Aberdeenshire Council

Deveron at Huntly Flood Study
Update
April 2010

Halcrow Group Limited

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Contents Amendment Record

This report has been issued and amended as follows:

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1	0	Draft for Comment	04/02/10	RE	PL
2	1	Update following AC comments	31/03/10	RE	PL
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Executive Summary

Aberdeenshire Council appointed Halcrow Group Limited (Halcrow) in December 2009 to undertake a review of the 2005 Deveron at Huntly flood study previously carried out by Halcrow, with specific regard to the flooding which occurred in the town during the 1st and 2nd of November 2009. The main objectives of the study were therefore to assess available hydrological data from the November 2009 event in order to establish its severity; to review the mechanisms of the flood event; and to provide recommendations on potential flood protection measures.

As a result of this study update, a clearer picture of flooding mechanisms in the area has been established, and the following conclusions and recommendations are made:

- The return period for the November 2009 event has been estimated using a range of different approaches and highlights the uncertainty inherent to such assessment. The best estimate based on hydrological analysis and hydraulic modelling is that of approximately 1% Annual Probability (1:100 year).

- Neither the scaffolding on the A96 bridge, nor the Huntly Castle Hotel access bridge have been found to have had any significant effect on the flooding experienced in November 2009.

- The hydrological analysis update has resulted in an approximate 5 to 10% increase in design flows (depending on the return period) and therefore will cause a slight rise in design levels. Should any of the proposed options be taken forwards to detailed design stage and construction, these flows should be used and the model be run with proposed options in place for a range of return periods in order to inform the appropriate design levels. It is also recommended to consider reviewing further the hydrological analysis and generating a further hydrological growth regime, after conducting a review of the suitability of a number of Scottish gauging stations to improve the geographical similarity of the Flood Estimation Handbook (FEH) pooling group.

- The preferred mitigation option recommended during the original modelling study based on raised embankments along the Deveron and

Meadow Burn remains the most effective way to minimise the risk of flooding to properties in Huntly from both the Deveron and Meadow Burn. It is suggested however to set back the embankments from the watercourses as much as land availability allows.

- A number of other options have been considered as part of this update, including flood storage and flow diversion from the Meadow Burn, but because of the very flat nature of the Meadow area which is a natural floodplain, they have all been found to be unsuitable due to topographical and hydraulic constraints.

- The preferred option should now be developed under the processes of the Water Environment (Controlled Activities) Regulations 2005 and Flood Risk Management (Scotland) Act 2009.

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Appendices

1 Introduction

1.1 *Context*

Aberdeenshire Council appointed Halcrow Group Limited (Halcrow) in December 2009 to undertake a review of the 2005 Deveron at Huntly flood study previously carried out by Halcrow, with specific regard to the flooding which occurred in the town during November 2009. The main objectives of the study are therefore to assess available hydrological data from the November 2009 event in order to establish its severity; to review the mechanisms of the flood event; and to provide recommendations on potential flood protection measures.

The town of Huntly is situated approximately 65 kilometres north-west of Aberdeen on the main A96 road. Several watercourses converge in or near to the town, compounding the potential risk of flooding. The River Deveron flows west-east, effectively forming the northern boundary of the town. The Ittingstone Burn joins the Deveron in the Milltown area at the west of the town, and the River Bogie joins the Deveron about 1km downstream of Huntly Castle. Between the town centre and the Deveron there is a flat low-lying area called "The Meadows", through which the Meadow Burn runs approximately parallel to the Deveron. In recent decade, this floodplain area has been developed for both housing and leisure purposes (Meadows Housing development, care home and Caravan Park). A general map of the area can be seen in Figure 1-1, and a more detailed description of the area and catchment can be found in the 2005 report.

Huntly has experienced several significant flood events within living memory, and damage has been caused to many residential and commercial properties, with The Meadows area being particularly severely affected. The Meadows was flooded in September 1995, April 2000, October and November 2002, and most recently September and November 2009. After the 1995 event, a flood protection embankment was built on the south bank of the Deveron which affords protection against direct inundation from the Deveron; however the flooding mechanism in the area is complex, with overland flow from the Deveron upstream and the Ittingstone Burn also posing a significant risk to the Meadows.

Figure 1-1: Location Overview

1.2 *Scope of the study*

The scope of the study update is outlined below:

- An investigation of the November 2009 flood event at the Meadows including potential causes and mechanisms

- Analysis of river flows during November 2009 flood event to obtain return period estimate using latest information from SEPA, including any recently updated flow rating curves at gauging stations

- A review of analyses undertaken in 2005 from the perspective of any recent changes in Huntly including updating the existing hydraulic model and undertaking model runs to represent the November 2009 event

- Report and recommendations

1.3 *Extent of Study Area*

The study area as defined during the 2005 study is the land between the River Deveron and Meadow Burn from the Ittingstone Burn on the west, to Huntly Castle on the east. This area remains appropriate for the study update.

1.4 *Methodology*

As stated in Section 1.1, flooding in the Meadows area is caused by the combined flows from the River Deveron and the overflow coming from Ittingstone Burn which occurs when high flows are present on the Deveron.

Given that detailed hydrodynamic modelling of the River Deveron and its tributaries was undertaken during the 2005 study, no additional model runs have been undertaken. However a thorough review has been undertaken to confirm the flowing mechanisms identified in 2005 remain valid. A brief description of the previous hydraulic modelling approach is included in Section 2.9 for clarity.

Data relating to the 1st November 2009 flood event was collected from a variety of sources including Aberdeenshire Council, SEPA and online news reports. These have been collated and used to assess both the nature and extent of the event.

Hydrological data from river gauging stations on the Deveron and Bogie has been obtained for the time period up to and including the November 2009 event. This means that approximately 6 further years of hydrological data has been retrieved and considered, and some aspects of the original hydrological analysis within the catchment have been reassessed using this additional data.

An additional gauging station has been recently installed by SEPA in Huntly itself. As this has happened only recently, there is not sufficient recorded data for this site yet to enable a meaningful statistical analysis of flows to be carried out. Since it is situated within the existing modelled reach, however, it has been possible to use observed flows at this gauge in conjunction with the previously generated model results to create an estimated water surface profile along the Deveron in Huntly.

Topographical survey data provided by Aberdeenshire Council has been used to generate a ground surface model, which has been analysed to identify low points and potential surface water flow paths in areas of key interest.

2 Data Collection

2.1 *Overview*

This section outlines the sources and types of data collected and their purpose within this study.

2.2 *Hydrological information*

2.2.1 Flow and Rainfall

SEPA operate several river gauging stations within the vicinity of the study area: 9004 Bogie at Redcraig, about 3-4km upstream of the confluence with the Deveron; 9001 Deveron at Avochie approximately 5-6km downstream of Huntly Castle; and the recently installed gauge within Huntly itself sited upstream of the Gibston Bridge. Data from the first two gauges formed the basis of the hydrological analysis undertaken during the 2005 study, and updated flow and stage series have been obtained for the subsequent period between the initial analysis and this update. The updated annual maximum flows for both stations were obtained from SEPA, as well as 15-min data stretching back to 1989, and including the 1st November event on both watercourses. The above data was used to review the hydrological study estimates and to establish the return period of the 1st November 2009 event.

The SEPA gauge at Huntly was installed during the spring of 2009, and the full record period for this gauge has been obtained. This data was used in conjunction with the modelling results from the original study to generate an estimated maximum water surface elevation along the Deveron reach for the 1st November 2009 event.

2.2.2 Deveron Level Only Gauge

A level-only gauge was previously installed by Mountain Environment (ME) for Aberdeenshire Council at the A96 Bridge. Data from this gauge was used for model calibration during the original study. This gauge is no longer operational, and therefore no additional data has been obtained from this source for use in this study.

2.3 *Topographical survey*

A significant amount of topographical survey data was gathered during the original study from a variety of sources. This was used in both model construction and development of flooding mechanisms and further details can be found within the 2005 report. Additional survey data was obtained during this study update in order to better understand the overland flow paths, and verify anecdotal reports of the 1st November 2009 event. This additional data is summarised below:

- Topographical survey of the Deveron banks and floodplain upstream of the Meadows (source: Aberdeenshire Council).

- Post-flood event survey of trash marks in several locations on the Deveron, taken by a Halcrow survey team following a smaller flood event in September 2009

These sources were combined with the existing survey data to update the ground surface model, creating increased resolution in key areas of interest, and a best representation of the actual terrain.

2.4 Flooding mechanism

The observed flooding mechanism during the November 2009 event was described by Aberdeenshire Council during the project inception meeting and a marked up sketch of inundated areas provided. This was in general similar to the mechanism identified during the 2005 study, however further detail was provided regarding flows across the A920.

In general the flood mechanism can be summarised as follows:

- High flows in the River Deveron cause a backwater effect on Ittingstone Burn, and together with the water from the Deveron itself overtopping the embankment in the area of Milltown, they run eastwards to the A96(T), joining the Meadow Burn in the vicinity of the A920/A96 crossroad.

- The combined flows from the Meadow Burn, Ittingstone Burn and the Deveron cause flooding on the south area of the Meadows due to the insufficient capacity of Meadow Burn channel.

- Additional flooding occurs when the Deveron waters overtop the embankment at Hill of Haugh flowing south-westerly towards the Caravan Park.

Figure 2-1, which is a reproduction of Figure 20 of the 2005 report illustrates these complex flooding mechanisms.

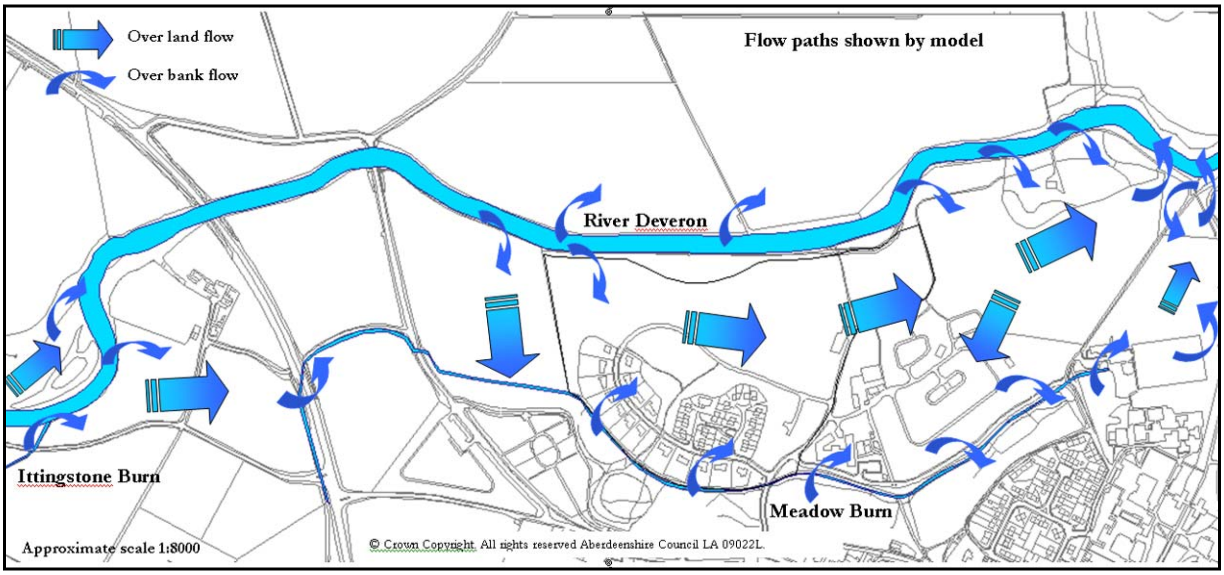


Figure 2-1: Flooding mechanism and flow paths described by hydraulic model

2.5 ***Walkover Surveys***

During the original project, several site walkover surveys were conducted during the autumn and winter of 2004/5. In addition, a site walkover survey was also conducted at the commencement of this study update, on December 14th 2009. The purpose of these visits has been to record photographic evidence of previous flood events, e.g. wrack marks, waterlines, and to identify any likely bank weaknesses or significant flow constraints. During the most recent walkover in December 2009, several indications of the extent of the November flooding were observed and recorded. Erosion of the embankment along the River Deveron was also noted.

2.6 ***Photographic Sources***

Several sources of photographic data have been obtained for use in this study: Aberdeenshire Council has provided aerial photography of the Huntly area which provides a useful overview of the study area and has been used in geo-locating several site photographs; Aberdeenshire Council has also provided a large selection of photographs taken in the days following the November 2009 event; SEPA has provided annotated photos taken by their staff in the area after the same event; and a large number of photographs have been taken by Halcrow during site visit for both the original study and the update.

2.7 *Historical Information*

The Deveron catchment has a long history of flooding, with the earliest recorded incident reported in 1739, and periodic occurrences since then. Further information regarding the nature and extent of historic flood events on the Deveron can be found in the original 2005 report; however a brief timeline of reported events is also included below:

- 1739
- 1829
- 1865
- February 1923
- April 2000
- October 2002
- November 2002
- September 2009
- November 2009

2.8 *Local and National Media*

Online news reports were obtained to gather as much information as possible regarding the nature of the 1st November 2009 flood, and a wide range of sources were searched, including online newspapers, the BBC, other online news services, the MET office, and hydrological reports. Aberdeenshire Council also provided scanned copies of the Huntly Express published on the 6th November 2009. These sources were used to determine the characteristics of the storm event, and the extent of Huntly affected.

2.9 *Scope of 2005 modelling study*

The calculations, results and reporting from the 2005 project have been retrieved from archive for review during this study. They include hydraulic modelling results and hydrological analysis. A summary of the modelling approach used during the original study is given here for clarity, although no new modelling has been undertaken:

- A hydrological assessment of river peak flows for the River Deveron for a range of return periods was carried out using the methodology of the Flood Estimation Handbook (FEH) (Institute of Hydrology, 1999). The peak flows for Ittingstone Burn and Meadow Burn were estimated using the Rainfall-runoff methodology. The hydrological assessment was reviewed by an independent senior hydrologist from Halcrow.

- A one-dimensional numerical hydraulic model of the three water courses was constructed using Infoworks RS software from topographical survey data of the watercourses and floodplains. The model outputs were used to prepare flood inundation maps (for 75 year, 200 year and 200 year plus climate change events), describe the flooding mechanisms and provide a number of recommendations.

- A detailed assessment of the capacity of culverts along the Meadow Burn was also undertaken.

3 Hydrological assessment

3.1 *General*

Flood risk involves both the statistical probability of an event occurring and the scale of the potential consequences. The degree of risk is calculated and expressed in terms of the expected frequency of a flood for a given magnitude e.g. the 50 year, 100 year or 200 year flood. The risk is expressed in terms of these 'return periods'. This means that there is a 2%, 1% and 0.5% chance respectively of such an event happening in any given year. Over a longer period of time, the probability of occurrence is considerably greater. For example:

For the 100 year return period:

- there is a 1% chance of it occurring in any year, but
- a 26% chance of at least one such flood in a 30 year period, and
- a 51% chance of at least one such flood in 70 years, the minimum lifespan of many developments.

For the 200 year return period:

- there is a 0.5% chance of it occurring in any year, but
- a 14% chance of at least one such flood in a 30 year period, and
- a 30% chance of at least one such flood in 70 years.

3.2 *2005 Hydrological Analysis*

During the original study, extensive hydrological analysis was undertaken and independently verified. This analysis is not repeated in detail here, and only a brief summary is given for those elements that have subsequently been updated. The reader is referred to Section 3 of the 2005 report for a full description of the approach taken and results obtained previously.

3.3 *Description of the catchment*

The study catchment was defined at the confluence of the River Deveron and River Bogie (NJ53900, 41200). This is a conservative approach since the above point was about 1km downstream of the end of the modelling area (Huntly Castle); however, it was considered adequate for hydrological calculation purposes.

The study catchment area is approximately 230km² and is predominantly rural. The upper catchment of the Deveron is mainly moorland while the lower catchment (around Huntly) consists of pasture and arable land.

There are several SEPA gauging stations within the vicinity of the study area; 9005 Allt Deveron at Cabrach, 9001 Deveron at Avochie, 9004 Bogie at Redcraig, and the recently installed gauge in Huntly upstream of the Gibston Bridge. Of these, gauge 9005 is situated within the catchment but is considered too far upstream to be representative. The new Huntly gauge is also situated within the study catchment, however due to its recent installation, less than 1 year of recorded data is available, making it unsuitable for statistical analysis. Therefore, gauging stations 9001 and 9004 have underpinned the basis of the hydrological analysis on the watercourse, due to their position close to the catchment outlet.

The extent of the study catchment and the locations of the SEPA gauging stations used in the study are shown in Figure 3-1.

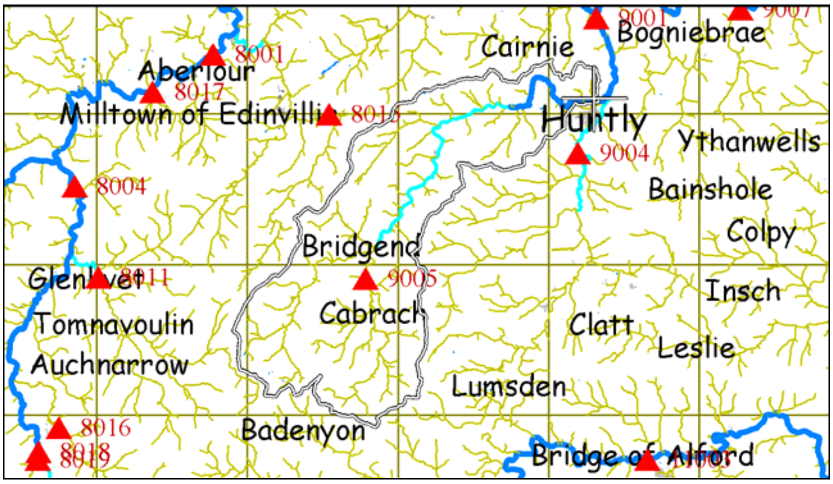


Figure 3-1: Subject site catchment

3.4 ***Flood flow assessment methodology***

The hydrological assessment undertaken for the 2005 study used two methodologies for flood flow estimation. The flows for the Deveron were estimated using the FEH statistical methodology, whilst the flows for the two small burns (Meadow Burn and Ittingstone Burn) were estimated using the FEH Rainfall-Runoff method. Further details on each of these methods can be found in Section 3 of the 2005 report.

For the purpose of this update, the hydrological analysis of the tributary watercourses has not been reviewed and the analysis has focused on the River Deveron as it was the source of the November 2009 flood. The flood flow assessment was updated using the additional national gauging station network data collected between 2004 and 2009. In addition, a comparison has been made using the updated FEH statistical methodology brought into use in 2009.

3.5 ***Update of Q_{MED}***

The FEH statistical methodology is based on the derivation of an index flow, Q_{MED}, representative of the 1 in 2 year flood event, and a growth curve, which allows the flood peak for any given return period to be estimated. This method draws on an extensive national rainfall and river flow dataset across the UK.

Q_{MED} can be calculated from recorded data when available, or at ungauged catchments estimated from the FEH catchment descriptors based on digital data. And adjustment can then be made by using a nearby "donor" gauged catchment.

During the 2005 analysis, Q_{MED} was derived for the ungauged catchment on the Deveron immediately upstream of its confluence with the Bogie, and several donor sites were investigated. The Deveron at Avochie (9001) and Bogie at Redcraig (9004) were considered most appropriate, and the Deveron at Avochie ultimately chosen as the preferred donor. Given that at donor sites, the recorded annual maxima (AM) series is used to obtain Q_{MED} estimates, the additional 5 years of gauged data recorded between 2004 and 2009 has the potential to impact on the calculated Q_{MED} value, and was therefore reassessed.

The values obtained during the 2005 study can be seen in Table 3-1 below:

Table 3-1: Original Calculated Q_{MED} Values

Station	9001	9004	Deveron u/s of Bogie
Q_{MED} (Catchment Descriptors) (m^3/s)	81.4	31.2	60.05
Q_{MED} (Annual Maxima) (m^3/s)	129.3	27.3	-
Q_{MED} Deveron u/s of Bogie (using station as donor catchment) (m^3/s)	**94.7**	**52.7**	**-**

The annual maxima series were then updated with data provided by SEPA for both the Deveron at Avochie (9001) and the Bogie at Redcraig (9004), and Q_{MED} at the study site reassessed. The Q_{MED} values generated using catchment descriptors remained unchanged at this point, and the calculated values shown in Table 3-2.

Table 3-2: Updated AMAX Calculated Q_{MED} Values

Station	9001	9004	Deveron u/s of Bogie
Q_{MED} (Catchment Descriptors) (m^3/s)	81.4	31.2	60.05
Q_{MED} (Annual Maxima) (m^3/s)	131.0	27.6	-
Q_{MED} Deveron u/s of Bogie (using station as donor catchment) (m^3/s)	**96.0**	**53.2**	**-**

It can be seen that the inclusion of the additional annual maxima years for the period 2005-2009 causes a small increase in calculated Q_{MED} values: indeed the inclusion of more high magnitude events such as November 2009, results in an increase to the median flow value.

During 2009, an update to the FEH statistical method was implemented, and a new method of calculating Q_{MED} from catchment descriptors introduced. This revised equation was developed through empirical analysis of over 600 rural catchments throughout the UK, and the weighting applied to individual catchment descriptors have changed significantly.

The Q_{MED} values obtained using the new equation can be seen in Table 3-3:

Table 3-3: Updated FEH Methodology Calculated Q_{MED} Values

Station	**9001**	**9004**	**Deveron u/s of Bogie**
Q_{MED} (Catchment Descriptors) (m^3/s)	101.3	36.2	76.1
Q_{MED} (Annual Maxima) (m^3/s)	131.0	27.6	-
Q_{MED} Deveron u/s of Bogie (using station as donor catchment) (m^3/s)	**98.4**	**58.1**	**-**

Whilst the values of Q_{MED} calculated from catchment descriptors can be seen to be significantly higher, they have been brought closer to the observed AM values, thus reducing the scaling ratio, and causing a small overall increase in the values calculated for the Deveron upstream of its confluence with the Bogie. One of the advantages of the revised Q_{MED} calculation method is that in general it produces values that are closer to those obtained from AMAX data, and it is therefore generally considered to produce more reliable output.

3.6 *Updated Flood Frequency Curves*

Extensive analysis was undertaken during the original study to establish an appropriate pooling group for generation of the flood frequency curve. The first stage in reviewing the hydrology has therefore been to maintain this pooling group and update it with the additional data from the period 2004-2009. In doing so, several sites from the original pooling group were identified as no longer suitable for pooling: this could be due to unreliable data recording in recent years, or changes to station ratings. These were excluded, however the extended data period meant that a total pooling record length of 1023 years was achieved which is still considered suitable for estimation of the 200 year event.

Variation between the original and updated pooling group components can be seen in Appendix A.

As with Q_{MED}, the statistical procedures behind pooling group creation have been revised with the introduction of the WINFAP v3 software. This uses different algorithms to assess the similarity of potential pooling gauges to the subject site; therefore it was felt it would be of interest to compare the output of a new pooling group generated using this method. The details of this pooling group can be seen in Appendix A.

As established during the original study, the Generalised Logistic statistical distribution was considered to be most appropriate, and the growth factors from this distribution were used in conjunction with the Q_{MED} from updated AMAX data to generate two alternative updated flood frequency curves for the Deveron upstream of the Bogie confluence.

These can be seen in Figure 3-2. Also plotted on the graph is data from a series of overlapping AMAX flows from gauging stations 9001 and 9004. Where peak flows occurred on the same date, they were subtracted, and the result considered to approximate the actual flow in the Deveron upstream of its confluence with the Bogie. It can be seen that in general there is a slight discrepancy, as observed during the 2005 study, and is attributed to a small difference in catchment areas.

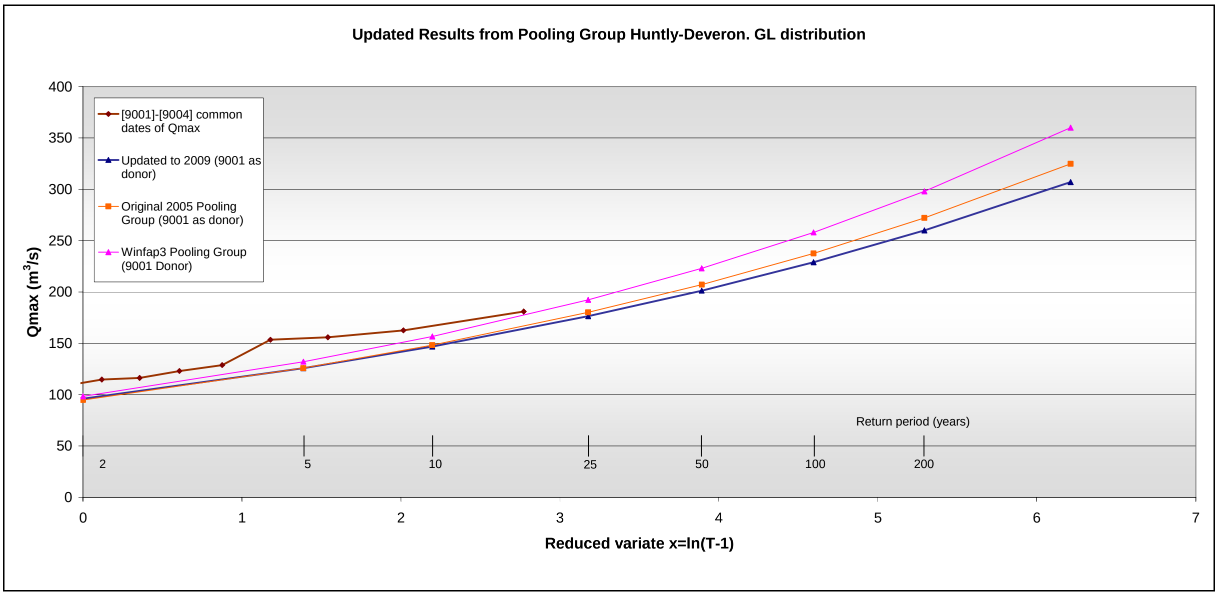


Figure 3-2: Flood Frequency Curve Comparison

Estimate flows for a range of return periods using all three flood frequency curves can be seen in Table 3-4.

Table 3-4: Comparison of Calculated Flows of the Deveron in Huntly

Flow Return Period	2yr (m^3/s)	5yr (m^3/s)	10yr (m^3/s)	25yr (m^3/s)	50yr (m^3/s)	100yr (m^3/s)	200yr (m^3/s)	500yr (m^3/s)
Original 2005 Pooling Group (9001 as donor)	94.7	125.9	148.2	180.1	207.2	237.6	272.1	324.8
Original Pooling group updated to 2009 data (9001 as donor)	96.0	125.8	146.8	176.4	201.2	229.0	260.0	306.9
New pooling group using Winfap3 method (9001 as donor)	98.4	132.1	156.7	192.4	223.1	258.0	298.0	360.0

The difference in results is particularly notable for higher return periods and is illustrated by considering the value of the original 100 year flow: 231.7 m^3/s. Considering the pooling group data updated to 2009, the same flow equates to approximately a 108 year event, however considering the Winfap3 group, it is reduced to approximately a 60 year event. This illustrates the inherent uncertainty of hydrological estimates in general, which is discussed further below.

The variation from a 100yr to a 108yr event magnitude is attributable to the inclusion of a longer data series across all pooled sites, some of which may have experienced lower flow in recent years, and cumulatively this has the effect of slightly increasing the return period of any given flow.

The decrease in magnitude of the original 100 year flow to a 60 year event is much more significant. The pooling group selected achieved a similar degree of homogeneity as the original, however the sites included were different, and it was not possible to alter the site ranking to force a dominance of Scottish sites on the results. This is an area that may warrant further investigation if future updates to the hydraulic modelling are required for detailed design purpose, as this may have a significant impact in terms of standard of protection for flood protection measures.

3.7 ***Meadow Burn and Ittingstone Burn***

No review of the hydrological analysis of the Meadow Burn and Ittingstone Burn has been taken at this stage, as these watercourses are ungauged.

3.8 ***Return Period Assessment of November 2009 Event***

One of the key drivers of this study was to assess the return period of the 1st November 2009 event. Significant damage was caused to properties, local infrastructure and vulnerable residents, and establishing an estimated return period for the event will allow Aberdeenshire Council to understand the likelihood of a similar event occurring in the future and to inform future flooding strategies in the area.

Data for the event was provided by SEPA at 15-minute intervals for the new Huntly Gauge, the Deveron at Avochie (9001), and the Bogie at Redcraig (9004). A plot of the observed stage and flow series at these locations during the event can be seen in Figure 3-3.

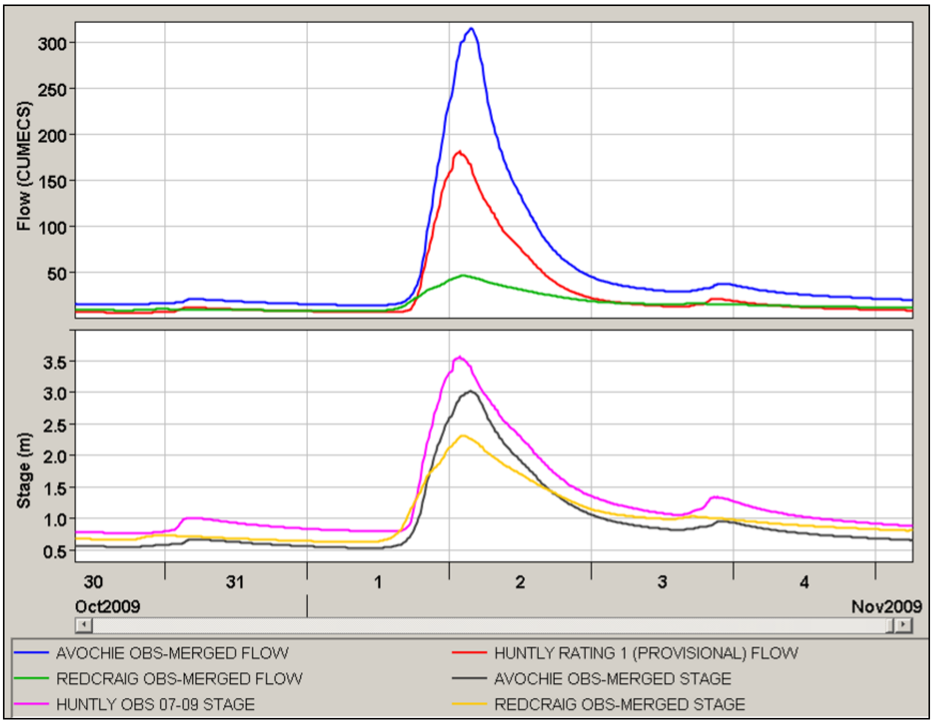


Figure 3-3: November 1st 2009 Observed Data

The maximum gauged stage and flow at each location are shown in Table 3-5.

Table 3-5: 1st November 2009 Maximum Event Data

Station	Max Stage (m)	Max Flow (m^3/s)
9001 Deveron at Avochie	3.02	315.13
9004 Bogie at Redcraig	2.31	45.65
New Huntly Gauge upstream of Gibston Bridge	3.57	180.88

It should be noted that the flow at the new Huntly gauging station is based on a provisional rating developed at that site, and may be subject to change in the future once spot gaugings across a variety of flows are obtained by SEPA and the rating reassessed.

The recorded stage in each case is also to a local datum, and is highly dependent on the channel profile and size at the gauging station; therefore it has been included for information, rather than comparison between locations.

A single site statistical analysis at gauging stations 9001 and 9004 was undertaken to consider the additional observed data between 2004 and 2009. Figure 3-4 shows the original and updated growth curves, with the maximum gauged flows observed during the 1st November event superimposed.

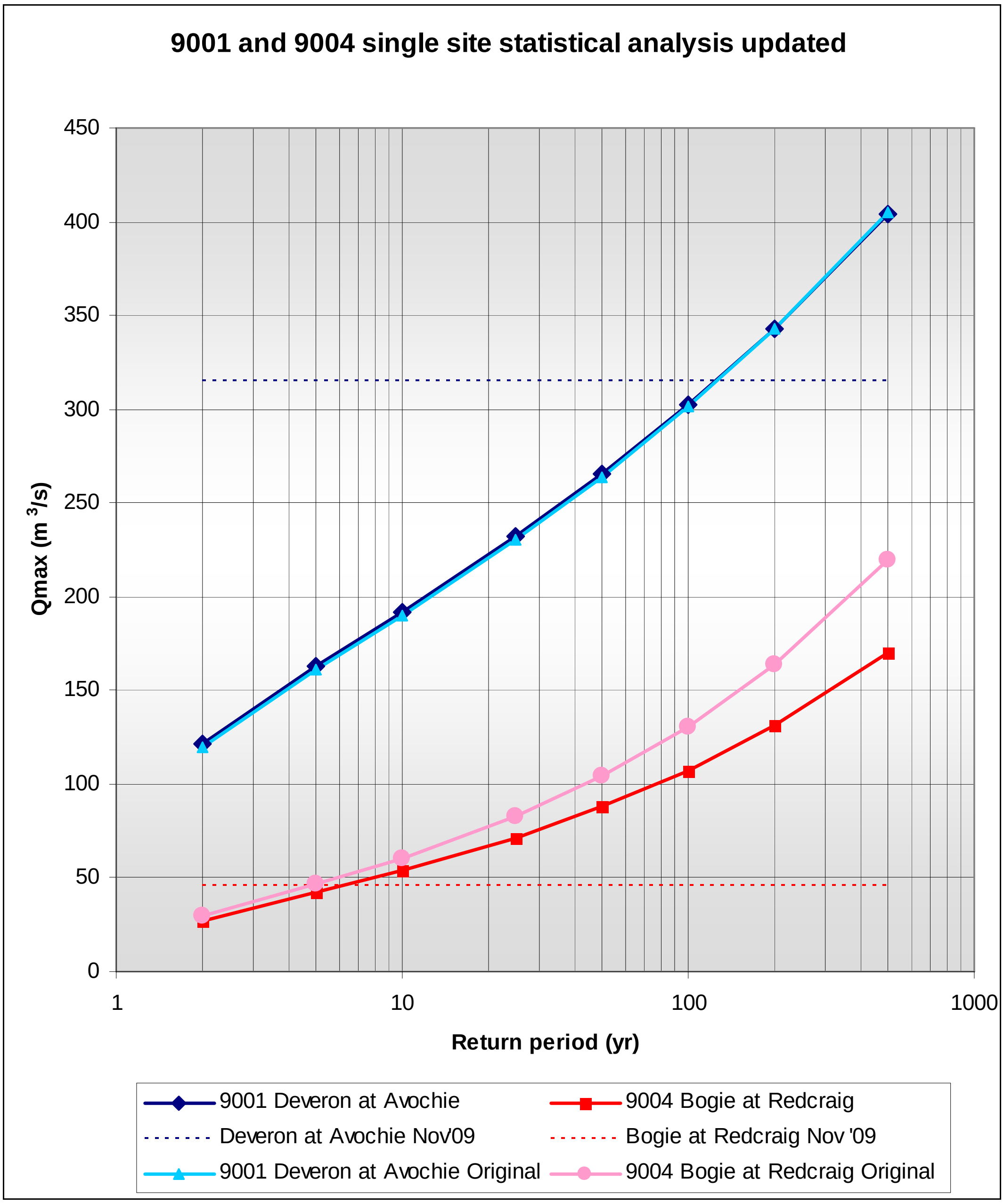


Figure 3-4: 1st November 2009 Event Magnitude

From this it can be seen that the updated statistical analysis has a negligible impact on the Deveron at Avochie growth curve, due to the longer available data series, however it has a significant impact on the Bogie at Redcraig. Extrapolating from the graph, the estimated return periods for the 1st November 2009 are shown in Table 3-6 below.

Table 3-6: November 1st 2009 Return Period Comparisons

Station	Estimated Return Period (years)
Deveron at Avochie	126
Bogie at Redcraig Original	5
Bogie at Redcraig Updated	7

From this it can be seen that Deveron catchment was significantly more affected by this particular storm event than the Bogie catchment. Updating the Bogie flood frequency curve increases the severity of the event by approximately 2 years.

It has not been possible to carry out a single site statistical analysis at the new Huntly gauging station, as the data period (9 months) is unsuitable for this task. Comparing the November 2009 event with the growth curves developed for the Deveron upstream of its confluence with the Bogie (See Figure 3-2) indicates the event is between a 25 and 50 year event.

However, this is an under-estimation of flows in the Deveron, due to bypassing of the gauging station by flow leaving the Deveron around Milltown, upstream of the A96. In order to assess the potential flow deficit, a further analysis was undertaken using observed data at both the Deveron at Avochie and Bogie at Redcraig gauges. Flows at these stations were scaled by area to the confluence of the Deveron and Bogie, and subtracted. Theoretically, the resulting flow should be a close approximation of the gauged flow at Huntly, for any given event, however for the November 2009 event, there was found to be a 73.6m^3/s deficit in the peak flows, summarised in Table 3-7. This deficit is deemed to represent the flows that spilled over the embankment in the Milltown area and bypassing the gauging station. Full details of the scaling calculation can be found in Appendix B.

Table 3-7: Scaling Results

Location	Nov 09 Flow (m3/s)
1. Deveron at Avochie	315.13
2. Deveron at Avochie scaled to downstream of confluence with River Bogie	304.11
3. Bogie at Redcraig	45.60
4. Bogie at Redcraig scaled to confluence	49.63
5. Deveron Calculated Flow at Huntly upstream of confluence with River Bogie	254.48
6. Observed Flow at Huntly gauging station	180.88
7. Huntly Flow Deficit (5 – 6)	73.6
8. Revised Deveron Model Inflow	254.48

This revised flow estimate was then plotted against the pooled-analysis growth curves developed for the Deveron at Huntly, as can be seen in Figure 3-5.

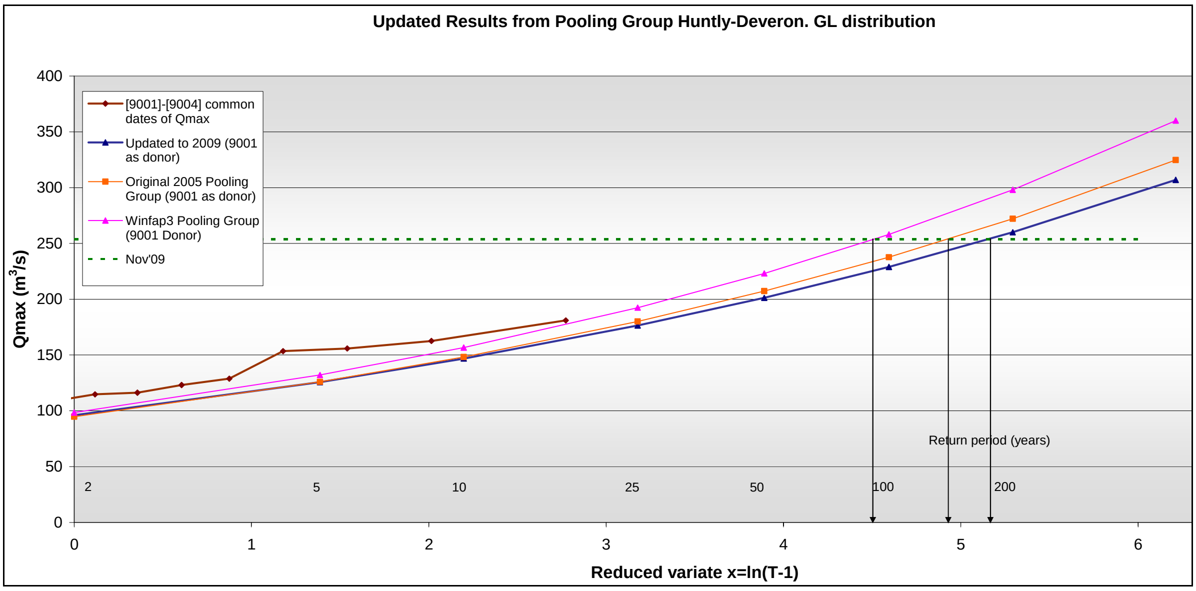


Figure 3-5: Nov '09 Event RP from Pooled Analysis

It can be seen that each pooling analysis generates a different return period, highlighting the general uncertainty in hydrological analysis. These return periods range from 94 years to 177 years, therefore it is recommended that a return period of approximately 100 years is adopted for the event, based on the Winfap3 method with site 9001 as a donor catchment is adopted, which represents current hydrological best practice. Considering catchment scaling in this way brings the November 2009 event magnitude at Huntly much more closely in line with that observed on the Deveron at Avochie, where a good flow record provides confidence in the adopted return period.

3.9 *Impact on Design Flows*

As discussed in Section 3.6, revision of QMED and the hydrological pooling group has resulted in an alteration of design flows. Of the two update methods used (update of the original pooling group with new data, and generation of a new Winfap3 pooling group), it is recommended that the Winfap3 updated flows be adopted as the current best estimates of design flows for the Deveron.

Should any of the defence options analysed in the subsequent section of the report be progressed to the detailed design stage, these updated flows will require to be modelled to quantify the specific impact this has on defence levels or storage volumes in each location of interest. Modelling of a range of design events is also required in order to undertake a benefit-cost analysis of any proposed works, which may be required to secure local or national funding. The revised design flows are shown in Table 3-8, along with a comparison to the original study design flows.

Table 3-8: Comparison of original and updated design flows for the Deveron at Huntly

Flow Return Period	2yr (m^3/s)	5yr (m^3/s)	10yr (m^3/s)	25yr (m^3/s)	50yr (m^3/s)	100yr (m^3/s)	200yr (m^3/s)	500yr (m^3/s)
Winfap3 Deveron at Huntly Design Flows	98.4	132.1	156.7	192.4	223.1	258.0	298.0	360.0
2005 Study Design Flows	94.7	125.9	148.2	180.1	207.2	237.6	272.1	324.8
Difference	3.7	6.2	8.5	12.3	15.9	20.4	25.9	35.2

The 200 year event is considered the critical standard to which many flood protection works are designed, and it can be seen that the revised hydrological analysis results in an increase of approximately 26 m^3/s, or 9.5% of the original design flow. Given the sensitivity of flooding in Huntly to bank overtopping in a number of locations, ensuring any future design is based on the most up to date levels is vital, and the adoption of the updated Winfap3 flows is likely to result in a slight elevation in design levels compared to the 2005 results for any proposed defence elements.

4 November 1st 2009 Flood Event

4.1 *General*

The event of 1st November 2009 caused widespread disruption to the community of Huntly in Aberdeenshire, with the Meadows area being particularly badly affected. Many properties were inundated, local infrastructure disrupted, and the aftermath will be felt by the community for many months to come. Aberdeenshire Council is therefore keen to fully understand the mechanisms of flooding during that event, and establish the extent of the affected area. In addition to the hydrological analysis presented in Section 3, Halcrow has undertaken a review of a number of sources of information regarding the event itself; from local and national media, to weather reports and post-flood photographs. The information drawn from these sources is summarised in the following sections.

4.2 *Information sources*

The online archives of the following news providers were searched to highlight any mentions of the 2nd November flood event in Huntly. Where articles were available, the key facts were noted.

- BBC News
- The Guardian
- The Daily Record
- Virgin Media
- The Press and Journal
- The Scotsman

In addition scanned copies of the Huntly Advertiser from the time of the event were provided by Aberdeenshire Council.

Internet searches also revealed news bulletins from several other organisations concerning the flood event:

- First Minister's Question Time
- The British Red Cross
- Aberdeenshire Council
- The Met Office
- The National Environment Research Council

Post flood photography was also obtained from Aberdeenshire Council, SEPA and Halcrow.

4.3 ***Weather Conditions***

During the last week of October, an area of low pressure developed and deepened close to the UK. Met Office forecasts of the weather system indicated the possibility of widespread heavy rain and gales across the UK. The depression deepened as forecast, hitting the south-west of Britain during the night of Saturday 1st November, moving up through Wales and northern England during the course of Sunday and continuing north to Scotland on Sunday evening, where the North-East area bore the brunt of the heavy rainfall.

This weather front came on the back of a prolonged period of wet weather during the previous week, meaning the ground was already saturated and river levels high when the additional heavy rain began to fall. The rain gauge at Dyce, outside Aberdeen, recorded 53mm between 21:00 on 31st October and 09:00 on 2nd November, almost 64% of the monthly average at that location of 83mm. As a whole, the UK registered its wettest November since records began in 1914, and rain fell on all but a couple of days in most areas.

4.4 ***Ground Surface Profile***

In order to assess the overland flow mechanisms in detail, topographic survey data was used to develop a ground surface model of the study area. Aberdeenshire Council undertook an extensive survey of the area during late 2009, which was provided for use in this study, and was supplemented with survey data gathered during the original project. The ground surface profile generated using these sources can be seen in Figure 4-1.

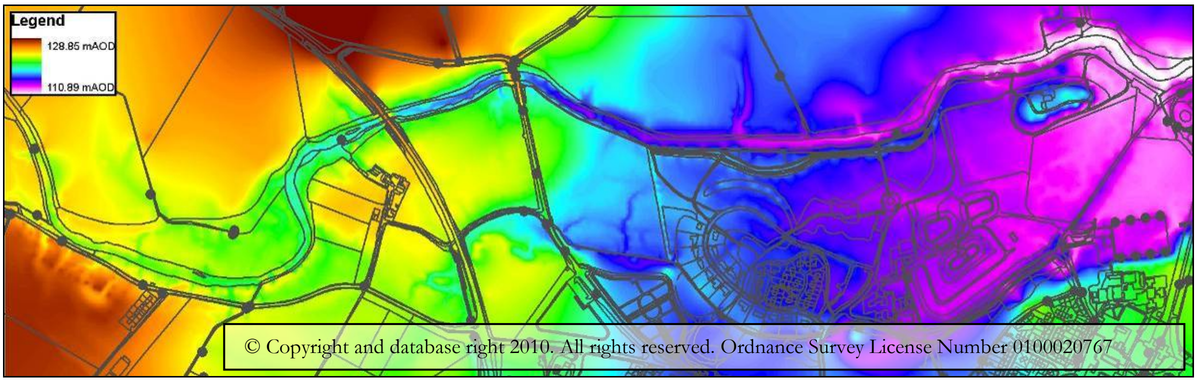


Figure 4-1: Ground Surface Profile

The ground surface model was interrogated in order to identify low points along key local roads that may provide a flow route for out of bank flow from the Deveron to reach to the Meadows. Several low lying areas were identified that could serve as overland flowpaths during flood events. Surface elevation plots have been generated along these roads, and the low lying areas identified on the map as shown in Figure 4-2. The fluctuation in levels observed in the profile plots is due to the conversion of topographical point data into a continuous raster surface profile, however the oscillation should be ignored and the general trend considered rather than specific elevation values at any given point.

It can be seen that two lower areas on the A920 have been identified that may facilitate flow movement from the north side across the road, or indeed along the road itself, where the junction with the A96 is also in a slight depression. This is a flow mechanism that was not identified during the original study. It was previously thought that flow remained on the North side of the A920, however the extracted ground surface levels are backed up by post-event photographs, as discussed in Section 4.6. Similarly on the A96, there is a slight depression notable close to the upstream extent of the Meadow Burn, which provides a possible route for flow passing from the Deveron to the Meadow Burn and on into the wider Meadows area, and confirms the mechanisms identified during the 2005 study.

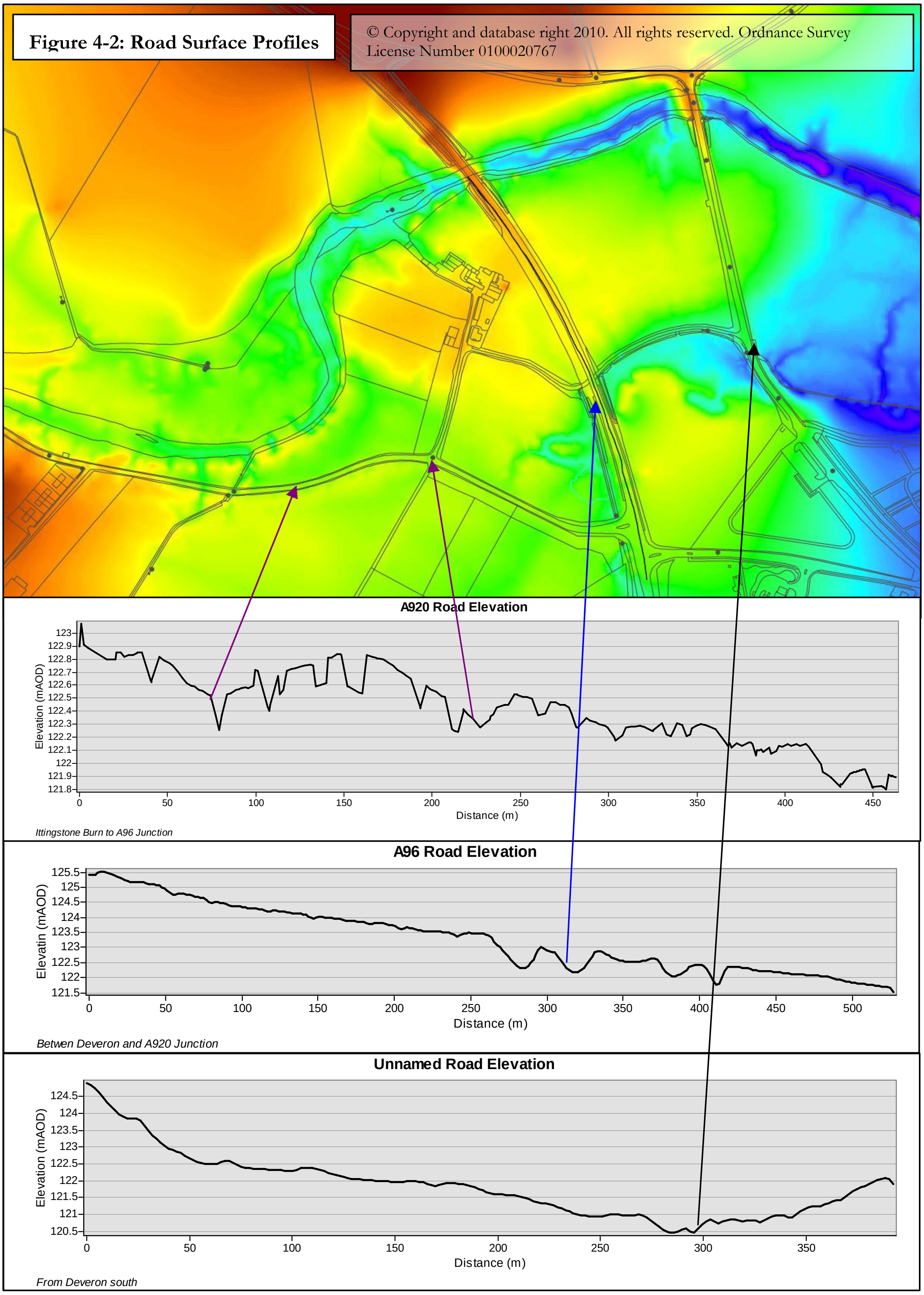


Figure 4-2: Road Surface Profiles

4.5 ***New Huntly Gauging Station Data***

As mentioned previously, 15-minute observed stage data was provided for the newly installed SEPA gauge upstream of Gibston Bridge in Huntly. A flow series was also provided based on the provisional station rating. In order to make best use of this data, capturing the flood event in Huntly itself, the flow hydrograph recorded at the gauging station was used in conjunction with the updated flow magnitude to model the event.

The gauge is located in the approximate vicinity of existing model section D11. Currently the levels recorded at the gauge are relative to a local datum, as the recorded zero has not been surveyed and tied into surrounding ground levels, although SEPA plan to undertake this imminently. The recorded stage readings are converted to flow using the provisional rating developed at the gauge, however this may be subject to amendment in the future once further spot-gaugings are undertaken to calibrate it. The rating curve can be seen in Appendix C.

The existing hydraulic model was subsequently updated using recent topographical survey data provided by Aberdeenshire Council. Key areas of update were to the spill sections between the Deveron and Meadow Burn in the upstream half of the model, in order to best recreate the conditions prevalent during the November 2009 event. The model was then re-run using the revised Deveron inflow of 254.48m^3/s (See Section 3.8).

The peak stage recorded at the Huntly gauge during the November 1st 2009 event was 3.57m above local datum, corresponding to a derived flow of 180.88m^3/s, and as discussed previously is considered an underestimation due to flow bypassing.. The maximum modelled flow results for the November 2009 event, obtained at Section D11, close to the gauging station can be seen in Table 4-1. More detailed hydraulic modelling results can be seen in Appendix D.

Table 4-1: Section D11 Updated Model Results

Event	Maximum Flow (m3/s)	Maximum Stage (mAOD)
Nov09	219.17	121.05

Table 4-1 highlights that the modelling results do not exactly match the SEPA recorded flow of 180.88m^3/s at Huntly gauging station, with an apparent over prediction of flows by 38.29m^3/s. This model validation error can be attributed to three primary sources: the uncertainty associated with the November 2009 flow estimates (See Section 3.8); the uncertainty in the SEPA rating due to the short data series; and the inherent uncertainty when undertaking 1D hydraulic modelling. There is insufficient information available to resolve the discrepancy between observed and modelled flows.

The model spill sections were analysed to identify areas where out of bank flow spread into the floodplain, and these locations can be seen in Figure 4-3. The gauging station location is also shown. Both left and right banks have been included for completeness, however it is right bank flooding that is of primary importance for the communities at risk in Huntly.

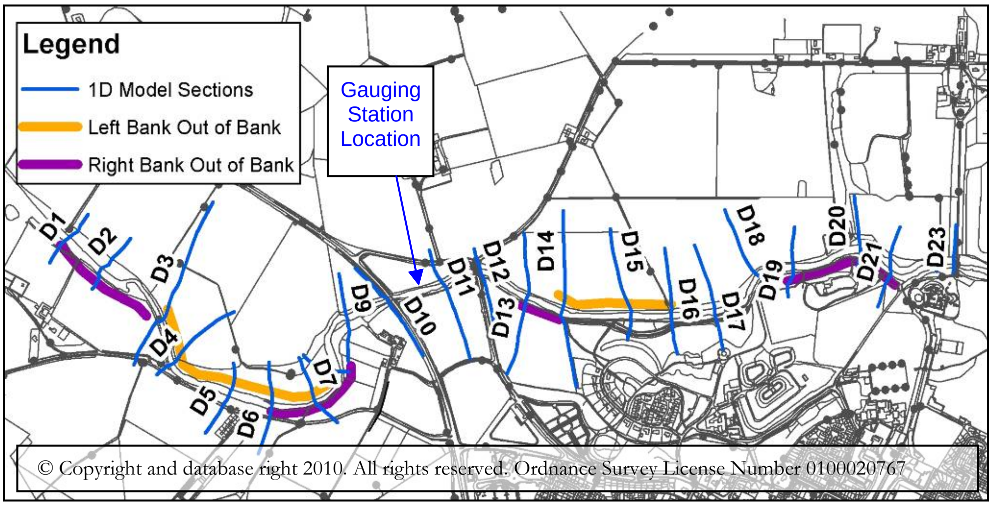


Figure 4-3: Overtopping Locations

4.6 *Comparison with post-flood event information*

Several sources of post-flood data and photography were gathered in order to assess the validity of the ground surface analysis and water level extrapolation. These included an estimated flood extent sketch from Aberdeenshire council, post event photographs from Aberdeenshire Council and SEPA, site visit photographs from Halcrow, and descriptions from local press and news sources as outlined in Section 4.2. The collation and use of all of these sources helps to establish an accurate picture of the flooding experienced in Huntly on the 1st November 2009, and is valuable as a baseline for assessing and developing future protection or mitigation strategies.

Relevant information gleaned from these data sources has been input into GIS, and Figure 4-4 shows a map of the affected area, with a number of specific locations highlighted. For each of these locations, there is a descriptive text entry in Table 4-2, and post-flood photographs at these points are shown in Appendix

E. In general the post-flood event photographs tie in well with the estimated extent and predicted bank overtopping, whilst several support the potential flow-paths identified across the major local roads for flow passing from the Deveron/Ittingstone Burn to the Meadow Burn.

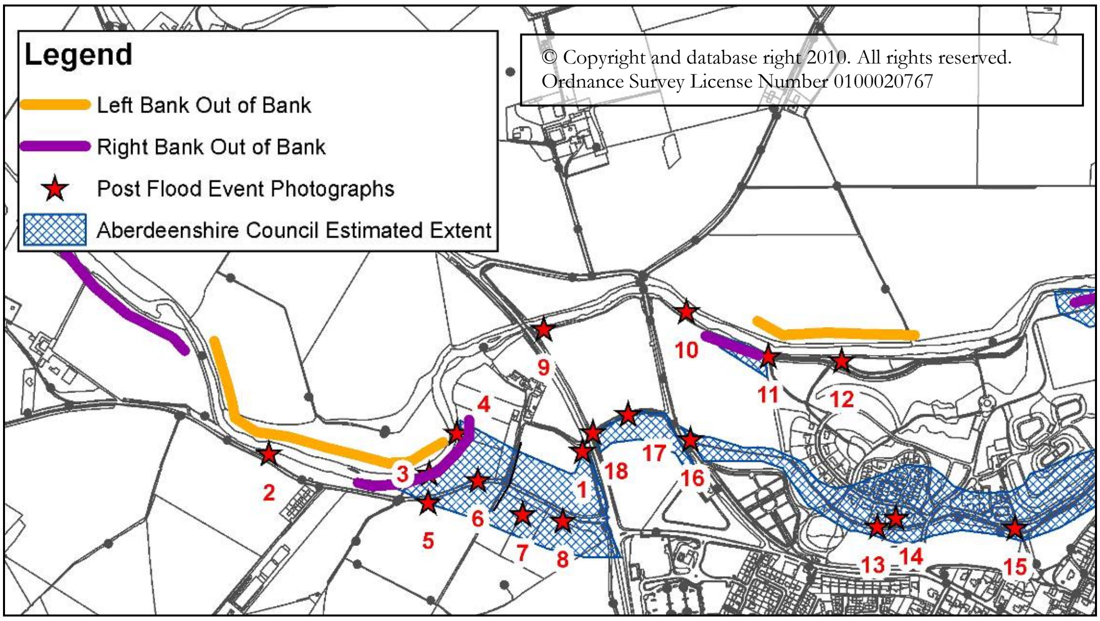


Figure 4-4: November 1st 2009 Post Event Information

Table 4-2: November 1st 2009 Information Summary

Location	Comment
1	Trash caught top of fence along right bank of burn looking upstream
2	Flattened vegetation on right bank looking downstream indicates out of bank flow
3	Significant debris including branches trapped by fence on right bank indicating out of bank flow
4	SEPA comments indicate the right bank was overtopped along this section, which is confirmed by trash caught in fences
5	Trash in fence on right hand side of road indicates flow across road in approximate location of identified low point
6	Trash in fence on both sides of road indicates flow across road as for location 5
7	Trash visible in near and far fence indicating inundation in this area
8	Extensive debris deposition and damage to fencing indicates significant flow in this area
9	Damage to scaffolding works in bridge indicates water level at soffit and high velocity
10	Debris and damaged scaffolding torn from upstream bridge and deposited downstream
11	Wrack marks across path indicate flow out of bank in this area
12	Flattened area of grass indicates out of bank flow route on right bank
13	Wooden boundary fence flattened and foundations pulled out by force of water
14	Waterline of properties observable at approximately mid-door height (1m) but local news reports indicate in some properties water depth may have reached 1.5m (5ft)

15	Trash caught in fence indicates flow out of bank towards road
16	Debris trapped to top of fence height and fence flattened indicating significant flow in this area
17	Significant debris trapped in fence on right bank upstream of bridge
18	Tarmac broken up, pipes displaced fences damaged and general debris and silt deposition in surrounding area indicate significant flow and velocity at this location

4.7 ***Scaffolding at A96 Bridge***

Following the flood event on the 1st November, concerns were raised by local residents that scaffolding on the A96 bridge may have exacerbated the flooding problem. Information provided by SEPA indicates that this is not the case, and their conclusion is summarised in this report.

The new SEPA gauging station is situated a short distance downstream of the A96 bridge, and SEPA provided Aberdeenshire Council with an extract of the recorded stage, reproduced here as Figure 4-5.

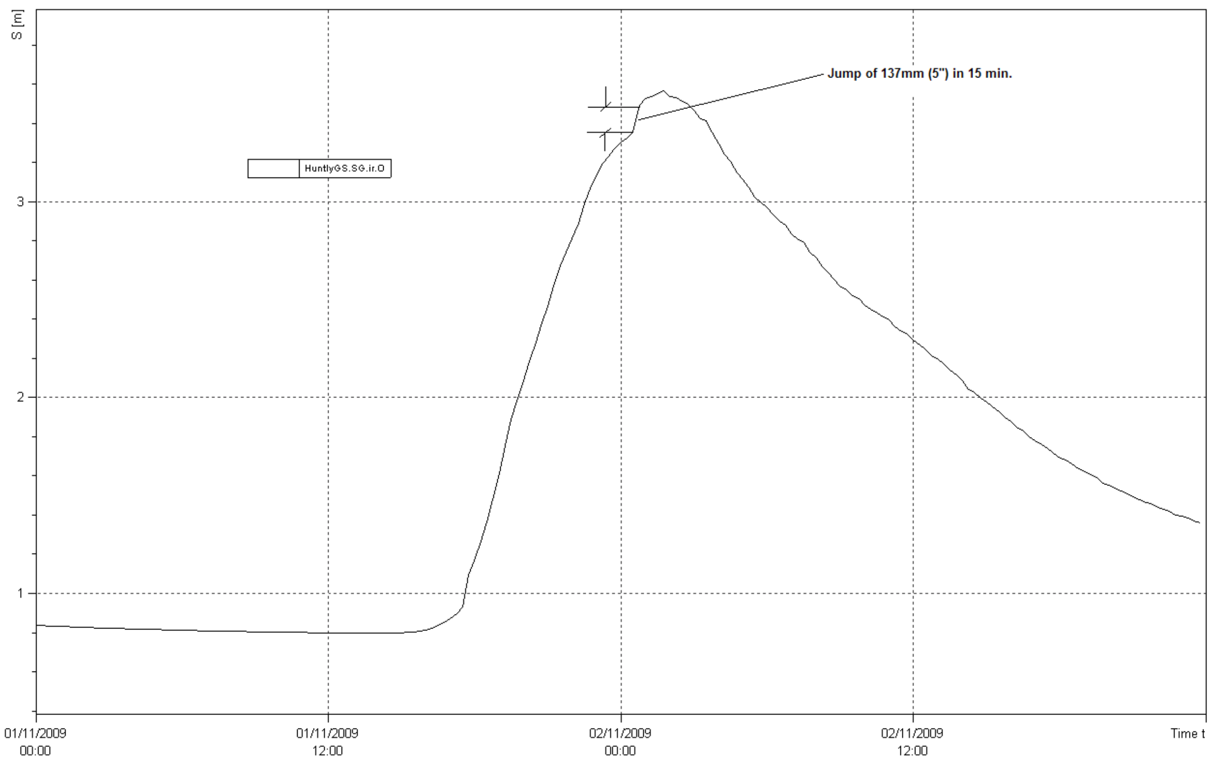


Figure 4-5: Nov 09 Stage at Huntly Gauging Station

It can be seen that there is a sudden jump in level of around 137mm in approximately 15 mins shortly after midnight on the 2nd November 2009. SEPA agree that this could have been caused by the sudden collapse of the scaffolding on the A96 bridge at this time, however the key concern is whether or not the presence or collapse of the scaffolding exacerbated the flooding that occurred.

It can be seen that following the jump, the water levels continue to rise, which is likely to have occurred with or without the scaffolding collapse, and its potential impact is to have caused a relatively minor local alteration to the rate of water level rise, rather than the ultimate maximum stage reached.

Much of the flooding was due to water leaving the Deveron in the Milltown area upstream of the A96 bridge, and flowing over the agricultural land and road, then into the Meadow Burn as described previously. It is felt by SEPA that this occurred far enough upstream not to be affected by the backwater effects caused by scaffolding on the A96 bridge, which therefore is not considered to have played a significant role in either the cause or extent of flooding experience in Huntly.

After reviewing the available information and comments from SEPA, Halcrow is of the same opinion that the presence of scaffolding on the A96 bridge which was subsequently washed away by the floodwater did not significantly influence the flood event of the 1st and 2nd November 2009.

4.8 ***Bridge at Huntly Castle***

Aberdeenshire Council have requested confirmation whether or not the private road bridge that forms the access to Huntly Castle Hotel acted as a flow restriction during the November 2009 flood event.

The bridge is a stone arch bridge built during the 19th Century and spans the Deveron where it flows through a shallow gorge-like channel with large boulders and bedrock forming the channel bed, creating fast flowing water and local turbulence.

The height of the bridge soffit is approximately 10m above the channel bed, and the arch spans the entire channel width. Because of these dimensions, the bridge is unlikely to form a significant flow restriction, even during large flood events. In order to confirm this supposition, the original 2005 200yr design event was re-run both with the bridge present, and removed. Figure 4-6 shows the resulting long section plot of the Deveron with both sets of maximum stage results superimposed.

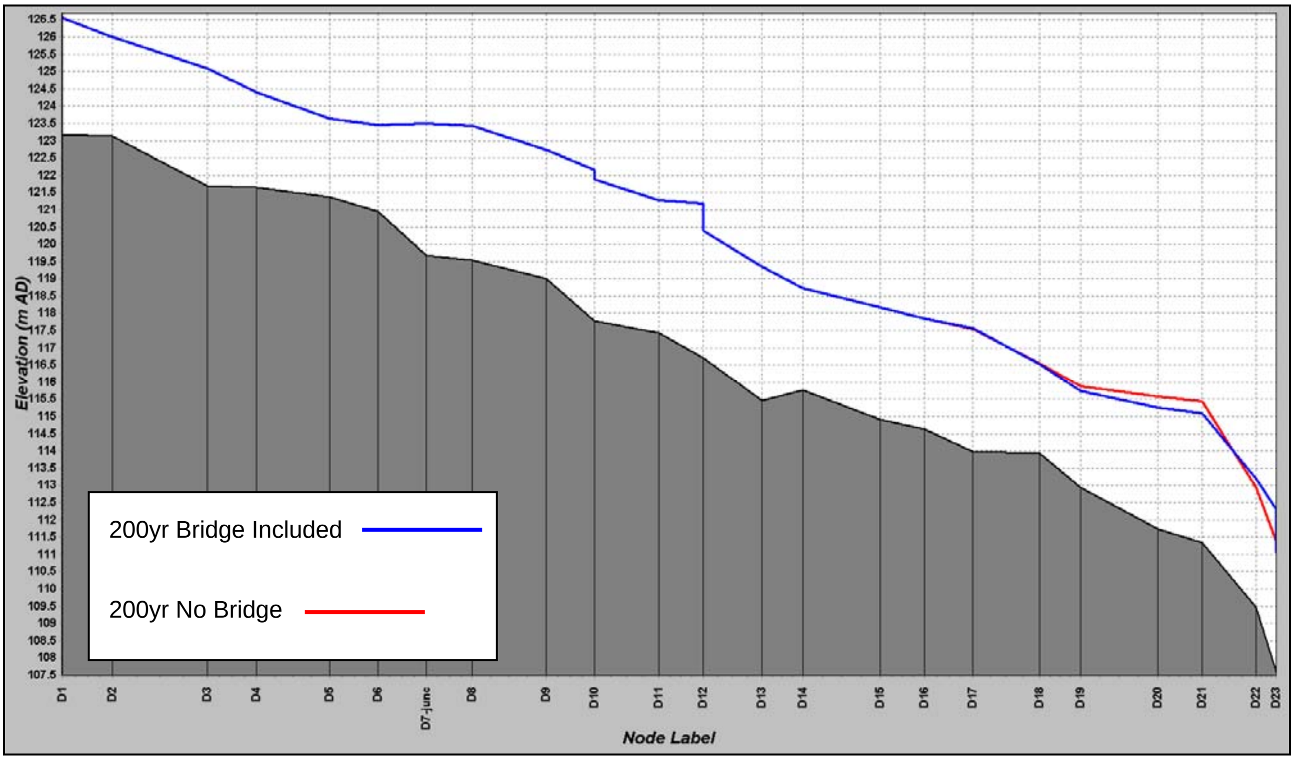


Figure 4-6: Long Section showing impact of Huntly Castle Access Bridge

It can be seen that in general the presence of the bridge has primarily a localised effect on water levels that does not extend beyond section D18-19, and no impact throughout the upstream Deveron model reach.

Given that the November 2009 event is estimated at a 100 year event, and that the flooding source primarily occurred in the upstream reaches of the model, it is concluded that the access bridge to Huntly Castle did not act as a significant flow restriction during the event, or cause the flooding experienced to be significantly greater than would have been the case if it had not been present.

4.9 ***Deveron Road Residential Development***

Since the original study was undertaken in 2005, a significant residential development has been constructed on Deveron Road, adjacent to the cemetery, comprising over 60 units in a variety of houses and flats.

Aberdeenshire Council requested that an assessment was made as to the impact of this development, in terms of both removal of flood plain storage, and increased runoff, and whether either of these was a significant contributing factor during the November 2009 event.

Aberdeenshire Council planning portal was used to retrieve documents relating to the planning application, including the adopted site layout. The site layout can be seen in Figure 4-7 below, overlaid with the 200 and 200+ Climate change event extents developed during the original study.

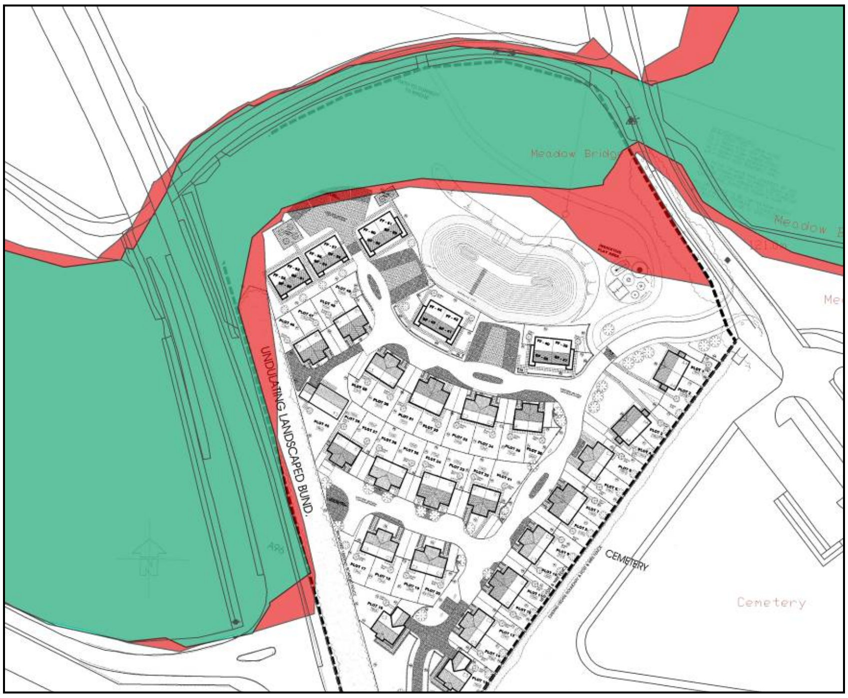


Figure 4-7: Site Layout and original study flood extents

It shows that the proposed development is generally outwith the 200 year extent and largely also outwith the 200 year plus climate change event. Land has been raised across the development site to afford additional protection from flooding, and to tie in with existing levels to the south of the site. Up to date topographical survey data of the site was provided by Aberdeenshire Council, and compared to the original ground surface profile to identify areas of cut and fill, and can be seen in Figure 4-8 below.

It can be seen that there is a relatively small proportion of fill extending within the 200 year and 200 year plus climate change flood extents. However given that the November 09 event has been estimated at approximately 100 year and considering the extent of the wider floodplain and the magnitude of flows associated with the event, it is unlikely that changes to the site topography had any significant impact on this event.

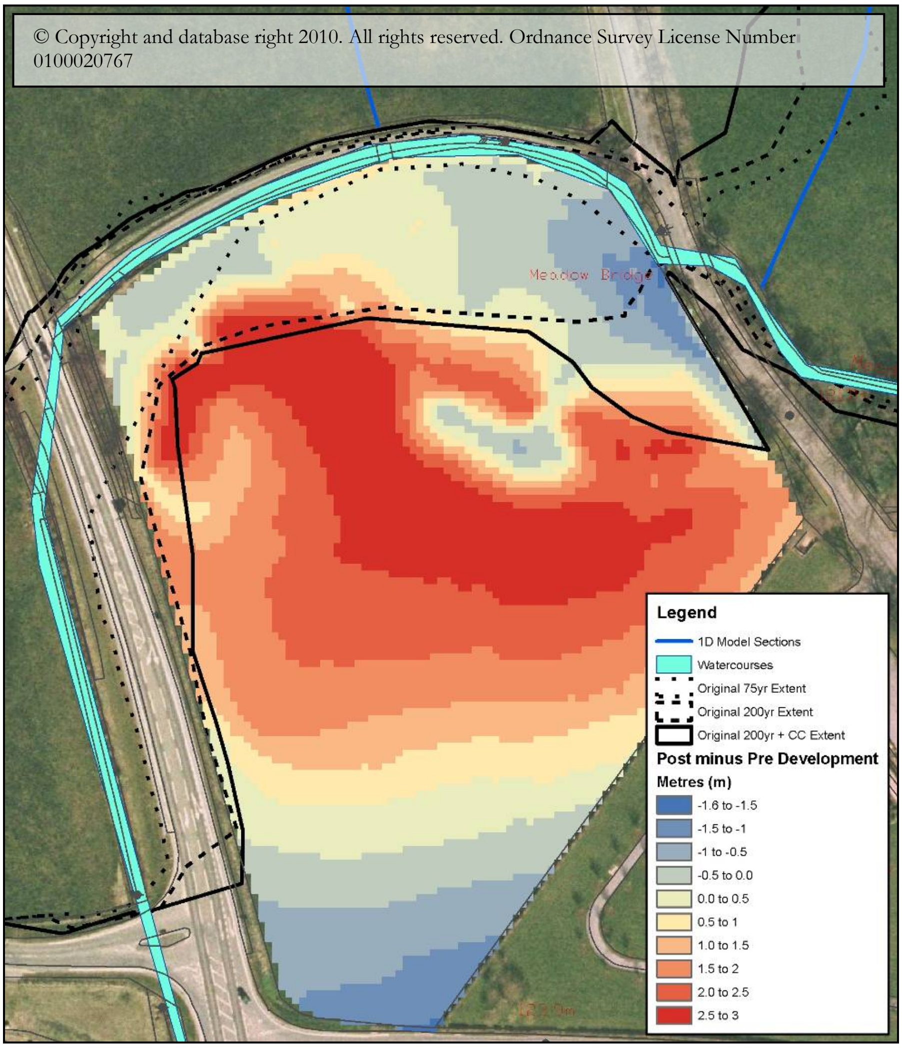


Figure 4-8: Post minus Pre Development Topography Changes

The impact of the additional development runoff has been assessed, using the IoH 124 method of flow assessment for small catchments. This method involves the generation of an index flood, Q_{BAR}, which is then multiplied by growth factors to generate values for a range of return periods.

The pre-development assessment has been carried out assuming the site use to be rural, and the post-development assessment takes into the impermeable areas of the site such as roofs, roads, driveways, pavements and residential paving. These areas were estimated from the proposed layout plans. The post development flows do not account for any attenuation provided on site as part of the development (SUDS). Full details of the calculation undertaken can be seen in Appendix F.

The pre-development site index flood runoff (Q_{BAR}) was calculated to be 8.3l/s, and the post development runoff 13.3l/s, corresponding to approximately a 60% increase in runoff at the development site. These index runoff rates were then factored up using the regional growth curve parameters to obtain rates for a variety of return periods as can be seen in Table 4-3.

Table 4-3: Calculated Runoff Rates

Return Period	Growth Factor	Pre Dev. (l/s)	Pre Dev. (m3/s)	Post Dev. (l/s)	Post Dev (m3/s)
25yr	1.8	14.94	0.015	23.91	0.024
100yr	2.467	20.48	0.020	32.77	0.033
200yr	2.8	23.24	0.023	37.20	0.037
500yr	3.267	27.12	0.027	43.40	0.043

The peak flow in the Meadow Burn for the 200yr event is estimated at 2.61m^3/s therefore it can be seen that the additional flow from the development will constitute less than 1% of this.

Furthermore, the Drainage Impact Assessment carried out during the development design stage and obtained from the Aberdeenshire Council planning portal states that the storm-water and SUDS drainage are designed to attenuate runoff to the 100yr event, and only for storm events greater than this magnitude should overland flow pass directly to the Meadow Burn.

It is concluded therefore that the development at Deveron Road has not had a significant impact on the flows in the Meadow Burn, or to the flood event on the 1st November 2009.

5 Alleviation Options

5.1 *General*

In addition to the alleviation options outlined in the 2005 report, several new alleviation proposals have been considered at the request of Aberdeenshire Council. The focus of these options has been to return out of bank flow to the Deveron and prevent it from entering the Meadow Burn, thus reducing the impacts of flooding from this source. Three options have been considered:

- Option1: Restriction of flow in the Meadow Burn at the A96 culvert to reduce flow volume passing into the Meadow Burn
- Option 2: An overflow channel from the Meadow Burn upstream of the A96 culvert, discharging into the Deveron next to Milltown
- Option 3: An overflow from the Meadow Burn downstream of Meadow Bridge to a flood storage area and meandering channel discharging back into the Deveron east of the Bridge of Gibston.

In order to assess these options, a combination of GIS and hydraulic model analysis has been undertaken, and the feasibility of each option is discussed in the following sections.

5.2 *Option 1 – Restricting overflows to Meadow Burn west of A96 (storage)*

As described in Section 2.4, a significant element of the flood mechanism in Huntly is associated with flow leaving the Deveron downstream of the Ittingstone Burn confluence (model sections D7 and D8), flowing across the agricultural land and joining the Meadow Burn around the A96. Option 1 investigates how it may be possible to restrict such flow immediately upstream of the A96 underpass channel and store the water in the fields west of the A96 (see Figure 5-1), thus reducing the volume of water flowing downstream along the Meadow Burn.

The survey data and generated ground surface profile was used to assess the potential storage capacity to the west of the A96 road embankment and identify the potential maximum water level in the storage area before flow would overtop either the A96 or A920 roads, thus bypassing the A96 underpass Meadow Burn channel and finding an alternative overland route to the Meadow Burn downstream. This level was defined as 121.6mAOD, and Figure 5-1 shows this contour and the extent of potential storage area. The low point is shown in the green circle, where water would spill over the roads should the water level in the storage area rise above 121.6mAOD.

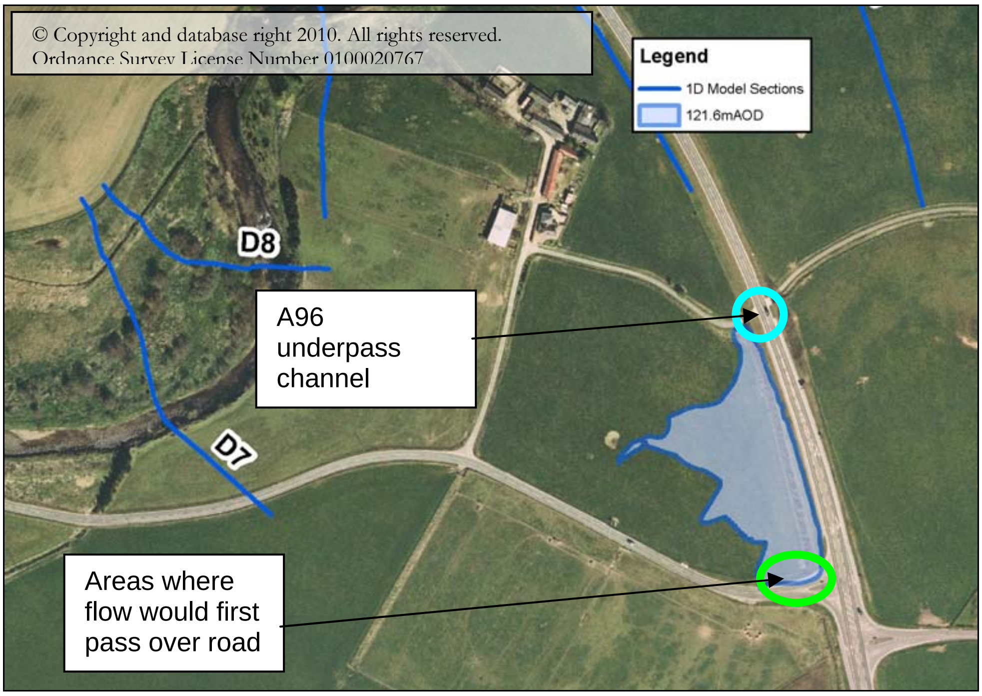


Figure 5-1: Potential Storage Capacity to west of A96

Comparison of the 121.6mAOD contour and the ground surface profile indicated that a maximum storage capacity of approximately 4680m^3 would be available to attenuate flood water upstream of the A96. In order to assess the potential attenuating effects of this on the flood peak, the peak flow spilling from the Deveron around section D7 was obtained from the hydraulic modelling results for the November 2009 flood event as 30.96m^3/s. At this rate, it can therefore be seen that the storage capacity would be filled within approximately 151s, or 2.5 minutes, after which time flow would spill over the road, and eventually join the Meadow Burn downstream of the A96 culvert.

Due to the insufficient storage capacity, no investigation has been made about the hydraulic structure necessary to control the flow at the A96 underpass channel. Control of the flow would require a complex structure and possibly active management with an automated system to ensure that the storage is available at the right time during a flood event and that the storage is not filled too early. This would therefore require more detailed and costly investigations.

On this basis, Option 1 in not considered feasible and it is not recommended for further detailed assessment.

5.3 *Option 2 – Restricting overflows to Meadow Burn west of A96 (overflow channel to Deveron)*

The second option to prevent out of bank flow from the Deveron entering the Meadow Burn is the construction of an overflow structure upstream of the A96 underpass channel, and an associated diversion channel running along the west of the road embankment to convey flow back into the Deveron next to Milltown. This general layout can be seen in Figure 5-2.

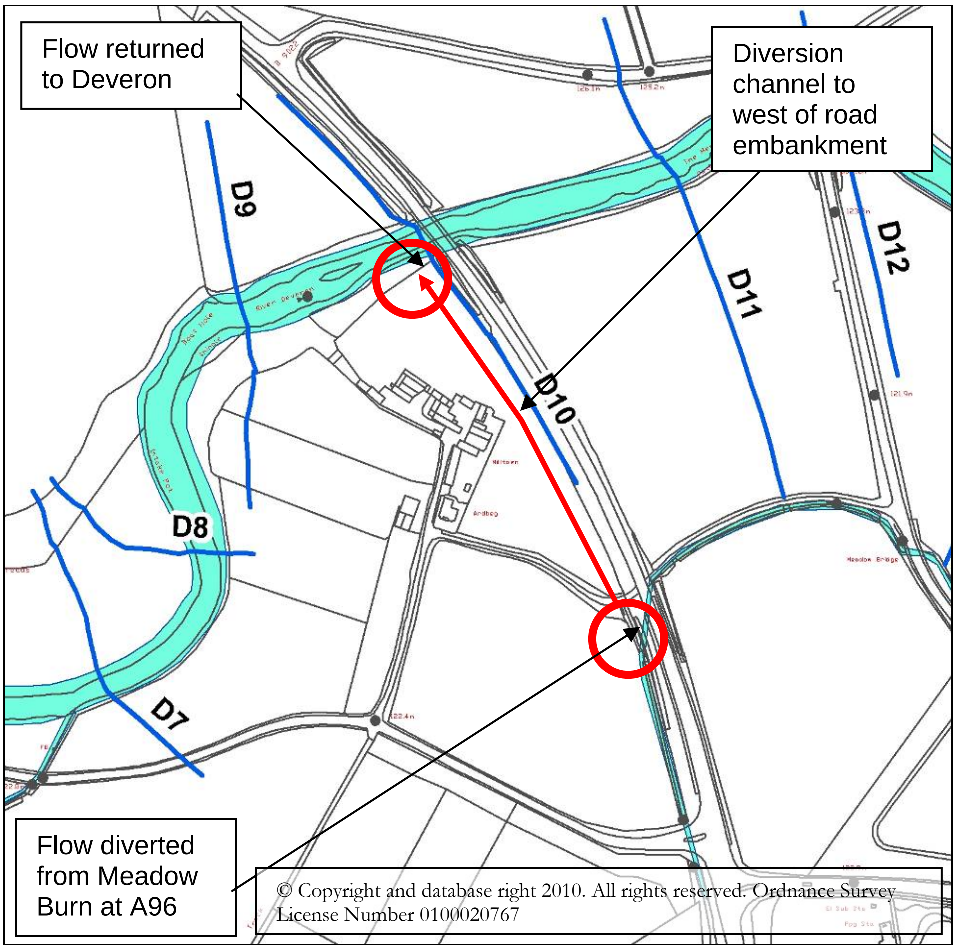


Figure 5-2: Option 2 Layout

A simplified hydraulic model of this arrangement was built in order to assess the potential flow capacity of such a diversion channel, and the impact on water levels elsewhere. A schematic of the modelled option can be seen in Figure 5-3.

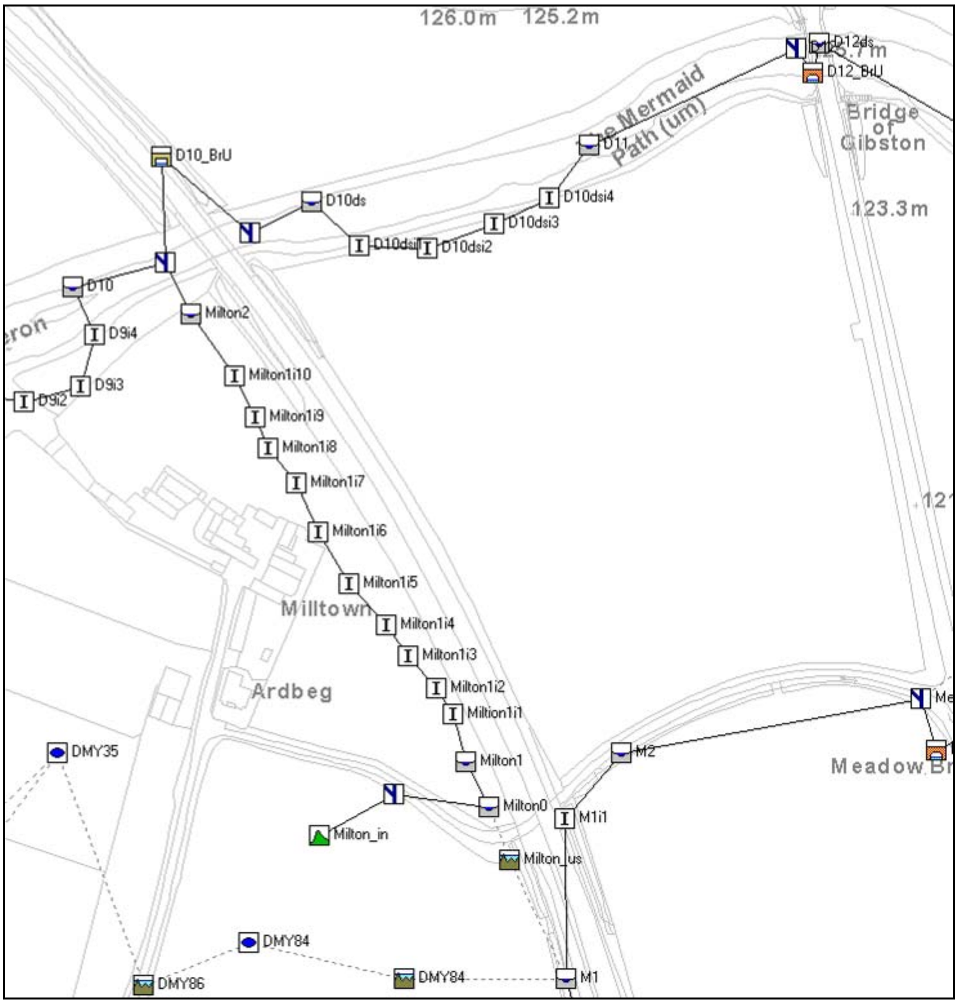


Figure 5-3: Option 2 Model Schematic

The area along the proposed diversion channel is relatively flat with a limited gradient for the channel, as levels are ranging from approximately 121mAOD upstream to 121.25 mAOD downstream. In order to prevent flow conveyance in the opposite direction, from the Deveron to the Meadow Burn, the diversion spill crest level was set at 121.3mAOD, a relatively high level compared to the existing level of the Meadow Burn upstream of the A96 (119.95mAOD) although it only provides a small hydraulic head along the length of the diversion channel. Modelling of this scenario has shown that the likely flow conveyance capacity of the channel is in the region of 1-3m3/s, depending on the event and adopted diversion structure crest level.

As discussed previously regarding Option 1 in Section 5.2, during the 200 year event, the predicted peak flow spilling from the Deveron around model section D7 is 36.6m³/s, which is in excess of 10 times greater than the diversion capacity. The impact of the diversion on peak water levels in the Meadows area is therefore minimal, as the majority of flow would still remain in the Meadow Burn, indicating that Option 2 is also unfeasible due to the local topography and flooding mechanisms.

5.4 ***Option 3 – Overflow channel downstream of Meadow Bridge***

The third option considered involves the diversion of flows from the Meadow Burn downstream of Meadow Bridge, via a meandering channel and attenuation area, returning to the River Deveron to the east of the Bridge of Gibston. This general layout can be seen in Figure 5-4.

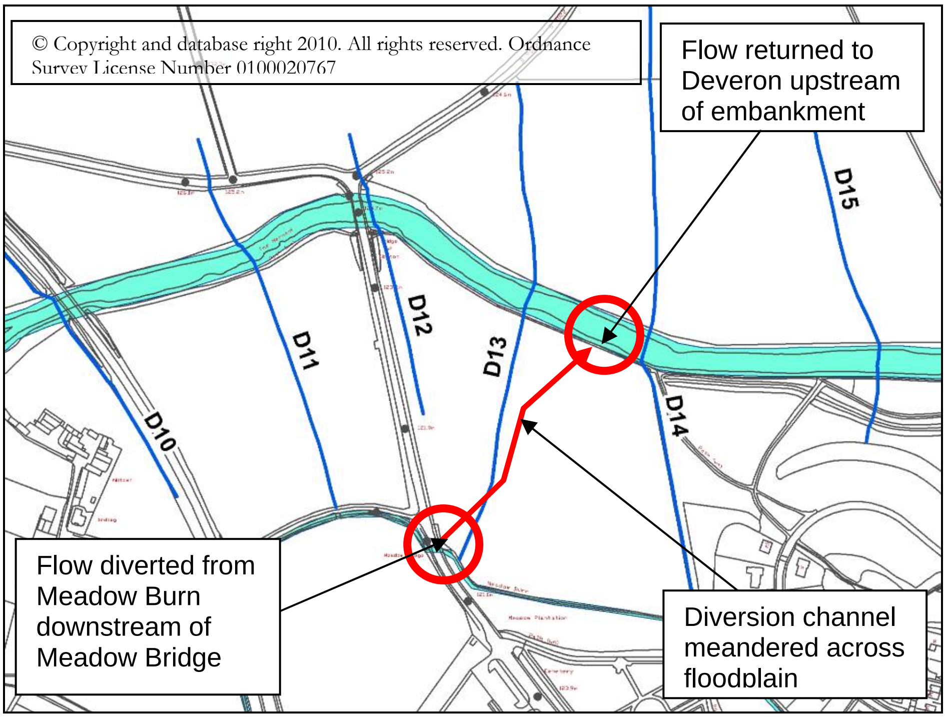


Figure 5-4: Option 3 Layout

Analysis of the existing model indicated that this area of very flat floodplain is already hydraulically connected with both the River Deveron and Meadow Burn, with flows passing from the Deveron to the Burn during extreme flood events. Therefore constructing a diversion channel across this area would formalise this flood pathway, and have the potential effect of exacerbating rather than mitigating flooding. During major flood events, this low lying area forms part of the Deveron floodplain and is inundated, making it unsuitable as an additional flood storage area, although it will perform this function to some extent naturally. Furthermore the slope across the floodplain is shallow, meaning similar problems are likely to be encountered as in Option 2, where the possible flow conveyance is significantly less than that required to have a mitigating effect of water levels in the areas at risk.

It is therefore concluded that Option 3 is unfeasible.

5.5 ***Original Report Option 4 – Raising of embankments along Deveron and Meadow Burn***

Several options were proposed in the original report, and the preferred mitigation solution was flood protection scenario 4. This remains the situation following the review of the three additional scenarios discussed in the preceding sections, and can be summarised as follows:

- New sluice gate next to the existing flap valve at the downstream end of the Ittingstone Burn to prevent backing up from the Deveron
- Raising of embankment along the Deveron at Milltown (model sections D7-D8) to above the 1 in 200 year plus climate change event
- Raising of embankment along the Deveron downstream of Gibston Bridge
- Raising of embankment along the Meadow Burn

Detailed information on these proposals can be found within Section 6 of the original report documentation.

During the updated analysis undertaken to assess Options 1-3 as described previously, several additional pertinent points relating to Option 4 were identified, and should be considered in conjunction with the original recommendations.

- The effectiveness of raising the embankment at sections D7-8 and downstream of Gibston Bridge could be increased by altering the position of the raised embankments to maximise the attenuation provided by the natural flood plain.

- Setting the embankments as far back from the watercourse as is feasible increases the flow being contained within the Deveron, allowing it to spread in a controlled manner across a wider area, thus potentially reducing flow velocities, and depths. This is illustrated in Figure 5-5.

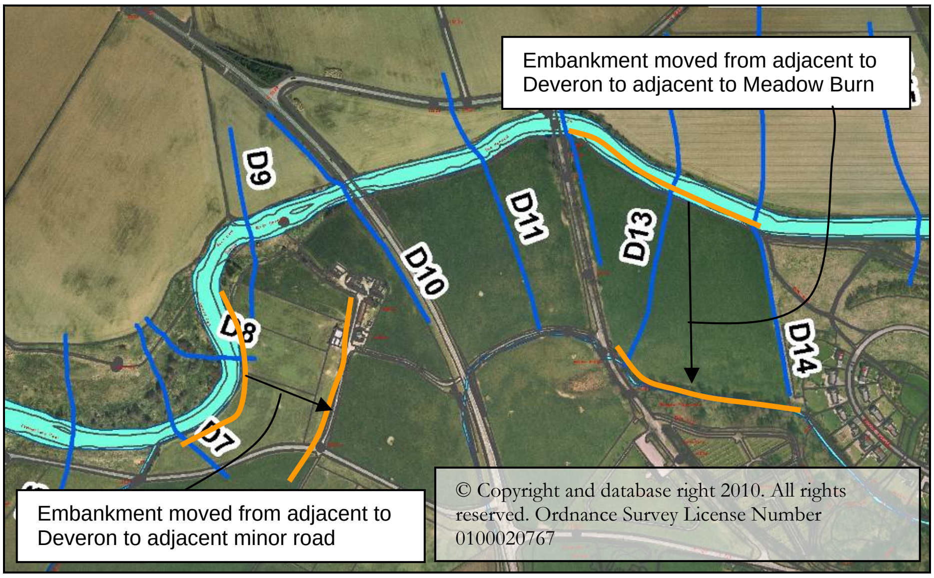


Figure 5-5: Option 4 – Proposed refinement of embankments alignment

- It should be noted that raising the embankment in either of these locations in isolation is not sufficient to generate a mitigating effect, and modelled results show that implementation of either one is likely to cause an associate increase in out of bank flow at the other.

- The embankment alignments shown in Figure 5-5 are broadly indicative of the principle only, and detailed design would require to be undertaken to determine their optimum location, subject to tying-in to surrounding ground levels.

6 Conclusions and Recommendations

Flooding in Huntly has been and continues to be a significant concern for both local residents and Aberdeenshire Council, with the Meadows area being particularly at risk from both the River Deveron and Meadow Burn. As a result of this study update, a clearer picture of flooding mechanisms in the area has been established, and the following conclusions and recommendations are made:

- The return period for the November 2009 event has been estimated using a range of different approaches and highlights the uncertainty inherent to such assessment. The best estimate based on hydrological analysis and hydraulic modelling is that of approximately 1% Annual Probability (1:100 year).

- The hydrological analysis update has resulted in an approximate 5 to 10% increase in design flows (depending on the return period) and therefore will cause a slight rise in design levels. Should any of the proposed options be taken forwards to detailed design stage and construction, these flows should be used and the model be run with proposed options in place for a range of return periods in order to inform the appropriate design levels. It is also recommended to consider reviewing further the hydrological analysis and generating a further hydrological growth regime, after conducting a review of the suitability of a number of Scottish gauging stations to improve the geographical similarity of the Flood Estimation Handbook (FEH) pooling group.

- The preferred mitigation option recommended during the original modelling study based on raised embankments along the Deveron and Meadow Burn remains the most effective way to minimise the risk of flooding to properties in Huntly from both the Deveron and Meadow Burn.

- A number of other options have been considered as part of this update, including flood storage and flow diversion from the Meadow Burn, but because of the very flat nature of the Meadow area which is a natural floodplain, they have all been found to be unsuitable due to topographical and hydraulic constraints.

- Recommendations have been made regarding the re-alignment of embankments to maximise flood plain attenuation as well as providing protection. This is a departure from the preferred option during the original modelling study, and therefore if this approach was to be taken forwards, detailed modelling of the defence proposals would require to be carried out in order to assess the impact on water levels at the site and elsewhere in the model.

- Current guidance is that a design freeboard of a minimum of 600mm should be added to any embankment design.

- Embankment raising and strengthening are proposed, however before this work can progress, a detailed condition assessment of the existing embankments should be carried out in order to determine their structural integrity and identify areas of potential weakness that may require further remedial work.

- Since the original study was undertaken in 2005, SEPA have implemented the Water Environment (Controlled Activities) Regulations 2005, which require the grant of a CAR licence by SEPA for any activities that :
    - Discharge to water or groundwater
    - Impound watercourses
    - Abstract from water bodies
    - Involve engineering activities on or near a watercourse

  Therefore any flood protection works taken forwards by Aberdeenshire Council would require to be licensed under this legislation.

- Given the nature of the preferred option, including the construction and upgrading of both new and existing embankments, it is likely that it will require progression as a Flood Protection Scheme under the new Flood Risk Management (Scotland) Act 2009, in order to apply for national funding and satisfy national planning procedures.

- As part of this process, environmental and socio-economic issues will require to be considered. Consultation with statutory stakeholders, residents and local businesses will be also of key importance.

- Aberdeenshire Council will also require to consider its obligations under the CDM regulations 2007.

Appendix A

Hydrology – Pooling Group

Appendix A: Hydrological Pooling Group Contents

ORIGINAL POOLING GROUP

Station	years	L-CV	L-Skewness	L-Kurtosis	Discordancy	Distance
9001 (Deveron @ Avochie)	45	0.218	0.162	0.099	0.172	0.577
9003 (Isla @ Grange)	34	0.249	0.144	0.031	0.842	0.452
9004 (Bogie @ Redcraig)	23	0.32	0.322	0.217	2.244	0.892
8004 (Avon @ Delnashaugh)	51	0.233	0.217	0.112	0.275	0.495
8009 (Dulnain @ Balnaan Bridge)	50	0.189	0.156	0.086	0.221	0.413
8011 (Livet @ Minmore)	21	0.203	0.095	0.028	0.606	0.439
205011 (Annacloy @ Kilmore)	23	0.135	0.171	0.055	1.421	0.203
17005 (Avon @ Polmonthill)	32	0.235	0.322	0.215	0.576	0.239
12008 (Feugh @ Heugh Head)	18	0.191	0.068	0.178	0.497	0.252
12006 (Gairn @ Invergairn)	24	0.215	0.12	0.072	0.303	0.262
68018 (Dane @ Congleton Park)	32	0.172	0.261	0.275	0.64	0.307
28061 (Churnet @ Basford Bridge)	16	0.1	0.017	0.31	2.546	0.315
203022 (Blackwater @ Derrymeen Bridge)	16	0.192	0.412	0.133	2.283	0.329
21012 (Teviot @ Hawick)	30	0.102	0.144	0.211	0.951	0.34
21024 (Jed Water @ Jedburgh)	31	0.229	0.211	0.145	0.163	0.415
28043 (Derwent @ Chatsworth)	33	0.273	0.296	0.153	0.818	0.422
203019 (Claudy @ Glenone Bridge)	31	0.145	0.244	0.199	0.587	0.432
21025 (Ale Water @ Ancrum)	30	0.198	0.124	0.111	0.085	0.449
21032 (Glen @ Kirknewton)	22	0.252	0.144	0.234	1.541	0.454
66006 (Elwy @ Pont-y-gwyddel)	21	0.195	0.269	0.132	0.444	0.454
202002 (Faughan @ Drumahoe)	17	0.184	0.214	-0.005	1.932	0.456
27035 (Aire @ Kildwick Bridge)	27	0.069	0.138	0.334	2.579	0.468
47008 (Thrushel @ Tinhay)	25	0.235	0.228	0.248	0.779	0.477
45008 (Otter @ Fenny Bridges)	19	0.293	0.175	0.106	1.338	0.504
27055 (Rye @ Broadway Foot)	17	0.177	-0.143	0.078	2.304	0.52
203024 (Cusher @ Gamble's Bridge)	22	0.153	-0.032	0.132	0.898	0.521
47005 (Ottery @ Werrington Park)	30	0.216	0.19	0.26	0.816	0.528
7001 (Findhorn @ Shenachie)	33	0.22	0.23	0.162	0.127	0.541
203011 (Main @ Dromona)	20	0.118	-0.065	0.065	1.298	0.546
67005 (Ceiriog @ Brynkinalt Weir)	18	0.217	0.331	0.221	0.571	0.569
76008 (Irthing @ Greenholme)	27	0.196	0.131	0.08	0.206	0.571
40007 (Medway @ Chafford Weir)	24	0.202	0.378	0.284	1.154	0.576
205008 (Lagan @ Drummiller)	19	0.184	0.016	0.055	0.597	0.579
201005 (Camowen @ Camowen Terrace)	21	0.15	0.356	0.371	2.187	0.582
40004 (Rother @ Udiam)	29	0.202	-0.033	0.018	1.2	0.595
202001 (Roe @ Ardnargle)	18	0.087	-0.033	0.1	1.486	0.607
201002 (Fairy Water @ Dudgeon Bridge)	22	0.103	0.103	0.139	0.932	0.615
201007 (Burn Dennet @ Burndennett Bridge)	27	0.18	0.234	0.124	0.383	0.449
Total	998					
Weighted means		0.204	0.185	0.142		

UPDATED ORIGINAL POOLING GROUP

Station	years	L-CV	L-Skewness	L-Kurtosis	Discordancy	Distance
9001 (Deveron @ Avochie)	47	0.217	0.157	0.09	0.284	0.583
9003 (Isla @ Grange)	44	0.218	0.179	0.086	0.318	0.455
9004 (Bogie @ Redcraig)	23	0.329	0.323	0.196	2.666	0.899
8004 (Avon @ Delnashaugh)	51	0.221	0.166	0.076	0.401	0.497
8009 (Dulnain @ Balnaan Bridge)	51	0.173	0.107	0.056	0.439	0.419
8011 (Livet @ Minmore)	23	0.196	0.036	0.011	1.267	0.44
205011 (Annacloy @ Kilmore)	27	0.132	0.236	0.061	1.522	0.203
17005 (Avon @ Polmonthill)						
12008 (Feugh @ Heugh Head)	18	0.192	0.07	0.174	0.714	0.248
12006 (Gairn @ Invergairn)	25	0.21	0.065	0.064	0.752	0.264
68018 (Dane @ Congleton Park)						
28061 (Churnet @ Basford Bridge)	31	0.216	0.218	0.283	1.331	0.315
203022 (Blackwater @ Derrymeen Bridge)	16	0.074	0.082	0.161	1.229	0.332
21012 (Teviot @ Hawick)	47	0.157	0.139	0.193	0.247	0.34
21024 (Jed Water @ Jedburgh)	31	0.214	0.17	0.126	0.136	0.413
28043 (Derwent @ Chatsworth)	38	0.247	0.234	0.161	0.521	0.424
203019 (Claudy @ Glenone Bridge)	35	0.123	0.242	0.205	0.859	0.434
21025 (Ale Water @ Ancrum)	30	0.208	0.126	0.108	0.221	0.444
21032 (Glen @ Kirknewton)	38	0.265	0.23	0.193	0.969	0.455
66006 (Elwy @ Pont-y-gwyddel)						
202002 (Faughan @ Drumahoe)	30	0.17	0.252	0.086	0.837	0.453
27035 (Aire @ Kildwick Bridge)	39	0.16	0.331	0.301	1.921	0.463
47008 (Thrushel @ Tinhay)	37	0.227	0.276	0.194	0.55	0.475
45008 (Otter @ Fenny Bridges)						
27055 (Rye @ Broadway Foot)						
203024 (Cusher @ Gamble's Bridge)	35	0.13	-0.003	0.225	2.038	0.514
47005 (Ottery @ Werrington Park)						
7001 (Findhorn @ Shenachie)	44	0.202	0.174	0.087	0.228	0.542
203011 (Main @ Dromona)	16	0.085	0.061	0.22	1.529	0.549
67005 (Ceiriog @ Brynkinalt Weir)	48	0.21	0.216	0.152	0.14	0.572
76008 (Irthing @ Greenholme)	39	0.139	0.227	-0.014	2.755	0.565
40007 (Medway @ Chafford Weir)						
205008 (Lagan @ Drummiller)	32	0.175	-0.077	0.082	2.286	0.574
201005 (Camowen @ Camowen Terrace)	34	0.13	0.298	0.289	1.826	0.589
40004 (Rother @ Udiam)						
202001 (Roe @ Ardnargle)	31	0.079	0.03	0.112	1.322	0.604
201002 (Fairy Water @ Dudgeon Bridge)	35	0.119	0.189	0.159	0.532	0.622
201007 (Burn Dennet @ Burndennett Bridge)	28	0.18	0.22	0.135	0.157	0.452
Total	1023					
Weighted means		0.197	0.172	0.13		

Records highlighted in yellow are no longer considered suitable for pooling group inclusion

WINFAP V3 POOLING GROUP

Station	years	L-CV	L-Skewness	Q_{MED} AM	Discordancy	Distance
12008 (Feugh @ Heugh Head)	21	0.201	0.11	141.628	0.287	0.188
21013 (Gala Water @ Galashiels)	43	0.273	0.305	51.535	0.91	0.257
67008 (Alyn @ Pont-y-capel)	42	0.165	0.346	21.854	1.983	0.295
45005 (Otter @ Dotton)	46	0.261	0.379	68.146	1.942	0.296
8009 (Dulnain @ Balnaan Bridge)	54	0.169	0.097	94.451	0.522	0.317
45012 (Creedy @ Cowley)	44	0.26	0.189	72.632	0.382	0.323
47006 (Lyd @ Lifton Park)	39	0.274	0.286	82.139	0.605	0.34
52005 (Tone @ Bishops Hull)	47	0.192	0.071	43.874	1.024	0.351
9004 (Bogie @ Redcraig)	26	0.312	0.274	31.622	1.28	0.358
21032 (Glen @ Kirknewton)	43	0.281	0.24	43.3	0.662	0.399
202002 (Faughan @ Drumahoe)	32	0.164	0.256	134.9	1.544	0.412
54038 (Tanat @ Llanyblodwel)	36	0.155	0.152	78.168	0.685	0.414
53007 (Frome(somerset) @ Tellisford)	47	0.177	0.13	57.75	0.828	0.415
55014 (Lugg @ Byton)	40	0.253	0.252	27.587	0.503	0.422
11004 (Urie @ Pitcaple)	18	0.306	0.268	21.42	1.146	0.429
9003 (Isla @ Grange)	47	0.218	0.148	49.309	0.418	0.443
23005 (North Tyne @ Tarset)	19	0.154	0.06	220.569	1.262	0.45
83004 (Lugar Water @ Langholm)	34	0.217	0.188	133.21	0.825	0.486
203024 (Cusher @ Gamble's Bridge)	37	0.132	-0.012	48.522	2.95	0.517
84014 (Avon Water @ Fairholm)	42	0.178	0.212	163.858	0.275	0.518
27206 (Esk @ Briggswath)	15	0.225	-0.016	140.325	2.143	0.583
24003 (Wear @ Stanhope)	50	0.187	0.312	117.712	0.814	0.598
27035 (Aire @ Kildwick Bridge)	41	0.158	0.319	67.482	1.407	0.601
96001 (Halladale @ Halladale)	31	0.174	0.186	105.526	0.411	0.606
9001 (Deveron @ Avochie)	47	0.217	0.157	129.252	0.191	0.924
Total	941					
Weighted means		0.213	0.202			

POOLING GROUP VALIDITY

Pooling Group	Heterogeneity
Original	2.422
Original Updated	2.43
Winfap 3	2.39

Appendix B

Hydrology – Flow Scaling for the River Deveron

Calculation title: Appendix B – Deveron Scaled Flows	Created by:	Ruth Ellis	Project code:	WBHUNT
	Date:	23/03/2010	Serial no:	
Subject: Hydrological comparison of 1st Nov 09 event based on flows at Avochie, Redcraig & Huntly	Verified by:	P Lardet	Sheet no:	1
	Date	29/03/10	Revision:	

References/results

Return period analysis of the flood event of the 1st November 2009 has been undertaken using single site analysis for the Deveron at Avochie and the Bogie at Redcraig, and pooled analysis of the Deveron at Huntly.

This resulted in the following event return period estimations being made:

Deveron at Avochie: 126 years
Bogie at Redcraig: 7 years
Deveron at Huntly: 25-50 years

It was felt that this estimate at Huntly was likely to significantly underestimate the magnitude, due to the significant flow bypassing the station via the Meadow Burn.

Therefore the gauged flows at Avochie and Redcraig have been used to attempt to assess the flow deficit at Huntly, and thus revise the return period estimation.

The method adopted has been to scale the Avochie flow back to just downstream of the Bogie and Deveron confluence by area, and similarly scale the Redcraig flow up to just upstream of the Bogie and Deveron confluence. The difference of these flows should theoretically be approximately equal to the flow in the Deveron at Huntly, which can be compared with the observed flow at the new SEPA gauging station and any deficit quantified.

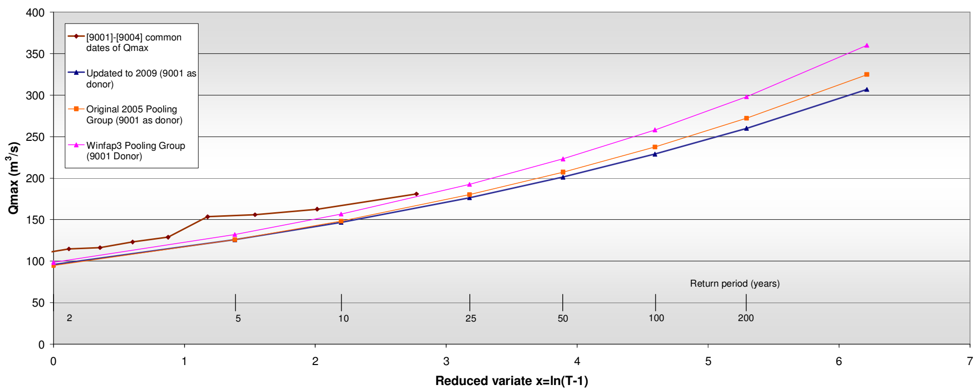
Location	Catchment Area	1st Nov 09 Max Gauged Flow
Deveron @ Avochie	441.6 km^2	315.13 m^3/s
Bogie @ Redcraig	182.43 km^2	45.60 m^3/s
Deveron @ Huntly	230.25 km^2	180.88 m^3/s
Deveron d/s of Bogie confluence	429.24 km^2	
Bogie u/s of Deveron confluence	198.54 km^2	

1) Deveron @ Avochie scaled back to Deveron d/s of Bogie confluence:
   = (429.24 / 441.6) * 315.13
   = 304.11 m^3/s
2) Bogie @ Redcraig scaled to Bogie u/s of Deveron confluence:
   = (198.54 / 182.43) * 45.60
   = 49.63 m^3/s
3) Predicted flow at Huntly equal to 1) minus 2)
   = 304.11 – 49.63
   = 254.48 m^3/s
4) Deficit at Huntly equal to 3) minus observed Deveron @ Huntly flow
   = 254.48 – 180.88
   = 73.6 m^3/s

Revised Nov '09 flow at Huntly gauging station therefore 254.48 m^3/s

Based on pooled analysis, shown below, this corresponds to a return period of between 94 and 177 years.

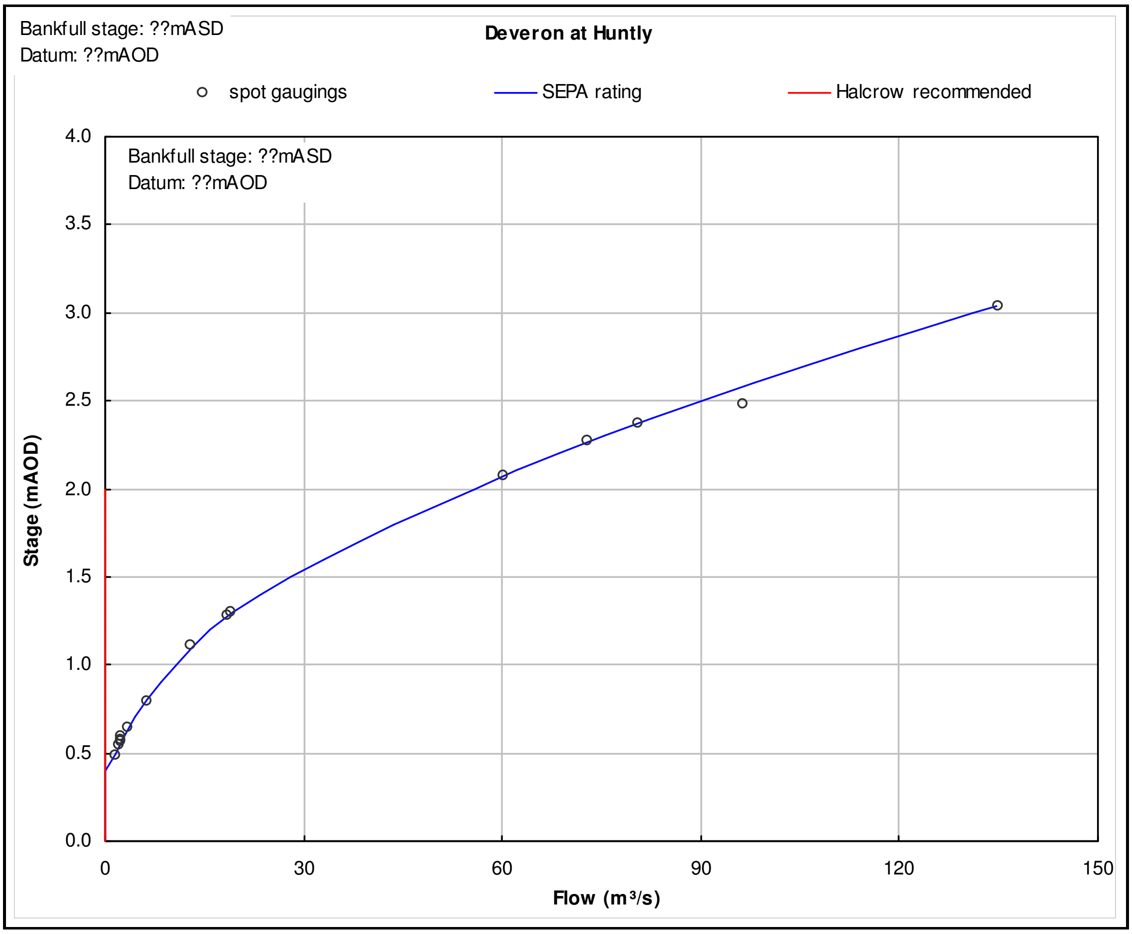
Updated Results from Pooling Group Huntly-Deveron. GL distribution



Appendix C

Huntly gauging station rating curve

Appendix C: Huntly Gauging Station Provisional Rating



Rating equation at Huntly (provisional)

section	min stage	max stage	K	a	p	
a	0.484	0.548	0.04769	1.03612	8.21718	0.484 < SG < 0.548m; $Q(SG) = 0.0476899 * (SG + 1.03612)^{8.21718}$
b	0.548	1.273	18.8945	- 0.30123	1.57318	0.548 < SG < 1.273m; $Q(SG) = 18.8945 * (SG - 0.301232)^{1.57318}$
c	1.273	3.04	29.3078	-0.5268	1.65415	1.273 < SG < 3.040m; $Q(SG) = 29.3078 * (SG - 0.526797)^{1.65415}$

Appendix D

Hydraulic modelling results for November 2009 event

Updated Model November 2009 Event

River Deveron at Huntly Flood Study			
Hydraulic Model Results. Summary Table			
November 2009 Event		Extracted Results	
Node	Chainage (m)	Max Stage (mAOD)	Max Flow (m^3/s)
D1	0.0	254.00	126.48
D2	138.5	253.90	125.94
D3	402.5	253.68	125.03
D4	538.7	169.55	124.38
D5	742.5	150.74	123.58
D6	876.1	96.27	123.31
D7-junc	1010.7	65.06	123.23
D7	1010.7	63.83	123.23
D8	1136.8	67.61	123.24
D9	1341.5	219.22	122.47
D10	1476.0	219.21	121.90
D10ds	1476.0	219.21	121.67
D11	1656.0	219.17	121.05
D12	1778.0	219.11	120.95
D12ds	1778.0	219.11	120.30
D13	1941.6	219.21	119.31
D14	2056.2	213.95	118.70
D15	2269.4	212.46	118.12
D16	2392.5	212.04	117.80
D17	2526.2	211.73	117.52
D18	2712.0	210.75	116.50
D19	2825.6	202.47	115.68
D20	3041.5	141.96	115.16
D21	3163.9	238.77	114.99
D22	3313.3	245.78	113.03
D23	3368.4	245.78	112.14
D23b	3368.4	245.78	111.03
ITT1	0.0	2.05	123.41
ITT2	40.3	2.05	123.34
ITT3	106.9	2.05	123.29
ITT4	120.3	2.05	123.23
ITT5	142.2	2.00	123.23
ITT6	152.4	2.00	123.23
ITT6-copied	152.4	2.00	123.23
M1	0.0	2.09	122.07
M2	179.0	34.46	120.42
MeadBr-us	344.6	34.42	119.00
MeadBr-ds	344.6	34.42	118.97
M3	545.6	3.07	118.88
M3_05	618.2	37.03	118.69
M4	760.8	34.02	117.85
M4_05	968.1	11.76	117.28
M5	1049.3	11.75	116.52
M6	1194.3	6.90	115.69
M7	1402.5	12.28	115.20
M8	1507.9	13.05	115.10
M8_05	1588.2	11.28	115.03
M9	1774.2	11.28	114.82
Cast-rd-cul-ds	1799.1	0.00	114.86
Cast-rd-cul-us	1799.1	0.00	114.86
M10	1810.3	5.91	114.53

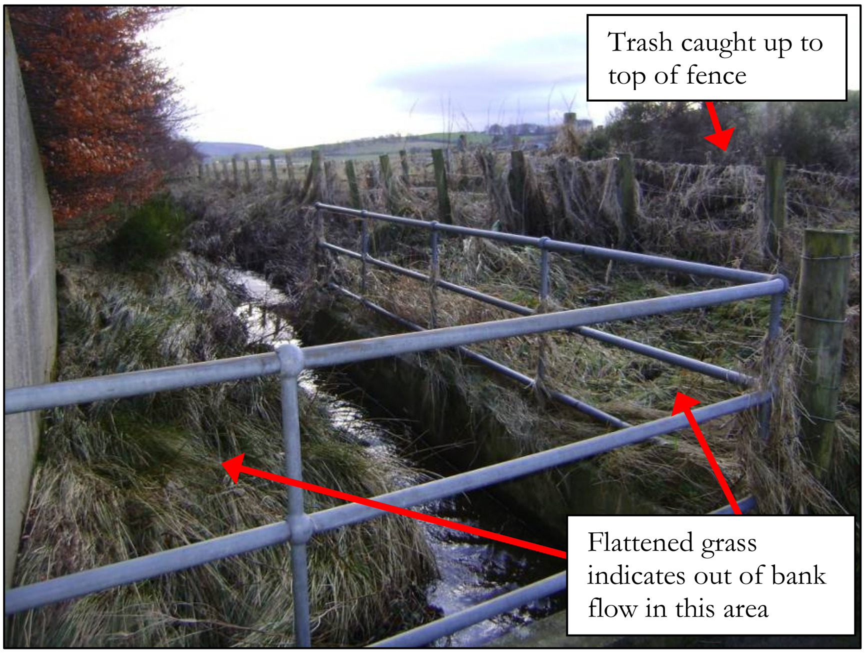
Appendix E

November 2009 post flood event photographs

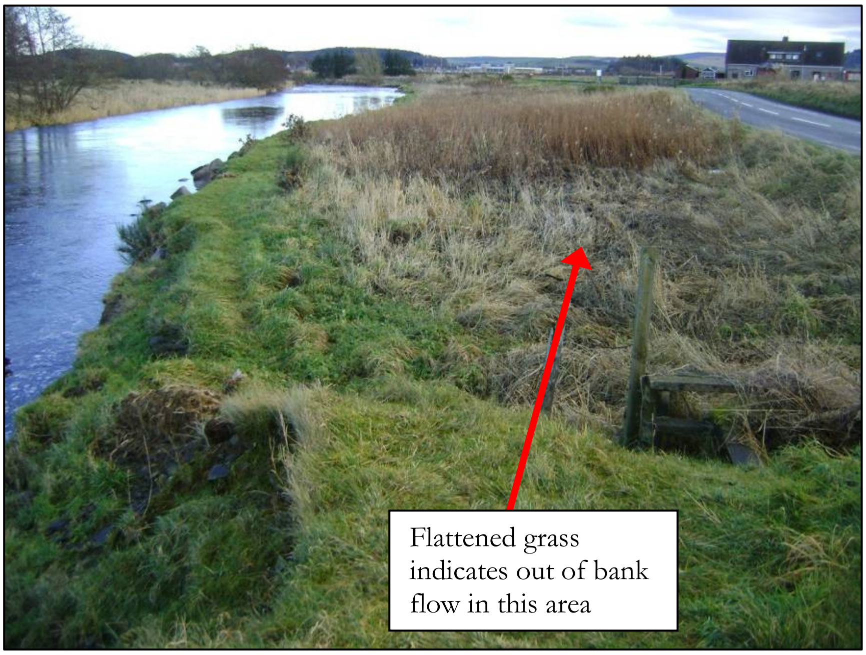
Appendix E

November 2009 Post Flood Event Photographs

Note: Photographs provided by SEPA



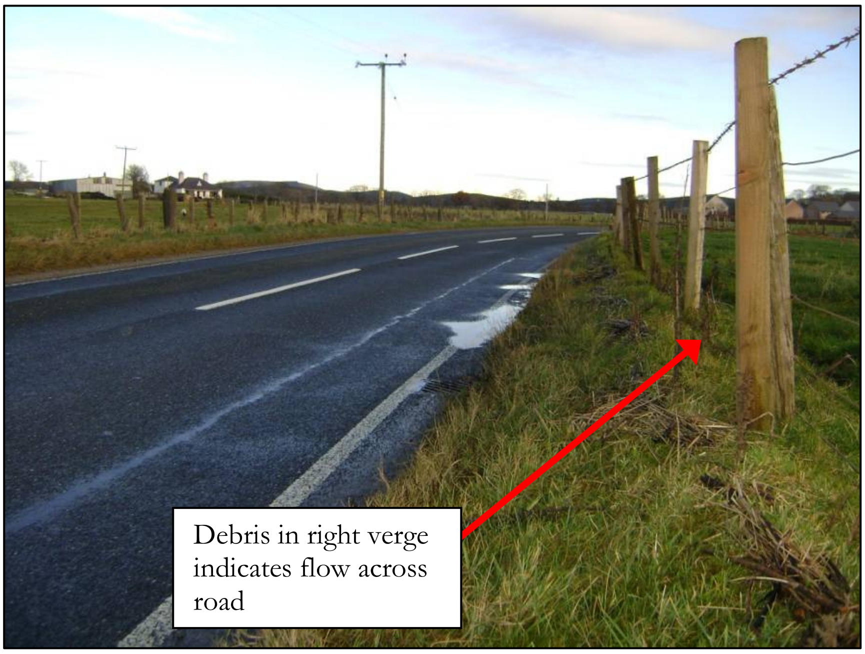
Photograph 1



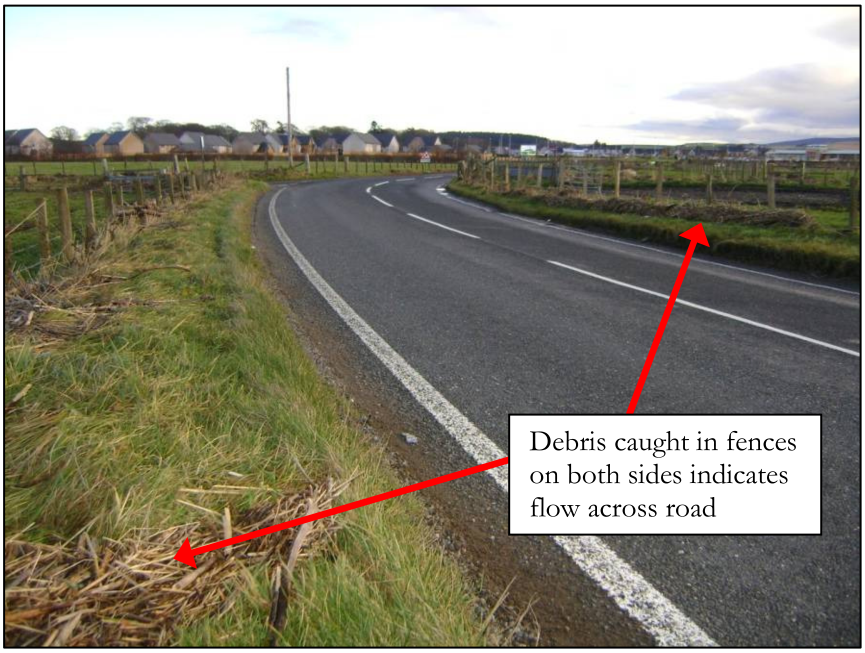
Photograph 2

Photograph 3

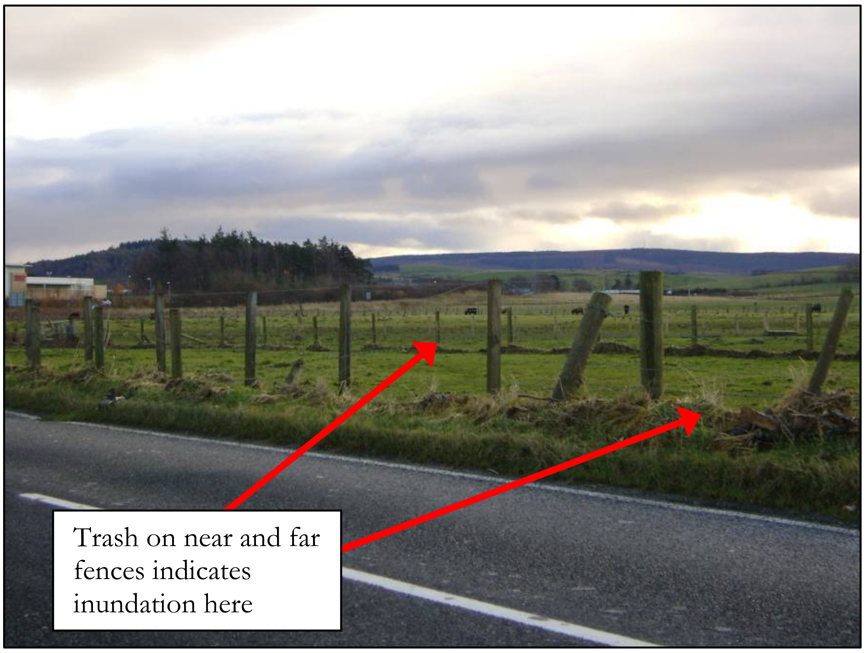
Photograph 4



Photograph 5



Photograph 6



Photograph 7

Photograph 8

Photograph 9

Photograph 10

Photograph 11

Photograph 12

Photograph 13

Photograph 14

Photograph 15

Photograph 16

Photograph 17

Photograph 18

Appendix F

Assessment of impact of Deveron Road development

Calculation title: Appendix F Assessment of Impact of Deveron Road Development	Created by:	Ruth Ellis	Project code:	WBHUNT
	Date:	29/03/2010	Serial no:	
Subject: Assessment of additional runoff caused by residential development at Deveron Road	Verified by:		Sheet no:	1
	Date		Revision:	

References/results

Since the 2005 study was undertaken, a residential development has been constructed in the previously field adjacent to the Cemetery off Deveron Road.

Analysis has been undertaken to assess whether this has increased flows in the Meadow Burn.

The impact of the additional development runoff has been assessed, using the IoH 124 method of flow assessment for small catchments.

The pre-development assessment has been carried out assuming the site use to be rural.

$QBAR_{RURAL} = 0.00108 * AREA^{0.89} * SAAR^{1.17} * SOIL^{2.17}$

For the site:
AREA = 2.25Ha ($0.0225km^2$)
SAAR = 868mm (from FEH CD)
SOIL (SPR) = 0.316 (from FEH CD)

So $QBAR_{RURAL}$ = 8.3l/s or 3.69l/s/ha

Post development was carried out factoring in the urban development

$QBAR_{URBAN} = QBAR_{RURAL} * (1 + URBAN)^{2NC} * (1 + (URBAN)*(21/CIND) – 0.3)$

CIND = 102.4 * SOIL + 0.28 * (CWI – 125)

NC = 0.92 – 0.00024 * SAAR for 500<= SAAR <= 1100

For the site:
SOIL = 0.316 (From FEH CD)
URBAN (percentage impermeable area – estimated from site layout – assumed all roads, drives, paving and houses impermeable, plus 5% of house area added for residential patios etc) = 1.02Ha ($0.0102km^2$) → 45%
CWI = 121 (using above formula)
NC = 0.712 (using above formula)

So $QBAR_{URBAN}$ = 13.285l/s or 5.9l/s/ha

This corresponds to a 60% increase in runoff for the site area

Site is in UK hydrological region 1, so growth curve factors as follows, and scaled flows for the post-development scenario:

Return period	Growth Factor	Q
25yr	1.8	23.91l/s ($0.024m^3/s$)
100yr	2.467	32.77l/s ($0.033m^3/s$)
200yr	2.8	37.2l/s ($0.037m^3/s$)
500yr	3.267	43.4l/s ($0.043m^3/s$)

The peak flow in the Meadow Burn for the 75yr event is estimated at $2.61m^3/s$ therefore it can be seen that the additional flow from the development will constitute less than 1% of this. Furthermore, the Drainage Impact Assessment carried out during the development design stage states that the stormwater and SUDS drainage are designed to attenuate runoff to the 100yr event, and only for storm events greater than this magnitude should overland flow pass directly to the Meadow Burn. It is concluded therefore that the development at Deveron Road has not had a significant impact on the flows in the Meadow Burn, or to the flood event on the 1st November 2009.