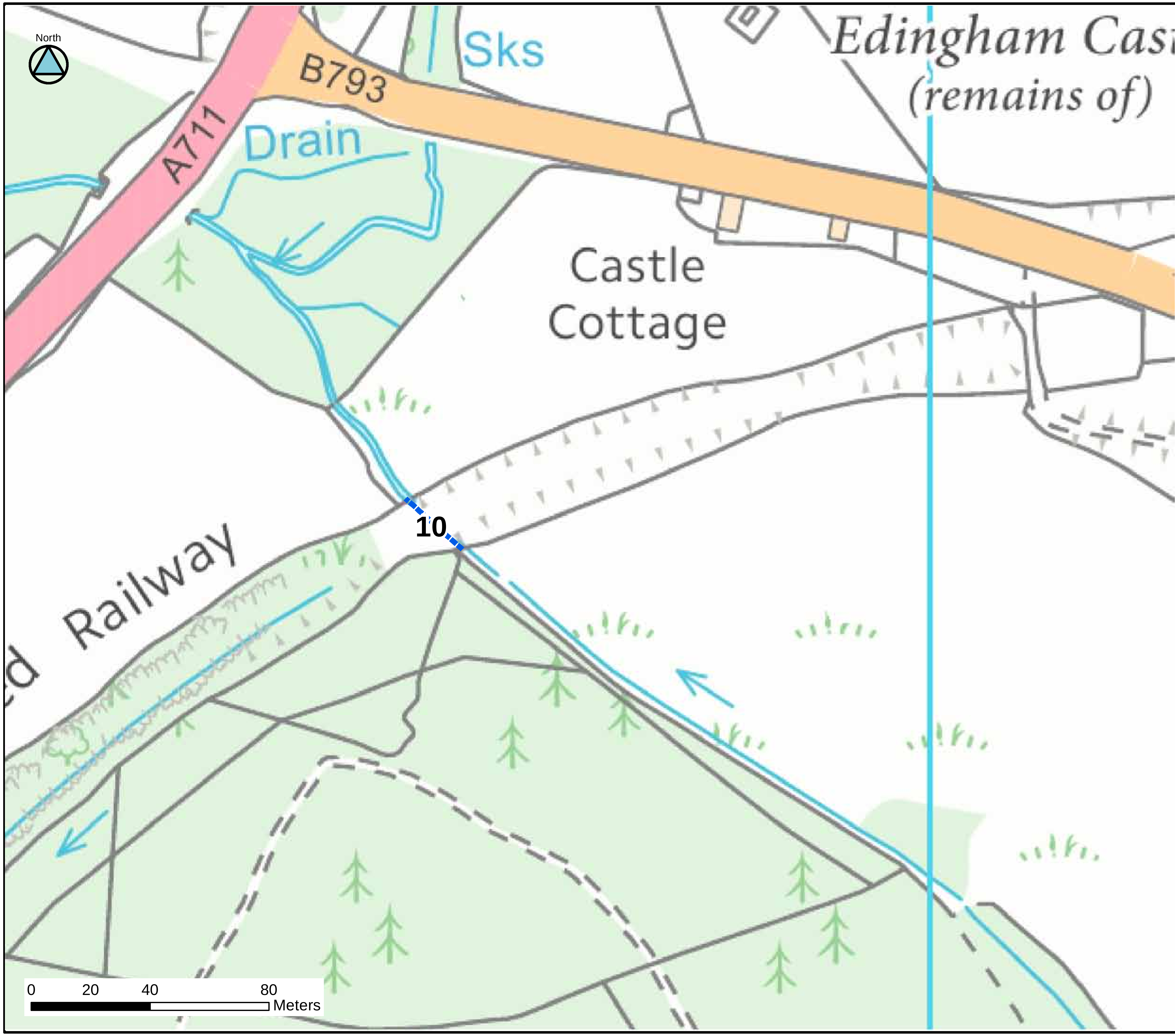
LEGEND

Surveyed culverts

Aproximate culvert location

JBA consulting

CULVERT LOCATIONS AND SURVEY FOR CULVERT 10

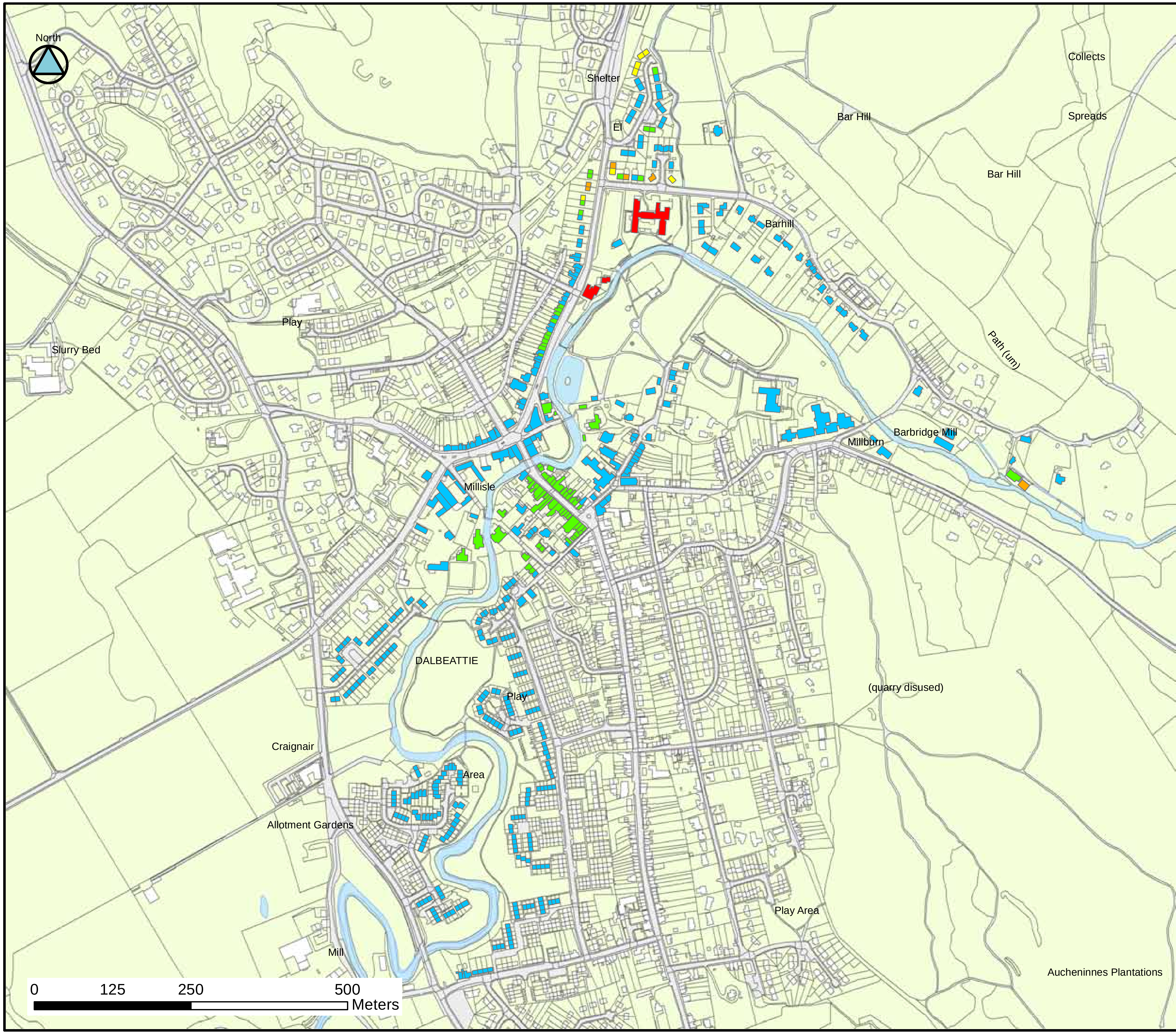


LEGEND

Surveyed culverts

Aproximate culvert location

CULVERT LOCATIONS AND SURVEY FOR CULVERT 10



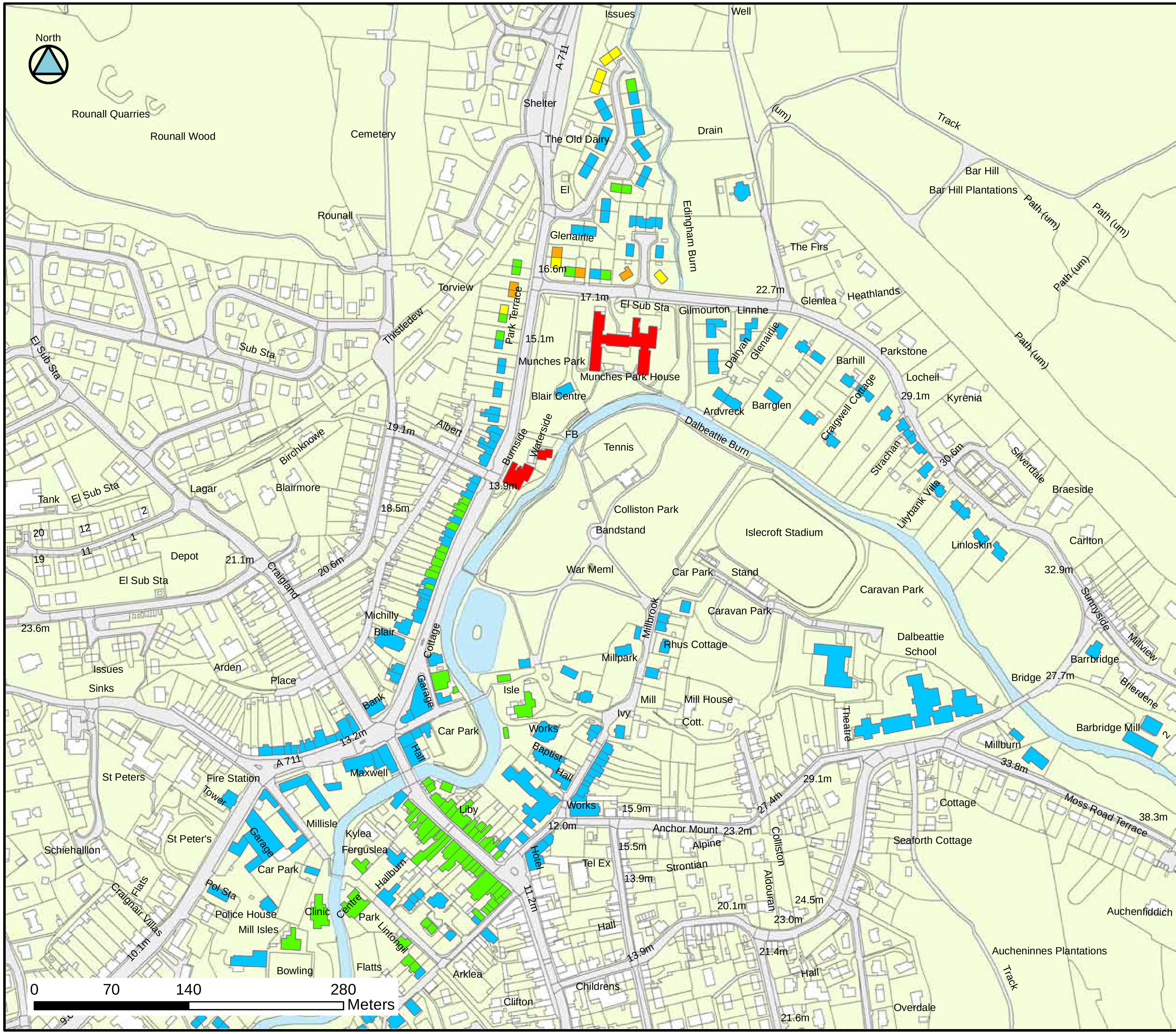
LEGEND

Standard of Protection

- 2 year (3 properties)
- 50 year (6 properties)
- 100 year (7 properties)
- 200 year (71 properties)
- 1000 year (410 properties)

STANDARD OF PROTECTION FOR PROPERTIES AT RISK IN DALBEATTIE

Note: A 100 year SOP suggests that properties would not flood at the 100 year flood, but would be at risk from a 200 year flood.



LEGEND

Standard of Protection

- 2 year (3 properties)
- 50 year (5 properties)
- 100 year (7 properties)
- 200 year (70 properties)
- 1000 year (182 properties)

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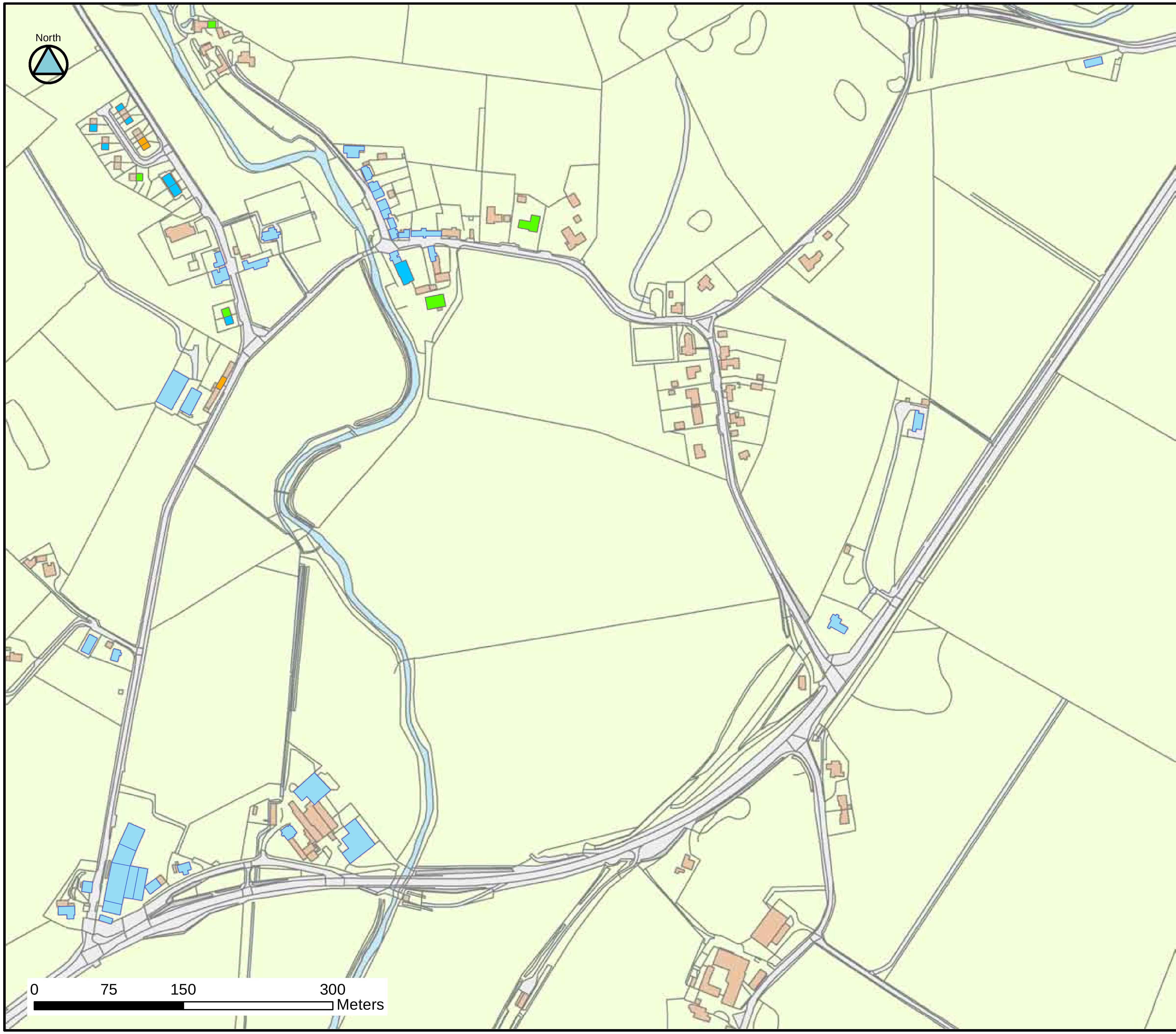
STANDARD OF PROTECTION FOR PROPERTIES AT RISK IN DALBEATTIE

Note: A 100 year SOP suggests that properties would not flood at the 100 year flood, but would be at risk from a 200 year flood.



LEGEND

SOP1

- 50 (3 properties)
- 200 (5 properties)
- 1000 (8 properties)

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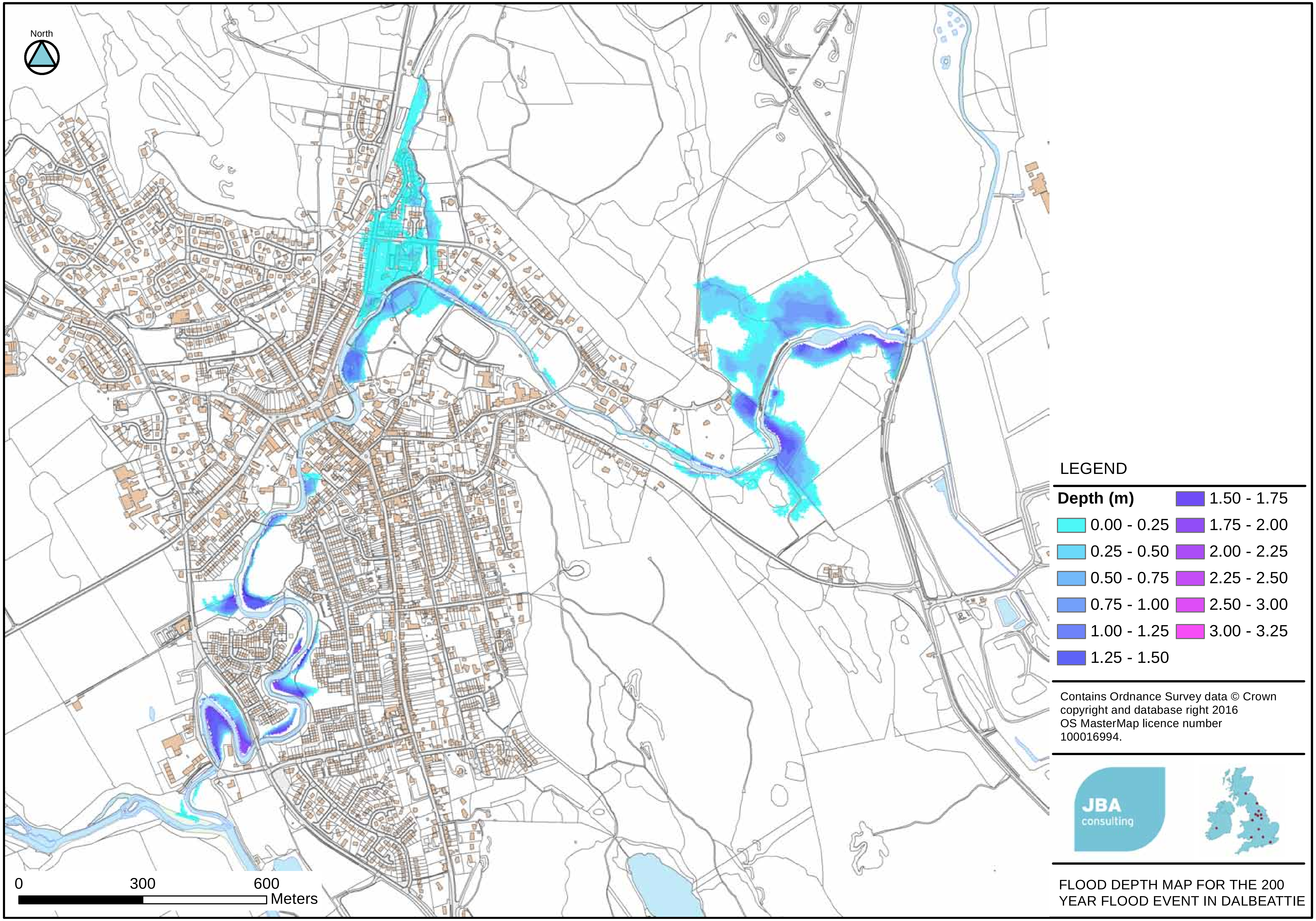
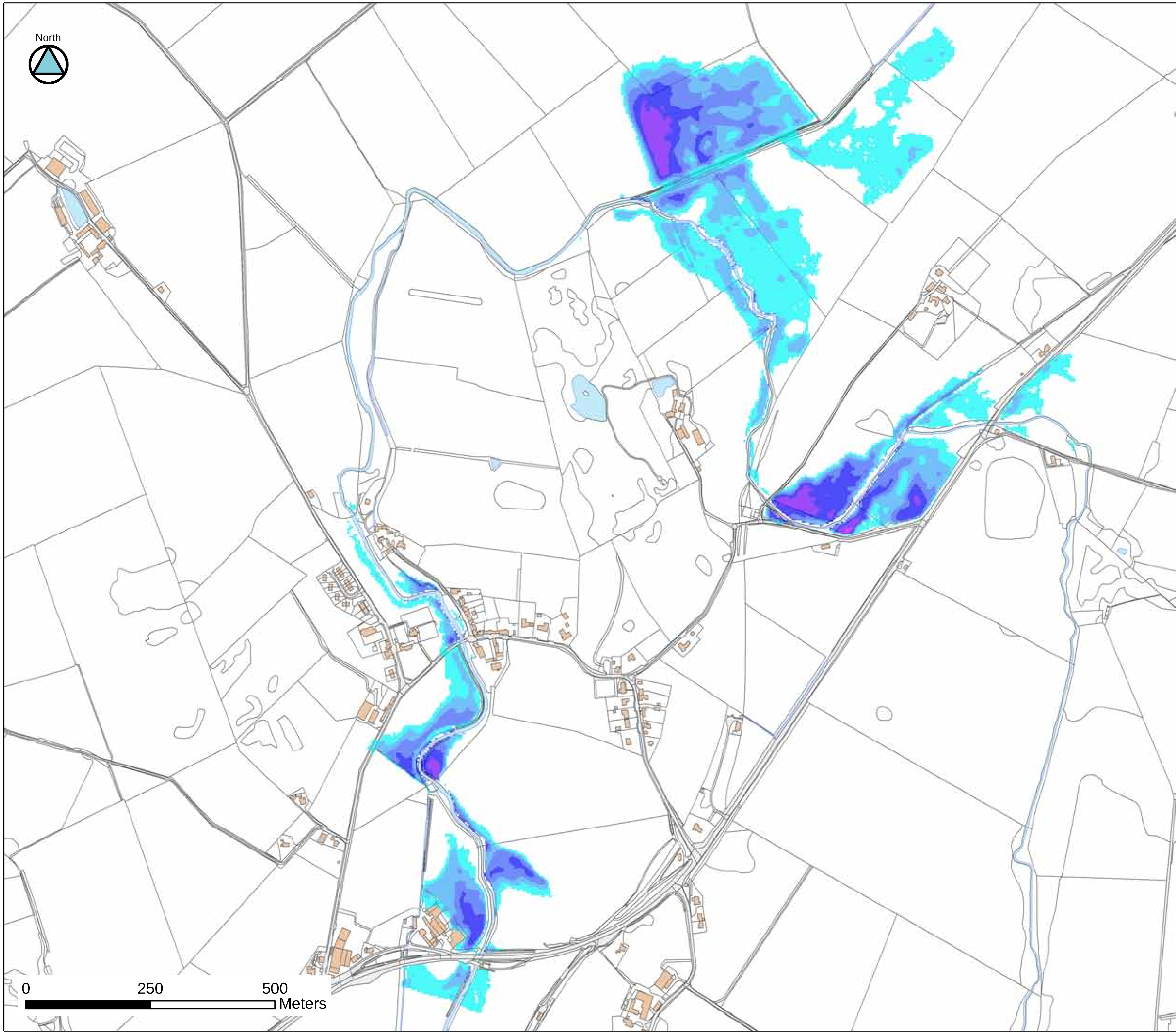
STANDARD OF PROTECTION FOR PROPERTIES AT RISK IN KIRKGUNZEON

Note: A 100 year SOP suggests that properties would not flood at the 100 year flood, but would be at risk from a 200 year flood.



FLOOD DEPTH MAP FOR THE 200 YEAR FLOOD EVENT IN DALBEATTIE



LEGEND

Depth (m)

- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- 1.25 - 1.50
- 1.50 - 1.75

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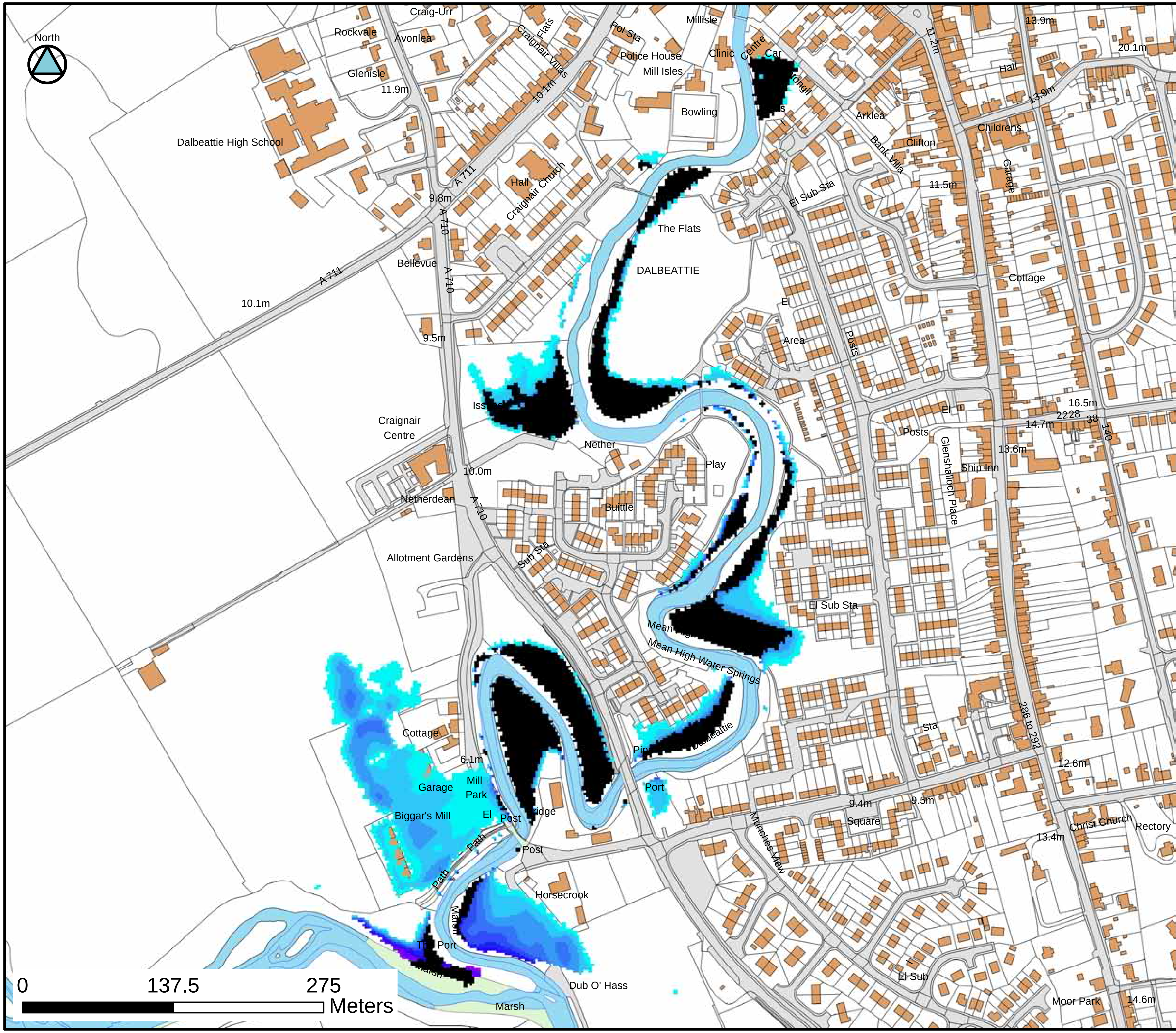
FLOOD DEPTH MAP FOR THE 200 YEAR FLOOD EVENT IN KIRKGUNZEON



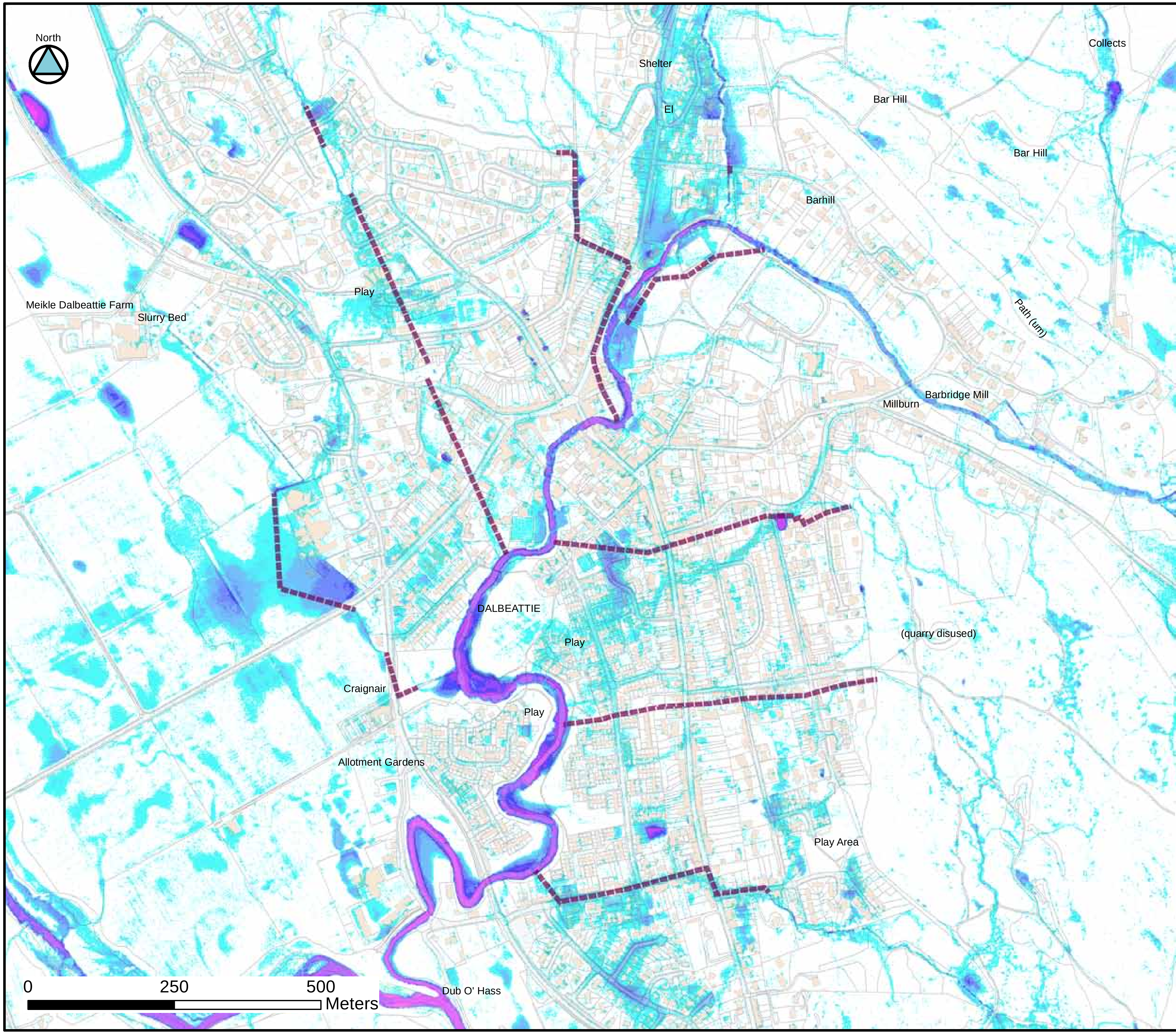
LEGEND

200yr Fluvial Extents

200yr Fluvial with 200 year Tidal

0.00 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.25
1.25 - 1.50
1.50 - 1.75
1.75 - 2.00
2.00 - 2.25
2.25 - 2.50
2.50 - 3.00
3.00 - 3.25

COMPARISON OF FLUVIAL AND COASTAL FLOOD EXTENTS (COASTAL - 200YR WITH FLUVIAL 200 YR)



Legend

Approximate culvert location

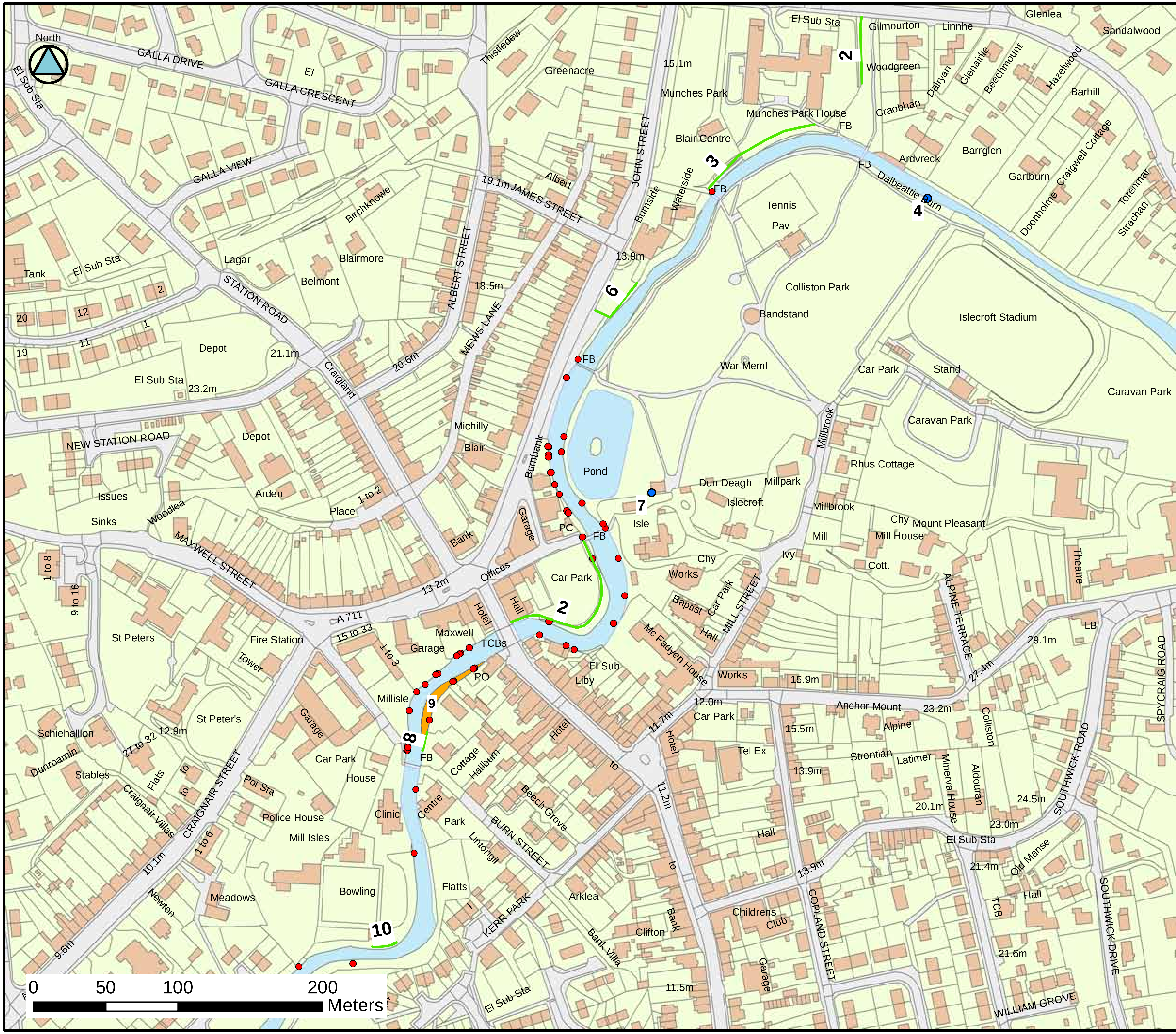
200 year pluvial flood - 1 hour

Depth (m)

- 0.05 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25
- 1.25 - 2.00
- 2.00 - 5.00

JBA consulting

SURFACE WATER FLOOD DEPTH MAP FOR THE 200 YEAR 1 HOUR DURATION STORM



LEGEND

- Culverts requiring flap valves

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RECOMMENDATIONS AND QUICK WINS FOR DALBEATTIE

Appendices

A Appendix A - Flood Estimation

A.1 Introduction

This section provides further details on the estimation of flows using the FEH.

A.2 Additional checks on catchment characteristics and choice of method

Although the FEH CD-ROM BFIHOST values appeared reasonable in comparison to the available geological information[13], the BFI Scotland map[14] suggested a BFI value of 0.27 for the Kirgunzeon Lane at Dalbeattie. This value is much smaller than the BFIHOST value of circa 0.476 derived from the FEH CD-ROM. The BFI Scotland map also suggested BFI values of 0.27 for all of the other subcatchments apart from the Drumjohn Burn where a value of 0.24 was identified (in comparison to the FEH CD-ROM value of 0.358). Interestingly, the map indicated a similar BFI value (0.35) for the Urr Water at Dalbeattie in comparison to the FEH CD-ROM value of 0.376.

The choice of BFI (and SPR) value was investigated using a BFI value of 0.27 and SPR value of 57.16[15] for all of the watercourses (except Drumjohn Burn where a BFI value of 0.24 and SPR value of 58.48) was used to generate an alternative set of peak flows for both watercourses using the FEH Statistical method. From Table C-1 and Table C-2, it can be seen that the flows are much higher than those derived from the unadjusted datasets (for example, the 0.5% AP, 200 year, flow is estimated to be 88 m^3/s for the Kirgunzeon Lane at Dalbeattie before BFI and SPR adjustment and circa 141 m^3/s after adjustment). When input to the hydraulic model, the higher flows generated a frequency of flooding which was inconsistent with the flood history (i.e. flooding was estimated to occur too frequently). The default BFI and SPR values from the FEH CD-ROM were therefore retained and the resulting flows used within the hydraulic model.

With respect to choice of approach for estimating flood flows, the FEH Statistical method was judged to be the most appropriate method given the rural nature of the catchments and the availability of the nearby Urr Water at Dalbeattie as a potential donor site, the Statistical method was therefore assumed to be the most reasonable approach for estimating flood flows for all of the watercourses near the site except the watercourse at Castle Cottage (see below). In order to provide consistency in flood estimation across the catchment, a single pooling group was used for all of the Kirgunzeon Lane subcatchments (i.e. at Dalbeattie, Corra Bridge, upstream of Drumjohn Burn and Drumjohn Burn). A different pooling was used for Edingham Burn because of the smaller catchment size (4.41 km^2). In each case, the Urr Water at Dalbeattie was used as a donor site for QMED estimation and the Generalised Logistic distribution was used to fit the growth curve.

The tributary of the Edingham Burn at Castle Cottage has a fairly small catchment area (0.65 km^2). The gauging station data available for pooling in the FEH Statistical method generally have larger catchment areas than this and the FEH Statistical method was therefore deemed unsuitable for this particular catchment. Instead, both the FEH Rainfall Runoff method and ReFH2 were tested as alternative approaches (Table C-3). ReFH2 was found to produce flood estimates which were much smaller than those generated using the FEH Rainfall Runoff method. For example, the 0.5% AP (200 year) event was estimated to be 1.2 m^3/s using ReFH2 and 2.9 m^3/s using the FEH Rainfall Runoff method. Closer investigation revealed that ReFH2 used a larger time to peak (Tp) value of 2.52 h than the 1.18 h used by the FEH Rainfall-Runoff method and consequently generated much smaller flood flows. Given the small catchment area, the Tp value associated with the FEH Rainfall Runoff method was deemed to be more realistic for this catchment and this method was selected for use.

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

14 Institute of Hydrology (1986), Base Flow Index Scotland map.

15 Per FEH Volume 3, equation 13.25.

Table C-1: FEH Statistical Estimates without BFI and SPR adjustments

Annual Probability (AP)	Return period (years)	Kirgunzeon Lane at Dalbeattie (m³/s)	Kirgunzeon Lane at Corra Bridge (m³/s)	Kirgunzeon Lane U/S of Drumjohn Burn (m³/s)	Drumjohn Burn (m³/s)	Edingham Burn (m³/s)	Castle Cottage (m³/s)
50	2	35.9	17.8	8.0	11.6	2.6	0.8
20	5	45.0	22.4	10.0	14.5	3.6	1.1
10	10	51.6	25.6	11.5	16.7	4.3	1.4
4	25	61.0	29.9	13.6	19.7	5.5	1.6
3.33	30	63.0	31.3	14.0	20.3	5.7	1.7
2	50	69.0	34.2	15.3	22.3	6.5	2.1
1.33	75	74.1	36.8	16.5	23.9	7.2	2.3
1	100	77.9	38.7	17.3	25.2	7.7	2.5
0.5	200	88.1	43.7	19.6	28.4	9.1	2.9
0.5 + 20% CC	200 + CC	105.7	52.5	23.5	34.1	10.9	3.5
0.2	500	103.6	51.4	23.0	33.4	11.3	3.6
0.1	1000	117.2	58.1	26.1	37.8	13.4	4.3

Table C-2: FEH Statistical Estimates with BFI and SPR adjustments

Annual Probability (AP)	Return period (years)	Kirgunzeon Lane at Dalbeattie (m³/s)	Kirgunzeon Lane at Corra Bridge (m³/s)	Kirgunzeon Lane U/S of Drumjohn Burn (m³/s)	Drumjohn Burn (m³/s)	Edingham Burn (m³/s)	Castle Cottage (m³/s)
50	2	57.3	29.2	16.6	14.6	3.5	0.9
20	5	72.0	36.7	20.9	18.3	4.8	1.3
10	10	82.5	42.1	23.9	21.0	5.9	1.5
4	25	97.5	49.2	28.2	24.8	7.4	1.9
3.33	30	100.7	51.3	29.2	25.6	7.7	2.0
2	50	110.3	56.2	31.9	28.1	8.8	2.3
1.33	75	118.4	60.4	34.3	30.1	9.7	2.5
1	100	124.6	63.5	36.1	31.7	10.4	2.7
0.5	200	140.8	71.8	40.8	35.8	12.3	3.2
0.5 + 20% CC	200 + CC	169.0	86.1	48.9	43.0	14.7	3.8
0.2	500	165.6	84.4	48.0	42.1	15.3	3.9
0.1	1000	187.3	95.5	54.2	47.6	18.1	4.7

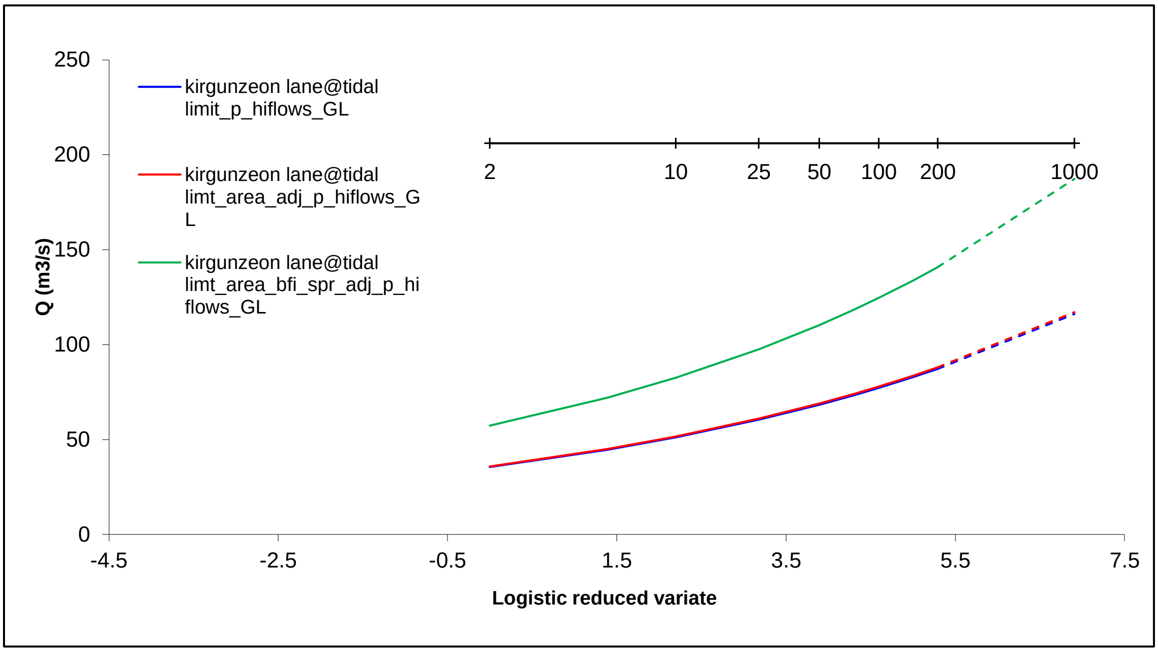
Table C-3: Comparison of Rainfall Runoff methods for Castle Cottage

Annual Probability (AP)	Return period (years)	ReFH2 (m³/s)	FEH Rainfall Runoff (m³/s)
50	2	0.4	0.8
20	5	0.5	1.1
10	10	0.6	1.4
4	25	0.7	1.6
3.33	30	0.7	1.7
2	50	0.9	2.1
1.33	75	0.9	2.3
1	100	1.0	2.5
0.5	200	1.2	2.9
0.5 + 20% CC	200 + 20% CC	1.5	3.5
0.2	500	1.6	3.6
0.1	1000	1.9	4.3

A.3 FEH Statistical Method supporting information

The following provides additional information on the FEH Statistical method used. Note that, as the same pooling group was used for the Kirgunzeon Lane at Dalbeattie, Corra Bridge, upstream of Drumjohn Burn and at Drumjohn Burn, this information is only shown once.

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Kirgunzeon Lane at tidal limit (downstream of Dalbeattie)		
NGR	NX 8210 6100		
Type of problem/objective of	Peak flows for FPS appraisal		
Type of catchment	Rural		
QMED $_{site\ cd}$	61.6	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Urr at Dalbeattie		
Station number	80001		
NGR	NX 8210 6100		
Proximity (km)	2.00		
Adjustment	0.9312		
Site Chosen	Y		
QMED $_{site}$ adjusted by data transfer (m^3/s)	35.9	Specific Q (l/s/ha)	3.7
Q_{100} growth curve factor	2.17	Q100/ area (l/s/ha)	8.1
Q_{100} (m^3/s)	**77.9**		
Summary Data			
FEH catchment area	94.99		km^2
Adjusted catchment area	96.01		km^2
URBEXT 1990	0.006		
URBEXT 2010	0.007		
URBEXT Adjustment Method	Urbext2000		
SAAR	1258		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFIHOST		
QMED	35.86		m^3/s
5	45.05		m^3/s
10	51.62		m^3/s
30	61.00		m^3/s
50	68.98		m^3/s
75	74.09		m^3/s
100	77.95		m^3/s
200	88.08		m^3/s
1000	117.16		m^3/s
Climate Change Region	South-West Scotland		
Climate change adjustment	20.0%		
200 + cc	105.7		m^3/s
Donor/ Analogues Used	Urr at Dalbeattie		
Calcs by:	David Cameron	Date:	06/08/2015
Checked by:	Angus Pettit	Date:	19/10/2015



POOLING GROUP DETAILS

Original Default Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
203028 (Agivey @ Whitehill)	0.345	40	64.444	0.154	0.230	0.552
203039 (Clogh @ Tullynewey)	0.423	31	37.453	0.056	-0.055	1.983
73008 (Bela @ Beetham)	0.438	43	36.936	0.185	0.158	0.199
203033 (Upper Bann @ Bannfield)	0.502	37	67.053	0.126	0.001	0.407
48003 (Fal @ Tregony)	0.505	49	11.038	0.162	0.271	0.318
203043 (Oonawater @ Shanmoy)	0.563	26	30.461	0.169	0.059	0.421
48012 (Fal @ Trenowth)	0.633	15	10.210	0.138	0.357	2.730
205008 (Lagan @ Drumiller)	0.650	38	28.775	0.156	-0.073	1.033
205005 (Ravernet @ Ravernet)	0.659	40	14.355	0.218	0.330	1.778
96003 (Strathy @ Strathy Bridge)	0.665	21	50.021	0.192	0.236	0.335
78004 (Kinnel Water @ Redhall)	0.732	40	78.224	0.118	0.011	0.438
203019 (Claudy @ Glenone Bridge)	0.734	41	34.081	0.128	0.269	0.854
52004 (Isle @ Ashford Mill)	0.735	50	34.188	0.227	0.016	2.675
206001 (Clanrye @ Mountmill Bridge)	0.764	36	20.208	0.145	0.126	0.277
Total		507				
Weighted means				0.155	0.134	

Default Pooling Group Catchment Descriptors

	Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
1	203028 (Agivey @ Whitehill)	0.345	100.330	1270.000	0.093	0.999	0.003
2	203039 (Clogh @ Tullynewey)	0.423	98.370	1296.000	0.074	0.986	0.001
3	73008 (Bela @ Beetham)	0.438	127.450	1294.000	0.093	0.952	0.010
4	203033 (Upper Bann @ Bannfield)	0.502	101.640	1261.000	0.062	0.951	0.001
5	48003 (Fal @ Tregony)	0.505	89.030	1211.000	0.066	0.983	0.017
6	203043 (Oonawater @ Shanmoy)	0.563	88.590	1003.000	0.078	0.974	0.002
7	48012 (Fal @ Trenowth)	0.633	67.870	1243.000	0.071	0.979	0.019
8	205008 (Lagan @ Drumiller)	0.650	84.980	1016.000	0.069	0.992	0.001
9	205005 (Ravernet @ Ravernet)	0.659	73.530	947.000	0.107	0.934	0.000
10	96003 (Strathy @ Strathy Bridge)	0.665	120.870	1090.000	0.074	0.895	0.000
11	78004 (Kinnel Water @ Redhall)	0.732	76.170	1466.000	0.060	0.999	0.000
12	203019 (Claudy @ Glenone Bridge)	0.734	126.360	1131.000	0.152	0.992	0.004
13	52004 (Isle @ Ashford Mill)	0.735	87.41	891	0.084	0.979	0.026
14	206001 (Clanrye @ Mountmill Bridge)	0.764	120.540	975.000	0.064	0.972	0.004

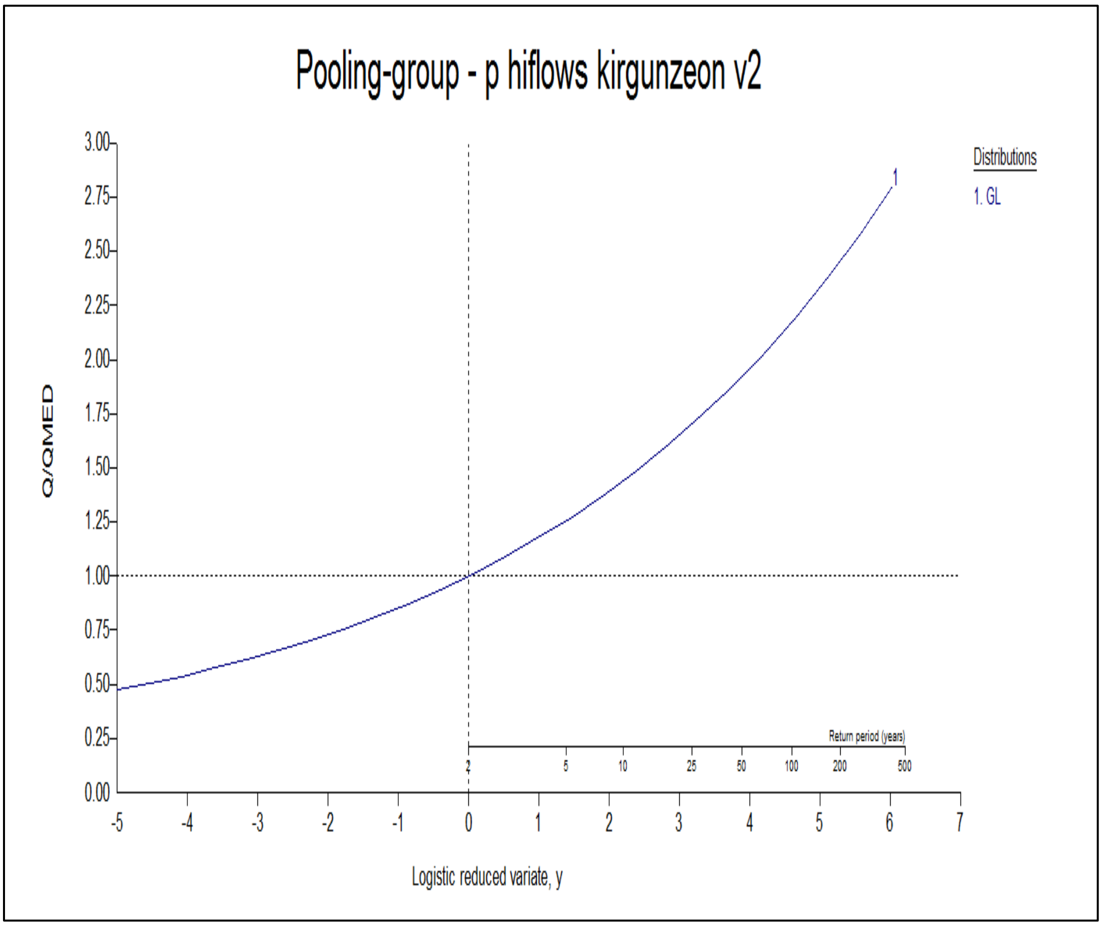
Final Pooling Group

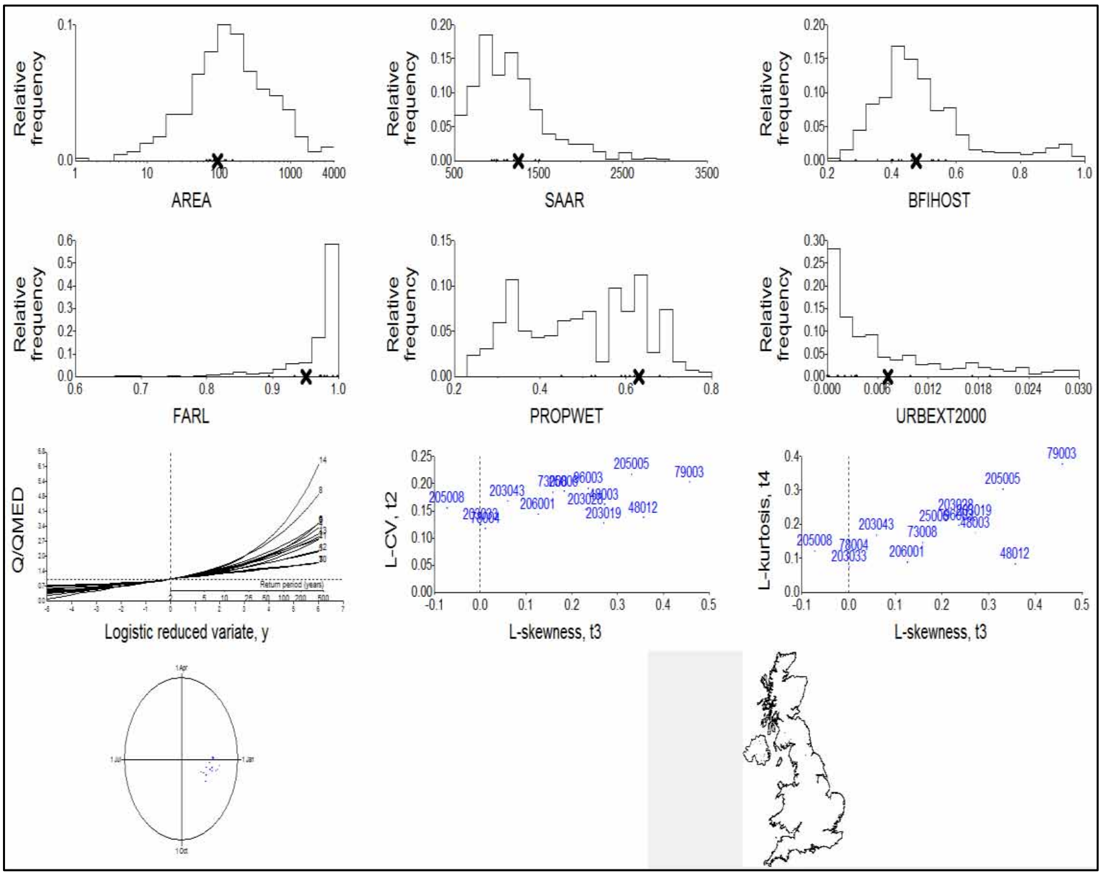
Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
203028 (Agivey @ Whitehill)	0.345	40	64.444	0.154	0.230	0.489
73008 (Bela @ Beetham)	0.438	43	36.936	0.185	0.158	0.775
203033 (Upper Bann @ Bannfield)	0.502	37	67.053	0.126	0.001	0.724
48003 (Fal @ Tregony)	0.505	49	11.038	0.162	0.271	0.226
203043 (Oonawater @ Shanmoy)	0.563	26	30.461	0.169	0.059	0.459
48012 (Fal @ Trenowth)	0.633	15	10.210	0.138	0.357	2.782
205008 (Lagan @ Drumiller)	0.650	38	28.775	0.156	-0.073	1.297
205005 (Ravernet @ Ravernet)	0.659	40	14.355	0.218	0.330	1.172
96003 (Strathy @ Strathy Bridge)	0.665	21	50.021	0.192	0.236	0.501
78004 (Kinnel Water @ Redhall)	0.732	40	78.224	0.118	0.011	1.110
203019 (Claudy @ Glenone Bridge)	0.734	41	34.081	0.128	0.269	1.624
206001 (Clanrye @ Mountmill Bridge)	0.764	36	20.208	0.145	0.126	0.447
25006 (Greta @ Rutherford Bridge)	0.811	52	76.763	0.186	0.183	0.308
79003 (Nith @ Hall Bridge)	0.902	55	70.779	0.203	0.457	2.086
Total		533				
Weighted means				0.163	0.185	

Final Pooling Group

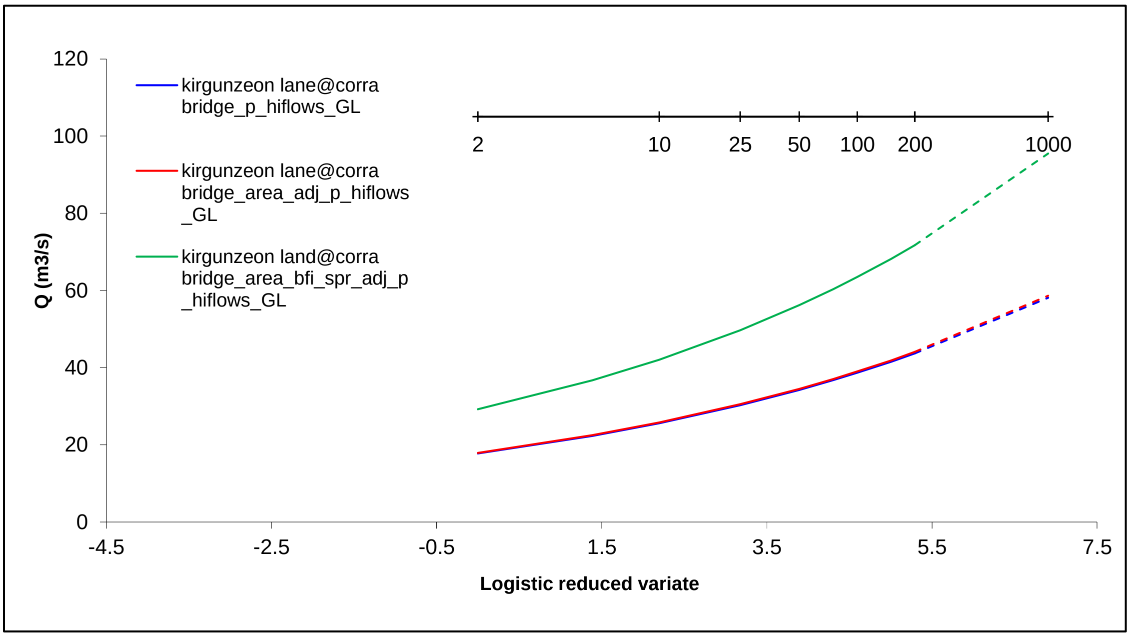
Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
203028 (Agivey @ Whitehill)	0.345	100.330	1270.000	0.093	0.999	0.003
73008 (Bela @ Beetham)	0.438	127.450	1294.000	0.093	0.952	0.010
203033 (Upper Bann @ Bannfield)	0.502	101.640	1261.000	0.062	0.951	0.001
48003 (Fal @ Tregony)	0.505	89.030	1211.000	0.066	0.983	0.017
203043 (Oonawater @ Shanmoy)	0.563	88.590	1003.000	0.078	0.974	0.002
48012 (Fal @ Trenowth)	0.633	67.870	1243.000	0.071	0.979	0.019
205008 (Lagan @ Drumiller)	0.650	84.980	1016.000	0.069	0.992	0.001
205005 (Ravernet @ Ravernet)	0.659	73.530	947.000	0.107	0.934	0.000
96003 (Strathy @ Strathy Bridge)	0.665	120.870	1090.000	0.074	0.895	0.000
78004 (Kinnel Water @ Redhall)	0.732	76.170	1466.000	0.060	0.999	0.000
203019 (Claudy @ Glenone Bridge)	0.734	126.360	1131.000	0.152	0.992	0.004
206001 (Clanrye @ Mountmill Bridge)	0.764	120.540	975.000	0.064	0.972	0.004
25006 (Greta @ Rutherford Bridge)	0.811	86.810	1127.000	0.042	0.999	0.001
79003 (Nith @ Hall Bridge)	0.902	155.760	1512.000	0.066	0.973	0.003

DERIVING A POOLED GROWTH CURVE					
Site	Kirgunzeon Lane downstream of Dalbeattie			√	Ungauged site
NGR	NX 8300 6050				Gauged site
Attached Printouts					
	WINFAP-FEH station details				
	WINFAP-FEH summary information if gauged site				
Initial Pooling Group Details					
Name	p_hiflows_kirkgunzeon_default				
Site of interest	Downstream of Dalbeattie				
Return period of interest	200 years				
Other information					
Version of WIN-FAP FEH	Version 3.0				
Data Files	Other				
If 'Other' chosen in Data Files enter file path here	G:\FEH\FEH CD_ROM and WINFAP\HiFlows-UK data_v3.3.4_(Aug 2014)				
Adjustment/ Changes made to Default Pooling Group. Also note sites that were investigated but retained in the group (i.e. for discordancy)					
Station number	**Name**	**Addition/ Deletion/ Move/ Investigate**	**Reason**		
203039	Clogh @ Tullynewey	D	Out of bank flows below QMED		
52004	Isle @ Ashford Mill	D	Bypassing at high flows		
25006	Greta @ Rutherford Bridge	A	Increase record length after deletions		
79003	Nith @ Hall Bridge	A	Increase record length (D&G distance mea		
Final Pooling Group Details					
Heterogeneity Measure					
H1	Possibly Heterogeneous				
H2	Heterogeneous				
Goodness of Fit					
Acceptable Fit	**Distribution**				
√	Generalised Logistic				
	Generalised Extreme Value				
	Pearson Type iii				
	Generalised Pareto				
Growth Curve Fittings					
Attached print outs	√	WINFAP-FEH growth curve fittings			
	√	WINFAP-FEH growth curve			
Name of Final Pooling Group	p_hiflows_kirkgunzeon_v2				


Pooling-group - p hiflows kirgunzeon v2
Q/QMED
Logistic reduced variate, y
Distributions
1. GL
Return period (years)
2 5 10 25 50 100 200 500

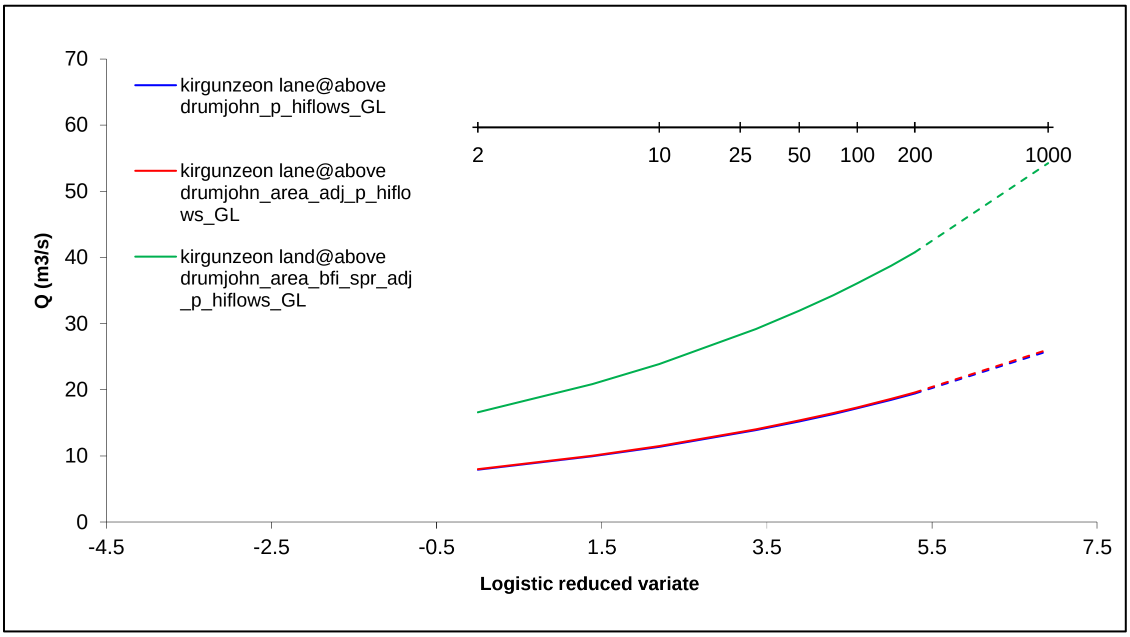

Relative frequency
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Q/QMED
Logistic reduced variate, y
L-CV, t2
L-skewness, t3
L-kurtosis, t4
79003
205005
205008
203043
206001
73008
48003
203019
48012
203033
73004

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Kirgunzeon Lane at Corra Bridge		
NGR	NX 8665 6600		
Type of problem/objective of	Peak flows for FPS appraisal		
Type of catchment	Rural		
$QMED_{site\ cd}$	31.3	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Urr at Dalbeattie		
Station number	80001		
NGR	NX 8210 6100		
Proximity (km)	2.00		
Adjustment	0.9331		
Site Chosen	Y		
$QMED_{site}$ adjusted by data transfer (m^3/s)	17.9	Specific Q (l/s/ha)	4.4
Q_{100} growth curve factor	2.17	Q100/ area (l/s/ha)	9.5
Q_{100} (m^3/s)	**39.0**		
Summary Data			
FEH catchment area	40.69		km^2
Adjusted catchment area	41.09		km^2
URBEXT 1990	0.000		
URBEXT 2010	0.001		
URBEXT Adjustment Method	Urbext2000		
SAAR	1303		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFIHOST		
QMED	17.95		m^3/s
5	22.54		m^3/s
10	25.83		m^3/s
30	30.53		m^3/s
50	34.52		m^3/s
75	37.08		m^3/s
100	39.01		m^3/s
200	44.08		m^3/s
1000	58.63		m^3/s
Climate Change Region	South-West Scotland		
Climate change adjustment	20.0%		
200 + cc	52.9		m^3/s
Donor/ Analogues Used	Urr at Dalbeattie		
Calcs by:	David Cameron	Date:	06/08/2015
Checked by:	Angus Pettit	Date:	19/10/2015



120
100
80
60
40
20
0
Q (m3/s)
kirgunzeon lane@corra bridge_p_hiflows_GL
kirgunzeon lane@corra bridge_area_adj_p_hiflows_GL
kirgunzeon land@corra bridge_area_bfi_spr_adj_p_hiflows_GL
2
10
25
50
100
200
1000
-4.5
-2.5
-0.5
1.5
3.5
5.5
7.5
Logistic reduced variate

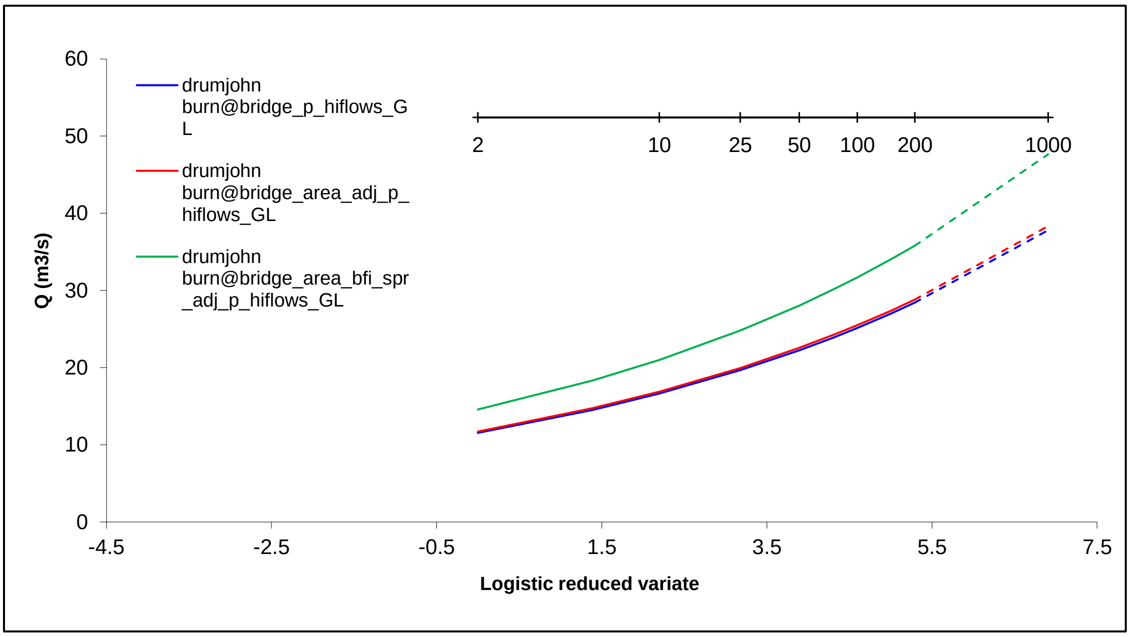
FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Kirgunzeon Lane upstream of Drumjohn Burn confluence		
NGR	NX 8710 6770		
Type of problem/objective of	Peak flows for FPS appraisal		
Type of catchment	Rural		
QMED site cd	17.8	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Urr at Dalbeattie		
Station number	80001		
NGR	NX 8210 6100		
Proximity (km)	2.00		
Adjustment	0.9331		
Site Chosen	Y		
QMED site adjusted by data transfer (m^3/s)	8.0	Specific Q (l/s/ha)	3.4
Q_{100} growth curve factor	2.17	Q100/ area (l/s/ha)	7.3
Q_{100} (m^3/s)	**17.3**		
Summary Data			
FEH catchment area	23.52		km^2
Adjusted catchment area	23.76		km^2
URBEXT 1990	0.000		
URBEXT 2010	0.001		
URBEXT Adjustment Method	Urbext2000		
SAAR	1284		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFIHOST		
QMED	7.98		m^3/s
5	10.02		m^3/s
10	11.48		m^3/s
30	14.02		m^3/s
50	15.35		m^3/s
75	16.48		m^3/s
100	17.34		m^3/s
200	19.60		m^3/s
1000	26.07		m^3/s
Climate Change Region	South-West Scotland		
Climate change adjustment	20.0%		
200 + cc	23.5		m^3/s
Donor/ Analogues Used	Urr at Dalbeattie		
Calcs by:	David Cameron	Date:	24/9/0215
Checked by:	Angus Pettit	Date:	19/10/2015



Q (m3/s)
70
60
50
40
30
20
10
0
kirgunzeon lane@above drumjohn_p_hiflows_GL
kirgunzeon lane@above drumjohn_area_adj_p_hiflows_GL
kirgunzeon land@above drumjohn_area_bfi_spr_adj_p_hiflows_GL
2
10
25
50
100
200
1000
-4.5
-2.5
-0.5
1.5
3.5
5.5
7.5
Logistic reduced variate

JBA consulting

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET			
Site	Drumjohn Burn at Drumjohn Bridge		
NGR	NX 8730 6705		
Type of problem/objective of	Peak flows for FPS appraisal		
Type of catchment	Rural		
QMED site cd	15.6	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Urr at Dalbeattie		
Station number	80001		
NGR	NX 8210 6100		
Proximity (km)	2.00		
Adjustment	0.9348		
Site Chosen	Y		
QMED site adjusted by data transfer (m^3/s)	11.7	Specific Q (l/s/ha)	9.0
Q_{100} growth curve factor	2.17	Q100/ area (l/s/ha)	19.6
Q_{100} (m^3/s)	**25.5**		
Summary Data			
FEH catchment area	12.81		km^2
Adjusted catchment area	13.02		km^2
URBEXT 1990	0.000		
URBEXT 2010	0.000		
URBEXT Adjustment Method	Urbext2000		
SAAR	1361		
Method Used	FEH Statistical Method		
Variation from Chosen Method			
Index Used	BFIHOST		
QMED	11.73		m^3/s
5	14.74		m^3/s
10	16.89		m^3/s
30	19.96		m^3/s
50	22.57		m^3/s
75	24.24		m^3/s
100	25.50		m^3/s
200	28.82		m^3/s
1000	38.33		m^3/s
Climate Change Region	South-West Scotland		
Climate change adjustment	20.0%		
200 + cc	34.6		m^3/s
Donor/ Analogues Used	Urr at Dalbeattie		
Calcs by:	David Cameron	Date:	06/08/2015
Checked by:	Angus Pettit	Date:	19/10/2015

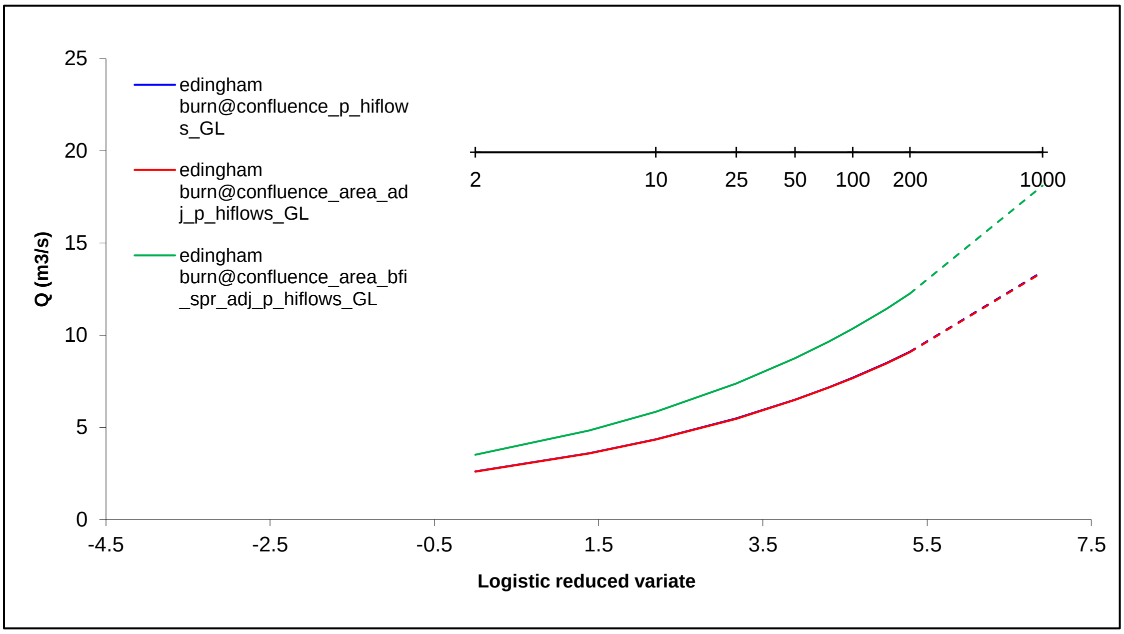

60
50
40
30
20
10
0
Q (m3/s)
drumjohn burn@bridge_p_hiflows_GL
drumjohn burn@bridge_area_adj_p_hiflows_GL
drumjohn burn@bridge_area_bfi_spr_adj_p_hiflows_GL
2
10
25
50
100
200
1000
-4.5
-2.5
-0.5
1.5
3.5
5.5
7.5
Logistic reduced variate

FEH STATISTICAL FLOOD ESTIMATION SUMMARY SHEET

Site	Edingham Burn upstream of Kirgunzeon Lane confluence		
NGR	NX 8355 6175		
Type of problem/objective of	Peak flows for FPS appraisal		
Type of catchment	Rural		
QMED site cd	2.8	m^3/s	
Donor/ Analogue Sites Considered			
Site name	Urr at Dalbeattie		
Station number	80001		
NGR	NX 8210 6100		
Proximity (km)	2.00		
Adjustment	0.9317		
Site Chosen	Y		
QMED site adjusted by data transfer (m^3/s)	2.6	Specific Q (l/s/ha)	5.9
Q_{100} growth curve factor	2.95	Q100/ area (l/s/ha)	17.4
Q_{100} (m^3/s)	**7.7**		

Summary Data		
FEH catchment area	4.43	km^2
Adjusted catchment area	4.41	km^2
URBEXT 1990	0.003	
URBEXT 2010	0.009	
URBEXT Adjustment Method	Urbext2000	
SAAR	1144	
Method Used	FEH Statistical Method	
Variation from Chosen Method		
Index Used	BFIHOST	
QMED	2.60	m^3/s
5	3.58	m^3/s
10	4.33	m^3/s
30	5.47	m^3/s
50	6.48	m^3/s
75	7.15	m^3/s
100	7.67	m^3/s
200	9.08	m^3/s
1000	13.41	m^3/s
Climate Change Region	South-West Scotland	
Climate change adjustment	20.0%	
200 + cc	10.9	m^3/s
Donor/ Analogues Used	Urr at Dalbeattie	

Calcs by:	David Cameron	Date:	06/08/2015
Checked by:	Angus Pettit	Date:	19/10/2015



POOLING GROUP DETAILS

Original Default Pooling Group

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
45816 (Haddeo @ Upton)	0.845	19	3.456	0.324	0.434	0.536
28033 (Dove @ Hollinsclough)	1.069	33	4.666	0.266	0.415	0.451
27051 (Crimple @ Burn Bridge)	1.165	40	4.539	0.222	0.149	0.321
76011 (Coal Burn @ Coalburn)	1.462	35	1.840	0.169	0.333	0.952
47022 (Tory Brook @ Newnham Park)	1.634	19	7.331	0.257	0.071	0.607
49006 (Camel @ Camelford)	1.649	6	8.832	0.110	-0.293	3.459
25011 (Langdon Beck @ Langdon)	1.657	26	15.878	0.241	0.326	1.368
25003 (Trout Beck @ Moor House)	1.690	39	15.164	0.176	0.291	0.583
91802 (Allt Leachdach @ Intake)	1.747	34	6.350	0.153	0.257	1.084
206006 (Annalong @ Recorder)	1.801	48	15.330	0.189	0.052	1.634
54022 (Severn @ Plynlimon Flume)	1.854	37	15.031	0.155	0.168	1.199
25019 (Leven @ Easby)	1.889	34	5.538	0.347	0.394	0.723
26802 (Gypsey Race @ Kirby Grindalythe	1.996	13	0.109	0.261	0.199	0.417
27010 (Hodge Beck @ Bransdale Weir)	2.130	41	9.420	0.224	0.293	0.124
44008 (South Winterbourne @ Winterbou	2.202	33	0.420	0.395	0.332	1.502
51002 (Horner Water @ West Luccombe)	2.271	31	8.354	0.382	0.326	1.472
203046 (Rathmore Burn @ Rathmore Brid	2.316	30	10.934	0.136	0.091	0.568
Total		518				
Weighted means				0.238	0.246	

Default Pooling Group Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
45816 (Haddeo @ Upton)	0.845	6.810	1210.000	0.011	1.000	0.005
28033 (Dove @ Hollinsclough)	1.069	7.930	1346.000	0.007	1.000	0.000
27051 (Crimple @ Burn Bridge)	1.165	8.150	855.000	0.013	1.000	0.006
76011 (Coal Burn @ Coalburn)	1.462	1.630	1096.000	0.074	1.000	0.000
47022 (Tory Brook @ Newnham Park)	1.634	13.450	1403.000	0.023	0.942	0.014
49006 (Camel @ Camelford)	1.649	12.860	1418.000	0.012	1.000	0.004
25011 (Langdon Beck @ Langdon)	1.657	12.790	1463.000	0.013	1.000	0.001
25003 (Trout Beck @ Moor House)	1.690	11.460	1904.000	0.041	1.000	0.000
91802 (Allt Leachdach @ Intake)	1.747	6.520	2555.000	0.003	0.992	0.000
206006 (Annalong @ Recorder)	1.801	13.660	1720.000	0.024	0.980	0.000
54022 (Severn @ Plynlimon Flume)	1.854	8.690	2483.000	0.010	1.000	0.000
25019 (Leven @ Easby)	1.889	15.070	830.000	0.019	1.000	0.004
26802 (Gypsey Race @ Kirby Grindalyt	1.996	15.85	757	0.03	1	0
27010 (Hodge Beck @ Bransdale Weir)	2.130	18.840	987.000	0.009	1.000	0.001
44008 (South Winterbourne @ Winterbo	2.202	20.170	1012.000	0.015	1.000	0.004
51002 (Horner Water @ West Luccomb	2.271	20.380	1485.000	0.003	0.978	0.000
203046 (Rathmore Burn @ Rathmore Br	2.316	22.510	1043.000	0.073	1.000	0.000

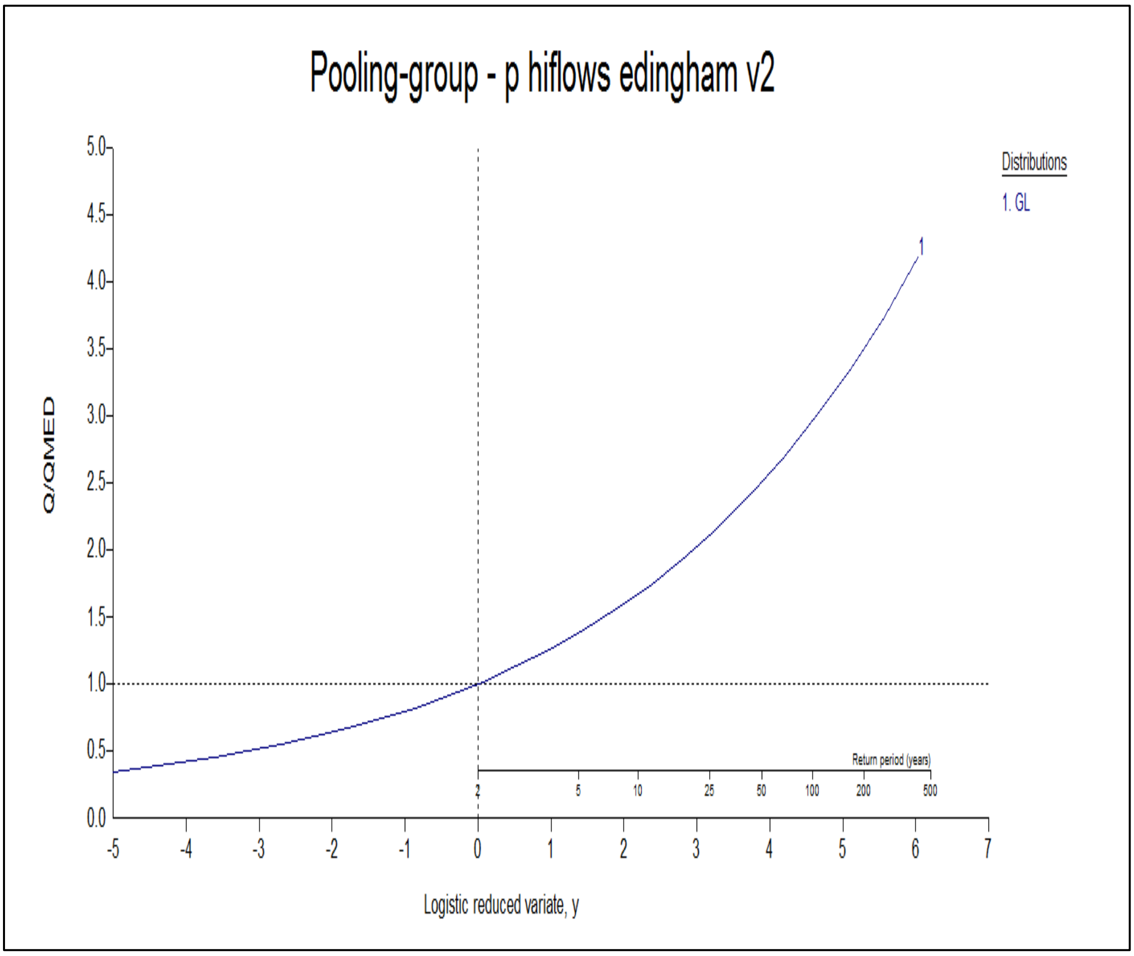
Final Pooling Group

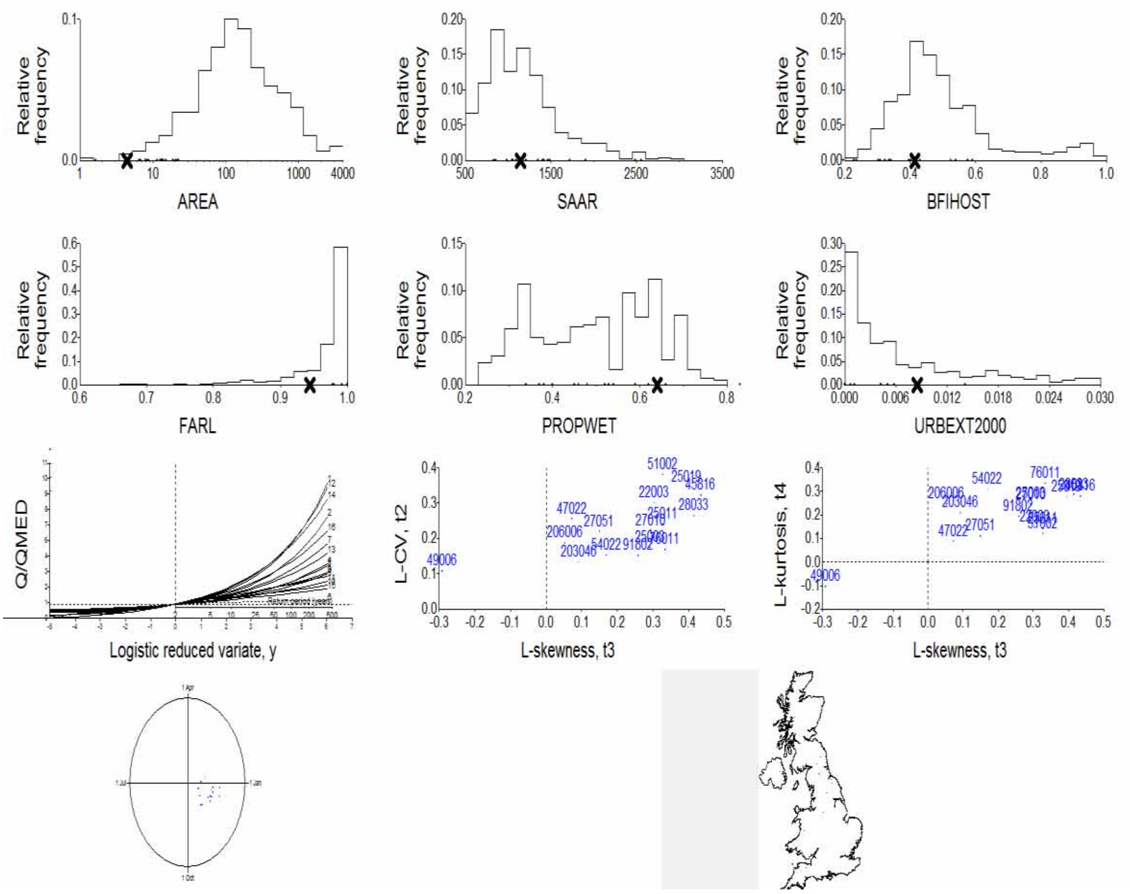
Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
45816 (Haddeo @ Upton)	0.845	19	3.456	0.324	0.434	0.641
28033 (Dove @ Hollinsclough)	1.069	33	4.666	0.266	0.415	0.395
27051 (Crimple @ Burn Bridge)	1.165	40	4.539	0.222	0.149	0.237
76011 (Coal Burn @ Coalburn)	1.462	35	1.840	0.169	0.333	0.910
47022 (Tory Brook @ Newnham Park)	1.634	19	7.331	0.257	0.071	0.714
49006 (Camel @ Camelford)	1.649	6	8.832	0.110	-0.293	3.243
25011 (Langdon Beck @ Langdon)	1.657	26	15.878	0.241	0.326	1.189
25003 (Trout Beck @ Moor House)	1.690	39	15.164	0.176	0.291	0.577
91802 (Allt Leachdach @ Intake)	1.747	34	6.350	0.153	0.257	1.171
206006 (Annalong @ Recorder)	1.801	48	15.330	0.189	0.052	1.866
54022 (Severn @ Plynlimon Flume)	1.854	37	15.031	0.155	0.168	1.183
25019 (Leven @ Easby)	1.889	34	5.538	0.347	0.394	1.138
27010 (Hodge Beck @ Bransdale Weir)	2.130	41	9.420	0.224	0.293	0.095
51002 (Horner Water @ West Luccombe)	2.271	31	8.354	0.382	0.326	1.618
203046 (Rathmore Burn @ Rathmore Brid	2.316	30	10.934	0.136	0.091	0.553
22003 (Usway Burn @ Shillmoor)	2.324	26	19.220	0.303	0.303	0.472
Total		498				
Weighted means				0.231	0.246	

Final Pooling Group

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
45816 (Haddeo @ Upton)	0.845	6.810	1210.000	0.011	1.000	0.005
28033 (Dove @ Hollinsclough)	1.069	7.930	1346.000	0.007	1.000	0.000
27051 (Crimple @ Burn Bridge)	1.165	8.150	855.000	0.013	1.000	0.006
76011 (Coal Burn @ Coalburn)	1.462	1.630	1096.000	0.074	1.000	0.000
47022 (Tory Brook @ Newnham Park)	1.634	13.450	1403.000	0.023	0.942	0.014
49006 (Camel @ Camelford)	1.649	12.860	1418.000	0.012	1.000	0.004
25011 (Langdon Beck @ Langdon)	1.657	12.790	1463.000	0.013	1.000	0.001
25003 (Trout Beck @ Moor House)	1.690	11.460	1904.000	0.041	1.000	0.000
91802 (Allt Leachdach @ Intake)	1.747	6.520	2555.000	0.003	0.992	0.000
206006 (Annalong @ Recorder)	1.801	13.660	1720.000	0.024	0.980	0.000
54022 (Severn @ Plynlimon Flume)	1.854	8.690	2483.000	0.010	1.000	0.000
25019 (Leven @ Easby)	1.889	15.070	830.000	0.019	1.000	0.004
27010 (Hodge Beck @ Bransdale Weir)	2.13	18.84	987	0.009	1	0.001
51002 (Horner Water @ West Luccomb	2.271	20.380	1485.000	0.003	0.978	0.000
203046 (Rathmore Burn @ Rathmore Br	2.316	22.510	1043.000	0.073	1.000	0.000
22003 (Usway Burn @ Shillmoor)	2.324	21.870	1056.000	0.006	1.000	0.000

DERIVING A POOLED GROWTH CURVE				
Site	Edingham Burn upstream of Kirgunzeon Lane confluence		√	Ungauged site
NGR	NX 8355 6175			Gauged site
Attached Printouts				
	WINFAP-FEH station details			
	WINFAP-FEH summary information if gauged site			
Initial Pooling Group Details				
Name	p_edingham_default			
Site of interest	Edingham Burn upstream of Kirgunzeon Lane confluence in Dalbeattie			
Return period of interest	200 years			
Other information				
Version of WIN-FAP FEH	Version 3.0			
Data Files	Other			
If 'Other' chosen in Data Files enter file path here	G:\FEH\FEH CD_ROM and WINFAP\HiFlows-UK data_v3.3.4_(Aug 2014)			
Adjustment/ Changes made to Default Pooling Group. Also note sites that were investigated but retained in the group (i.e. for discordancy)				
Station number	**Name**	**Addition/ Deletion/ Move/ Investigate**	**Reason**	
49006	Camel @ Camelford	I	Discordancy from short record	
44008	Winterbourne @ Winterbourne Stee	D	Chalk. BFI 0.811	
26802	Gypsey Race @ Kirby Grindalythe	D	Chalk. BFI 0.959	
22003	Usway Burn @ Shillmoor	A	Increase record length to circa 500 years	
Final Pooling Group Details				
Heterogeneity Measure				
H1	Heterogeneous			
H2	Possibly Heterogeoeous			
Goodness of Fit				
Acceptable Fit	**Distribution**			
√	Generalised Logistic			
	Generalised Extreme Value			
	Pearson Type iii			
	Generalised Pareto			
Growth Curve Fittings				
Attached print outs	√	WINFAP-FEH growth curve fittings		
	√	WINFAP-FEH growth curve		
Name of Final Pooling Group	p_hiflows_edingham_v2			


Pooling-group - p hiflows edingham v2
Distributions
1. GL
Q/QMED
Logistic reduced variate, y
Return period (years)
2 5 10 25 50 100 200 500


Relative frequency
AREA
SAAR
BFIHOST
FARL
PROPWET
URBEXT2000
Q/QMED
Logistic reduced variate, y
L-CV, t2
L-skewness, t3
L-kurtosis, t4
L-skewness, t3

B Appendix B - Asset summary

A Appendix B - Asset summary

A.1 Dalbeattie and District Flood Prevention Scheme 1981

A full walkover survey was undertaken to assess the condition of individual flood defence assets in Dalbeattie and Kirkgunzeon. These defence assets (listed below) collectively make up the Dalbeattie and District FPS 1980.

Category	Comments
Date of inspection(s)	22 June 2015 20 October 2015
Inspector(s)	Angus Pettit
General Inspection Information	Weather at the time of inspections was dry and sunny.
Scheme Information	Works inspected were promoted by Dumfries and Galloway Council as part of the Dalbeattie and District FPS 1980. Date of construction was 1981. The assets are now 34 years old.
Drawings	The operations are shown on drawings 6297/FPA/1/2/3/4/5. These drawings are available on the Scottish Flood Defence Asset Database and have been provided to JBA as part of this project.
Nature of inspection(s)	The inspections were walkover surveys and visual inspection of the flood defence assets shown on the drawings and referred to in the FPS. Photographs were taken. Separate topographic survey was undertaken of key assets of concern.
Nature of Assets	Flood defence assets were constructed at the following five locations: • Kirkgunzeon Lane (Dalbeattie Burn) through Dalbeattie, and the Edingham Burn. • Culvert through the disused railway embankment on an unnamed tributary of the Edingham Burn. • Flood embankments along the Kirkgunzeon Lane near Maidenholm Farm. • Flood embankments along the Kirkgunzeon Lane upstream of Corra Bridge in the vicinity of Kirkgunzeon. • Flood embankments along the Drumjohn Burn near Drumjohn Bridge.
Comments from Residents	No comments were received from residents regarding any of the FPS works.
General condition/comments	The assets were found to be in good condition consistent with asset age.

A.2 Edingham Burn

Operations listed from Upstream to Downstream and referenced by the original Scheme Works Operation Number.

<table>
<tr><th>Barhill Road culvert</th><th>Ref: FPS Operation 1</th></tr>
<tr><td>
Downstream face

Overflow 'slots' through downstream wall</td><td>Type: Culvert
Bank: N/A
Upstream Grid Ref:
Height (m) (river side): N/A
Height (m) (landward side): N/A
Width (m): 0.825m dia
Length (m): 12m
Material: Concrete culvert/headwall
Condition: Grade 2 (Good)
Part of FPS: Yes
Comments:
• Not inspected internally, but free flowing.
• Headwalls in good condition.
• No sign of blockage - openings clear
• Some sediment through bed of culvert (loss of capacity, but retains sediment movement.
Change in condition since 2006:
• No significant change to culvert.
• Unstable bank on right bank upstream of culvert noted.
• Presence of Hemlock Water-dropwort in channel.
• Slots in downstream road parapet noted. This allow water bank into the channel.</td></tr>
<tr><td>
Downstream wingwalls</td><td></td></tr>
</table>

Edingham Burn downstream of Barhill Road	Ref: FPS Operation 2
 *Looking Upstream*	**Type**: Channel realignment **Bank**: N/A **Upstream Grid Ref:** **Height (m) (river side)**: N/A **Height (m) (landward side)**: N/A **Width (m)**: 2m channel width **Length (m)**: ~50m **Material**: Stone laid in concrete. **Condition**: Grade 2 (Good) **Part of FPS**: Yes **Comments**: • Presence of Hemlock Water-dropwort in channel **Change in condition since 2006**: • No significant change • Right bank wall levels not previously surveyed

A.2.1 Non FPS assets identified during the site visit

The following additional assets were identified during the site visit. These represent assets that were not part of the original FPS, but may have an impact on flood risk.

Asset:	Description
	• Informal brick wall adjacent to Edingham Burn (Queens Grove).
	• Surface water drainage holes through property boundary wall. On the corner of Barhill Road and John Street).

A.3 Kirkgunzeon Lane (Dalbeattie Burn) through Dalbeattie

Operations listed from Upstream to Downstream and referenced by the original Scheme Works Operation Number.

Operations unable to be explicitly inspected:

- Operation 22 - Strengthening and underpinning or otherwise improving as required existing embankments and walls to Kirkgunzeon Lane at various locations.
- Operation 23 - Regrading and minor realignment as required of the bed of Kirkgunzeon Lane at various locations.
- Operation 24 - Carrying out work as required to protect an maintain services and prevent reverse flow in drains at various locations.

Name: Footbridge replacement	FPS Operation 21
 ***Upstream face of new footbridge***	**Type**: Footbridge replacement and approaches in Colliston Park **Bank**: N/A **Upstream Grid Ref:** **Soffit (m)**: 15.87mAOD **Opening width (m)**: 8.18m **Material**: Steel beams with concrete deck and steel railings **Condition**: Grade 2 (Good) **Part of FPS**: Yes **Comments**: • Good condition. • Abutments in good condition with rock armour placed at base. • Service pipes on upstream face. **Change in condition since 2006**: • No significant changes.

Name: Embankment adjacent to Munches Park	Ref: FPS Operation 3
 *From Right Bank looking upstream*	**Type**: Embankment **Bank**: Right **Upstream Grid Ref:** **Height (m) (river side)**: 1.4-3.0m **Height (m) (landward side)**: 1.40m **Width (m)**: 0.40m **Length (m)**: 115m **Material**: Earth **Condition**: Grade 2 (Good) **Part of FPS**: Yes **Comments**: • Ties into footbridge and stone wall downstream and high ground upstream. • Landward side is well maintained in boundary of Munchies Park House. • Crest and river side very overgrown. • River side made up of rock armour, mortared wall and stone pitching in various sections. Some erosion of base evident. • Un-flapped outfall present on right bank at downstream end. **Change in condition since 2006**: • No significant change
 *Right bank rock armour*  *Right bank stone wall*	 *Right bank rock armour and eroded concrete sill*  *Un-flapped outfall*

Name: Raised abutments and deck (John Street to Munches Park)	FPS Operation 20
 *Upstream face of new footbridge*	**Type**: Raised abutment and deck levels of bridges in Colliston Park (Footbridge No. 4) **Bank**: N/A **Upstream Grid Ref:** **Soffit (m)**: mAOD **Opening width (m)**: m **Material**: Steel beams with concrete deck and steel railings **Condition**: Grade 2 (Good) **Part of FPS**: Yes **Comments**: • Good condition. • Abutments in good condition with no scour. • Service pipe on upstream face. **Change in condition since 2006**: • No significant changes.
 *Upstream face of new footbridge*	**Type**: Raised abutment and deck levels of bridges in Colliston Park (Footbridge No. 3) **Bank**: N/A **Upstream Grid Ref:** **Soffit (m)**: mAOD **Opening width (m)**: m **Material**: Steel frame with concrete deck **Condition**: Grade 2 (Good) **Part of FPS**: Yes **Comments**: • Good condition. • Abutments in good condition with no scour. **Change in condition since 2006**: No significant changes.

<table>
<tr><th>Name: Embankment adjacent to Colliston Park</th><th>FPS Operation 4</th></tr>
<tr><td>
Looking upstream. Approximate location of removed weir.</td><td>Type: Weir removal and channel modification. Walls were not part of FPS but do act as flood protection to riparian properties.
Bank: N/A
Upstream Grid Ref:
Wall Height (m) (river side): Variable
Wall Height (m) (landward side): Variable - 0.2m D/S, 1.05m U/S.
Wall Width (m): 0.30m
Wall Length (m): 35m
Material: Concrete foundation, mortared stone and 'fyfestone' walls.
Condition: Grade 2 (Good)
Part of FPS: No
Comments:
• Walls are not part of FPS, but do offer flood protection
Change in condition since 2006:
• No significant change</td></tr>
<tr><td>
Concrete foundation and mortared stone walls</td><td>
Loss of caulking / sealant between wall sections</td></tr>
</table>

Name: Pipe to supply water to pond in Colliston Park	FPS Operation 5
 *Inlet and screen*	**Type**: Culvert **Bank**: Left **Upstream Grid Ref:** **Height (m) (river side)**: N/A **Height (m) (landward side)**: N/A **Width (m)**: 0.15m diameter **Length (m)**: 200m **Material**: UNKNOWN **Condition**: UNKNOWN **Part of FPS**: Yes **Comments**:
 *Outlet into pond*	• Three manholes in Colliston Park identified but not inspected internally. • Inlet structure has informal weir across burn to elevate water levels locally. • Inlet structure has steel cover. • Inlet has trash screen present. Screen is partially blocked and deformed. Screen is not to current design standards. **Change in condition since 2006**: • Not previously inspected. • Culvert flows full - unable to CCTV culvert at upstream end.
 *Approach to inlet on Kirkgunzeon Lane*	

Name: Flood wall along John Street — FPS Operation 6

Looking upstream at right bank

Downstream end of wall tied into wall

Type: Wall
Bank: Right
Upstream Grid Ref:
Height (m) (river side): 2.4m to bed
Height (m) (landward side): 1m
Width (m): 0.35m
Length (m): 97m
Material: Stone
Condition: Grade 2 (Good)
Part of FPS: Yes
Comments:

- Possible bypassing route identified at upstream end through garden wall gate.
- Crest level lower at footbridge
- Un-flapped culvert at upstream end (see below)

Change in condition since 2006:

- No significant change

Possible bypassing route through gate at U/S end

Crest lower at footbridge

Name: Footbridge replacement	FPS Operation 19

Upstream face of new footbridge

Type: Footbridge replacement and approaches from Water Street and Isle Croft House

Bank: N/A

Upstream Grid Ref:

Soffit (m): 12.68mAOD

Opening width (m): 18.07m

Material: Steel deck and railings

Condition: Grade 2 (Good)

Part of FPS: Yes

Comments:

- Good condition.
- Abutments in good condition, no scour.
- Presence of Hemlock Water-dropwort in channel on left bank.

Change in condition since 2006:

- No significant changes.

Name: Wall and embankment between Pond and High Street	FPS Operation 7

Stone face (pond side) with embankment to rear

Wall crest level lowered

Type: Embankment (U/S) with stone face on pond side

Bank: Left

Upstream Grid Ref:

Height (m) (river side): 1.30m

Height (m) (landward side): 1.60m

Width (m): Variable

Length (m): 35m

Material: Earth/mortared stone

Condition: Grade 4 (Poor)

Part of FPS: Yes

Comments:

- Ties into wall downstream
- Vegetation growth on crest/bank
- Poorly maintained
- Crest level is not uniform

Change in condition since 2006:

- Some degradation in crest observed
- Vegetation has grown significantly on top/rear of embankment.

River side wall looking D/S

Landward side of wall looking D/S

Type: Wall (D/S)
Bank: Left
Upstream Grid Ref:
Height (m) (river side): 3.0m
Height (m) (landward side): 0.9m
Width (m): 0.75m
Length (m): ~95m
Material: Segmental concrete wall
Condition: Grade 2 (Good)
Part of FPS: Yes
Comments:

- Rear of wall well maintained.
- Uniform crest level.
- Outfall through wall has a flap valve present.
- Minor vegetation growth on wall.
- Presence of Hemlock Water-dropwort in channel at U/S end of wall

Change in condition since 2006:

- Not previously inspected.

Name: Wall upstream of High Street Bridge	**FPS Operation 8**

Looking from right to left bank

Type: Wall on top of concrete foundation
Bank: Left
Upstream Grid Ref:
Height (m) (river side): 1.5m
Height (m) (landward side): 0.9m, then 1.5m to bed (concrete foundation)
Width (m): 0.3m
Length (m): 16m
Material: Concrete
Condition: Grade 2 (Good)
Part of FPS: Yes
Comments:

- Uniform crest level
- Tied into bridge at D/S end
- Tied into stone wall at U/S end

Change in condition since 2006:

- Not previously inspected.

Name: Wall between Water Street and High Street	FPS Operation 9

Right bank from left

Type: Wall
Bank: Right
Upstream Grid Ref:
Height (m) (river side): 3.0m
Height (m) (landward side): 0.8 - 1.0m
Width (m): 0.6m
Length (m): 115m
Material: Concrete
Condition: Grade 2 (Good)
Part of FPS: Yes
Comments:

- Uniform crest level
- Tied into footbridge wall at U/S end
- Drop in level to ramp to High Street at U/S end
- Presence of Hemlock Water-dropwort in channel
- Un-flapped outfall in D/S end (see below)

Change in condition since 2006:

- Not previously inspected.

Right bank looking upstream (downstream end)

Tied into footbridge wall at U/S end

Drop in level to ramp to High Street at U/S end

Name: Scour protection at High Street road bridge	FPS Operation 10

Upstream face of High Street Bridge

Type: Concrete scour protection
Bank: Left and right
Upstream Grid Ref:
Height (m) (river side): Variable 0.4-0.8m
Width (m): N/A
Length (m): 50m
Material: Concrete
Condition: Grade 2 (Good)
Part of FPS: Yes
Comments:

- Concrete benching in good condition.
- No sign of cracking
- Little vegetation growth
- No obvious scour holes

Change in condition since 2006:

- Not previously inspected.

Downstream left bank

Downstream right bank

Name: Weir removal	FPS Operation 11

Upstream face of High Street Bridge

Type: Weir removal
Bank: N/A
Upstream Grid Ref:
Height (m) (river side): Unknown
Width (m): N/A
Length (m): ~17m
Material: Unknown
Condition: N/A
Part of FPS: Yes
Comments:

- Small bedrock weir now present.
- Walls and banks appear to be in reasonable condition and stable.

Change in condition since 2006:

- Not previously inspected.

Name: Wall upstream of Burn Street	FPS Operation 12/15
 *Rear side of wall in Kylea property*  *Rear side of wall in Ferguslea property*	**Type**: Demolition of old wall and construction of new concrete wall **Bank**: N/A **Upstream Grid Ref:** **Height (m) (river side)**: **Height (m) (landward side)**: **Width (m)**: 0.6m **Length (m)**: 95m **Material**: Unknown **Condition**: N/A **Part of FPS**: Yes **Comments**: • Walls and banks appear to be in reasonable condition and stable. • Presence of leyandii behind defences. **Change in condition since 2006**: • Not previously inspected.
 *Downstream limit of wall behind Craignair Church Hall*	 *Wall downstream of footbridge (looking downstream)*

Name: Demolition and re-build of Craignair Church Hall	FPS Operation 13
	Type: Demolition and re-build of Craignair Church Hall **Bank**: Left **Upstream Grid Ref:** **Comments**: N/A

Name: Tree felling and excavation	FPS Operation 14
	**Type**: Tree felling and excavation of 125m of bed/bank to aid Operation 15. **Bank**: Left **Upstream Grid Ref:** **Comments**: Area has become overgrown.

Name: Wall on right bank	FPS Operation 16
 *River side of wall looking downstream*  *Rear side of wall looking downstream*	**Type**: Concrete segmental wall **Bank**: Right **Upstream Grid Ref:** **Height (m) (river side)**: 2.7m **Height (m) (landward side)**: 0.74m **Width (m)**: 0.5m **Length (m)**: 66m **Material**: Concrete **Condition**: Grade 2 (Good) **Part of FPS**: Yes **Comments**: • Uniform crest level • Concrete benching and rock armour at base • Tied into retaining walls at U/S and D/S end • Presence of Hemlock Water-dropwort in channel • Access ladder present on river side of wall. **Change in condition since 2006**: • Buildings at downstream end have been demolished. Building exterior wall acts as extension to flood defence.
 *Concrete scour protection and rock armour*	 *Wall tied into older brick wall (previously the building external wall) leading to footbridge*

<table>
<tr><th>Name: Footbridge replacement (Burn Street)</th><th>FPS Operation 18</th></tr>
<tr><td>
Upstream face of new footbridge</td><td>Type: Footbridge replacement and approaches from Mill Isle and Burn Street
Bank: N/A
Upstream Grid Ref:
Soffit (m): 10.34mAOD
Opening width (m): 11.22m
Material: Steel beam and railings
Condition: Grade 2 (Good)
Part of FPS: Yes
Comments:
• Good condition.
• Abutments in good condition, no scour.
Change in condition since 2006:
• No significant changes.</td></tr>
</table>

<table>
<tr><th>Name: Wall on right bank downstream of Burn Street footbridge</th><th>FPS Operation 17</th></tr>
<tr><td>
River side of wall looking downstream

Rear side of wall looking downstream</td><td>Type: Wall
Bank: Right
Upstream Grid Ref:
Height (m) (river side): 1.4m (2.55 to bed)
Height (m) (landward side): 1.3m - 1.6m
Width (m): 0.4m
Length (m): 62m
Material: Stone
Condition: Grade 2 (Good)
Part of FPS: Yes
Comments:
• Uniform crest level
• Concrete retaining structure at base of wall
• Sealant in good condition (see below)
• Wall ties into bridge abutment upstream and into embankment downstream
Change in condition since 2006:
• No significant changes.</td></tr>
</table>

 *Concrete scour protection and rock armour*	 *Wall tied into older brick wall (previously the building external wall) leading to footbridge*

Name: Embankment around bowling green	FPS Operation 17 continued
 *Embankment looking downstream*  *Rock armour downstream of tie in with wall*	**Type**: Embankment (armoured for short section at upstream end) **Bank**: Right **Upstream Grid Ref:** **Height (m) (river side)**: 0.8m **Height (m) (landward side)**: 0.8m **Width (m)**: 1.0m **Length (m)**: 75m **Material**: Earth **Condition**: Grade 2 (Good) **Part of FPS**: Yes **Comments**: • Uniform crest level • Well maintained embankment • Stone armoured on river side face for 8m at upstream end of embankment • Tied into retaining walls at U/S • Embankment at downstream end is not tied into high ground **Change in condition since 2006**: • No significant change. • Embankment gap was present in 2006.

 *End of embankment and low point*	

Name: Channel modification	FPS Operation 25
 *Embankment looking upstream from footbridge*	**Type**: Channel widening and removal of obstructions. **Bank**: N/A **Upstream Grid Ref:** **Height (m) (river side)**: N/A **Height (m) (landward side)**: N/A **Width (m)**: River width **Length (m)**: 245m **Material**: N/A **Condition**: Grade 3 (Average) **Part of FPS**: Yes **Comments**: • Change in bed levels/shape unknown. • Vegetation on banks has matured since works. **Change in condition since 2006**: • No significant change.

A.4 Edingham Burn upstream

Name: Construction of flood relief culvert	FPS Operation 26
 *Embankment through which culvert flows*  *Downstream face*	**Type**: New flood relief culvert **Bank**: N/A **Upstream Grid Ref:** **Height (m) (river side)**: N/A **Height (m) (landward side)**: N/A **Width (m)**: 1.1m dia **Length (m)**: 23m **Material**: Concrete **Condition**: Grade 3 (Average) **Part of FPS**: Yes **Comments**: • Culvert barrels are approximately 50% blocked with sediment. **Change in condition since 2006**: • Culverts blocked

A.5 Kirkgunzeon Lane at Maidenholm

Operations unable to be explicitly inspected:

- Operation 28 - Removal of scrub and trees and heightening of the existing embankment on the north bank of the Kirkgunzeon Lane adjacent to Maidenholm Farm.

Name: Embankment	FPS Operation 27
 ***Embankment from Maidenholm Farm looking US***  ***Embankment from B793 looking DS***	**Type**: Embankment **Bank**: RB **Upstream Grid Ref:** **Height (m) (river side)**: 1.7-2.2m **Height (m) (landward side)**: 0.7-1.4m **Width (m)**: 1.5m **Length (m)**: 520m **Material**: Concrete **Condition**: Grade 2 (Good) **Part of FPS**: Yes **Comments**: • Not maintained. • Trees have matured on river side. • Vegetation growth. **Change in condition since 2006**: • No significant change.

A.6 Kirkgunzeon Lane at Kirkgunzeon

Name: Embankment	FPS Operation 29
 *Embankment from A711 looking US*  *Retrofitted culvert through embankment without flap valve*	**Type**: Embankment **Bank**: Right bank **Upstream Grid Ref:** **Height (m) (river side)**: 1.2m **Height (m) (landward side)**: 1.2m **Width (m)**: 1.0m **Length (m)**: 360m **Material**: Earth **Condition**: Grade 3 (Average) **Part of FPS**: Yes **Comments**: • Not actively maintained. • Crest levels are uniform. • Some cattle poaching at bed. • Farm access at downstream end (leading to the bridge) is a possible low point in embankment. **Change in condition since 2006**: • New pipe (unflapped) located through embankment. Informal rock outfall added.

Name: Pipe through embankment	FPS Operation 29 continued
 *Outlet through embankment*	**Type**: Blocking of lade at its upstream end and carrying out such work to ensure the continuation of the existing tile and natural drainage. **Bank**: Right bank **Upstream Grid Ref:** **Height (m) (river side)**: N/A **Height (m) (landward side)**: N/A **Width (m)**: 0.3m diameter pipe **Length (m)**: N/A **Material**: N/A **Condition**: Grade 3 (Average) **Part of FPS**: Unknown **Comments**: • Unclear if this was part of original works or not. **Change in condition since 2006**: • Culvert not noted by previous survey. Unclear if this has been added or not. *Recently dredged material on left bank of drainage channel downstream*

 *Inlet from lade through embankment*	

Name: Flap valve	FPS Operation 30
 *Flap valve on Corra Mill Lade*	**Type**: Flap valve **Bank**: N/A **Upstream Grid Ref:** **Height (m) (river side)**: N/A **Height (m) (landward side)**: N/A **Width (m)**: 2m **Length (m)**: N/A **Material**: Steel **Condition**: Grade 3 (Average) **Part of FPS**: Unknown **Comments**: • Flap is stuck open by debris and bed material. • Debris in channel needs to be removed. **Change in condition since 2006**: • Not visited previously.

A.6.2 Non FPS assets identified during the site visit

The following additional assets were identified during the site visit. These represent assets that were not part of the original FPS, but may have an impact on flood risk.

Asset:	Description
	• Arch bridge over river at Kirkgunzeon. • Water gate below structure on downstream side. • Possible blockage risks.

	• Informal agricultural embankment on right bank.
 	• Weir and pipe leading to lade on right bank.
	• Recent raising of left bank embankment by local landowners using dredged material from the river.

	• Rock armour along right bank (adjacent to lade).
	• Footbridge across river.
	• Stop log at downstream end of lade. In good condition. • Part of complex return of lade back to river and into pipe through embankment.

	• Widening of river opposite FPS embankment in lower reach. • Recently completed.
	• Electric livestock barrier across river.
	Watergate upstream of A711 bridge.
	• A711 bridge and old arch bridge downstream. • Farm access on right bank through arch.

A.7 Culvert at A711 at Mossfoot

Operations unable to be explicitly inspected:

- Operation 32 - Widening and regrading of existing ditches at Mossfoot

<table>
<tr><th>Name: Culvert</th><th>FPS Operation 31</th></tr>
<tr><td>
Channel upstream of inlet

Screen on inlet</td><td>Type: Culvert with screen on upstream face
Bank: N/A
Upstream Grid Ref:
Height (m) (river side): 1m screen height
Height (m) (landward side): N/A
Width (m): 0.73 diameter culvert
Length (m): 231m
Material: Concrete
Condition: Grade 3 (Average)
Part of FPS: Unknown
Comments:
• Channel is overgrown and not maintained.
• Screen in good condition.
• Pile of grass cuttings on right bank upstream (risk of blockage).
• Culvert head and wingwalls of brick construction in good condition.
• Security fence around inlet.
• Outlet unable to be found.
Change in condition since 2006:
• Channel is more overgrown (seasonal).
• Pipe CCTV survey undertaken. See separate report.</td></tr>
</table>

A.8 Drumjohn

Operations unable to be explicitly inspected:

- Operation 35 - Strengthening and underpinning or otherwise improving existing embankments and walls to burns, lades and ancillary ditches at various locations.
- Operation 36 - Regrading and minor realigning of the bed as required to burns, lades and ancillary ditches at various locations.
- Operation 37 - Carrying out work as required to protect and maintain services and prevent reverse flow in drains.

<table>
<tr><th>Name: Embankment</th><th>FPS Operation 33</th></tr>
<tr><td>
Embankment along road

Maintenance of embankment sides along A711 only</td><td>**Type**: Embankment
Bank: Left bank
Upstream Grid Ref:
Height (m) (river side): 1.7m
Height (m) (landward side): 0.7-1.3m
Width (m): 1.0m
Length (m): 470m
Material: Earth
Condition: Grade 3 (Average)
Part of FPS: Yes
Comments:
• Embankment is very overgrown.
• Access over embankment is a possible low spot.
• River is eroding the bank at the downstream end leading to overly steep embankment and risk of breaching.
• Crest not maintained or easily inspected.
• Section along A711 maintained by roads department.
Change in condition since 2006:
• No significant change.

Access over embankment into field</td></tr>
</table>

Name: Cut-off Embankment	FPS Operation 34
 *Cut of embankment*	**Type**: Large 'embankment'/raised ground to prevent flow route to the south. **Bank**: N/A **Upstream Grid Ref:** **Height (m) (river side)**: 2.5m **Height (m) (landward side)**: N/A **Width (m)**: 20m **Length (m)**: 30m **Material**: Concrete **Condition**: Grade 3 (Average) **Part of FPS**: Unknown **Comments**: • Embankment cuts off flow path along historic railway line and under road bridge. **Change in condition since 2006**: • No significant change. • Original location of embankment incorrectly defined.

A.8.3 Non FPS assets identified during the site visit

The following additional assets were identified during the site visit. These represent assets that were not part of the original FPS, but may have an impact on flood risk.

Asset:	Description
	• Water gate beneath access bridge. • Relief culvert with screen on downstream side.
	• Water gate downstream of above access bridge located on line of disused railway.

	• Watergate beneath A711 road bridge.

C Appendix C - Culvert Hydraulic analysis

C.1 Introduction and conceptual modelling approach

This section describes how two culverts close to Dalbeattie have been modelled in order to estimate culvert capacity and the impact of blockages on the conveyance of flood waters.

Both watercourses were modelled using HEC-RAS (Hydraulic Engineering Center - River Analysis System). HEC-RAS is a one dimensional model software package developed by the US Army Corps of Engineers and is a standard tool for hydraulic modelling in the UK.

Factors that contribute to blockage risks include the opening size, capacity, presence and type of screen and type and condition of upstream channel/catchment contributing reaches, the last of which has not been modelled in the present study.

C.2 Topographic survey of watercourse and structures

A survey of the river channel cross sections at either end of the structure was carried out by JBA in 2015. These drawings are provided in Appendix B and their detail determined the watercourse geometries used in the model.

C.3 Key structures and culvert capacity modelling

1D modelling was undertaken to determine the capacity of two culvert locations in the Dalbeattie area. The first culvert is a double culvert which occupies the channel of the Edingham Burn close to the village of Edingham. The second culvert is a single culvert and occupies a minor transient watercourse which drains a small catchment artificially isolated from the Drumjohn catchment near the village of Kirkgunzeon.

Figures 1 & 2 show the locations of the two culverts and Table 1 shows images taken from the up and downstream faces. Table 2 provides details of the two locations modelled along with the parameters and boundary conditions used in the model runs.

Figure 6. Location map of Edingham Burn culvert

Figure 7. Location map of culvert adjacent to A711

Table 4. Photographs of culvert inlets and outlets

Edingham Burn Culvert	Culvert adjacent to A711
Upstream: 	Upstream: 
Downstream: 	Downstream: 

Table 5. Modelled structures and model setup parameters for Edingham Burn and A711 culverts

Structure name	Edingham Burn Culvert	Culvert adjacent to A711
Location	OS NGR 283816, 562496 (U/S) - 283836, 562483 (D/S)	OS NGR 287253, 566418 (U/S) - 287101, 566243 (D/S)
Diameter (m)	1.25 (per culvert - double culvert)	0.75 (single culvert)
Opening area (m2)	2.46 (both culverts)	0.44

Culvert length (m)	23	231
Screen and method of blockage	No Screen. 50% blockage at time of survey (Aug. 2015) due to sediment aggradation.	Screen upstream of inlet. Blockage modelled as weir.
Modelled reach length (m)	43	251
U/S Invert level (m)	28.00	63.79
U/S Soffit level (m)	29.25	64.52
D/S Invert level (m)	27.97	63.03
D/S Soffit level (m)	29.09	63.78
Weir coefficient	1.4	1.4
Entrance loss coefficient	0.5	0.5
Exit loss coefficient	1.0	1.0
Steady flow boundary conditions	0.00361, Normal Depth	0.00298, Normal Depth
Culvert roughness - Manning's n for top	0.025	0.025
Culvert roughness - Manning's n for bottom	0.03	0.03
Channel roughness - Manning's n		
Left over bank	0.06	0.06
Channel	0.035	0.035
Right over bank	0.06	0.06

Model runs were carried out in both unblocked and blocked scenarios to test culvert capacity under different discharge events. Discharge events on the Edingham Burn were empirically determined by FEH flood runoff data from Caste Cottage. No data were available for the culvert adjacent to the A711 so a number of theoretical discharge events were created ranging from 0.1 to 2 m^3/s.

The Culvert adjacent to the A711 has a sloped trash screen, as shown in table 1. There is no default method for modelling culvert screens in HEC-RAS. By inserting a weir unit immediately upstream of the culvert and setting the weir crest to the height of the top of the screen, complete blockage of the screen can be represented. This models screen blockage correctly when screens block and water weirs over the top of the screen. This is not appropriate when a screen is flush with the inlet.

Two cross sections, representing the inlet and outlet of each structure location, respectively, were used to determine each model reach, along with a further cross section upstream and downstream of the culverts which took on the watercourse geometry from its nearest surveyed cross section. The elevations of these extrapolated cross sections were adjusted to fit a continuation of the slope of each culvert.

C.4 Results

Model results are presented in the following section. The model initially assumed no blockage which may be unrealistic in the modelled flood events, particularly given the sedimentation depicted in Figure 1.1 for the Edingham burn culvert when surveyed in August 2015. As a result, a model run was performed with 50% blockage in the Edingham burn culvert and with a blocked weir in the A711 culvert to provide a more realistic model output.

Full modelled flood level results for each burn are given in Appendix E.

C.5 Channel capacity and blockage results

An assessment was made of the capacity of the watercourses to identify reaches of poor conveyance, under capacity channels and locations where flood defences may be required. Whilst the watercourse capacity is impacted by backwater effects at structures the capacity of the watercourses has been assessed assuming no structure blockage. Furthermore, whilst structure upgrades can reduce these backwater impacts the assessment provides a first estimate of locations where overbank flood risk may be important.

The following broad findings have been ascertained:

- The Edingham burn culvert has sufficient capacity to convey the 1000 year flood without overtopping in the unblocked scenario but overtopping occurs with the 1000 year flood event where 50% blockage is assumed. A significant backwater effect results above the 100 year flood without blockage and above the 10 year flood event with 50% blockage.
- The culvert adjacent to the A711 exhibits good conveyance for small discharge events where the modelled 2 year and 5 year flood events represent discharges of 0.1 and 0.2m^3/s, respectively, as shown in Figures 5 & 6. Discharge events exceeding 0.4 cumecs, such as the modelled 25 year event cause a large backwater effect and overtopping of the modelled culvert. Model runs for an unblocked culvert and a two-thirds blocked screen resulted in similar outputs.

Table 6. Modelled culvert capacities in response to blockage for

Edingham Burn				
Return Period (empirical)	U/S water level (m)		D/S water level (m)	
	Current	50% blockage	Current	50% blockage
2 year	28.53	29.08	28.32	28.32
5 year	28.62	29.20	28.40	28.40
10 year	28.70	29.32	28.48	28.48
25 year	28.76	29.43	28.53	28.53
30 year	28.78	29.49	28.55	28.55
50 year	28.88	29.75	28.64	28.64
75 year	28.93	29.89	28.68	28.68
100 year	28.98	30.05	28.72	28.72
200 year	29.07	30.40	28.80	28.80
500 year	29.25	31.10	28.94	28.94
1000 year	29.47	31.51	29.07	29.07
Maximum discharge before which overtopping occurs (m^3/s) (return period)	4.3m^3/s (1000 year)	3.6m^3/s (200 year)		

Culvert adjacent to A711				
Return Period (theoretical)	U/S water level (m)		D/S water level (m)	
	Current	Screen blockage modelled as upstream weir	Current	Screen blockage modelled as upstream weir
2 year	64.10	64.10	63.10	63.10
5 year	64.25	64.25	63.19	63.19
10 year	64.69	64.69	63.32	63.32
25 year	65.23	65.23	63.42	63.42
30 year	65.37	65.37	63.52	63.52
50 year	65.47	65.48	63.61	63.61
75 year	65.52	65.52	63.70	63.70
100 year	65.55	65.55	63.78	63.78
200 year	65.58	65.58	63.85	63.85
500 year	65.60	65.60	63.91	63.91
1000 year	65.62	65.62	63.96	63.96
Maximum discharge before which overtopping occurs (m^3/s) (return period)	0.4m^3/s (10 year)	0.4 m^3/s (10 year)		

As a result of the method of blockage in the model for the culvert adjacent to the A711 the water levels up and downstream of the culvert are not affected by the blockage above the 10 year event. The cause of this is as follows. Small flows allow water to weir over the blocked screen into the culvert. When the culvert becomes full of water above the 10 year flood the backwater effect increases and overtopping occurs, meaning that the effect of the weir is minimal during discharge events greater than this. The similarities in Figures 3 and 4 demonstrate this effect.

Figure 8. Long profile model output for Edingham Burn culvert - no blockage

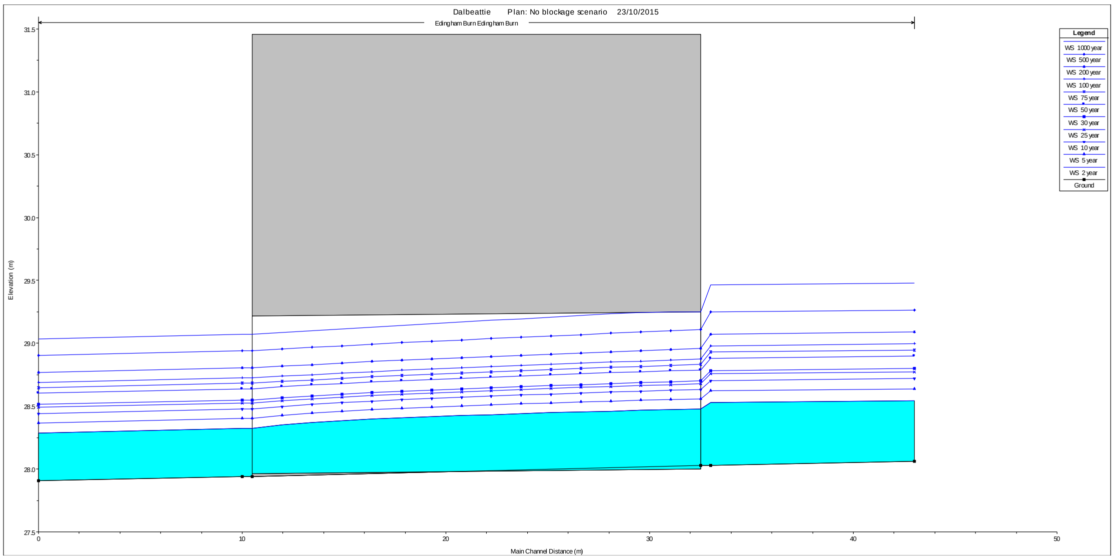


Figure 9. Long profile model output for Edingham Burn culvert - 50% blockage

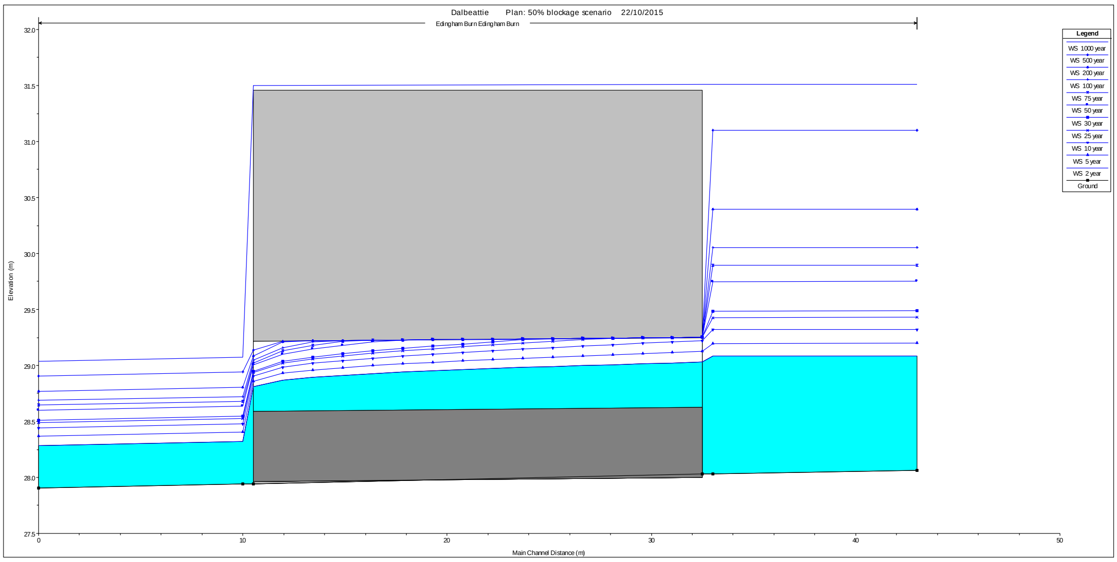


Figure 10. Long Profile model output for culvert adjacent to A711 - no blockage

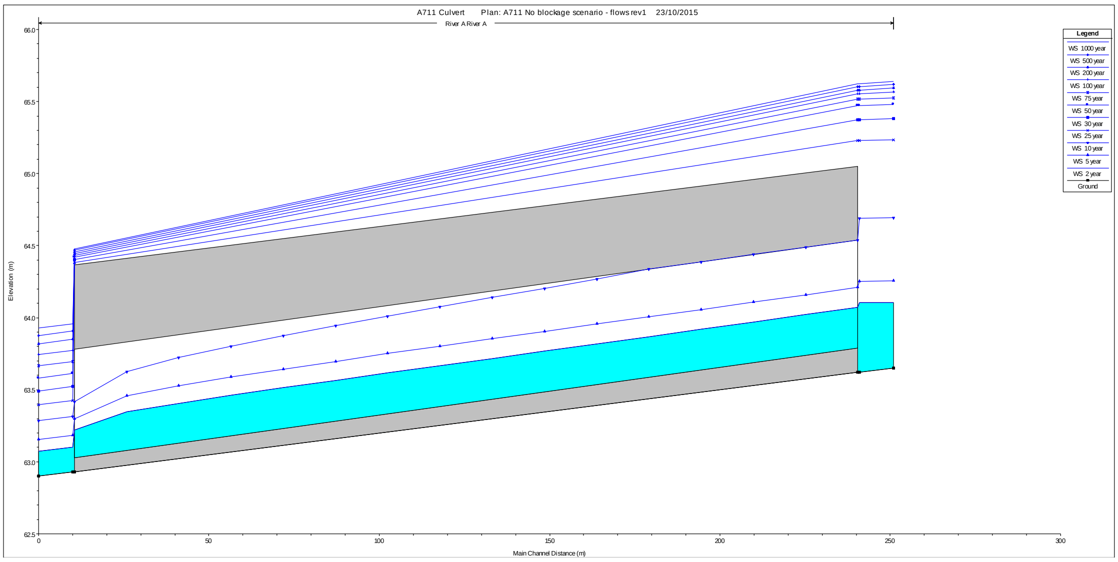
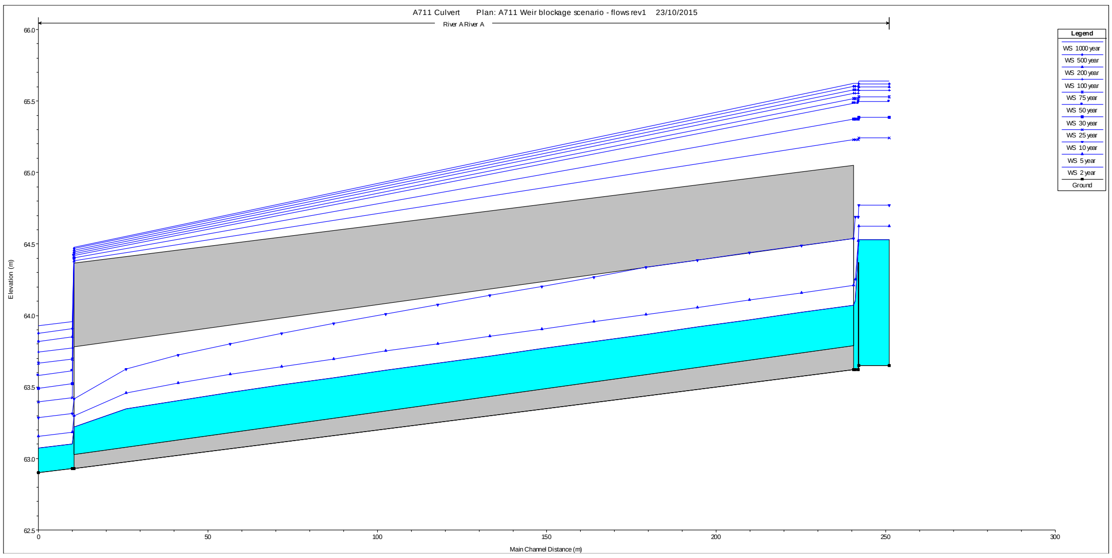


Figure 11. Long Profile model output for culvert adjacent to A711 - Two-thirds weir blockage



C.6 Conclusions and maintenance recommendations

The model outputs for the Edingham Burn culvert show that culverts are of sufficient capacity for the setting since overtopping is unlikely even considering the observed sediment blockage.

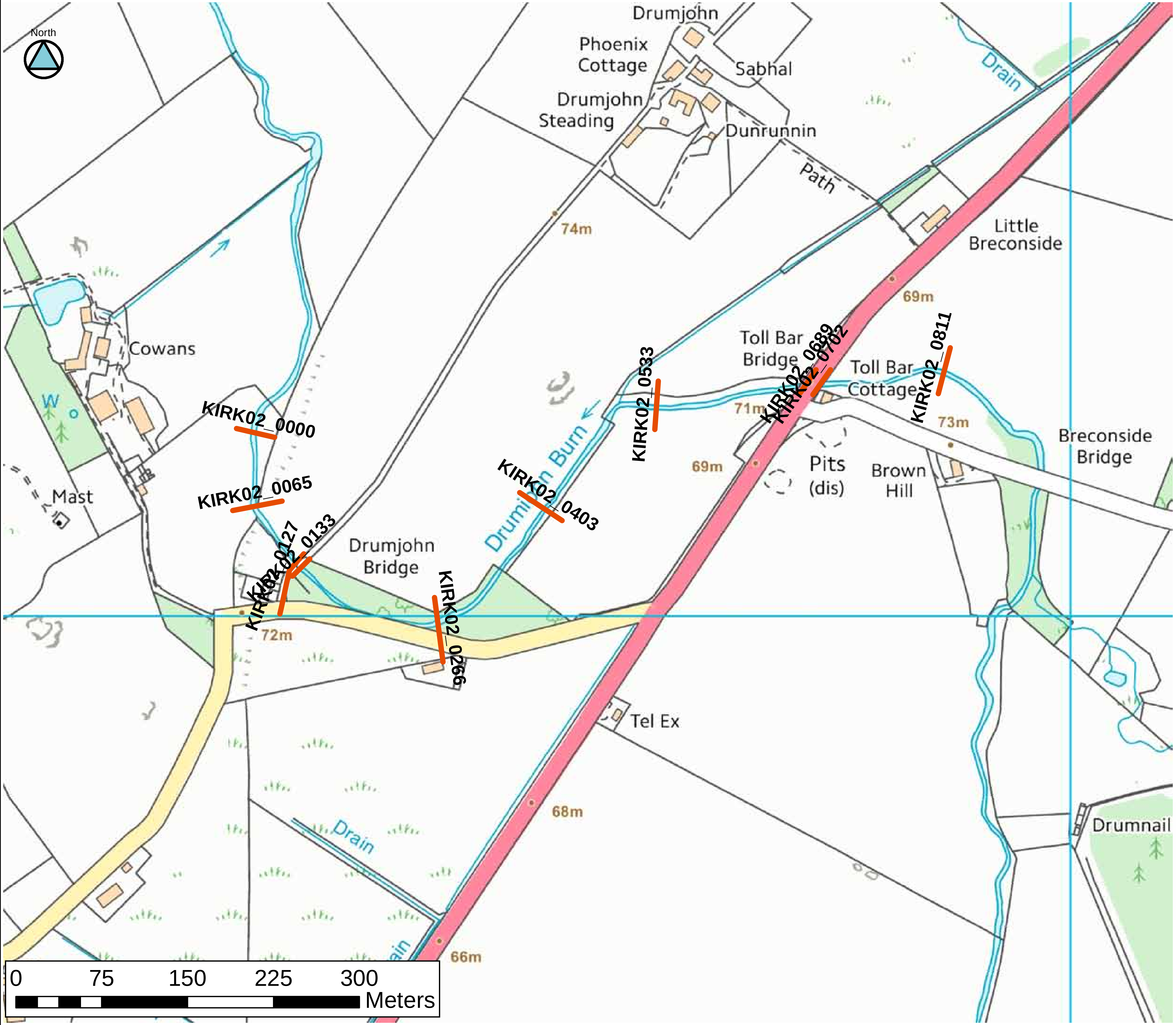
The modelling indicated that the A711 culvert may be at risk of overtopping, or more realistically pooling upstream, during discharge events exceeding $0.4m^3/s$. LiDAR data shows that rather than a simple slope between the soffit of the inlet and the soffit of the outlet there is a gradual increase in land surface elevations to a maximum of 97.00m (1.95m above the top of the modelled culvert) 84m from the inlet in the downstream direction. This would likely limit overtopping and instead cause pooling upstream of the culvert. This could have implications for the agricultural land and A711 to which the watercourse is adjacent. Water surface elevations of the modelled flows are not sufficient to compromise the A711 with the current model setup. Further modelling suggests that a flow of $10m^3/s$ may have the potential to flood the road.

D Appendix G - Flood Maps

E Appendix E - Flood levels

	Max Water Levels (mAOD)									
Node	2yr	10yr	25yr	50yr	100yr	200yr	200yrCC	1000yr		200yrCC_adj
DALB01_3895	40.293	40.732	40.947	41.116	41.272	41.379	41.526	41.583		41.758
DALB01_3814	40.284	40.725	40.942	41.113	41.269	41.377	41.525	41.582		41.774
DALB01_3728	40.25	40.7	40.92	41.094	41.252	41.359	41.504	41.561		41.732
DALB01_3631	40.104	40.573	40.817	41.012	41.186	41.304	41.472	41.536		41.753
DALB01_3483	39.416	39.698	39.844	39.959	40.059	40.151	40.351	40.455		40.827
DALB01_3391	39.3	39.634	39.805	39.929	40.035	40.123	40.33	40.43		40.765
DALB01_3305	39.167	39.558	39.755	39.897	40.016	40.111	40.318	40.416		40.72
DALB01_3232	38.512	38.775	38.903	38.995	39.075	39.142	39.306	39.384		39.71
DALB01_3090u	37.251	37.44	37.535	37.606	37.675	37.736	37.911	38.002		38.425
DALB01_3090d	35.64	35.796	35.884	35.951	36.019	36.078	36.291	36.389		36.723
DALB01_3064	34.839	35.023	35.128	35.219	35.302	35.373	35.521	35.632		36.184
DALB01_3038	34.008	34.168	34.253	34.321	34.382	34.437	34.569	34.654		35.065
DALB01_3012	33.198	33.359	33.447	33.512	33.575	33.628	33.761	33.838		34.2
DALB01_2986	32.378	32.548	32.638	32.705	32.768	32.821	32.953	33.025		33.364
DALB01_2960	31.627	31.788	31.873	31.942	31.997	32.046	32.172	32.243		32.595
DALB01_2934	30.705	30.864	30.952	31.018	31.073	31.122	31.246	31.315		31.608
DALB01_2893	28.955	29.125	29.22	29.283	29.349	29.403	29.533	29.609		29.991
DALB01_2852	27.133	27.335	27.444	27.527	27.607	27.671	27.831	27.928		28.377
DALB01_2811	25.508	25.754	25.885	25.985	26.079	26.159	26.35	26.463		26.972
DALB01_2779	24.548	24.783	24.911	25.009	25.103	25.181	25.379	25.494		26.02
DALB01_2747	23.585	23.824	23.954	24.054	24.148	24.228	24.428	24.543		25.056
DALB01_2715	22.85	23.055	23.176	23.264	23.353	23.428	23.602	23.693		24.001
DA01_2715BU	22.85	23.055	23.176	23.264	23.353	23.428	23.602	23.693		24.001
DA01_2707BD	22.795	22.963	23.058	23.124	23.19	23.244	23.366	23.429		23.63
DALB01_2707	22.795	22.963	23.058	23.124	23.19	23.244	23.366	23.429		23.63
DALB01_2678	22.034	22.214	22.313	22.385	22.459	22.522	22.676	22.769		23.142
DALB01_2649	21.472	21.66	21.763	21.838	21.913	21.969	22.107	22.197		22.74
DALB01_2620	20.909	21.106	21.213	21.291	21.374	21.444	21.661	21.813		22.608
DALB01_2591	20.35	20.552	20.662	20.742	20.824	20.891	21.071	21.183		21.772
DALB01_2562	19.741	19.951	20.065	20.149	20.235	20.308	20.502	20.621		21.159
DALB01_2533	19.046	19.273	19.397	19.492	19.587	19.668	19.882	20.004		20.527
DALB01_2504	18.363	18.608	18.754	18.85	18.946	19.029	19.255	19.374		20.033
DALB01_2474	17.696	17.959	18.112	18.172	18.221	18.28	18.503	18.567		18.8
DALB01_2445	17.068	17.352	17.47	17.589	17.685	17.765	17.942	18.034		18.39
DALB01_2422	16.607	16.892	17.078	17.225	17.383	17.483	17.688	17.853		18.244
DALB01_2399	16.164	16.427	16.559	16.651	16.714	16.774	16.923	16.997		17.409
DALB01_2375	15.777	16.039	16.163	16.241	16.301	16.349	16.465	16.527		16.693
DALB01_2352	15.501	15.765	16.005	16.125	16.184	16.228	16.334	16.399		16.542
DALB01_2336	15.428	15.655	15.829	16.021	16.157	16.237	16.378	16.442		16.482
DALB01_2293U	14.907	15.123	15.206	15.273	15.33	15.381	15.506	15.573		16.353
DA01_2293BU	14.907	15.123	15.206	15.273	15.33	15.381	15.506	15.573		16.353
DA01_2293BD	14.891	15.103	15.182	15.247	15.302	15.352	15.475	15.54		15.841
DALB01_2293D	14.891	15.103	15.182	15.247	15.302	15.352	15.475	15.54		15.841
DALB01_2280	14.83	14.917	14.956	14.989	15.017	15.049	15.152	15.227		15.561
DALB01_2273	14.752	14.83	14.883	14.911	14.936	14.975	15.091	15.197		15.572
DALB01_2265	14.752	14.83	14.883	14.911	14.936	14.975	15.091	15.197		15.572
DALB01_2220	14.318	14.61	14.695	14.741	14.801	14.858	14.996	15.103		15.553
DALB01_2206	14.203	14.645	14.777	14.836	14.889	14.939	15.065	15.178		15.608
DALB01_2176U	13.732	14.102	14.244	14.352	14.45	14.531	14.71	14.822		15.35
DA01_2176BU	13.732	14.102	14.244	14.352	14.45	14.531	14.71	14.822		15.35
DA01_2176BD	13.731	14.101	14.244	14.351	14.45	14.531	14.71	14.821		15.286
DALB01_2176D	13.731	14.101	14.244	14.351	14.45	14.531	14.71	14.821		15.286
DALB01_2154	13.293	13.903	14.203	14.378	14.517	14.628	14.837	14.973		15.429
DALB01_2136	12.967	13.328	13.494	13.601	13.7	13.796	13.998	14.128		14.756
DALB01_2107	12.788	13.101	13.192	13.225	13.259	13.321	13.483	13.598		14.125
DALB01_2069	12.541	12.624	12.699	12.767	12.838	12.9	13.049	13.161		13.672
DALB01_2026U	12.483	12.524	12.575	12.635	12.711	12.791	12.983	13.117		13.764
DA01_2026BU	12.483	12.524	12.575	12.635	12.711	12.791	12.983	13.117		13.764
DA01_2026BD	12.483	12.524	12.575	12.635	12.711	12.791	12.983	13.117		13.554
DALB01_2026D	12.483	12.524	12.575	12.635	12.711	12.791	12.983	13.117		13.554
DALB01_1948	11.673	12.061	12.258	12.406	12.53	12.639	12.881	13.036		13.617
DALB01_1930	11.188	11.511	11.675	11.803	11.925	12.071	12.513	12.743		13.453
DALB01_1924	11.012	11.349	11.524	11.665	11.796	11.928	12.217	12.392		13.221
DALB01_1898U	10.922	11.262	11.434	11.569	11.697	11.821	12.093	12.258		13.062
DA01_1898BU	10.922	11.262	11.434	11.569	11.697	11.821	12.093	12.258		13.062
DA01_1898BD	10.922	11.262	11.434	11.569	11.697	11.821	12.093	12.258		12.979
DALB01_1898D	10.922	11.262	11.434	11.569	11.697	11.821	12.093	12.258		12.979
DALB01_1848	10.518	10.788	10.935	11.04	11.144	11.243	11.479	11.627		12.447
DALB01_1799	9.948	10.226	10.376	10.491	10.601	10.706	10.94	11.086		11.995
DALB01_1762	9.427	9.73	9.888	10.018	10.138	10.251	10.501	10.658		11.472
DA01_1762BU	9.427	9.73	9.888	10.018	10.138	10.251	10.501	10.658		11.472
DA01_1750BD	9.427	9.73	9.888	10.018	10.138	10.251	10.501	10.644		11.193
DALB01_1750	9.427	9.73	9.888	10.018	10.138	10.251	10.501	10.644		11.193
DALB01_1684	8.687	9.025	9.205	9.352	9.492	9.626	9.926	10.074		10.609
DALB01_1668	8.505	8.894	9.093	9.254	9.405	9.549	9.867	10.019		10.625
DALB01_1633U	8.085	8.425	8.58	8.708	8.823	8.916	9.118	9.252		9.819
DA01_1633BU	8.085	8.425	8.58	8.708	8.823	8.916	9.118	9.252		9.819
DA01_1633BD	8.085	8.425	8.58	8.708	8.822	8.915	9.117	9.252		9.819
DALB01_1633D	8.085	8.425	8.58	8.708	8.822	8.915	9.117	9.252		9.819
DALB01_1615	7.78	8.11	8.268	8.398	8.516	8.62	8.824	8.943		9.48
DALB01_1582	7.574	7.844	7.956	8.065	8.163	8.263	8.502	8.643		9.546
DALB01_1549	7.448	7.759	7.901	8.013	8.127	8.234	8.485	8.623		8.903
DALB01_1493	6.913	7.199	7.331	7.436	7.534	7.623	7.866	8.041		9.378
DALB01_1453	6.65	6.948	7.096	7.212	7.332	7.461	7.774	7.971		8.822
DALB01_1400U	6.311	6.702	6.885	7.049	7.208	7.365	7.762	8.016		9.205
DA01_1400BU	6.311	6.702	6.885	7.049	7.208	7.365	7.762	8.016		9.205
DA01_1400BD	6.227	6.519	6.652	6.795	6.943	7.077	7.406	7.589		8.643
DALB01_1400D	6.227	6.519	6.652	6.795	6.943	7.077	7.406	7.589		8.643
DALB01_1332	6.089	6.423	6.595	6.738	6.88	7.009	7.321	7.497		8.537
DALB01_1190	5.958	6.354	6.556	6.714	6.87	7.009	7.345	7.538		8.586
DALB01_1059U	5.67	6.056	6.246	6.397	6.545	6.677	7.006	7.172		8.407
DA01_1059BU	5.67	6.056	6.246	6.397	6.545	6.677	7.006	7.172		8.407
DA01_1059BD	5.67	6.056	6.246	6.397	6.545	6.677	7.006	7.172		8.318
DALB01_1059D	5.67	6.056	6.246	6.397	6.545	6.677	7.006	7.172		8.318
DALB01_0895	5.442	5.869	6.069	6.229	6.384	6.524	6.859	7.035		8.223
DALB01_0780	5.367	5.854	6.084	6.259	6.425	6.57	6.888	7.049		8.015
DALB01_0656	5.206	5.667	5.885	6.054	6.219	6.36	6.702	6.865		8.072
DALB01_0567	5.134	5.623	5.844	6.014	6.181	6.325	6.67	6.835		8.084
DALB01_0493	5.005	5.473	5.685	5.846	6.005	6.138	6.463	6.595		7.8
DA01_0493BU	5.005	5.473	5.685	5.846	6.005	6.138	6.463	6.595		7.8
DA01_0493BD	5.007	5.475	5.683	5.842	5.995	6.124	6.435	6.555		7.49
DALB01_0480	5.007	5.475	5.683	5.842	5.995	6.124	6.435	6.555		7.49
DALB01_0348	4.865	5.355	5.585	5.77	5.946	6.087	6.416	6.535		7.478
DALB01_0251	4.863	5.356	5.584	5.77	5.946	6.087	6.419	6.541		7.53
DALB01_0173	4.717	5.282	5.533	5.727	5.91	6.054	6.391	6.513		7.501
DALB01_0093	4.615	5.12	5.34	5.51	5.668	5.788	6.074	6.129		7.202
DA01_0093BU	4.615	5.12	5.34	5.51	5.668	5.788	6.074	6.129		7.202
DA01_0093BD	4.589	5.061	5.26	5.402	5.527	5.61	5.79	5.799		6.563
DALB01_0086	4.589	5.061	5.26	5.402	5.527	5.61	5.79	5.799		6.563
DALB01_0000	4.046	4.602	4.871	5.065	5.212	5.256	5.264	5.264		5.265
DALB01_D085	3.483	4.014	4.245	4.42	4.566	4.651	4.809	4.905		5.167
EDIN01_0529	22.371	22.484	22.519	22.536	22.555	22.583	22.615	22.648		22.663
EDIN01_0467	21.449	21.647	21.738	21.766	21.807	21.862	21.926	21.986		22.011
EDIN01_0464	21.356	21.534	21.606	21.659	21.718	21.823	21.947	22.036		22.071
EDIN01_0411	20.089	20.277	20.371	20.448	20.528	20.567	20.589	20.64		20.665
EDIN01_0368	19.076	19.263	19.366	19.458	19.551	19.677	19.786	19.826		19.842
EDIN01_0359	18.903	19.098	19.204	19.295	19.389	19.484	19.553	19.625		19.654
EDIN01_0321	18.348	18.574	18.698	18.798	18.86	18.927	18.966	19.033		19.053
EDIN01_0266	17.851	18.036	18.128	18.201	18.263	18.324	18.387	18.452		18.476
EDIN01_0250	17.752	17.941	18.036	18.111	18.187	18.278	18.359	18.437		18.467
EDIN01_0190	17.34	17.593	17.652	17.695	17.737	17.781	17.815	17.852		17.866
EDIN01_0186	17.287	17.563	17.621	17.663	17.706	17.751	17.786	17.828		17.847
EDIN01_0104	16.955	17.356	17.393	17.419	17.452	17.473	17.488	17.503		17.509
EDIN01_0103	16.954	17.367	17.415	17.454	17.496	17.534	17.565	17.603		17.62
ED01_0103U1	16.866	17.235	17.288	17.334	17.381	17.42	17.451	17.487		17.504
ED01_0089D1	16.717	17.012	17.073	17.13	17.187	17.227	17.257	17.291		17.307
ED01_0103U2	16.866	17.235	17.288	17.334	17.381	17.42	17.451	17.487		17.504
ED01_0089D2	16.717	17.012	17.073	17.13	17.187	17.227	17.257	17.291		17.307
ED01_0103U3	16.866	17.235	17.288	17.334	17.381	17.42	17.451	17.487		17.504
ED01_0089D3	16.717	17.012	17.073	17.13	17.187	17.227	17.257	17.291		17.307
EDIN01_0089	16.533	16.74	16.812	16.884	16.953	16.994	17.024	17.055		17.07
EDIN01_0087	16.455	16.652	16.725	16.805	16.873	16.906	16.928	16.95		16.961
EDIN01_0064	16.279	16.46	16.529	16.598	16.669	16.718	16.761	16.801		16.814
EDIN01_0044	15.722	15.919	16.001	16.064	16.127	16.175	16.215	16.256		16.284
EDIN01_0007U	14.943	15.148	15.221	15.282	15.35	15.4	15.443	15.486		15.677
ED01_0007BU	14.943	15.148	15.221	15.282	15.35	15.4	15.443	15.486		15.677
ED01_0007BD	14.831	14.955	15.017	15.064	15.119	15.167	15.234	15.312		15.622
EDIN01_0007D	14.831	14.955	15.017	15.064	15.119	15.167	15.234	15.312		15.622
EDIN01_0000	14.811	14.927	14.988	15.032	15.085	15.133	15.205	15.288		15.612

	Max Water Levels (mAOD)									
Node	**2yr**	**10yr**	**25yr**	**50yr**	**100yr**	**200yr**	**200yrCC**	**1000yr**		**200yrCC_adj**
KIRK02_0811	69.492	69.652	69.726	69.781	69.844	69.914	70.024	70.091		70.178
KIRK02_0811d	68.519	68.734	68.847	68.947	69.071	69.162	69.27	69.336		69.415
KIRK02_0702	68.05	68.307	68.445	68.572	68.731	68.804	68.86	68.88		68.897
KI02_0702BU	68.05	68.307	68.445	68.572	68.731	68.804	68.86	68.88		68.897
KI02_0689BD	68.051	68.305	68.44	68.565	68.721	68.792	68.843	68.86		68.874
KIRK02_0689	68.051	68.305	68.44	68.565	68.721	68.792	68.843	68.86		68.874
KIRK02_0553	67.649	67.777	67.85	67.878	67.894	67.909	67.992	68.082		68.153
KIRK02_0403	67.255	67.343	67.374	67.475	67.578	67.701	67.912	68.027		68.116
KIRK02_0266	66.907	67.145	67.314	67.435	67.545	67.671	67.894	68.003		68.067
KIRK02_0133	66.644	66.916	67.093	67.216	67.349	67.503	67.785	67.926		68.037
KI02_0133BU	66.644	66.916	67.093	67.216	67.349	67.503	67.785	67.926		68.037
KI02_0127BD	66.644	66.89	67.036	67.131	67.202	67.271	67.424	67.504		67.56
KIRK02_0127	66.644	66.89	67.036	67.131	67.202	67.271	67.424	67.504		67.56
KIRK02_0065	66.201	66.395	66.508	66.588	66.666	66.744	66.878	66.994		67.105
KIRK02_0000	65.887	66.084	66.194	66.261	66.3	66.331	66.344	66.347		66.378
Interpolated reach										
KIRK03_2200	65.582	65.685	65.767	65.82	65.872	65.979	66.152	66.248		66.304
KIRK03_2000	64.795	64.913	64.944	64.962	64.983	65.003	65.019	65.026		65.039
KIRK03_1800	64.005	64.173	64.258	64.289	64.318	64.398	64.466	64.497		64.526
KIRK03_1600	63.186	63.364	63.459	63.491	63.53	63.62	63.706	63.742		63.775
KIRK03_1400	62.368	62.543	62.637	62.668	62.706	62.795	62.881	62.918		62.95
KIRK03_1200	61.551	61.723	61.815	61.847	61.884	61.972	62.056	62.092		62.125
KIRK03_1000	60.735	60.905	60.996	61.026	61.063	61.15	61.233	61.268		61.3
KIRK03_0800	59.92	60.087	60.177	60.207	60.244	60.329	60.411	60.447		60.479
KIRK03_0600	59.106	59.271	59.358	59.387	59.424	59.505	59.586	59.618		59.646
KIRK03_0400	58.292	58.452	58.545	58.58	58.612	58.705	58.784	58.845		58.906
KIRK03_0200	57.481	57.644	57.72	57.737	57.785	57.838	57.878	57.895		57.861
End of interpolated reach										
KIRK01_0984	56.677	56.854	56.935	57.002	57.068	57.128	57.206	57.257		57.486
KIRK01_0984d	56.677	56.854	56.935	57.002	57.068	57.128	57.206	57.257		57.486
KIRK01_0879U	55.987	56.238	56.339	56.418	56.507	56.58	56.679	56.737		57.07
KI01_0879BU	55.987	56.238	56.339	56.418	56.507	56.58	56.679	56.737		57.07
KI01_0875BD	55.939	56.144	56.214	56.257	56.31	56.345	56.376	56.397		56.496
KIRK01_0879D	55.939	56.144	56.214	56.257	56.31	56.345	56.376	56.397		56.496
KIRK01_0757	55.208	55.315	55.336	55.361	55.381	55.415	55.478	55.499		55.692
KIRK01_0653u	54.979	55.115	55.145	55.174	55.178	55.216	55.301	55.323		55.62
KIRK01_0653d	54.667	54.692	54.777	54.824	54.887	54.963	55.09	55.145		55.494
KIRK01_0553U	54.503	54.684	54.794	54.846	54.915	54.998	55.131	55.194		55.561
KI01_0553BU	54.503	54.684	54.794	54.846	54.915	54.998	55.131	55.194		55.561
KI01_0553BD	54.503	54.68	54.787	54.838	54.907	54.991	55.13	55.192		55.56
KIRK01_0553D	54.503	54.68	54.787	54.838	54.907	54.991	55.13	55.192		55.56
KIRK01_0378	53.423	53.618	53.699	53.761	53.814	53.867	53.998	53.993		54.227
KIRK01_0241	52.732	52.942	53.032	53.109	53.179	53.249	53.423	53.449		54.056
KIRK01_0109	52.454	52.603	52.663	52.719	52.769	52.817	52.853	52.852		52.941
KI01_0109BU	52.454	52.603	52.663	52.719	52.769	52.817	52.853	52.852		52.941
KI01_0096BD	52.438	52.581	52.639	52.693	52.74	52.787	52.821	52.82		52.858
KIRK01_0096	52.438	52.581	52.639	52.693	52.74	52.787	52.821	52.82		52.858
KIRK01_0092U	52.348	52.436	52.46	52.485	52.5	52.51	52.536	52.533		52.53
KI01_0092BU	52.348	52.436	52.46	52.485	52.5	52.51	52.536	52.533		52.53
KI01_0092BD	52.348	52.436	52.46	52.484	52.499	52.509	52.533	52.531		52.528
KIRK01_0092D	52.348	52.436	52.46	52.484	52.499	52.509	52.533	52.531		52.528
KIRK01_0000	51.584	51.745	51.808	51.851	51.886	51.917	52.019	52.018		52.163



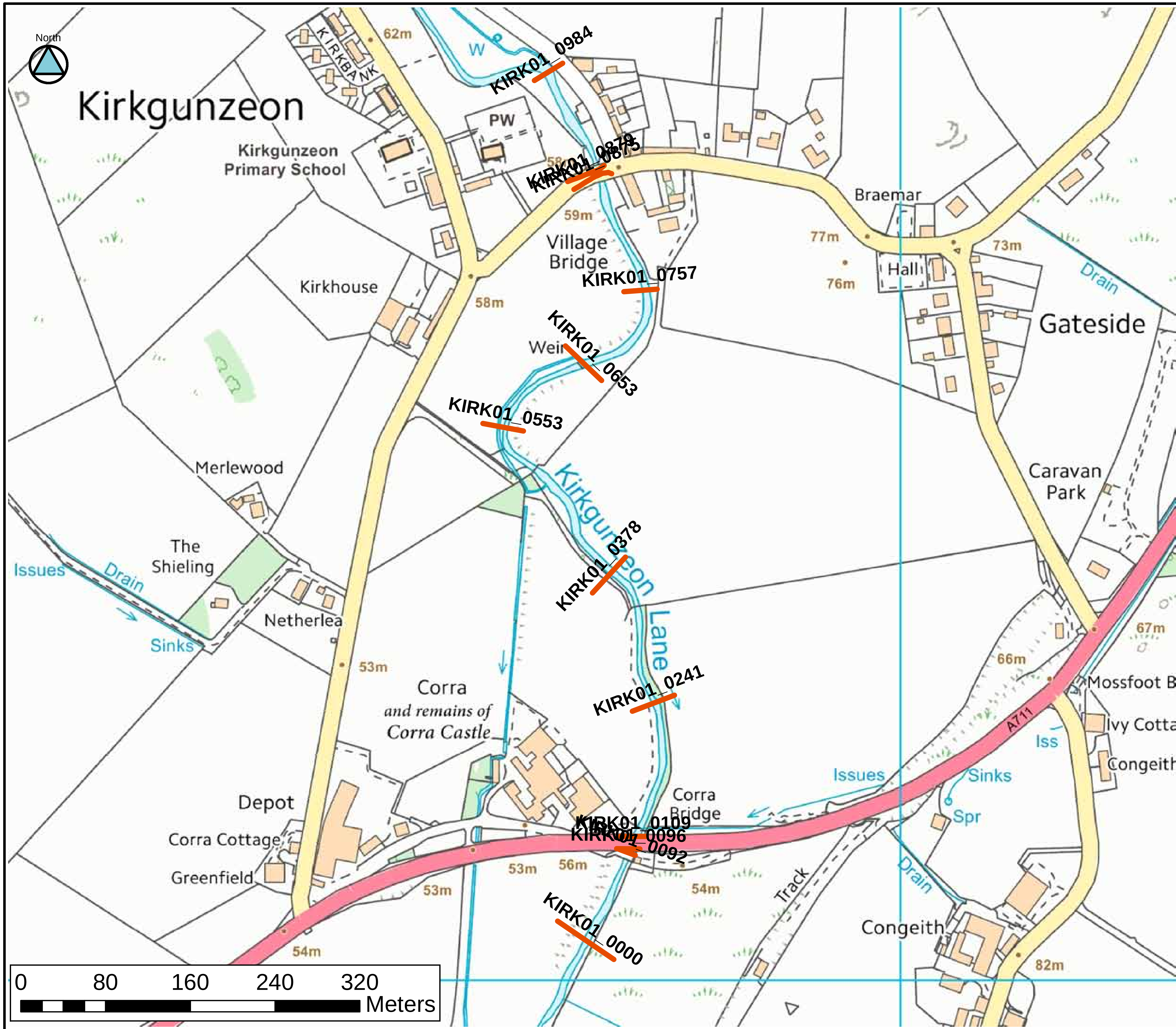
LEGEND

Cross Sections

JBA consulting

CROSS SECTION LOCATION PLAN 1

DRUMJOHN BURN



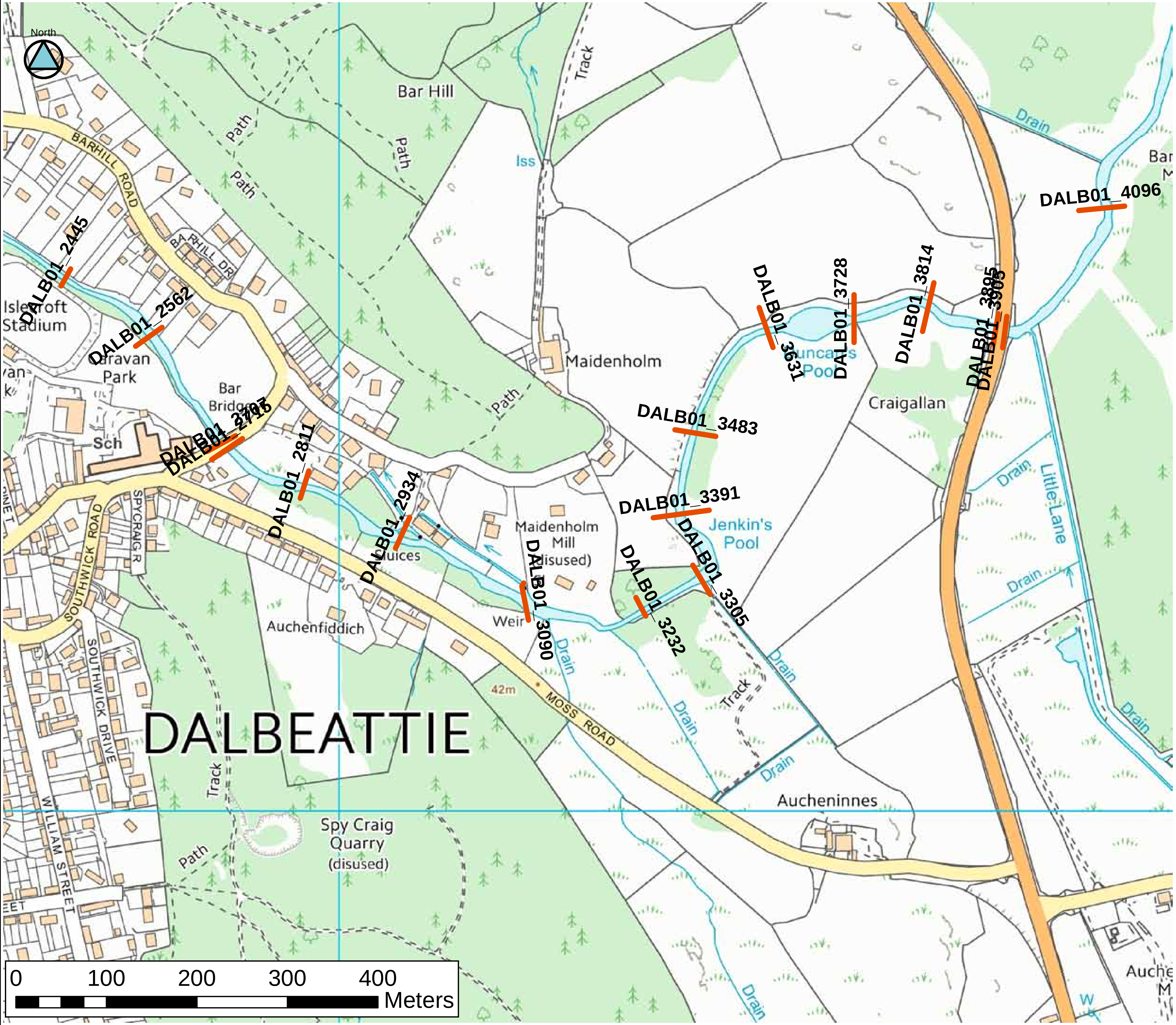
LEGEND

Cross Sections

JBA consulting

CROSS SECTION LOCATION PLAN 2

KIRKGUNZEON BURN



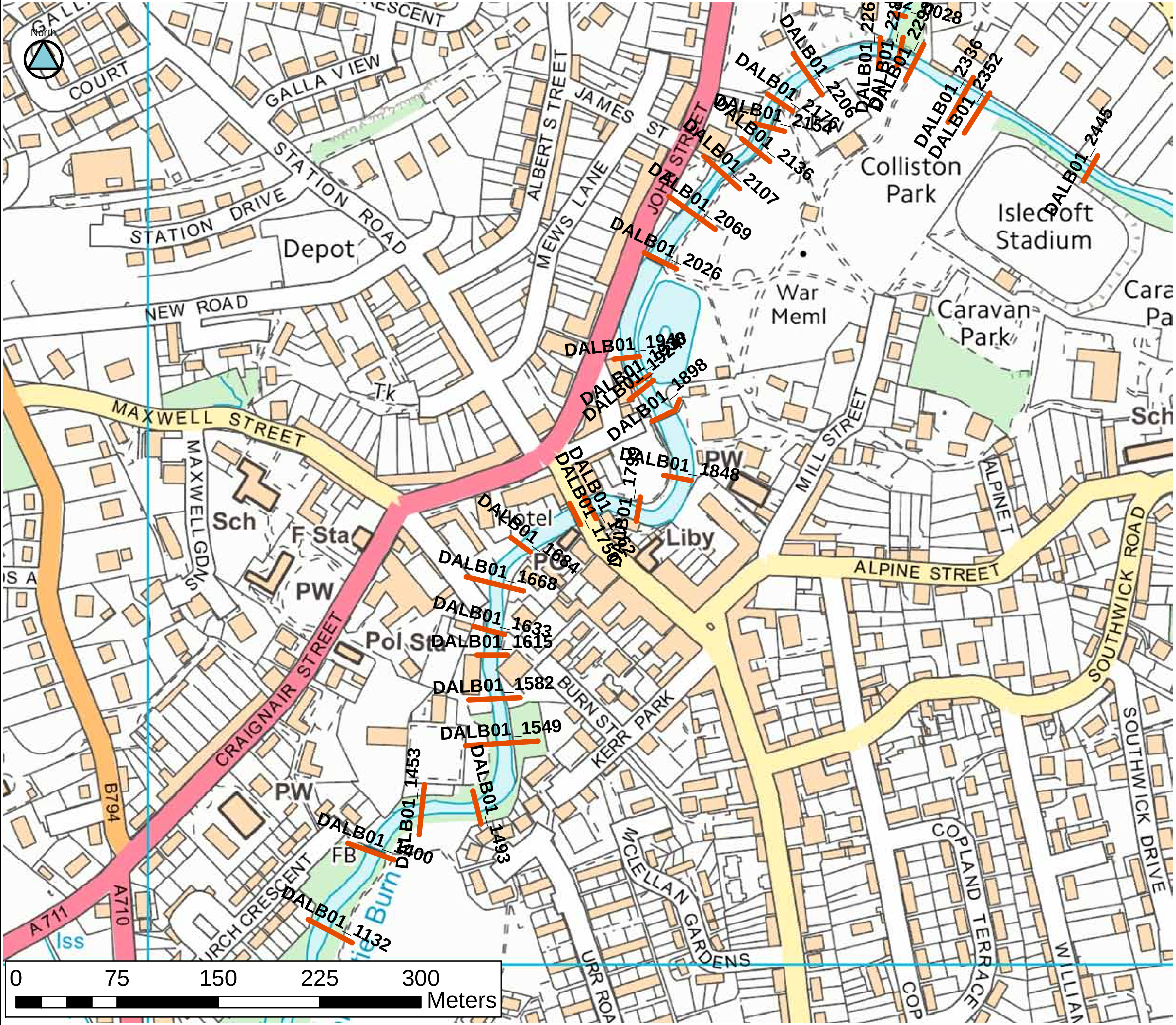
LEGEND

Cross Sections

JBA consulting

CROSS SECTION LOCATION PLAN 3

UPPER DALBEATTIE REACH OF KIRKGUNZEON LANE



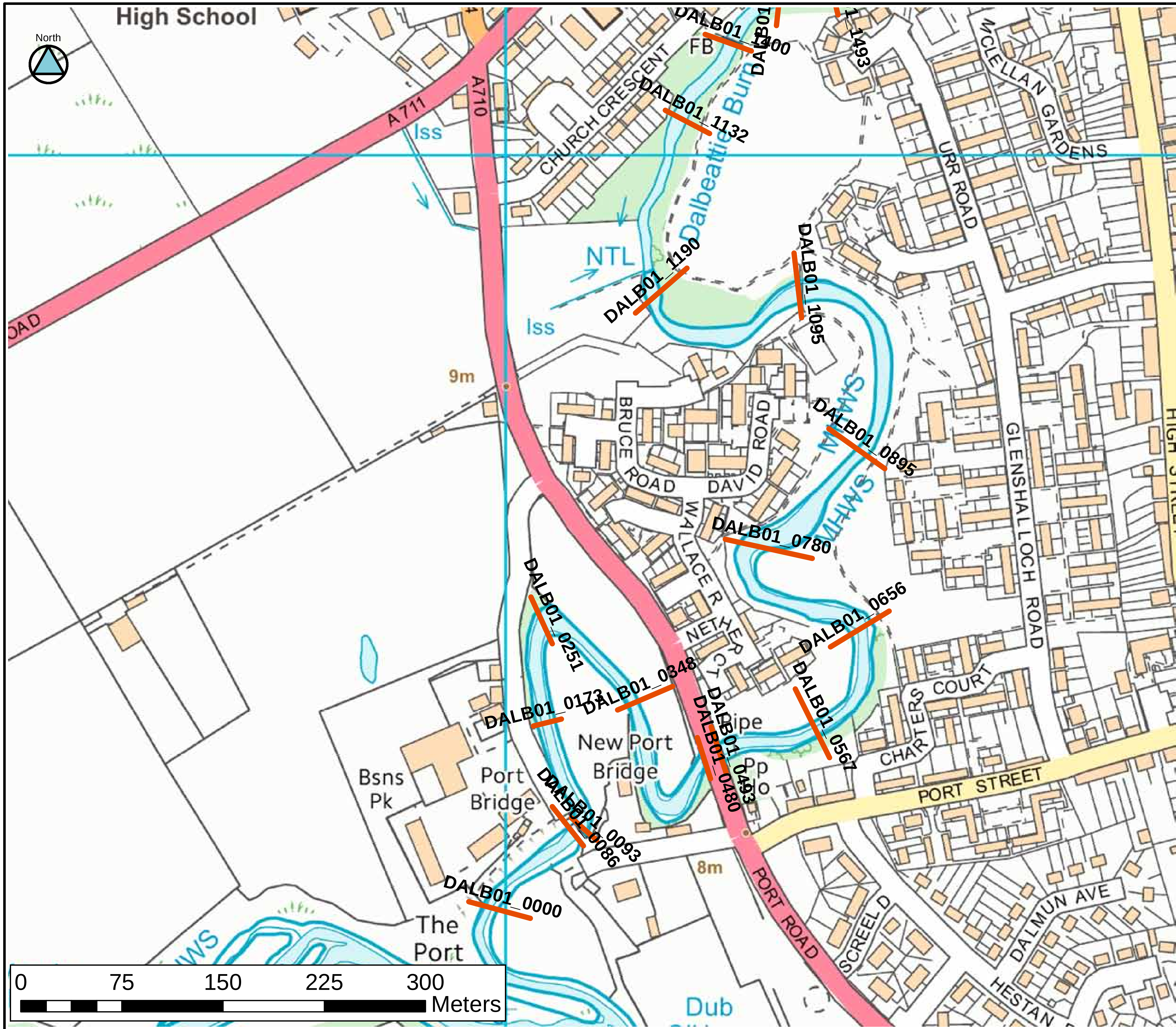
LEGEND

Cross Sections

JBA consulting

CROSS SECTION LOCATION PLAN 4

MIDDLE DALBEATTIE REACH OF KIRKGUNZEON LANE



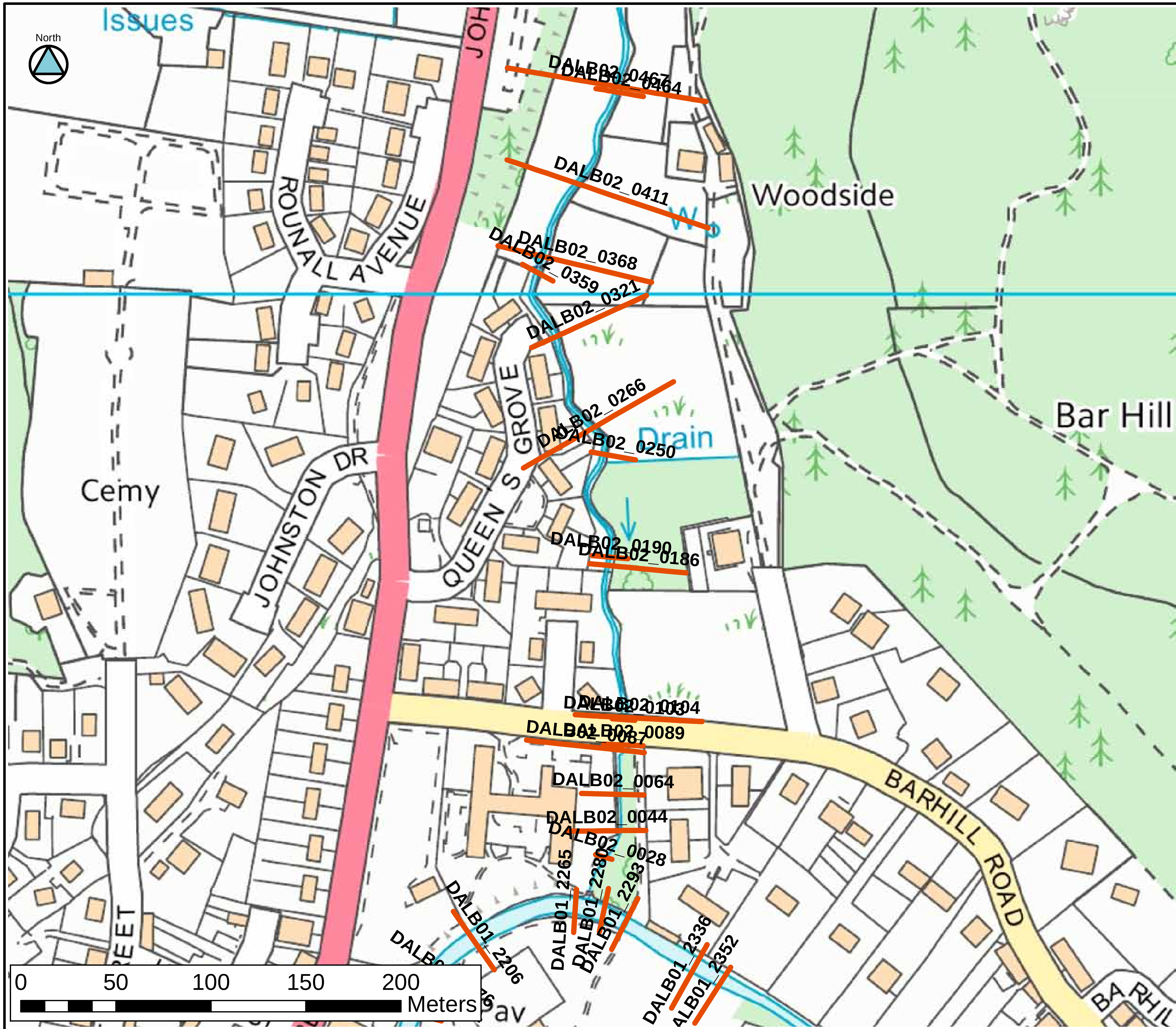
LEGEND

Cross Sections

JBA consulting

CROSS SECTION LOCATION PLAN 5

LOWER DALBEATTIE REACH OF KIRKGUNZEON LANE



LEGEND

Cross Sections

JBA consulting

CROSS SECTION LOCATION PLAN 6

EDINGHAM BURN

F Appendix F - Properties at risk

Table F-1: Key to properties at risk

No flooding to properties	
Flooding below threshold level (sub floor level, -0.3- 0.0m)	-0.10
Flooding above threshold level	0.15

Table F-2: Properties at risk of flooding and depths for range of flood events modelled

Property address	MCM code	10-yr	25-yr	50-yr	100-yr	200-yr	200-yr CC	1000yr
6 PARK TERRACE	122						-0.17	-0.17
7 PARK TERRACE	122						-0.21	-0.20
12 PARK TERRACE	122						-0.05	-0.02
19 JOHN STREET	131							-0.24
21 JOHN STREET	131							-0.15
22 JOHN STREET	131							-0.12
23 JOHN STREET	131							-0.28
13 JOHN STREET	131							-0.22
14 JOHN STREET	131							-0.17
15 JOHN STREET	131							-0.17
16 JOHN STREET	131							-0.17
10 JOHN STREET	131							-0.29
12 JOHN STREET	131							-0.18
MAIDENHOLM FORGE MILL	111						0.03	0.07
52 HIGH STREET	3							-0.05
52 HIGH STREET	3							-0.06
46 HIGH STREET	2							-0.17
44 HIGH STREET	2							-0.19
M. Mc Cowan & Son shop	2							-0.09
FLAT 3	2						-0.23	0.01
37 HIGH STREET	131						-0.21	0.01
35 HIGH STREET	2						0.01	0.22
33 HIGH STREET	131						0.04	0.22
31 HIGH STREET	3						-0.01	0.17
29 HIGH STREET	2						-0.08	0.11
21 HIGH STREET	131						0.11	0.28
DALBEATTIE LIBRARY	6						0.08	0.27
ISLECROFT GARAGE	2							-0.26
ISLECROFT GARAGE	2						0.21	0.37
ISLECROFT GARAGE	2							-0.20
24 HIGH STREET	2						0.08	0.23
26 HIGH STREET	2						0.20	0.35
32C HIGH STREET	2						0.02	0.17
32 HIGH STREET	2						0.09	0.25
CROWN HOTEL	51						-0.09	0.06
40 HIGH STREET	2							0.00
GARAGE 1	8							0.07
BURNBANK COTTAGE	2							0.11
28 HIGH STREET	2						0.15	0.30
A	2						0.30	0.45

14 HIGH STREET	2						0.17	0.32
19 HIGH STREET	131						0.12	0.29
12 HIGH STREET	2						0.15	0.29
17 HIGH STREET	2						0.19	0.36
15 HIGH STREET	2						0.37	0.53
15A HIGH STREET	111						0.47	0.64
BRIG'EN	121						0.37	0.54
DALBEATTIE BOWLING CLUB	6						-0.12	0.12
THE MECHANICS INSTITUTE	3						-0.23	0.01
8 BURN STREET	131							-0.13
6 BURN STREET	131							-0.07
4 BURN STREET	131							-0.10
2 BURN STREET	131							0.31
2A BURN STREET	131							0.11
66 HIGH STREET	3							0.02
64 HIGH STREET	2							-0.01
62 HIGH STREET	2							-0.18
56-60 HIGH STREET	2							0.20
ISLECROFT GARAGE	2						0.23	0.37
LINTONGIL	111							-0.07
1 THE FLATTS	131							-0.15
DUNIRA	131							-0.11
4 BEECH GROVE	128							-0.25
3 BEECH GROVE	128							-0.22
FERGUSLEA	111						0.54	0.66
DALBEATTIE AND DISTRICT DAY CENTRE	6						0.13	0.26
BURNSIDE HOTEL	51	0.10	0.19	0.24	0.27	0.34	0.42	0.50
WATERSIDE	111	-0.09	-0.04	0.00	0.03	0.09	0.17	0.25
8 PARK TERRACE	122					-0.03	0.03	0.06
MUNCHES PARK HOUSE	6	0.03	0.11	0.14	0.16	0.20	0.24	0.28
9 PARK TERRACE	122				-0.16	-0.15	-0.13	-0.11
11 PARK TERRACE	122						-0.18	-0.13
10 PARK TERRACE	122				-0.26	-0.25	-0.23	-0.18
2 GLENAIRLIE TERRACE	123					-0.23	-0.18	-0.13
1 GLENAIRLIE TERRACE	123				-0.21	-0.13	-0.06	-0.01
3 GLENAIRLIE TERRACE	123						-0.30	-0.27
4 GLENAIRLIE TERRACE	123				-0.24	-0.19	-0.15	-0.11
8 BARHILL CRESCENT	118					-0.26	-0.23	-0.20
1 BARHILL CRESCENT	118				-0.23	-0.21	-0.19	-0.18
6 GLENAIRLIE TERRACE	123						-0.29	-0.28
20 QUEEN'S GROVE	123							-0.30
19 QUEEN'S GROVE	123							-0.29
11 QUEEN'S GROVE	123							-0.29
7 QUEEN'S GROVE	123					-0.29	-0.20	-0.15
8 QUEEN'S GROVE	123					-0.15	-0.08	-0.04
MIROMAR	123					0.64	0.71	0.75
10 QUEEN'S GROVE	123					-0.25	-0.16	-0.12
WATERWHEEL	111				-0.14	-0.09	0.03	0.13

G Appendix G - Natural Flood Management Report

G.1 Natural Flood Management (NFM) Report, 2015

H Appendix H - Economic Appraisal Results

Project Summary Sheet

Client/Authority		Prepared (date)	
Dumfries and Galloway Council		Printed	04/08/2016
Project name		Prepared by	
Dalbeattie FPS Appraisal		Checked by	
Project reference	2015s2898	Checked date	
Base date for estimates (year 0)	Sep-2015		
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 name	Do Minimum	Option 1 (PLP)	Option 2 (Raised defence)	Do Minimum with climate change	Option 3 (Raised defence) incorporating Climate Change
COSTS:					
PV capital costs	0	179	331	0	424
Optimism bias adjustment	0	107	199	0	254
Total PV Costs £k excluding contributions	0	286	530	0	678
BENEFITS:					
Total monetised PV damages £k	1,322	210	210	1,609	274
Total monetised PV benefits £k		1,112	1,112		1,335
PV damages (from scoring and weighting)					
PV damages avoided/benefits (from scoring and weighting)					
PLP failure adjustment		-111			
Total PV damages £k	1,322	322	210	1,609	274
Total PV benefits £k		1,001	1,112		1,335
DECISION-MAKING CRITERIA:					
excluding contributions					
Based on total PV benefits (** in **cludes benefits from scoring and weighting and ecosystem services)					
Net Present Value **NPV**		714	582		657
Average benefit/cost ratio **BCR**		3.5	2.1		2.0
Incremental benefit/cost ratio **IBCR**			0.5		1.5
		Highest bcr			

Brief description of options:

Option 1	Do Minimum
Option 2	Option 1 (PLP)
Option 3	Option 2 (Raised defence)
Option 4	Do Minimum with climate change
Option 5	Option 3 (Raised defence) incorporating Climate Change

Comments and assumptions:

Summary Annual Average Damage

Sheet Nr.

Client/Authority			
Dumfries and Galloway Council			
Project name		**Option:**	
Dalbeattie FPS Appraisal		Do nothing	
Project reference	2015s2898		
Base date for estimates (year 0)	42248	First year of damage:	0
Scaling factor (e.g. £m, £k, £)	£k	Last year of period:	99
Discount rate	3.5%	PV factor for mid-year 0:	29.813
Applicable year (if time varying)			

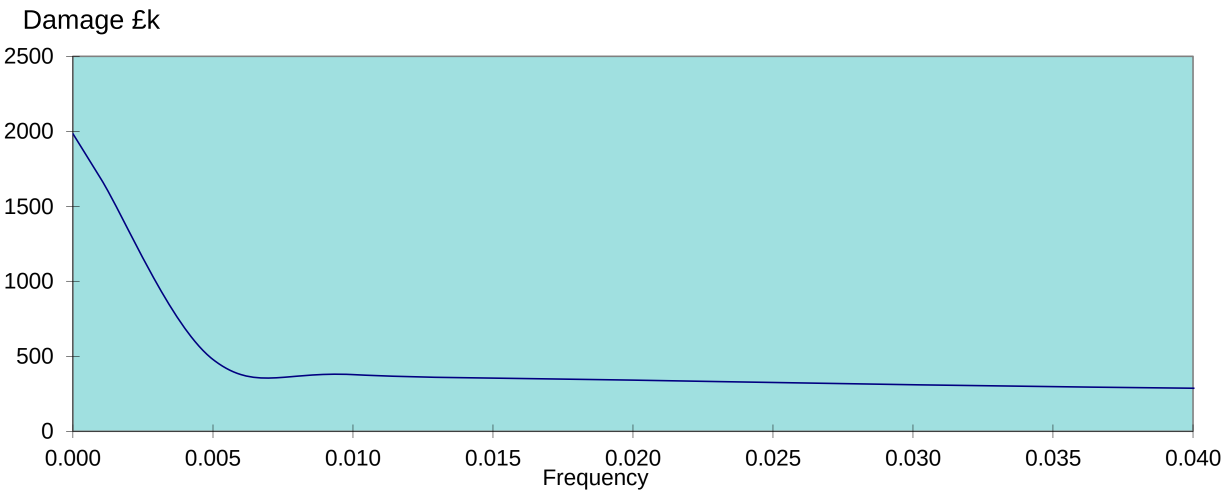
Prepared (date)	00/01/1900
Printed	04/08/2016
Prepared by	0
Checked by	0
Checked date	0

		Average waiting time (yrs) between events/frequency per year										Total PV
		1	1	2	10	25	50	100	200	1000	Infinity	£k
		1.000	1.000	0.500	0.100	0.040	0.020	0.010	0.005	0.001	0	
Direct Damage category		Damage £k										
Residential property		0	0	0	2	2	2	17	67	427	517	66
Ind/commercial (direct)		0	0	0	179	277	329	349	390	1150	1340	1942
Indirect Damage category		Damage £k										
Ind/comm (indirect)		0	0	0	5	8	10	10	12	35	40	58
Traffic related											0	0
Emergency services	0.107	0	0	0	0	0	0	2	7	46	55	7
Vehicle Damage		0	0	0	0	0	0	0	3	26	32	3
Evacuation / Temp Accom.		0	0	0	0	0	0	0	0	0	0	0
											0	0
Total damage	£k	0	0	0	6	8	10	12	21	106	127	
Area (damagexfrequency)			0.0	0.0	1.1	0.4	0.2	0.1	0.1	0.3	0.1	

Present value (assuming no change in damage or event frequency)	2008	67.4	
Capped PVd (direct property damage) from previous sheet	1196	40.1	(no DI)
Check on PVd capping	-812		
Total area, indirect damages	2		
Present value (assuming no change in damage or event frequency)	68		
Intangible AAD (Low Estimate (£286/yr)	2		
Intangible AAD (High Estimate (£2513/yr)	17		
Intangible PVd (Low Estimate)	58		
Intangible PVd (High Estimate)	510		
Total Present Value (assuming no change in damage or event freq.)	1322	44.4	2076

Notes
Area calculations assume drop to zero at maximum frequency.
Default value for the highest possible damage assumes continuation of gradient for last two points, an alternative value can be entered, if appropriate.
One form should be completed for each option, including 'without project', and for each representative year if profile changes during scheme life (e.g. sea-level rise)
Residential property, Industrial / commercial (direct), and Other damages are itemised in Asset AAD sheet and automatically linked to this sheet

Project: Dalbeattie FPS Appraisal **Option: Do nothing**



Summary Annual Average Damage

Sheet Nr.

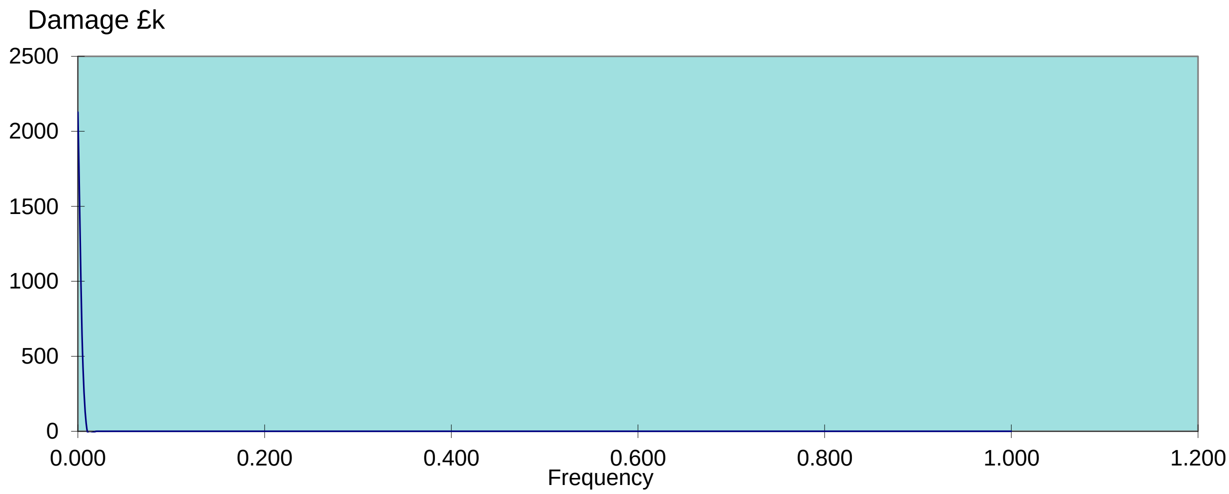
Client/Authority				
Dumfries and Galloway Council				
Project name		**Option:**		
Dalbeattie FPS Appraisal		Option 1 (PLP)		
Project reference	2015s2898			
Base date for estimates (year 0)	42248	First year of damage:	0	Prepared (date) 00/01/1900
Scaling factor (e.g. £m, £k, £)	£k	Last year of period:	99	Printed 04/08/2016
Discount rate	3.5%	PV factor for mid-year 0:	29.813	Prepared by 0
				Checked by 0
Applicable year (if time varying)				Checked date 0

	Average waiting time (yrs) between events/frequency per year										Total PV
	1	1	2	10	25	50	100	200	1000	Infinity	£k
	1.000	1.000	0.500	0.100	0.040	0.020	0.010	0.005	0.001	0	
Direct Damage category	Damage £k										
Residential property	0	0	0	0	0	0	2	67	427	517	49
Ind/commercial (direct)	0	0	0	0	0	0	0	390	1150	1340	158
Indirect Damage category	Damage £k										
Ind/comm (indirect)	0	0	0	0	0	0	0	12	35	40	5
Traffic related										0	0
Emergency services 0.107	0	0	0	0	0	0	0	49	169	199	22
Vehicle Damage	0	0	0	0	0	0	0	3	26	32	3
Evacuation / Temp Accom.	0	0	0	0	0	0	0	0	0	0	0
										0	0
Total damage £k	0	0	0	0	0	0	0	63	229	271	
Area (damagexfrequency)		0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.2	

Present value (assuming no change in damage or event frequency)	207	6.9	
Capped PVd (direct property damage) from previous sheet	154	5.2 (no DI)	
Check on PVd capping	-52		
Total area, indirect damages	1		
Present value (assuming no change in damage or event frequency)	30		
Intangible AAD (Low Estimate (£286/yr)	1		
Intangible AAD (High Estimate (£2513/yr)	8		
Intangible PVd (Low Estimate)	26		
Intangible PVd (High Estimate)	232		
Total Present Value (assuming no change in damage or event freq.)	210	7.1	237

Notes
Area calculations assume drop to zero at maximum frequency.
Default value for the highest possible damage assumes continuation of gradient for last two points, an alternative value can be entered, if appropriate.
One form should be completed for each option, including 'without project', and for each representative year if profile changes during scheme life (e.g. sea-level rise)
Residential property, Industrial / commercial (direct), and Other damages are itemised in Asset AAD sheet and automatically linked to this sheet

Project: Dalbeattie FPS Appraisal **Option: Option 1 (PLP)**



Summary Annual Average Damage

Sheet Nr.

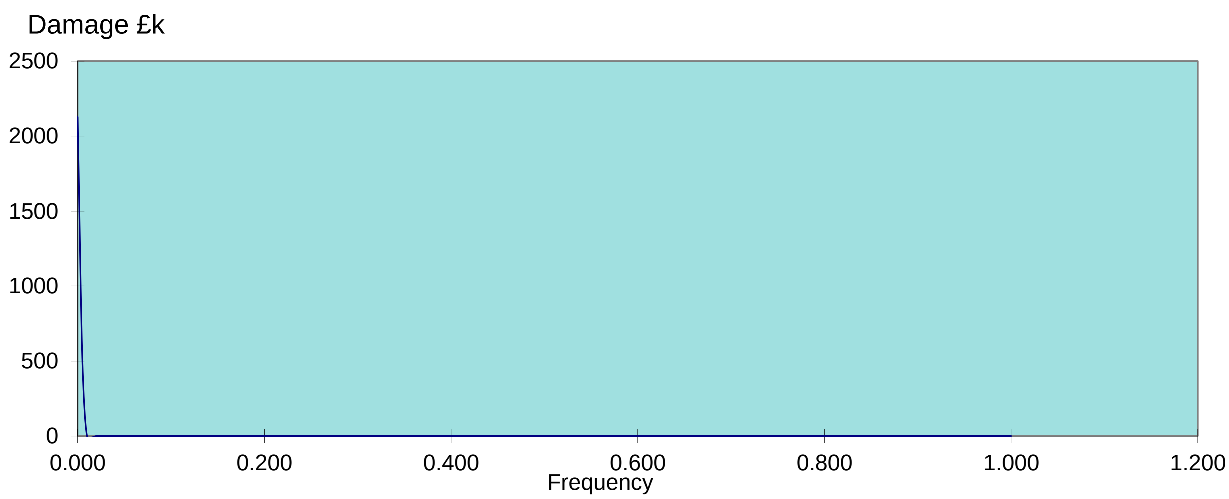
Client/Authority				
Dumfries and Galloway Council				
Project name		**Option:**		
Dalbeattie FPS Appraisal		Option 2 (Raised defence)		
Project reference	2015s2898			
Base date for estimates (year 0)	42248	First year of damage:	0	Prepared (date) 00/01/1900
Scaling factor (e.g. £m, £k, £)	£k	Last year of period:	99	Printed 04/08/2016
Discount rate	3.5%	PV factor for mid-year 0:	29.813	Prepared by 0
				Checked by 0
Applicable year (if time varying)				Checked date 0

Average waiting time (yrs) between events/frequency per year	1	1	2	10	25	50	100	200	1000	Infinity	Total PV £k
	1.000	1.000	0.500	0.100	0.040	0.020	0.010	0.005	0.001	0	
Direct Damage category	Damage £k										
Residential property	0	0	0	0	0	0	2	67	427	517	49
Ind/commercial (direct)	0	0	0	0	0	0	0	390	1150	1340	158
Indirect Damage category	Damage £k										
Ind/comm (indirect)	0	0	0	0	0	0	0	12	35	40	5
Traffic related										0	0
Emergency services 0.107	0	0	0	0	0	0	0	49	169	199	22
Vehicle Damage	0	0	0	0	0	0	0	3	26	32	3
Evacuation / Temp Accom.	0	0	0	0	0	0	0	0	0	0	0
										0	0
Total damage £k	0	0	0	0	0	0	0	63	229	271	
Area (damagexfrequency)		0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.2	

Present value (assuming no change in damage or event frequency)	207	6.9	
Capped PVd (direct property damage) from previous sheet	154	5.2 (no DI)	
Check on PVd capping	-52		
Total area, indirect damages	1		
Present value (assuming no change in damage or event frequency)	30		
Intangible AAD (Low Estimate (£286/yr)	1		
Intangible AAD (High Estimate (£2513/yr)	8		
Intangible PVd (Low Estimate)	26		
Intangible PVd (High Estimate)	232		
Total Present Value (assuming no change in damage or event freq.)	210	7.1	237

Notes
Area calculations assume drop to zero at maximum frequency.
Default value for the highest possible damage assumes continuation of gradient for last two points, an alternative value can be entered, if appropriate.
One form should be completed for each option, including 'without project', and for each representative year if profile changes during scheme life (e.g. sea-level rise)
Residential property, Industrial / commercial (direct), and Other damages are itemised in Asset AAD sheet and automatically linked to this sheet

Project: Dalbeattie FPS Appraisal **Option: Option 2 (Raised defence)**



Client/Authority
Dumfries and Galloway Council
Project name
Dalbeattie FPS Appraisal
Project reference 2015s2898
Base date for estimates (year 0) Sep-2015
Scaling factor (e.g. £m, £k, £) £k

Results £k	
	Option 1
	Do Minimum
PV total costs (Low Intangi	**1,609**

Results £k	
	Option 2
	Option 2 (Raised defence)
PV total costs (Low Intangi	**274**

			Option 1	Do Minimum		**TOTALS:**	**PV**	**PV**	**PV**	Option 2	Option 3 (Raised defence) in		**TOTALS:**	**PV**	**PV**	**PV**
			Direct	**Indirect**	**Intangible - Low**		**Direct**	**Indirect**	**Intangible - Low**	**Direct**	**Indirect**	**Intangible - Low**	**Cash**	**Capital**	**Maint**	**Other**
		cash sum	5419.2	349.9	303.6	8740.1	1442.7	89.4	77.1	693.098747	135.127906	240.929367	3186.13	185.13	35.90	53.08
year	**Year**	**Discount Factor**														
0	2015	1.000	40.1	2.3	1.9	61.5	40.1	2.3	1.9	5.2	1.0	0.9	14.83	5.18	0.99	0.88
1	2016	0.966	40.4	2.3	2.0	62.1	39.1	2.2	1.9	5.2	1.0	0.9	15.22	5.05	0.97	0.89
2	2017	0.934	40.8	2.3	2.0	62.7	38.1	2.2	1.9	5.3	1.0	1.0	15.61	4.91	0.94	0.89
3	2018	0.902	41.1	2.4	2.0	63.3	37.1	2.1	1.8	5.3	1.0	1.0	16.00	4.78	0.92	0.89
4	2019	0.871	41.4	2.4	2.0	63.8	36.1	2.1	1.8	5.3	1.0	1.0	16.39	4.66	0.90	0.89
5	2020	0.842	41.7	2.4	2.1	64.4	35.1	2.0	1.7	5.4	1.0	1.1	16.78	4.53	0.87	0.89
6	2021	0.814	42.1	2.5	2.1	65.0	34.2	2.0	1.7	5.4	1.0	1.1	17.18	4.41	0.85	0.89
7	2022	0.786	42.4	2.5	2.1	65.6	33.3	1.9	1.7	5.5	1.1	1.1	17.57	4.29	0.83	0.89
8	2023	0.759	42.7	2.5	2.1	66.2	32.4	1.9	1.6	5.5	1.1	1.2	17.96	4.18	0.80	0.88
9	2024	0.734	43.0	2.5	2.2	66.8	31.6	1.9	1.6	5.5	1.1	1.2	18.35	4.07	0.78	0.88
10	2025	0.709	43.4	2.6	2.2	67.4	30.7	1.8	1.6	5.6	1.1	1.2	18.74	3.96	0.76	0.88
11	2026	0.685	43.7	2.6	2.2	68.0	29.9	1.8	1.5	5.6	1.1	1.3	19.13	3.85	0.74	0.87
12	2027	0.662	44.0	2.6	2.2	68.6	29.1	1.7	1.5	5.7	1.1	1.3	19.52	3.75	0.72	0.86
13	2028	0.639	44.3	2.6	2.3	69.2	28.3	1.7	1.5	5.7	1.1	1.3	19.91	3.65	0.70	0.86
14	2029	0.618	44.6	2.7	2.3	69.8	27.6	1.7	1.4	5.7	1.1	1.4	20.30	3.55	0.69	0.85
15	2030	0.597	45.0	2.7	2.3	70.4	26.8	1.6	1.4	5.8	1.1	1.4	20.70	3.45	0.67	0.84
16	2031	0.577	45.3	2.7	2.3	71.0	26.1	1.6	1.4	5.8	1.1	1.4	21.09	3.36	0.65	0.83
17	2032	0.557	45.6	2.8	2.4	71.6	25.4	1.5	1.3	5.9	1.1	1.5	21.48	3.27	0.63	0.82
18	2033	0.538	45.9	2.8	2.4	72.2	24.7	1.5	1.3	5.9	1.1	1.5	21.87	3.18	0.61	0.82
19	2034	0.520	46.3	2.8	2.4	72.8	24.1	1.5	1.3	5.9	1.2	1.5	22.26	3.09	0.60	0.81
20	2035	0.503	46.6	2.8	2.4	73.4	23.4	1.4	1.2	6.0	1.2	1.6	22.65	3.01	0.58	0.80
21	2036	0.486	46.9	2.9	2.5	74.0	22.8	1.4	1.2	6.0	1.2	1.6	23.04	2.93	0.57	0.79
22	2037	0.469	47.2	2.9	2.5	74.6	22.2	1.4	1.2	6.1	1.2	1.7	23.43	2.85	0.55	0.78
23	2038	0.453	47.6	2.9	2.5	75.2	21.6	1.3	1.1	6.1	1.2	1.7	23.82	2.77	0.54	0.77
24	2039	0.438	47.9	3.0	2.5	75.8	21.0	1.3	1.1	6.1	1.2	1.7	24.22	2.69	0.52	0.76
25	2040	0.423	48.2	3.0	2.6	76.4	20.4	1.3	1.1	6.2	1.2	1.8	24.61	2.62	0.51	0.74
26	2041	0.409	48.5	3.0	2.6	76.9	19.8	1.2	1.1	6.2	1.2	1.8	25.00	2.55	0.49	0.73
27	2042	0.395	48.8	3.0	2.6	77.5	19.3	1.2	1.0	6.3	1.2	1.8	25.39	2.48	0.48	0.72
28	2043	0.382	49.2	3.1	2.6	78.1	18.8	1.2	1.0	6.3	1.2	1.9	25.78	2.41	0.47	0.71
29	2044	0.369	49.5	3.1	2.7	78.7	18.3	1.1	1.0	6.3	1.2	1.9	26.17	2.34	0.45	0.70
30	2045	0.356	49.8	3.1	2.7	79.3	17.7	1.1	1.0	6.4	1.2	1.9	26.56	2.28	0.44	0.69
31	2046	0.346	50.1	3.1	2.7	79.9	17.3	1.1	0.9	6.4	1.2	2.0	26.95	2.22	0.43	0.68
32	2047	0.336	50.5	3.2	2.7	80.5	16.9	1.1	0.9	6.5	1.3	2.0	27.34	2.17	0.42	0.67
33	2048	0.326	50.8	3.2	2.8	81.1	16.6	1.0	0.9	6.5	1.3	2.0	27.74	2.12	0.41	0.67
34	2049	0.317	51.1	3.2	2.8	81.7	16.2	1.0	0.9	6.5	1.3	2.1	28.13	2.07	0.40	0.66
35	2050	0.307	51.4	3.3	2.8	82.3	15.8	1.0	0.9	6.6	1.3	2.1	28.52	2.02	0.39	0.65
36	2051	0.298	51.8	3.3	2.8	82.9	15.4	1.0	0.8	6.6	1.3	2.1	28.91	1.98	0.38	0.64
37	2052	0.290	52.1	3.3	2.9	83.5	15.1	1.0	0.8	6.7	1.3	2.2	29.30	1.93	0.38	0.63
38	2053	0.281	52.4	3.3	2.9	84.1	14.7	0.9	0.8	6.7	1.3	2.2	29.69	1.89	0.37	0.62
39	2054	0.273	52.7	3.4	2.9	84.7	14.4	0.9	0.8	6.7	1.3	2.2	30.08	1.84	0.36	0.61
40	2055	0.265	53.0	3.4	2.9	85.3	14.1	0.9	0.8	6.8	1.3	2.3	30.47	1.80	0.35	0.61
41	2056	0.257	53.4	3.4	3.0	85.9	13.7	0.9	0.8	6.8	1.3	2.3	30.86	1.76	0.34	0.60
42	2057	0.250	53.7	3.5	3.0	86.5	13.4	0.9	0.7	6.9	1.3	2.4	31.26	1.72	0.33	0.59
43	2058	0.243	54.0	3.5	3.0	87.1	13.1	0.8	0.7	6.9	1.3	2.4	31.65	1.68	0.33	0.58
44	2059	0.236	54.3	3.5	3.0	87.7	12.8	0.8	0.7	6.9	1.4	2.4	32.04	1.64	0.32	0.57
45	2060	0.229	54.7	3.5	3.1	88.3	12.5	0.8	0.7	7.0	1.4	2.5	32.43	1.60	0.31	0.56
46	2061	0.222	55.0	3.6	3.1	88.9	12.2	0.8	0.7	7.0	1.4	2.5	32.82	1.56	0.30	0.55
47	2062	0.216	55.3	3.6	3.1	89.5	11.9	0.8	0.7	7.1	1.4	2.5	33.21	1.52	0.30	0.55
48	2063	0.209	55.6	3.6	3.1	90.1	11.6	0.8	0.7	7.1	1.4	2.6	33.60	1.49	0.29	0.54
49	2064	0.203	56.0	3.7	3.2	90.6	11.4	0.7	0.6	7.1	1.4	2.6	33.99	1.45	0.28	0.53
50	2065	0.197	56.3	3.7	3.2	91.2	11.1	0.7	0.6	7.2	1.4	2.6	34.38	1.42	0.28	0.52
51	2066	0.192	56.6	3.7	3.2	91.8	10.8	0.7	0.6	7.2	1.4	2.7	34.77	1.38	0.27	0.51
52	2067	0.186	56.9	3.7	3.2	92.4	10.6	0.7	0.6	7.3	1.4	2.7	35.17	1.35	0.26	0.50
53	2068	0.181	57.2	3.8	3.3	93.0	10.3	0.7	0.6	7.3	1.4	2.7	35.56	1.32	0.26	0.49
54	2069	0.175	57.6	3.8	3.3	93.6	10.1	0.7	0.6	7.4	1.4	2.8	35.95	1.29	0.25	0.49
55	2070	0.170	57.9	3.8	3.3	94.2	9.9	0.6	0.6	7.4	1.4	2.8	36.34	1.26	0.25	0.48
56	2071	0.165	58.2	3.8	3.3	94.8	9.6	0.6	0.6	7.4	1.5	2.8	36.73	1.23	0.24	0.47
57	2072	0.160	58.5	3.9	3.4	95.4	9.4	0.6	0.5	7.5	1.5	2.9	37.12	1.20	0.23	0.46
58	2073	0.156	58.9	3.9	3.4	96.0	9.2	0.6	0.5	7.5	1.5	2.9	37.51	1.17	0.23	0.45
59	2074	0.151	59.2	3.9	3.4	96.6	8.9	0.6	0.5	7.6	1.5	3.0	37.90	1.14	0.22	0.45
60	2075	0.147	59.5	4.0	3.4	97.2	8.7	0.6	0.5	7.6	1.5	3.0	38.29	1.11	0.22	0.44
61	2076	0.143	59.8	4.0	3.5	97.8	8.5	0.6	0.5	7.6	1.5	3.0	38.69	1.09	0.21	0.43
62	2077	0.138	60.2	4.0	3.5	98.4	8.3	0.6	0.5	7.7	1.5	3.1	39.08	1.06	0.21	0.42
63	2078	0.134	60.5	4.0	3.5	99.0	8.1	0.5	0.5	7.7	1.5	3.1	39.47	1.04	0.20	0.42
64	2079	0.130	60.8	4.1	3.5	99.6	7.9	0.5	0.5	7.8	1.5	3.1	39.86	1.01	0.20	0.41
65	2080	0.127	**61.1**	**4.1**	**3.6**	100.2	7.7	0.5	0.5	**7.8**	**1.5**	**3.2**	40.25	0.99	0.19	0.40
66	2081	0.123	61.1	4.1	3.6	100.2	7.5	0.5	0.4	7.8	1.5	3.2	40.25	0.96	0.19	0.39
67	2082	0.119	61.1	4.1	3.6	100.2	7.3	0.5	0.4	7.8	1.5	3.2	40.25	0.93	0.18	0.38
68	2083	0.116	61.1	4.1	3.6	100.2	7.1	0.5	0.4	7.8	1.5	3.2	40.25	0.90	0.18	0.37
69	2084	0.112	61.1	4.1	3.6	100.2	6.9	0.5	0.4	7.8	1.5	3.2	40.25	0.88	0.17	0.36
70	2085	0.109	61.1	4.1	3.6	100.2	6.7	0.4	0.4	7.8	1.5	3.2	40.25	0.85	0.17	0.35
71	2086	0.106	61.1	4.1	3.6	100.2	6.5	0.4	0.4	7.8	1.5	3.2	40.25	0.83	0.16	0.34
72	2087	0.103	61.1	4.1	3.6	100.2	6.3	0.4	0.4	7.8	1.5	3.2	40.25	0.80	0.16	0.33
73	2088	0.100	61.1	4.1	3.6	100.2	6.1	0.4	0.4	7.8	1.5	3.2	40.25	0.78	0.15	0.32
74	2089	0.097	61.1	4.1	3.6	100.2	5.9	0.4	0.3	7.8	1.5	3.2	40.25	0.76	0.15	0.31
75	2090	0.094	61.1	4.1	3.6	100.2	5.8	0.4	0.3	7.8	1.5	3.2	40.25	0.73	0.14	0.30
76	2091	0.092	61.1	4.1	3.6	100.2	5.6	0.4	0.3	7.8	1.5	3.2	40.25	0.72	0.14	0.29
77	2092	0.090	61.1	4.1	3.6	100.2	5.5	0.4	0.3	7.8	1.5	3.2	40.25	0.70	0.14	0.28
78	2093	0.087	61.1	4.1	3.6	100.2	5.3	0.4	0.3	7.8	1.5	3.2	40.25	0.68	0.13	0.28
79	2094	0.085	61.1	4.1	3.6	100.2	5.2	0.3	0.3	7.8	1.5	3.2	40.25	0.67	0.13	0.27
80	2095	0.083	61.1	4.1	3.6	100.2	5.1	0.3	0.3	7.8	1.5	3.2	40.25	0.65	0.13	0.26
81	2096	0.081	61.1	4.1	3.6	100.2	5.0	0.3	0.3	7.8	1.5	3.2	40.25	0.63	0.12	0.26
82	2097	0.079	61.1	4.1	3.6	100.2	4.8	0.3	0.3	7.8	1.5	3.2	40.25	0.62	0.12	0.25
83	2098	0.077	61.1	4.1	3.6	100.2	4.7	0.3	0.3	7.8	1.5	3.2	40.25	0.60	0.12	0.24
84	2099	0.075	61.1	4.1	3.6	100.2	4.6	0.3	0.3	7.8	1.5	3.2	40.25	0.59	0.12	0.24
85	2100	0.074	61.1	4.1	3.6	100.2	4.5	0.3	0.3	7.8	1.5	3.2	40.25	0.57	0.11	0.23
86	2101	0.072	61.1	4.1	3.6	100.2	4.4	0.3	0.3	7.8	1.5	3.2	40.25	0.56	0.11	0.23
87	2102	0.070	61.1	4.1	3.6	100.2	4.3	0.3	0.3	7.8	1.5	3.2	40.25	0.55	0.11	0.22
88	2103	0.068	61.1	4.1	3.6	100.2	4.2	0.3	0.2	7.8	1.5	3.2	40.25	0.53	0.10	0.22
89	2104	0.067	61.1	4.1	3.6	100.2	4.1	0.3	0.2	7.8	1.5	3.2	40.25	0.52	0.10	0.21
90	2105	0.065	61.1	4.1	3.6	100.2	4.0	0.3	0.2	7.8	1.5	3.2	40.25	0.51	0.10	0.21
91	2106	0.063	61.1	4.1	3.6	100.2	3.9	0.3	0.2	7.8	1.5	3.2	40.25	0.49	0.10	0.20
92	2107	0.062	61.1	4.1	3.6	100.2	3.8	0.3	0.2	7.8	1.5	3.2	40.25	0.48	0.09	0.20
93	2108	0.060	61.1	4.1	3.6	100.2	3.7	0.2	0.2	7.8	1.5	3.2	40.25	0.47	0.09	0.19
94	2109	0.059	61.1	4.1	3.6	100.2	3.6	0.2	0.2	7.8	1.5	3.2	40.25	0.46	0.09	0.19
95	2110	0.057	61.1	4.1	3.6	100.2	3.5	0.2	0.2	7.8	1.5	3.2	40.25	0.45	0.09	0.18
96	2111	0.056	61.1	4.1	3.6	100.2	3.4	0.2	0.2	7.8	1.5	3.2	40.25	0.44	0.09	0.18
97	2112	0.055	61.1	4.1	3.6	100.2	3.3	0.2	0.2	7.8	1.5	3.2	40.25	0.43	0.08	0.17
98	2113	0.053	61.1	4.1	3.6	100.2	3.3	0.2	0.2	7.8	1.5	3.2	40.25	0.42	0.08	0.17
99	2114	0.052	61.1	4.1	3.6	100.2	3.2	0.2	0.2	7.8	1.5	3.2	40.25	0.41	0.08	0.16

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Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE

t:+44(0)1756 799919
e:info@jbaconsulting.com

Jeremy Benn Associates Ltd
Registered in England
3246693

Visit our website
www.jbaconsulting.com