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Event Tree Analysis for household protection flood defences at Stonehaven

Version 1.0 (August 2010, Angus Pettit)

Temporary defences are only effective if they are successfully deployed before the flood event takes place and once in place are effective for the duration of the event.
Temporary defences rely on a number of actions that have to be undertaken before the barrier can effectively perform its function.
Each action has a probability of success and these are multiplied together to generate an overall probability of success.
Normally this probability of success is then used to reduce the benefits accordingly in a performance and economic justification.

The following discrete actions are required from the initial warning for a flood event and the erection of the barrier at the specific site.
The assignment of probabilities of succes to each action is subjective.

Key

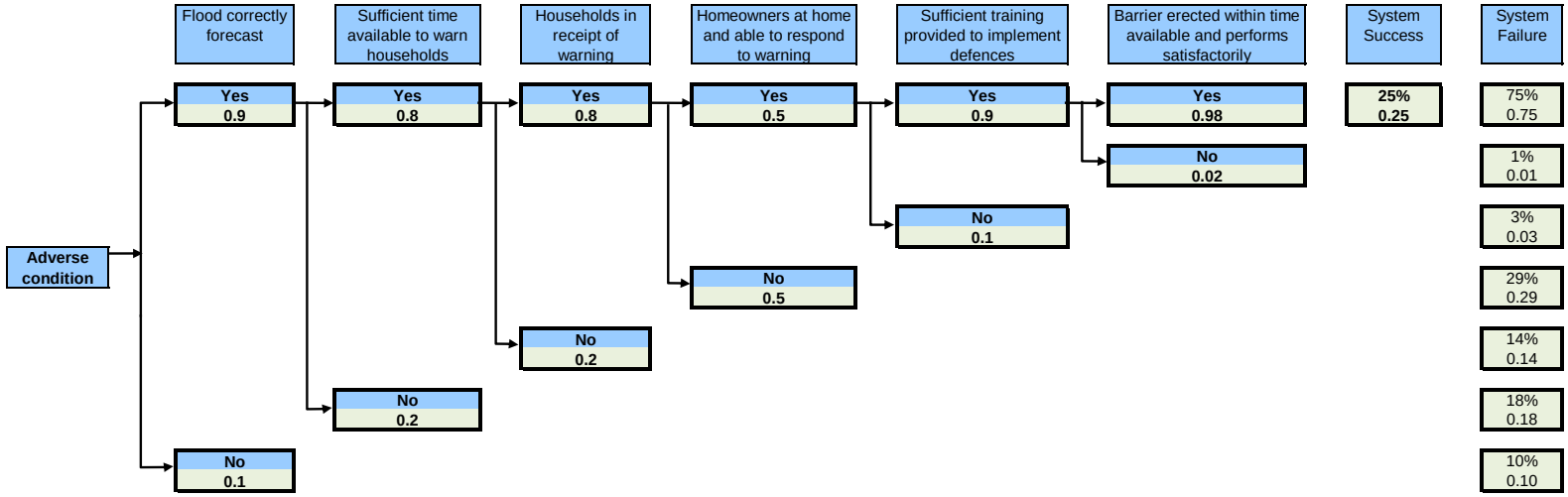
	User Input
	Header (do not change)
	Formula cell (do not change)

Spring Dam

Adverse condition requiring household barrier implementation	YES	NO	Comment
Flood correctly forecast	0.9	0.1	Assumes warning system can be implemented
Sufficient time available to warn households	0.8	0.2	Assumes warning system can provide early warnings
Households in receipt of warning	0.8	0.2	Assumes most will be aware of risk
Homeowners at home and able to respond to warning	0.5	0.5	Assumes high risk of failure or inability to react to warnings
Sufficient training provided to implement defences	0.9	0.1	Assumed sufficient training provided and practice events undertaken
Barrier erected within time available and performs satisfactorily	0.98	0.02	Risk of seepage/failure

System success	25%
System failure	75%

Event Tree Summary



H Additional options and scenarios

This section details the testing of additional options which were suggested by Aberdeenshire Council and Stonehaven residents during the project as scenarios whose impact on flooding is of interest.

H.1 Channel modification

H.1.1 Introduction

Channel modification can be used to increase the capacity of the river channel and therefore increase the maximum flow that can be accommodated before out of bank flooding occurs. There is some potential for channel modification in Stonehaven although it is unlikely to form a stand-alone solution to mitigate flood risk to the required standard of protection. However it has been reviewed in terms of what benefit it could achieve.

H.1.2 Approach to be assessed

A possible measure for channel modification was proposed as a result of discussion with Aberdeenshire Council. This is the removal of the remains of the weir immediately downstream of the Green Bridge, a potentially relatively "quick fix" option to address flood risk.

H.1.3 Removal of remains of weir at Green Bridge

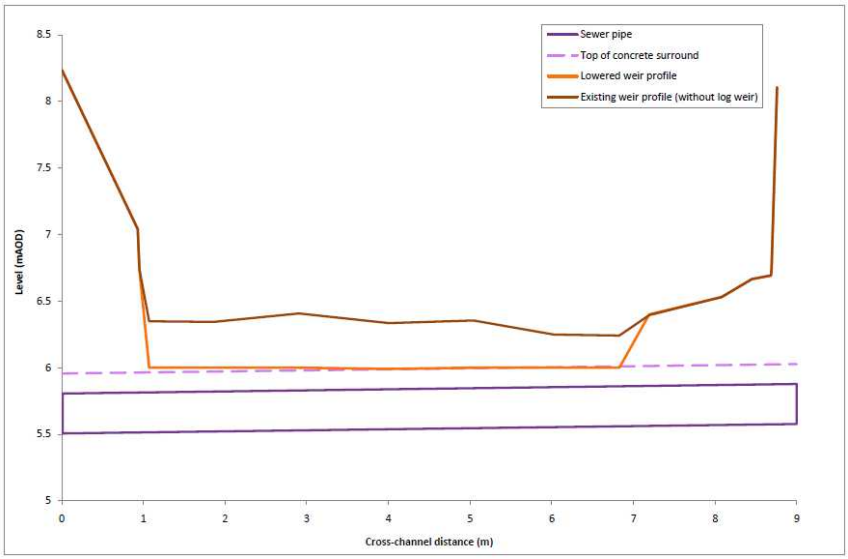
H.1.4 Description of measure

This measure is further channel modification at the weir below the Green Bridge. The crest was previously formed by a log but this was removed by the Council (leaving a concrete base - see Figure H-1 below) following JBA's 2010 report which showed that this would offer an improvement in channel capacity at this critical location.

Figure H-0-1: Remains of weir at Green Bridge

It is proposed that the remaining concrete base of the weir is removed and the channel bed smoothed through this section into the step and pool channel to the north of the island, in order to provide a further increase in channel capacity. This measure is unlikely to fully alleviate flooding in Stonehaven but rather is a short term improvement measure. The amount by which the bed can be lowered at the weir is constrained by the presence of a Scottish Water sewer beneath the channel at this location. The invert level and diameter of the sewer is known and it is assumed the sewer has a standard concrete surround (i.e. assumed to be 150 mm thick) around it. The change in the channel profile tested at the weir is shown in Figure H-2.

Figure H-0-2: Revised profile at weir section



H.1.5 Model findings and hydraulic feasibility

Figure H-3 and Figure H-4 below show the impact of removing the Green Bridge weir on the flood outline and peak water levels during the 0.5% AP (200 year) event respectively.

Figure H-0-3: 200 year event flood as existing and channel modification scenario outlines

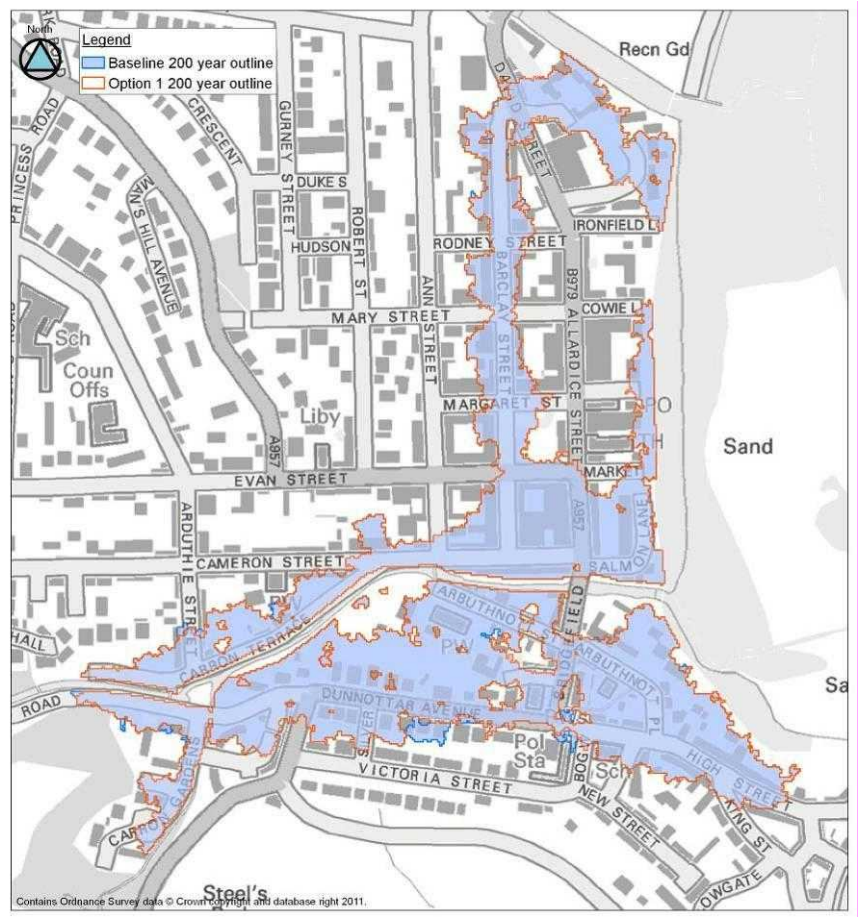
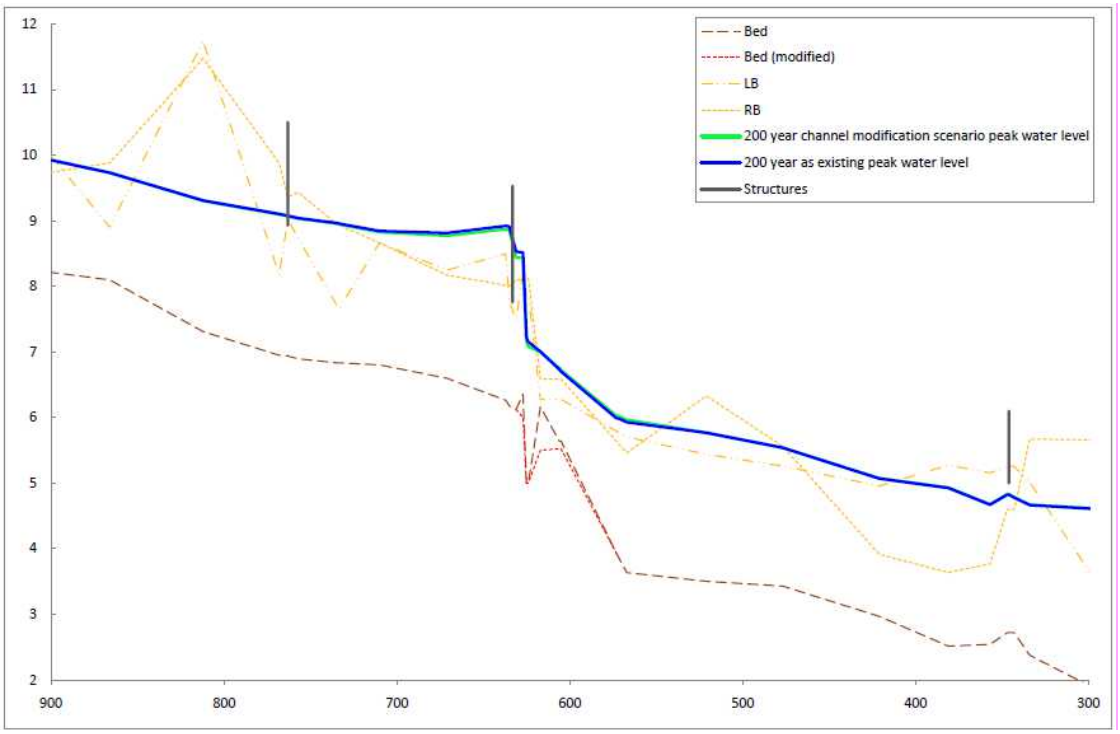


Figure H-0-4: 200 year existing and channel modification scenario peak water levels



The model results show a maximum reduction in water levels of approximately 90 mm, immediately upstream of the weir location, as a result of the modifications. There is a slight increase in water levels of up to 40 mm at the confluence with the Glaslaw Burn as a result. On the floodplain these works have a very limited impact on flood depths with a maximum change of approximately 50 mm. The modelled flood outlines show very little benefit offered by this approach as a standalone solution.

H.1.6 Structural feasibility

It is likely that the existing boulders either side of the weir are placed directly onto the ground, therefore any work to lower the weir could destabilise these boulders. Therefore they will need to be removed prior to the works and replaced at a lower level at the end of the works, with additional armouring to make up the difference.

The work to lower the bed level will be dependent on the nature of the river bed, together with the location of the sewer, its condition and the thickness and strength of the concrete surround. It is therefore advised that prior to starting work, the condition of sewer is established using a CCTV survey, and the concrete surround is exposed by excavating trial pits. If the concrete surround is not too thick hand tools may be used to 'chip' away the concrete in this location to the required depth. If the sewer is in fragile condition or has a substantially thicker surround than anticipated, it may be easier to replace this section of pipe.

The existing concrete base to the log weir may be broken out using a hydraulic breaker attached to a small excavator, providing this is not close to the sewer.

The work will need to reduce the impact to the river channel, so may be carried out in two halves working in a 'sandbag' cofferdam or similar.

H.1.7 Environmental feasibility

The environmental impacts of reducing the existing crest of the weir will be insignificant and restricted to the construction phase only. There will be a minor change in channel morphology but this is mitigated by the size of this proposal within the wider river habitat. Overall there will be no significant adverse ecological impacts as a result of this option.

Removal or reduction of weirs is likely to improve fish passage and be in line with SEPA goals.

The principle risk during removal will be pollution through sediment disturbance and risk of damage to the sewer. The use of silt interception techniques will prevent any long term

impacts upon the fisheries resource and other species. The non-native invasive Giant Hogweed is present throughout this reach.

H.1.8 Summary of feasibility and impacts

This option as a standalone solution offers a very limited benefit to reducing flood risk and therefore should be taken forward as part of a combined approach with other measures also undertaken.

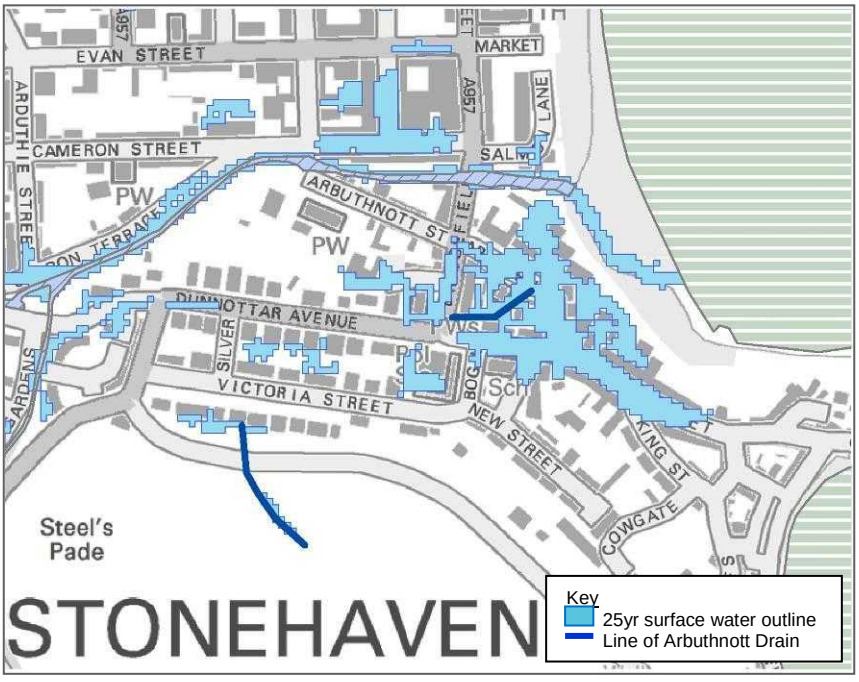
H.2 Opening Arbuthnott drain

Aberdeenshire Council are considering undertaking works on the Arbuthnott Drain which is culverted through the southeastern part of Stonehaven. The watercourse is currently an open drain for a short section between the Bridgefield and Arbuthnott Place (see Figure H-0-5).

Figure H-0-5: Photograph showing open section of Arbuthnott Drain

The Council are considering opening the lower section of the drain to the outfall to improve the drainage route of water and reduce the risk of ponding in this area. Figure H-0-6 shows the route of the drain compared to the 4% AP (25 year) surface water flood outline.

Figure H-0-6: Map showing route of Arbuthnott Drain and surface water flood outline



This map suggests that the area between the open section of drain and the coast represents a topographical low and as such is subject to ponding during a rainfall event. During the 4% AP (25 year) event as illustrated above, water ponds but with no route to the river or coast, and hence improving the routing through this area would offer a significant benefit to reducing flooding.

H.2.9 Environmental feasibility

De-culverting a watercourse is nearly always considered to have ecological benefits and Arbuthnott Drain is no exception, despite the limited available habitat upstream of Arbuthnott Place. It is possible that there may be some adverse impacts through re-connecting the drain to the Carron directly within the estuarine environment and this activity would require a Marine Licence from Marine Scotland.

H.3 Upstream tree planting

Natural flood management (NFM) methods such as changes in land use and upper catchment characteristics should be considered as part of flood mitigation schemes. One option for NFM which is subject to ongoing research is increasing floodplain roughness through tree planting.

Environment Agency literature published in 2004[55] collected and summarised evidence relating to the impact of afforestation on flood flows. The report suggests that all the UK studies, which focus on upland catchments dominated by conifer forest or rough grassland, show that afforestation affects the peak flow and time to peak, as well as generally reducing the water yield. However, it warns that the impact cannot be predicted easily and studies in the UK and Europe have given very variable results of the exact impact afforestation has.

Environment Agency guidance on the effect of afforestation as a catchment flood management plan future scenario[56] is that flood peaks may be reduced by approximately 5-10%. A reduction of flow on this scale would offer a benefit to Stonehaven, but would not be sufficient to mitigate flooding on its own. For example, a 5% reduction in the 0.5% AP (200 year) flow peak would give a new peak of approximately 42.8 m^3/s, or approximately the 160 year event.

Tree-planting is a long-term approach requiring large-scale changes in land use and with a delay in the benefits being experienced on the ground due to time needed for mature trees to become established. It could be considered as a long-term approach to help mitigate the impacts of climate change on catchment flows.

[55] Environment Agency, 2004. Review of impacts of rural land use and management on flood generation. R&D Technical Report FD2114/TR.

[56] Environment Agency, 2006. Catchment flood management plan future scenario. Guidance note number 583_06.

H.4 Effect of rock armour at coastal outfall

H.4.10 Description of scenario

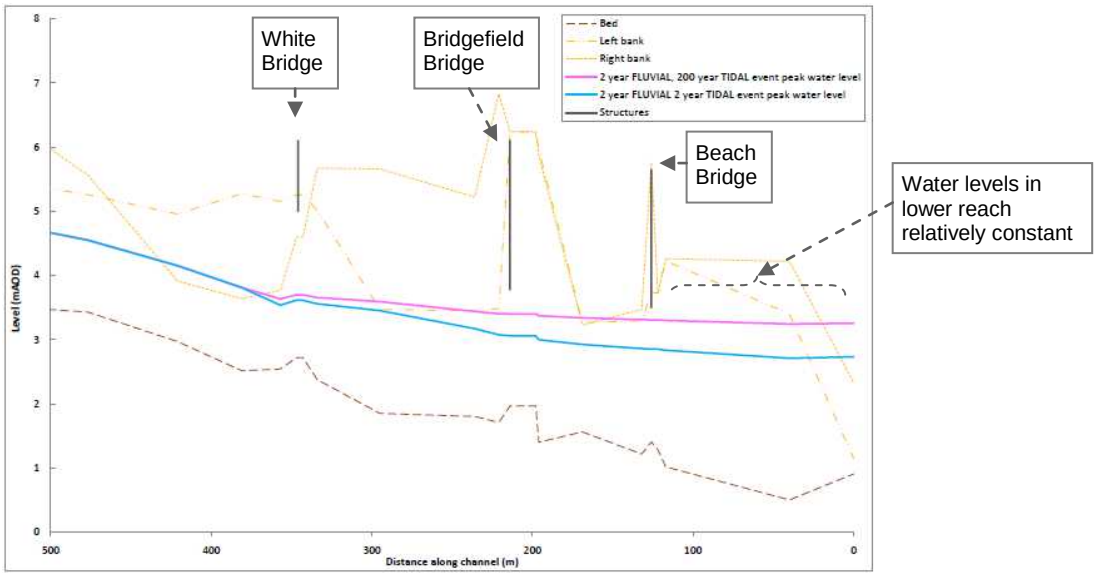
The coastal outfall of the River Carron has been modified to a rock armoured channel which is routed south beyond the beach bridge before turning east towards the sea (see Figure H-0-7 below). Residents noted that during high tides there is a backing up effect on water levels in the Carron and questioned whether the channel diversion and armouring was making this worse and increasing flood risk.

Figure H-0-7: The modified armoured channel of the Carron at the coastal outfall

The model was used to determine the extent of the tidal influence within the River Carron. Since the sea level will be the same wherever the river outfall is, the shape of the water level profile is significant in determining the influence of the tidal boundary.

A low return period fluvial event - the 50% AP (2 year) event - was used, as this is appropriate for the application of a baseline and high return period tidal boundary. The peak water levels in the lower reach of the Carron for each of these scenarios is shown in Figure H-0-8 below.

Figure H-0-8: Peak water levels showing tidal influence on lower reach of River Carron



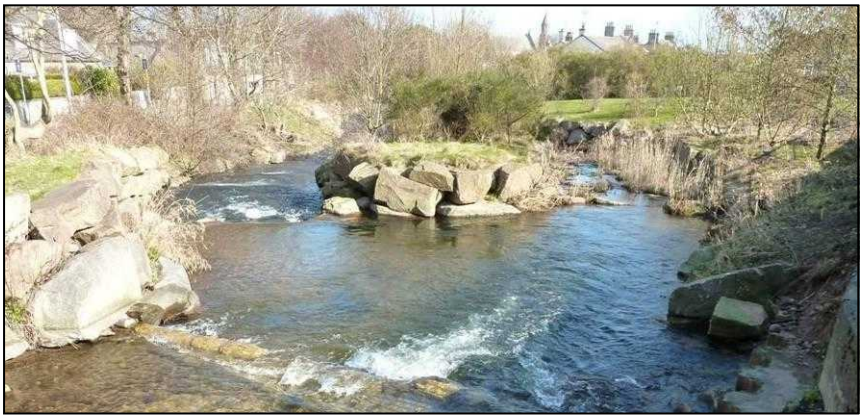
Looking at the water level profile, this suggests that should the reach length below the Beach Bridge be reduced, there will be little change in water levels further upstream as the peak water level in the reach below the Beach Bridge is relatively constant.

H.5 Removing the island

H.5.11 Description of scenario

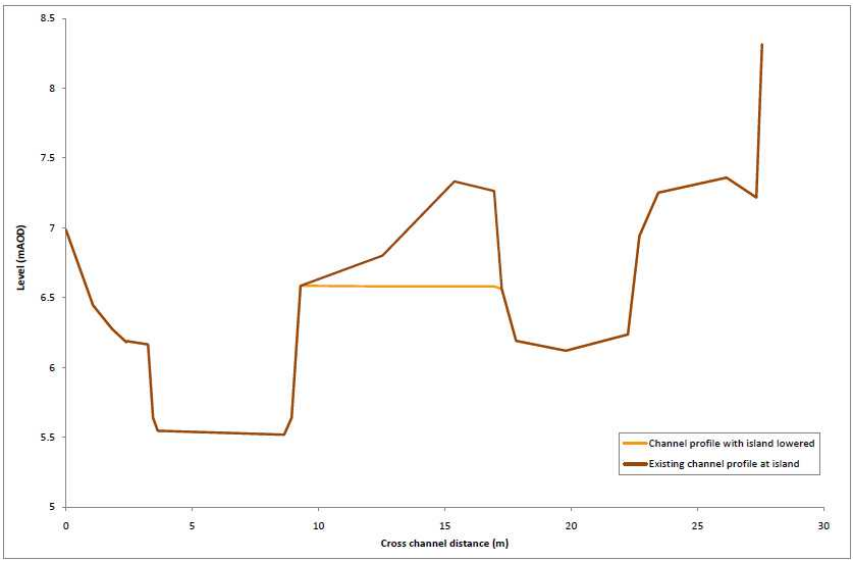
Residents of Stonehaven have raised questions over the effect of the island downstream of the Green Bridge on flood levels. Figure H-0-9 below shows a photograph of the island taken from the Green Bridge. It can be seen that the channel splits, with a low flow channel passing to the north (left) of the island, and a 'fish passage' channel to the south which has a slightly higher bed level. The combined width of the two channels is approximately 11.8 m, compared to a channel width of approximately 9.8 m upstream of the Green Bridge.

Figure H-0-9: Photograph of the island downstream of the Green Bridge



In order to help allay fears that the island is causing an obstruction to flow, the model was modified to represent a scenario where the island was substantially lowered in level. Figure H-0-10 below shows a model cross section at the island showing the 'as existing' section against that with the modifications made. The base model used was that with the remains of the Green Bridge weir removed (as described in Section 8), as should any works be proposed to the island, it would make sense to remove the remains of the weir as well.

Figure H-0-10: Model cross section showing changes to simulate lowering of the island

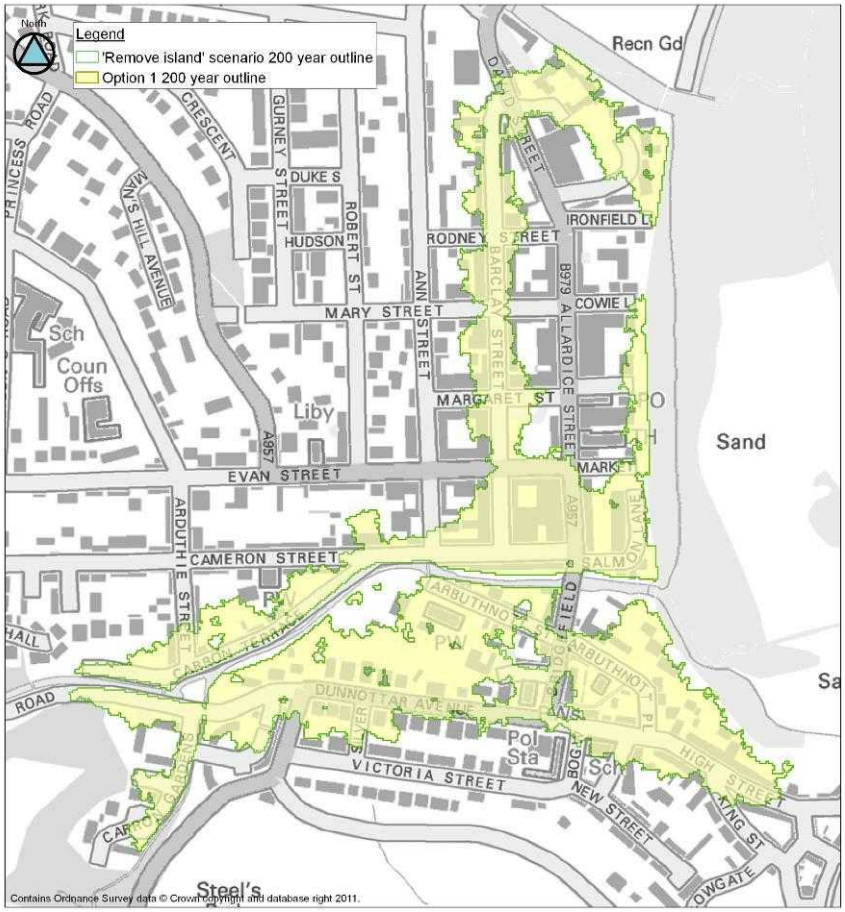


H.5.12 Impact

The model results for the 0.5% AP (200 year) event suggested that lowering of the island as described would lead to a reduction in water levels would lead to a slight reduction in water levels in the vicinity of the Green Bridge with a maximum reduction of approximately 60 mm immediately downstream of the weir location.

Figure H-0-11 below shows that removing the island has no impact on the flood outline for the 0.5% AP (200 year) event. The impact on floodplain depths is shown to be very limited with a maximum change of approximately 50 mm.

Figure H-0-11: 200 year event flood as existing and 'Remove island' scenario outlines



H.6 Removal of remains of weir at Green Bridge and modification of rear gardens at Cameron Street which encroach into channel

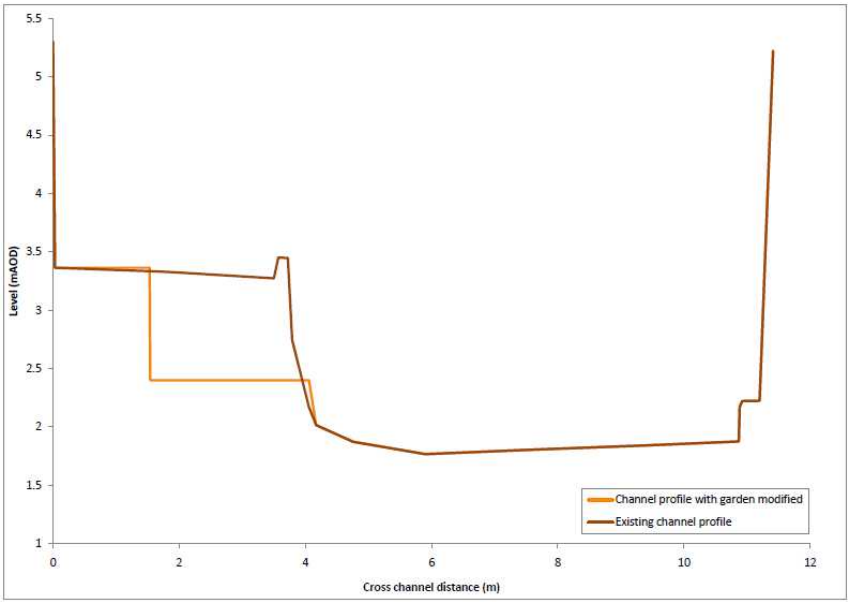
H.6.13 Description of scenario

To the rear of properties on Cameron Street are a number of private gardens which encroach into the river channel and thus reduce its capacity in this section. Figure H-0-12 shows a view of the River Carron channel looking downstream from the White Bridge, with Cameron Street to the left.

Figure H-0-12: Channel downstream of the White Bridge

A model scenario was therefore tested in which the garden areas were modified. A 1.5 m wide strip was left to allow access to the rear of the houses and a two-stage channel was created to maintain efficiency at low flows whilst improving the flow area available at high flows. An example of a channel cross section showing these amendments is show in Figure H-0-13 below.

Figure H-0-13: Example channel section showing revised profile



H.6.14 Model findings and hydraulic feasibility

Figure H-0-14 and Figure H-0-15 below show the impact of removing the Green Bridge weir and reclaiming the gardens at the rear of Cameron Street on the flood outline and peak water levels during the 0.5% AP (200 year) event respectively.

Figure H-0-14: 200 year event flood as existing and garden modification scenario outlines

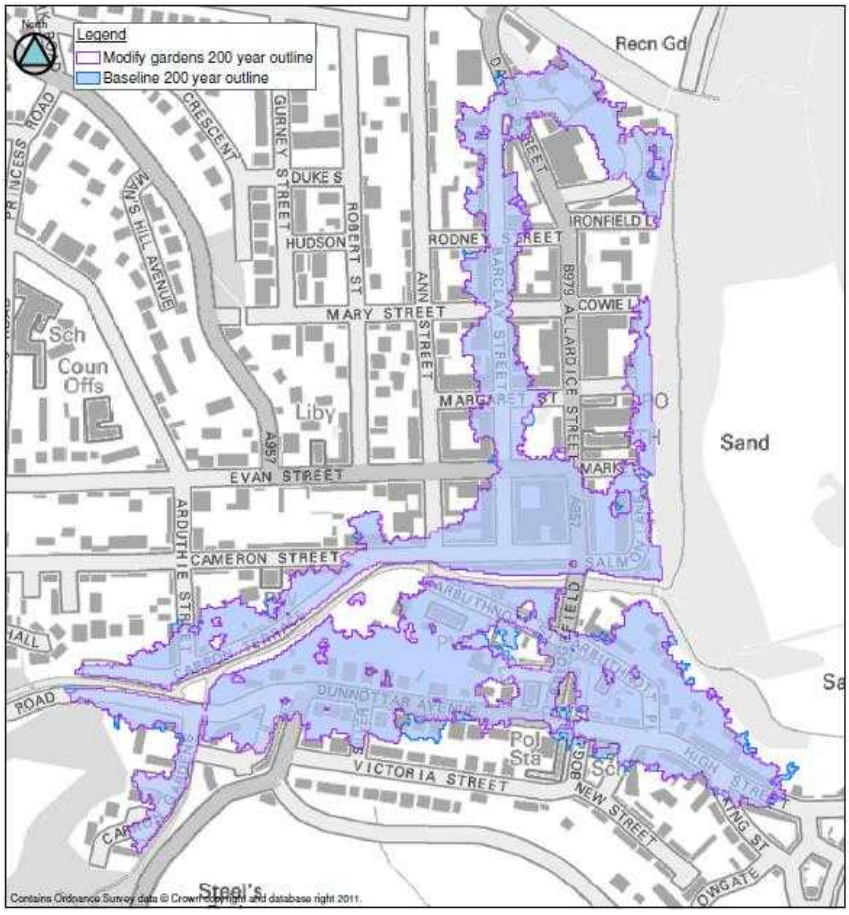
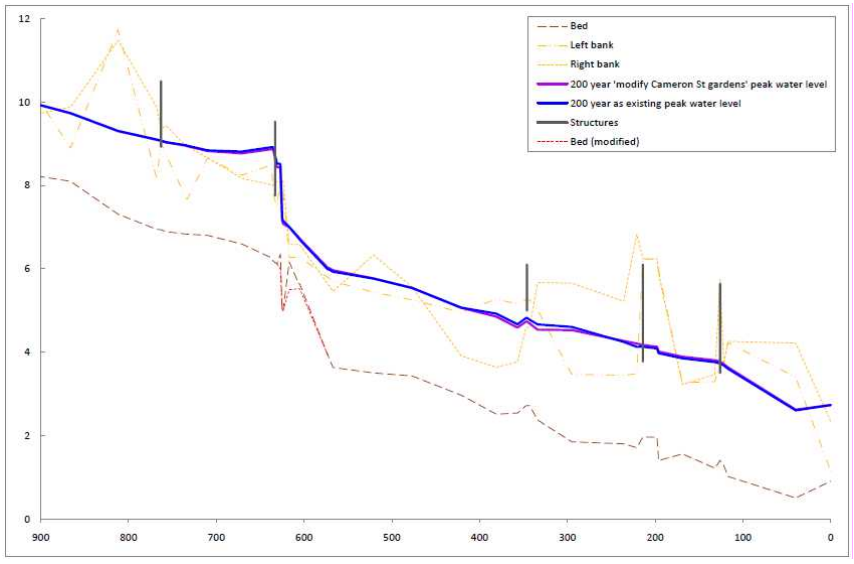


Figure H-0-15: 200 year existing and garden modification scenario peak water levels



The results suggest that again the reduction in water level upstream of the weir is approximately 90 mm at the peak, with a reduction of up to 130 mm downstream of the White Bridge. The modifications lead to a small reduction in the flood extent, with a few properties in the Dunnottar Avenue / High Street areas benefitting.

H.6.15 Structural feasibility

Increasing the width of the river channel by removing the gardens could potentially undermine the adjacent buildings. If this option were pursued, it would be necessary to be provide a new sheet pile retaining wall to retain the bank and protect the properties. As many properties have a door to the rear with access to a drying space it is recommended that a 1.5 m strip is left between the edge of the sheetpile wall and the rear walls of the existing properties. This will also provide adequate working space for the construction of the wall. Any works would have to be carried out from the river side, so a temporary working platform would need to be created on the river bed, this could block at least half the river channel.

To prevent wash off from the works an impermeable bund could be created alongside the platform. The runoff may be collected and treated, before being treated and disposed of in a safe manner.

Accessing the works will be difficult as the Bridgefield Road bridge and the White Bridge prevent access of vehicles over 1.6 m and 2.0 m high respectively. A ramp and temporary crossing point may be created at the end of Arbuthnott Street, just downstream of the White Bridge. This is likely to involve the demolition of some of the surrounding walls.

Figure H-0-16: Location of potential works access point

H.6.16 Environmental feasibility

This option will remove a number of garden habitat types from the river corridor including grassland (lawns), trees and scrub. There is a large amount of material which will require removal and access is restricted to the watercourse. This raises large-scale disturbance to silts within the channel, and the possibility of other pollution issues associated with the use of plant in watercourses. Robust pollution prevention techniques would be necessary.

Travel within the channel also raises issues of impacting upon fisheries; it is likely that due to spawning seasons for both coarse and salmonid species; works would need to be restricted to between mid-June and September, a period further complicated by the presence of breeding birds. Giant Hogweed is present within this area of the river.

This option also has the potential to cause over-widening of the channel as a whole and would therefore risk increasing sedimentation.

13.4.1 Summary of feasibility and impacts

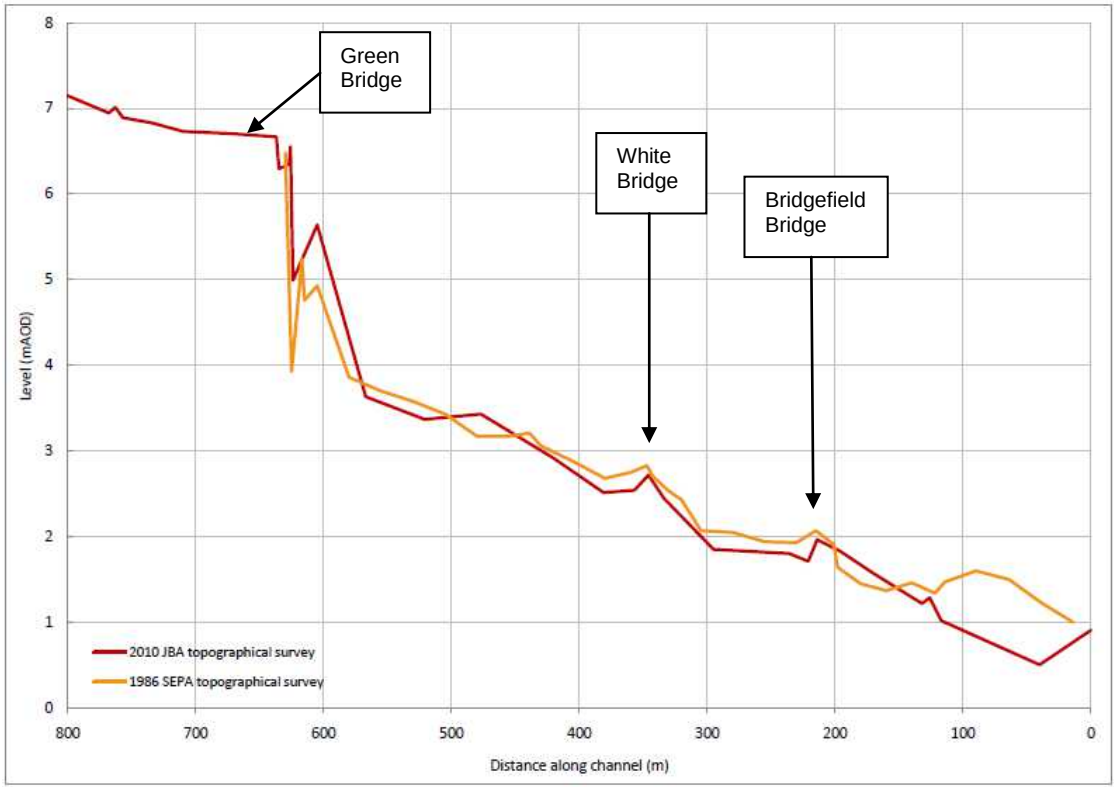
This option as a standalone solution offers a limited benefit to reducing flood risk and therefore if taken forward should form part of a combined approach with other measures.

H.7 Dredging

Dredging is frequently raised by Stonehaven residents as a potential option for flood mitigation. The Geomorphological Audit undertaken by JBA in 2010[57] suggested that there is a large supply of gravel and cobble material from a number of different erosion locations in the upper and middle Carron catchment which is transported downriver. Sediment stores are temporary and sediment is being constantly cycled through the town. This suggests that any dredging would only be a temporary solution to increasing channel capacity as further sediment would quickly replace it.

This ties in with observations of substantial shifts in the bed geometry over time and sudden changes occurring during large flood events, for example scouring during the November 2009 event that was quickly replenished. Figure H-0-17 shows the change in the surveyed bed level along the Carron between 1986 and 2010.

Figure H-0-17: Surveyed long sections in 1986 and 2010



The Geomorphological Audit suggests other modifications be made to the channel to target areas where deposition occurs due to the presence of structures and channel over-widening. It suggests that the removal of the log at the weir downstream of the Green Bridge is likely to negate the need for dredging here by increasing channel efficiency.

Dredging represents only a short-term solution and one that is not sustainable. The Carron channel would need to be monitored and dredged frequently as sediments would be quickly replaced. It is recommended that a longer-term, sustainable solution be pursued in preference.

[57] JBA Consulting, October 2010. Geomorphological Audit of the River Carron. Report for Aberdeenshire Council.

I Public Meeting Posters

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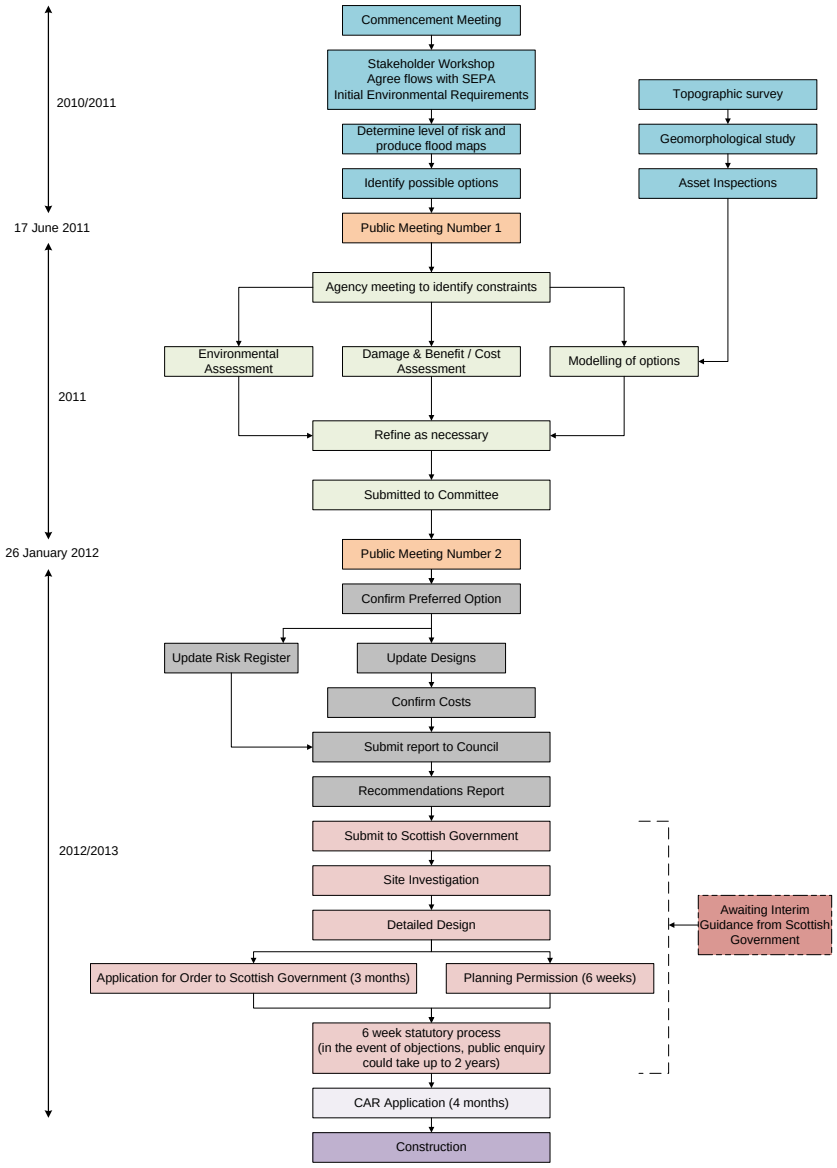
1 - SCHEME DEVELOPMENT & PROCESS

Scheme of Works / Programme



Scheme Objective

- To provide a long term flood alleviation scheme in Stonehaven.
- To reduce the likelihood and impact of fluvial flooding from the River Carron.
- To enhance or maintain the existing environment.
- To avoid adverse environmental or geomorphological impacts.

Standard of Protection (SoP)

- Scottish Government guidance relating to Flood Protection Schemes recommends that they should be designed to protect against flows up to a 1% AP (100 year) flood.
- However, the design event for planning purposes in Scotland is the 0.5% AP (200 year) flood. A consideration of climate change is also appropriate.
- A **target SoP** for the flood alleviation measures of the **0.5% AP (200 year) event** has been used for this study.

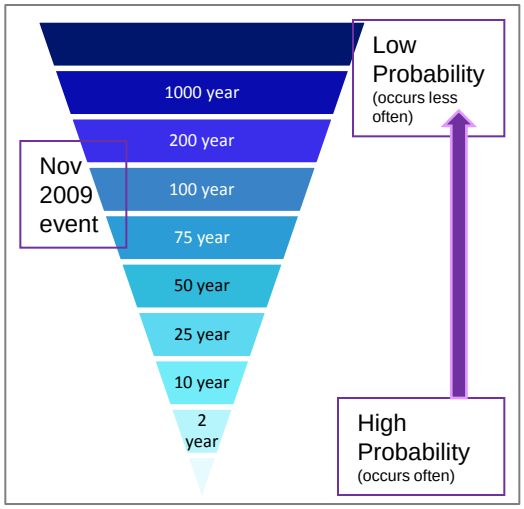
Definitions

- **Annual Probability (AP)** – % chance of being equalled or exceeded in any one year.
- **Return Period (years)** – denotes the average recurrence interval over an extended period of time.
    - e.g. 0.5% AP is equal to a 1 in 200 year return period
- **Geomorphology** – the study of landform and the processes that shape them.
- **1D hydraulic modelling** – one dimensional computer model which represents the channel dimension and used to model channel capacity.
- **2D hydraulic modelling** – two dimensional computer modelling allowing flood flows to be modelled as they pass out of channel and across the floodplain, thus representing overland flow routes.

2 - STONEHAVEN FLOOD ALLEVIATION STUDY: INTRODUCTION

What are the aims of the study?

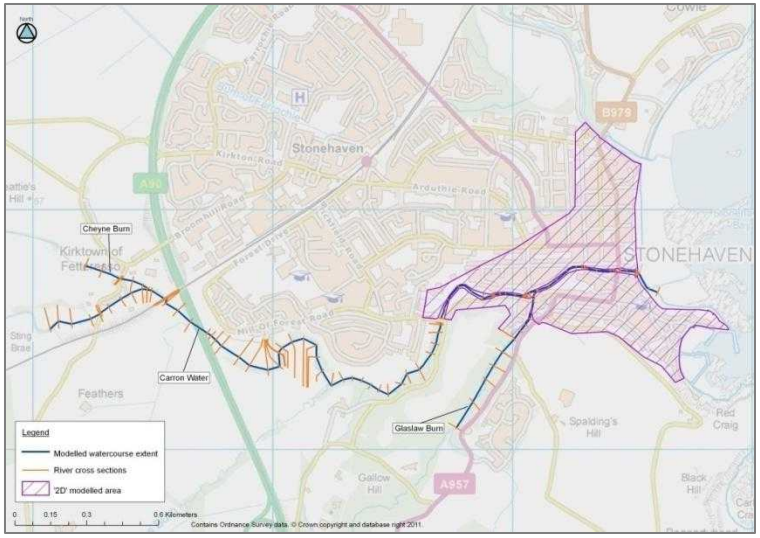
- Collate data on Stonehaven's flood history.
- Simulate different scenarios of flooding from the River Carron and Burn of Glaslaw.
- Identify where water flows across the floodplain.
- Estimate the potential impact of climate change on flooding.
- Consider the wider catchment environment.
- Develop long-term, sustainable options for flood mitigation.



Flood return periods

What IS included in the study?

- Construct a detailed 2D hydraulic model of the River Carron at Stonehaven to assess extent of overland flow and calibrate it to the November 2009 event.
- Derive a range of 'design' river flows to assess the flood risk for a number of scenarios.
- Identify the key mechanisms of fluvial flooding from the River Carron and Glaslaw Burn.
- Assess existing level of flood risk and flood mapping.
- Appraise options by considering engineering feasibility, environmental constraints, benefit-cost analysis, sustainability and public opinion.
- Identify a preferred option to inform outline design.



The extent of the River Carron model

What is NOT included in the study?

- Flood risk from the River Cowie.
- Flood risk from the sea.
- Drainage and sewer capacity.

3 - PAST FLOOD EVENTS IN STONEHAVEN

November 1873
Houses flooded to considerable depth.
The Scotsman, 8th November 1873

October 1906
Houses at the top of High Street and Arbuthnott Place flooded.
Means Leader, 25th October 1906

November 1946 & March 1947
River Carron out of bank but flooding of properties averted.
The Scotsman, 22nd November 1946 & 22nd March 1947

June 1938
Rivers Carron and Cowie in spate but no flooding to property.
The Scotsman, 3rd June 1938

October 1979
Severe flooding from the River Carron caused damage to properties in the town centre.
Press & Journal, 5th October 1979

April 1998
River Carron caused flooding to gardens along Cameron Street.

1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010

December 1882
Many houses in Stonehaven flooded to a depth of two to three feet.
The Scotsman, 18th December 1882

October 1907
Barclay Street and Market Square flooded.
The Scotsman, 11th October 1907

September 1956
River Carron out of bank, with residents on Cameron Street erecting flood barriers at their doors.
Mearns Leader, 7th October 1956

December 1985
Widespread flooding following sudden thaw combined with overnight rain.
Press & Journal, 7th December 1985


It Happened In The Mearns

November 2009
River Carron burst its banks and flooded businesses and houses, causing around 50 people to be evacuated.
Mearns Leader, 5th November 2009

Flood Event

4 - STUDY TO DATE

A number of studies have been undertaken to develop options and understand flood risk

Topographic survey and LiDAR

Provide levels for model and design

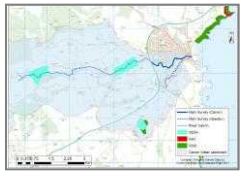
Geomorphology study

Recommended actions for the River Carron through Stonehaven:

A. Dredge bar deposits in conjunction with log weir removal
B. Remove log weir structure
C. Retain boulder weir complex
D. Create two-stage high flow channel where space allows
E. Retain gravel shoals under bridge and undertake periodic weed cutting
F. Remove in-channel structures on left bank
G. Remove in-channel structures on left bank and monitor bar sedimentation

Assess impact of gravel management on river

Environmental baseline study

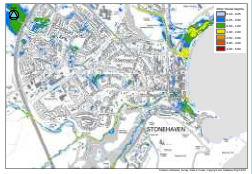


Assess environmental constraints & opportunities

Existing asset inspections

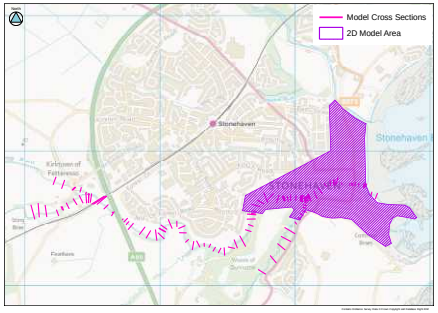
Asset inspection to confirm integrity of existing walls and structures

Surface water flood risk model



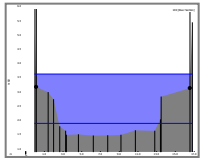
Shows areas where rain water will pond

Hydraulic (Computer) Modelling

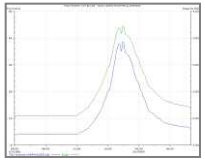


Extent of River Carron Model

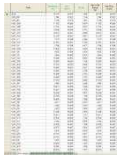
Peak water levels results at each section in the channel allow flood risk to be defined and informs feasibility.



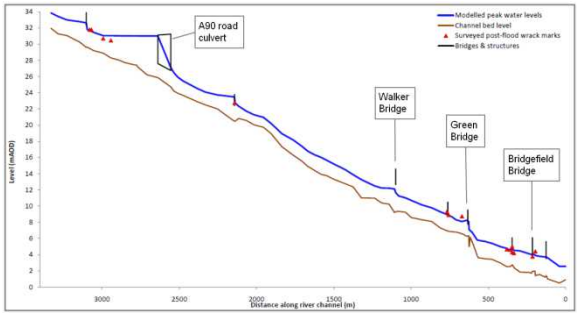
Peak water level



Time series results

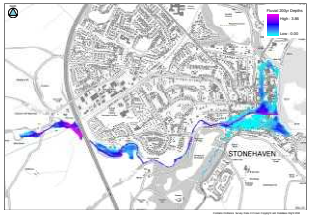


Data



Longitudinal section of water levels along the River Carron

Quantify Existing Flood Risk



Flood depths mapping on the floodplain

Define Potentially Suitable Options

Assess Option Feasibility

Present to Public Meeting No. 2

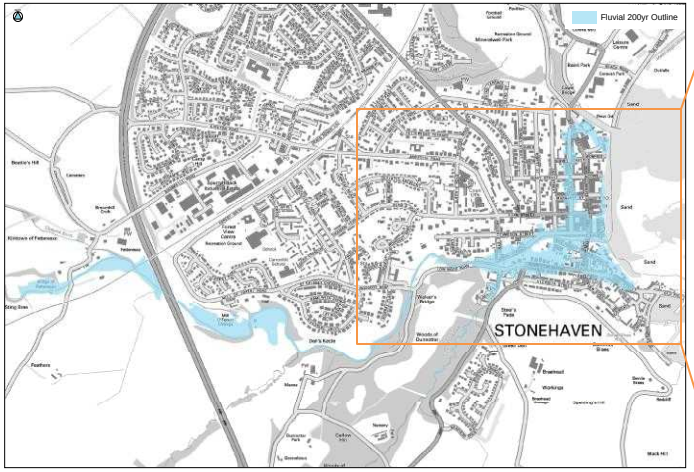
5 - FLOOD HAZARD FROM RIVER CARRON + GLASLAW

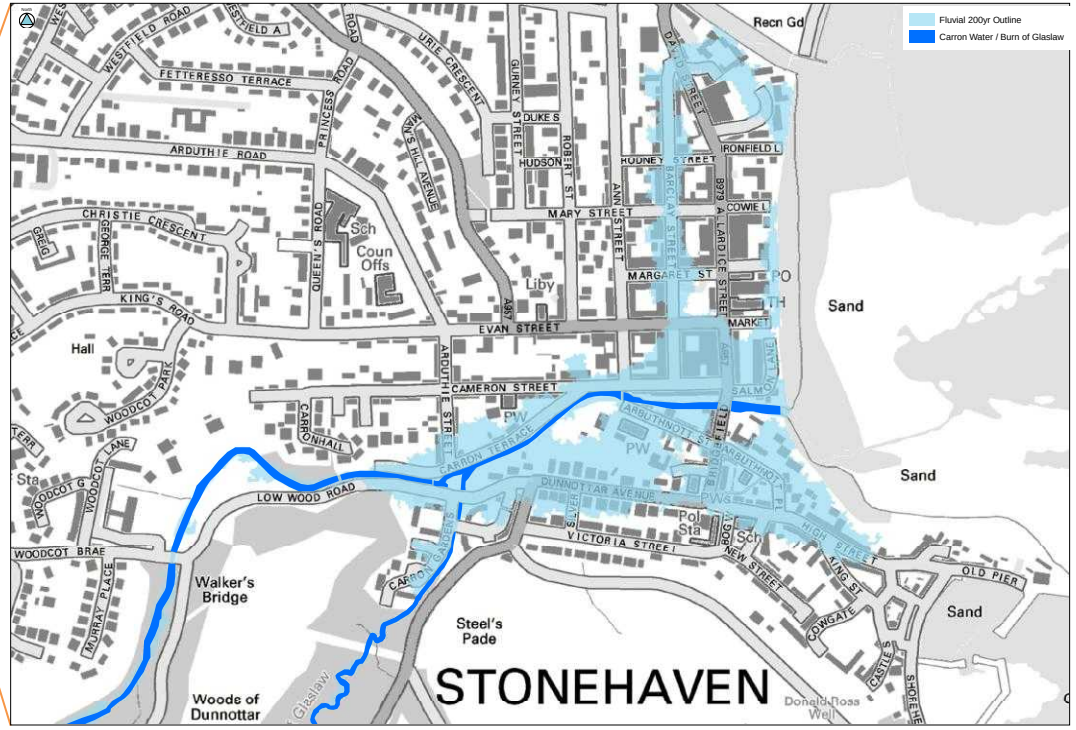
The map below shows the 0.5% AP (200 year) flood hazard area from the River Carron and lower section of the Glaslaw Burn.

Within the main town out of bank flow first commences along Low Wood Road and Carron Terrace.

In the event of a 0.5% AP (200 year) event occurring:

- 372 properties at risk
- £10.8m flood damages
- There is risk to life



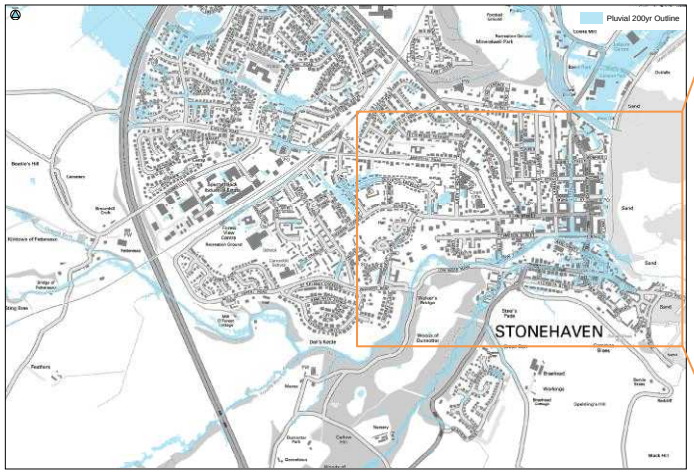


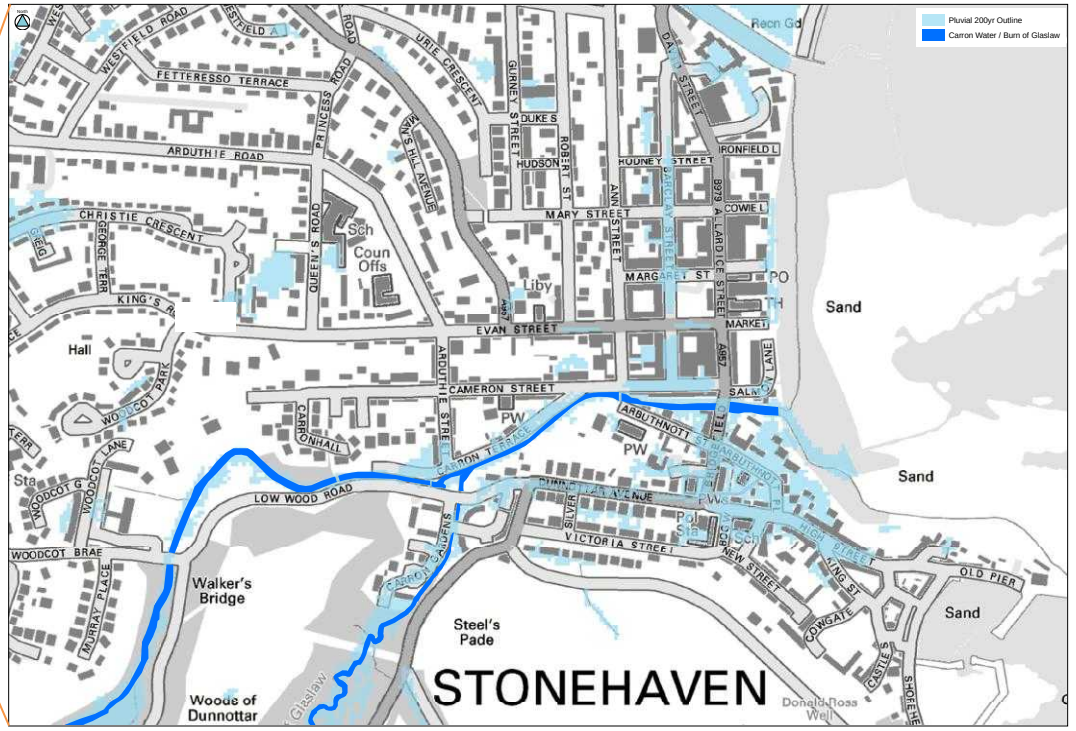
6 - FLOOD RISK FROM SURFACE WATER FLOODING

Surface water flooding is flooding as a direct result of rainfall onto the ground surface and its subsequent runoff via overland flow routes leading to ponding in topographically low-lying areas.

The map below shows the 0.5% AP (200 year) surface water flood risk area.

Identification of flood risk from this source allows this to be managed, even if flood risk from the Carron is removed.





What options have been considered?

Option 1	**Continuation of maintenance and repairs**	• Baseline scenario. • This does not significantly reduce flood risk.
Option 2	**Construction of direct defences**	• Direct defences are walls and embankments. • Provision of riverside flood walls. • In such cases it is important to make sure that any defences do not cause and impact elsewhere (i.e. Downstream).
Option 3	**Construction of direct defences combined with modifications to the channel and bridges**	• Bridges cause constrictions on the watercourse and can cause water levels to elevate upstream of the structure. It can therefore be advantageous to raise or remove bridges. • The old concrete weir at the Green Bridge causes water levels to back up and become elevated upstream. • Consideration given to raising the White Bridge.
Option 4	**Provision of upstream storage**	• Constructed storage areas upstream of the town may allow the flood peak to be stored upstream of the town and thus reduce peak flows and water levels in the town during floods. • A number of large embankments required across the valley.
Option 5	**Construction of direct defences combined with upstream storage**	• Providing a combination of direct defences and flood storage can result in the reduction in required wall heights and also the reduction of storage area required.
Option 6	**Provision of increased flood resilience**	• This option promotes the use of flood gates, vent guards, temporary flood defences and retrofitting flood resilience in buildings.

Emergency repairs in 2009

Example of direct defences

Example of upstream storage

Example of flood resilience measures

8 – PLAN SHOWING LOCATION OF DEFENCES

Within Stonehaven (Options 2/3/5)

LEGEND

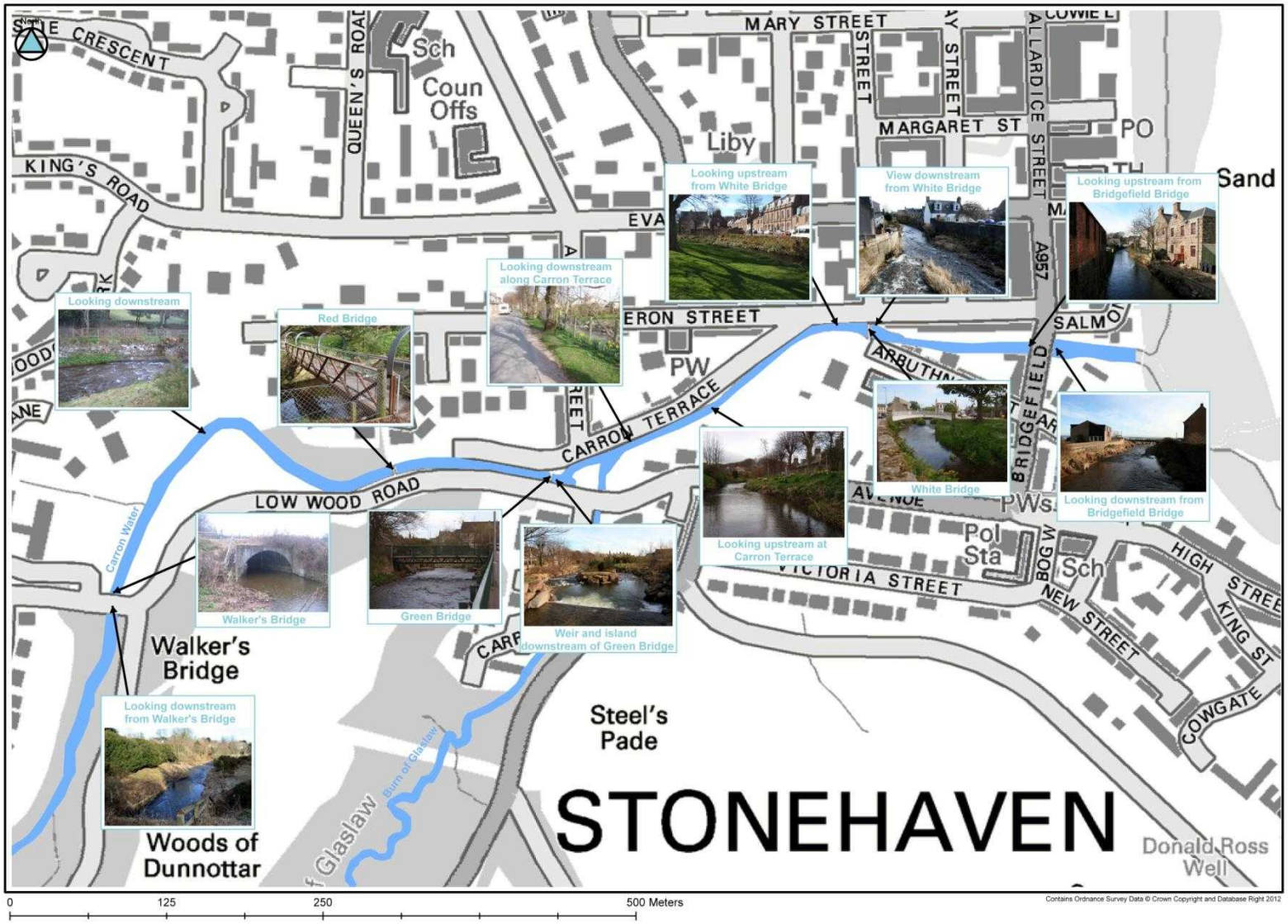
- New Wall Constructed
- Existing Wall Strengthened
- Wall / Embankment on Burn of Glaslaw
- Possible New Bridge Location
- Remove or Raise Existing Bridge
- Raise Ground Levels Locally
- Embankment
- Possible Storage Area

Upstream Storage (Options 4/5)

9 - OPTION 1: Continuation of Maintenance & Repairs

This option includes vegetation clearance, bank maintenance and tree management.

This is will not significantly reduce flood risk and is used as baseline in scheme appraisal.



10 - OPTION 2: Direct Defence as Stand Alone

This option includes the construction of riverside walls.

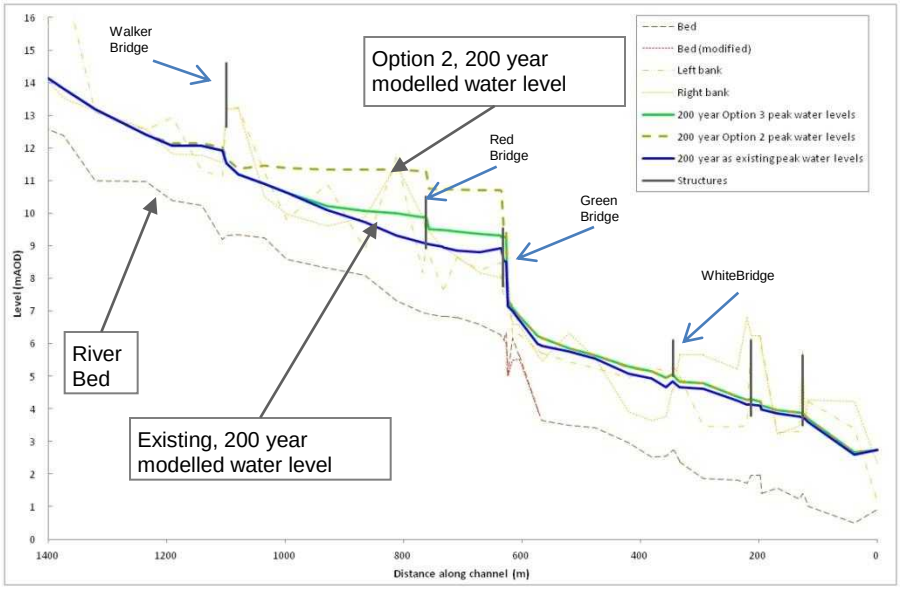
These increase channel capacity, but raise water levels in the channel against the walls and downstream.

Walls required along Low Wood Road, Carron Terrace and Cameron Street.

Locally significant wall heights required (including 300 mm freeboard).

This would provide a 0.5% AP (200 year) standard of protection.

	Average Defence Height (m)	Maximum Defence Height (m)
Carron Terrace on left bank (when looking downstream) **upstream of Green Bridge**	2.7	3.9
Low Wood Road on right bank (when looking downstream) **upstream of Green Bridge**	2.4	3.0
Carron Terrace on left bank (when looking downstream) **downstream of Green Bridge**	0.7	0.9
Cameron Street on left bank (when looking downstream) **downstream of White Bridge**	1.2	2.1



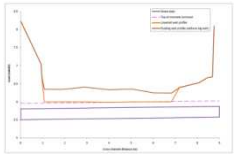
Long Section of Modelled Reach of the Carron

Example Photographs of Flood Walls

11 - OPTION 3: Defences with Channel & Bridge Modifications

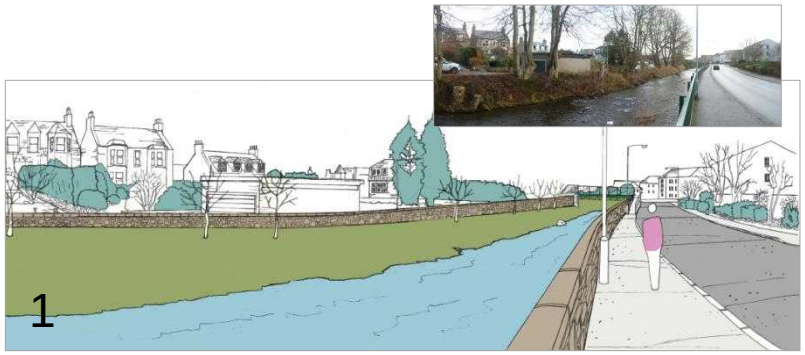
Lower Green Bridge Weir

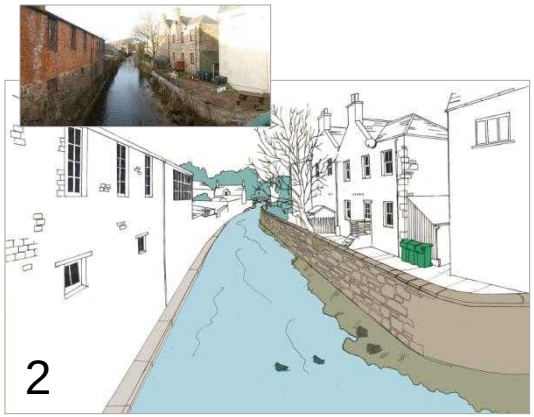
Weir

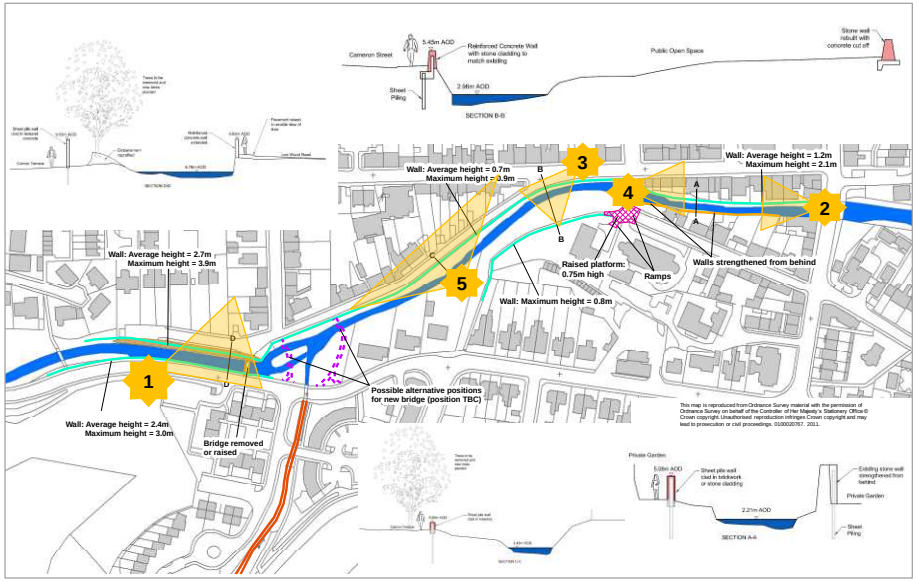


Channel Cross Section

- The Green Bridge & Weir elevate water levels upstream, therefore investigation of these structures has been undertaken combined with defences. Options include:
  - Lower the crest of the Green Bridge Weir
  - Raise the Green Bridge
  - Relocate the Green Bridge
  - Raise the White Bridge (tested although shown to have limited benefit)
- **This would reduce maximum wall heights by 1.4 m compared to Option 2.**
- Would provide a 0.5% AP (200 year) standard of protection.





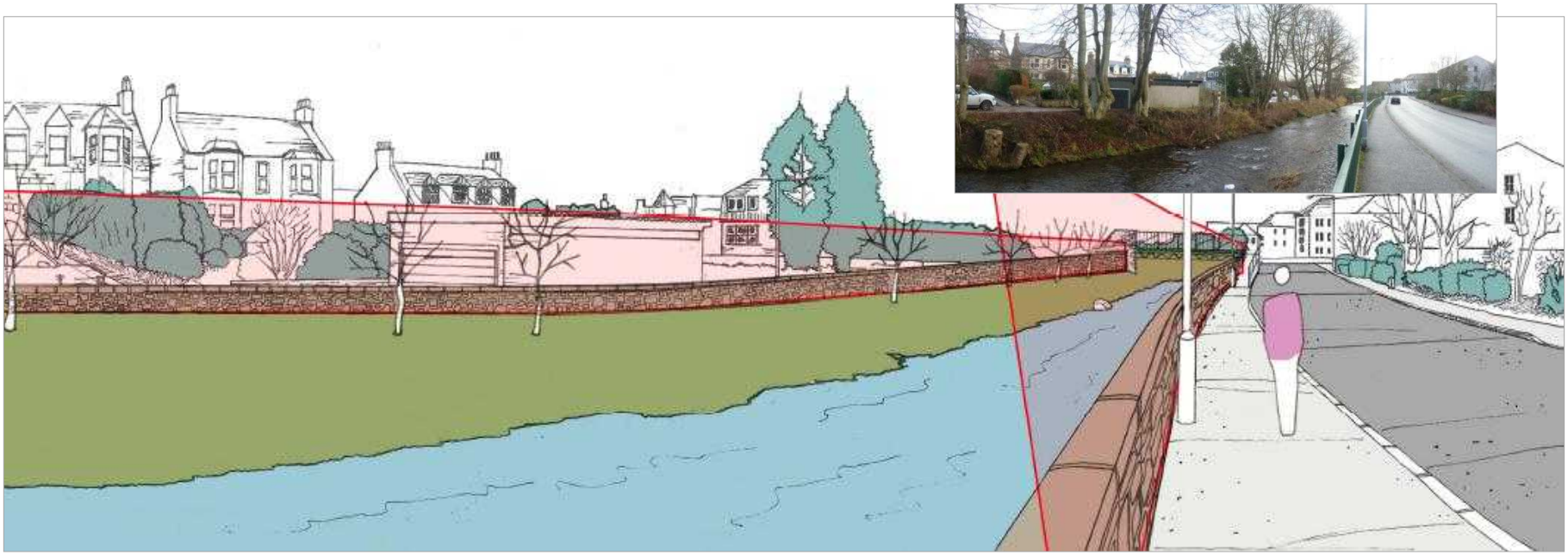


12 - COMPARISION OF OPTIONS 2 and 3

Options 2 and 3 would both provide a 0.5% AP (200 year) standard of protection.

However, stand alone direct defences (Option 2) would result in locally significant wall heights upstream of Green Bridge.

Option 3 (defences, raising of Green Bridge and lowering of weir) reduces the maximum wall heights by up to 1.4 m.



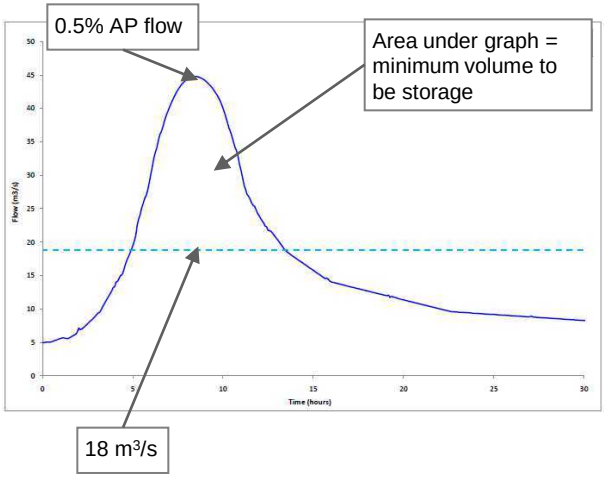
Red Line represents required wall height for Option 2 superimposed over wall heights required for Option 3

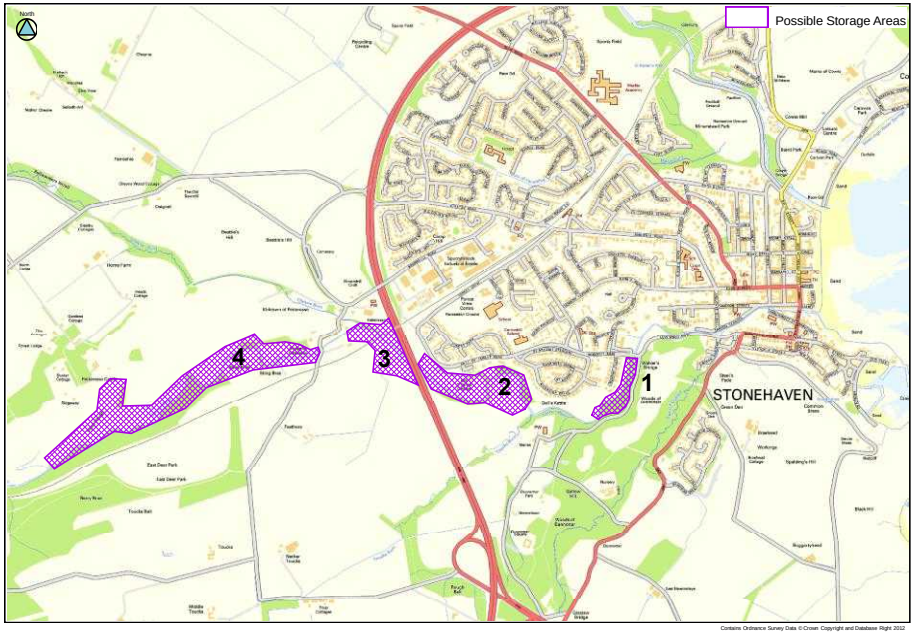
	Defence Heights Option 2		Defence Heights Option 3	
	Average Defence Height (m)	Maximum Defence Height (m)	Average Defence Height (m)	Maximum Defence Height (m)
Carron Terrace on left bank (when looking downstream) **upstream of Green Bridge**	2.7	3.9	1.9	2.5
Low Wood Road on right bank (when looking downstream) **upstream of Green Bridge**	2.4	3.0	1.0	1.6
Carron Terrace on left bank (when looking downstream) **downstream of Green Bridge**	0.7	0.9	0.7	0.9
Cameron Street on left bank (when looking downstream) **downstream of White Bridge**	1.2	2.1	1.2	2.1

13 - OPTION 4: Upstream Storage

How Does Upstream Storage Work?

- An estimated flow of 18 m^3/s can currently flow down the Carron without flooding out of bank.
- The 0.5% AP (200 year) flow is calculated as being (45 m^3/s)
- Storage would aim to store water upstream and then release this water once the flood peak has passed, restricting peak flows to only18 m^3/s in the town.
- The nearer the storage area is to the town the more successful it will be at attenuating the flood peak.





Plan showing possible locations of flood storage areas.

How much storage might be required to reduce the 0.5% AP flow?

- An estimated minimum volume of 0.45 Million (M) m^3 is required.
- 0.21 Mm^3 potentially available in all of the investigated areas combined.

Example: White Cart Water Flood Prevention Scheme

Blackhouse

Storage = 0.81 Mm^3
Embankment length = 350m
Crest Width = 3m
Maximum height = 15m

Kirkland Bridge

Storage = 1.08 Mm^3
Embankment length = 150m
Crest Width = 3m
Maximum height = 9m

Kittoch Bridge

Storage = 0.67 Mm^3
Embankment length = 300m
Crest Width = 3m
Maximum height = 15m

14 - OPTION 5: Upstream Storage and Defences

Option 5 is a combination of Options 3 and 4 to optimise wall heights and storage.

Option 3

Walls heights required for Option 3 range between a maximum of 0.9m and 2.5m.

Provides a 0.5% AP (200 year) standard of protection.

Option 4

Potentially 0.21 Million (M) m^3 of storage could be provided upstream. This would be in a number of large storage basins (0.21 Mm^3 is equivalent to 84 Olympic sized swimming pools).

This is estimated to be equivalent to the 2% AP (50 year) flow.

Therefore, this option alone is unlikely to provide a 0.5% AP (200 year) standard of protection.

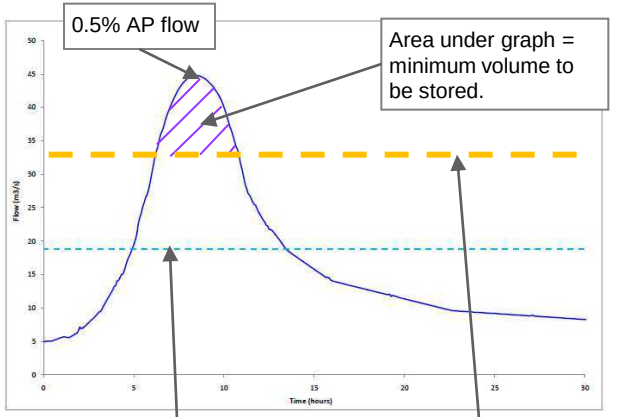
By combining storage and direct defences:

- The required defence heights within the town could be reduced.
- This may also reduce the size of the required storage areas.

Further Assessment Required

- Determine acceptable wall heights within the town.
- What standard of protection would these walls achieve?
- Can storage be found upstream to reduce the flows within the town to match that provided by the direct defences.

Example Photograph of Flood Defence - Galashiels



Flow Hydrograph

15 - OPTION 6: Increased Flood Resilience

This option promotes the use of flood gates, vent guards, temporary flood defences and retrofitting flood resilience in buildings.

Effective only up to moderate events and high risk of failures in systems due to short period of flood warning available on small catchments.

Does not provide a 0.5% AP (200 year) standard of protection.

Flood Wardens

Household Protection

Flood Resilience

Flood Warning

Temporary Defences

SEPA:

- Are looking to develop improved flood warning on the Carron.
- Have installed a new river level gauge upstream of the town at Fetteresso.

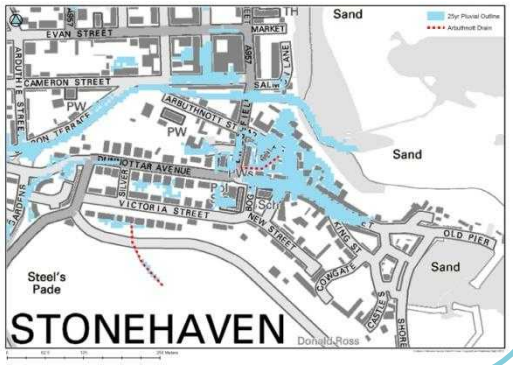
Supplementary Options have also been considered:

a. Open the Mill Lade under Arbuthnott Court (to act as flood relief drain)

Open section of Arbuthnott Drain

Under Arbuthnott Court

- The old mill lade passes beneath Arbothnott Court and flows into a soakaway at the edge of the beach.
- The area between the open section of drain and the coast represents a topographical low and as such is subject to ponding during a rainfall event.
- Opening up end of the culvert / soakaway or pumping would allow water to be evacuated more rapidly.



b. Promote land use changes in upper catchment to reduce run-off in extreme events

Cat Gill Wood, Yorkshire – Planted & Maintained on behalf of JBA

- Planting trees or other forms of land management practices to reduce runoff into the river.
- Peak flows could be reduced by 5-10% but large uncertainty in the effectiveness of the option.
- This could offer benefits in reducing the long term impacts of climate change to Stonehaven; but would not be sufficient enough to reduce the flood peak as a stand alone solution.

Cat Gill Wood, Yorkshire – Planted & Maintained on behalf of JBA

c. Modify / remove rock at coastal outfall

Rock armour along River Carron at its outfall into the North Sea

- The rock armour performs an important task in reducing direct wave action penetrating up the Carron from the open sea.
- Investigation shows that there is no benefit to be gained from undertaking further modifications here.

d. Modify island / twin channel structure downstream of Green Bridge

Island downstream of the Green Bridge

- Both the river modelling and direct observations on the night of the 1st November 2009 suggest that the island does not form a constriction in the current configuration.
- Modifications or removal would produce no flood alleviation benefits.
- However, modification to this area may be beneficial alongside channel modifications that are being investigated at the weir below Green Bridge.

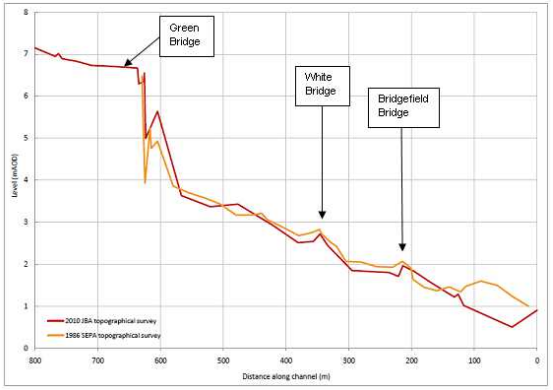
e. Modify gardens which encroach into river at Cameron Street

Looking upstream from Bridgefield Bridge

- Reference to old maps show that over a period of time, gardens in Cameron Street have encroached into the river channel and reduced the natural capacity of the river to cope with high flows.
- However, analysis demonstrates that the adverse impacts of this are limited to the river downstream of the White Bridge.
- Consider modifications to the gardens along with alleviation options.
- Further future encroachment should be avoided.

Looking downstream from White Bridge

f. Dredge the bed of the burn



Surveyed long section of the river bed in 1986 and 2010

- Dredging involves lowering the river bed by removing sediment.
- This is not sediment and vegetation management.
- Comparison with a detailed topographic survey shows that the bed of the Carron itself has not changed much over the years.
- When in spate the river transports a large quantity of sediment and on 1st November 2009, the river effectively dredged itself as demonstrated by the low bed levels post spate.
- Dredging can de-stabilise river banks and increase erosion of the river bed elsewhere.

18 - OPTION SUMMARY

The table below summarises each of the options considered with respect to the economic analysis undertaken to assess the cost effectiveness of each of the options.

Option	Effectiveness of Option	Estimated Cost (£ million)	Damages Avoided (£ million)	Residual Damages (£ million)	Benefit Cost Ratio	Standard of Protection	General Comments
1. Maintenance Only (baseline situation for assessments)	N/A	N/A	N/A	15.2	N/A	10 year	• Continuation of the present situation with minor works of maintenance and repair such as vegetation and sediment bank removal at choke points.
2. Direct Defences (Riverside walls only)	Effective	3.4	14.1	1.1	4.2	200 year	• Walls are raised to the required standard (1 in 200 year). • Containing water in channel raises water levels so maximum wall heights range from 0.9 to 3.9m. • Highly visible and disruptive to built and natural environment. • Enhanced risk if walls fail during flood event.
3. Direct Defences plus Channel and Bridges	Effective	3.4	14.1	1.1	4.2	200 year	• Walls are raised to required standard (1 in 200 year). • Including channel modification and bridge relocation allows wall heights to be reduced to maximum levels of between 0.9 and 2.5m. • Visible and disruptive to built and natural environment.
4. Upstream Storage	Moderately Effective	4.6	13.3	1.9	2.9	50 year	• Increased use of floodplain to store water upstream of Stonehaven reduces flows through town. • Effective against moderate flood events but insufficient available storage means this is only potentially effective up to 1 in 50 year.
5. Upstream Storage plus direct defences	Effective	6.1	14.1	1.1	2.3	200 year	• Using a combination of upstream storage, direct defences and channel / bridge modifications. • Allows wall heights in the town to be reduced further whilst still achieving the 1 in 200 year standard. • Further analysis required on upstream storage potential and wall heights in town.
6. Improved Resilience	Limited Effectiveness	3.7	3.5	11.7	0.9	10 year	• Promotes use of flood gates, vent guards, temporary flood defences and retrofitting flood resilience in buildings. • Effective only up to moderate events. • High risk of failures in systems due to short period of flood warning available on small catchment. • Important option as part of long term strategy as flood risk remains under all options, but not suitable as a stand alone solution to long term flood risk.

Benefit Cost Ratio is the ration of the benefits of the scheme relative to its costs. A benefit cost ration greater than 1 suggests that the scheme is cost effective.

19 - MULTI-CRITERIA ANALYSIS OF THE OPTIONS

At this stage in the assessment each option is considered against a range of criteria.

This assessment is subjective and will be refined as the scheme progresses.

	Option 2:	Option 3:	Option 4:	Option 5:	Option 6:
Criteria	Direct defences as stand alone	Direct defences + bridge raising + channel modification	Storage	Storage + direct defences	Resilience
Provides flood mitigation to required standard					
Benefit-cost ratio					
Impact on fisheries					
Impact on in-channel habitat					
Impact on out-of-channel habitat					
Impact on geomorphology					
Impact on flood water levels in channel					
Disruption during implementation					
Disruption during flood event					
Impact on amenity value of river					
Opportunities for improving footbridge access					
Requires effective warnings and manpower during event					
Impact of failure					
Risk of operational malfunction					
Complexity of design					
Cultural Heritage					
Long term maintenance requirements					

Colour	Result
	Positive result / no negative impact
	Intermediate / neutral result
	Negative result

20 - SUMMARY

Flood History: There is a long history of flooding from the River Carron in Stonehaven, with the most recent significant event occurring in 2009

Scheme Objective: To provide a long term, sustainable flood alleviation scheme for Stonehaven

There are a number of potential options to achieve this:

Option 1

Continuation of maintenance and repairs


Pros	Cons
• Low short term expenditure	• No real flood alleviation • Recurring or long term costs can add up • Potential environmental impacts

Option 2

Construction of direct defences


Pros	Cons
• Good benefit:cost ratio • Low operational requirements during flood event • Low maintenance costs	• Very high walls in town and increased damages if failure • Significant impact on amenity value of river • Impact on cultural heritage

Option 3

Construction of direct defences combined with modifications to the channel and bridges


Pros	Cons
• Good benefit:cost ratio • Potential to improve footbridge access • Low operational requirements during flood event • Opportunity for townscape improvements	• Raised walls in town • May impact on amenity value of river • May impact on cultural heritage

Option 4

Provision of upstream storage


Pros	Cons
• Construction outwith the town • Potential for creation of wetland areas	• Potential impact on fisheries and geomorphology • Complex design with high maintenance costs • Operational requirements during flood event

Option 5

Construction of direct defences combined with upstream storage

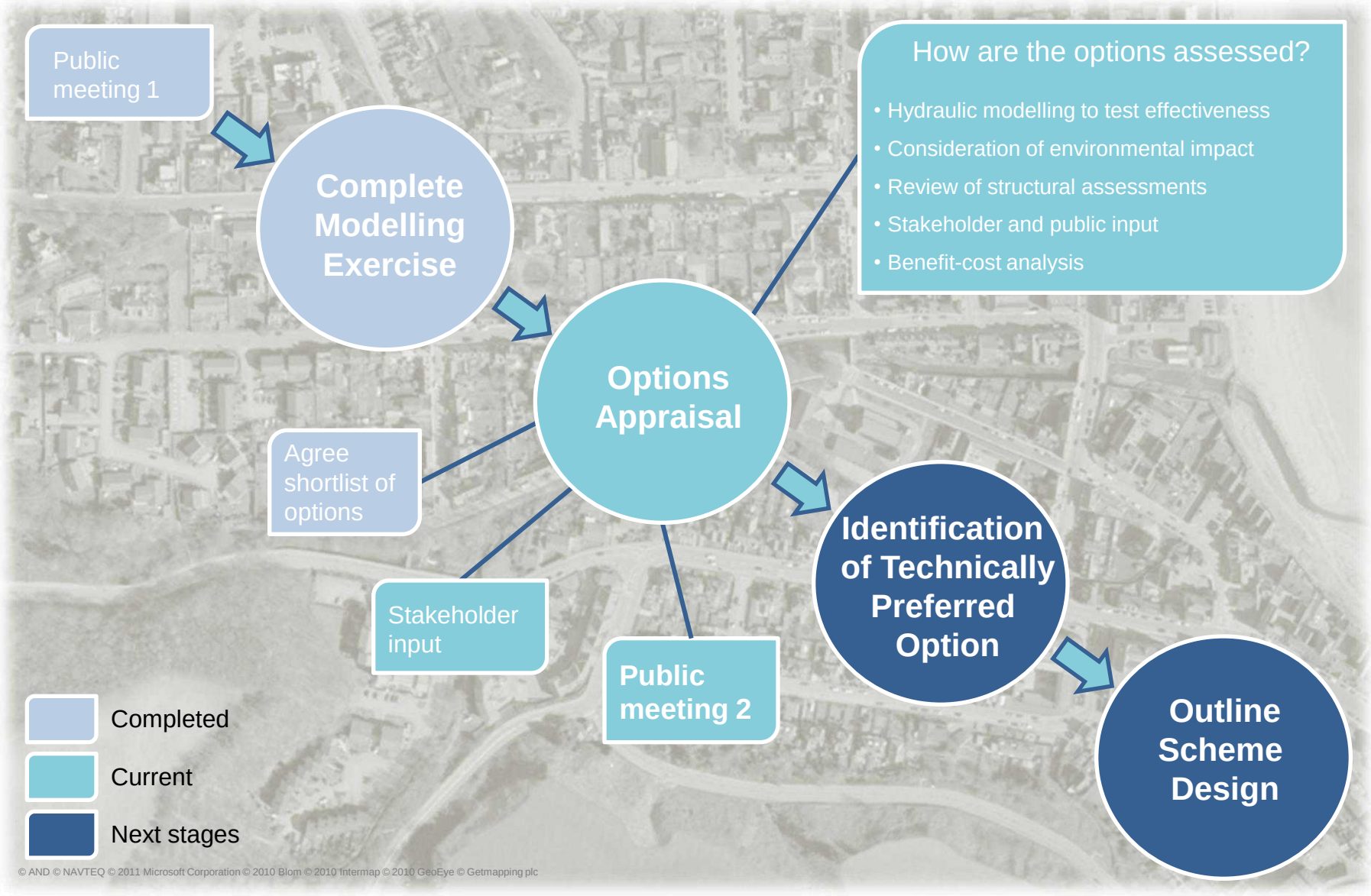

Pros	Cons
• Potential to improve footbridge access • Potential for creation of wetland areas • Robust scheme	• Potential impact on fisheries and geomorphology • Complex design with high maintenance costs • Operational requirements during flood event • Construction in and outwith town

Option 6

Provision of increased flood resilience


Pros	Cons
• Low short term expenditure • Community ownership of risk reduction • Limited disturbance during installation • Minimal environmental impact	• Limited effectiveness • Low benefit:cost ratio • Disruption during flood event • Provision of advanced warning may be limited

What happens next?



J Public Meeting Questionnaire and Public Feedback

J.1 Additional Comments

Comments	Within 200 year flood zone	Option Choice
1. Dredging of river from Red Bridge to Green Bridge.	Y	
2. Removal of Island downstream of Green Bridge.	Y	
3. Remember it is a conservation area.	Y	
4. Willing to accept risk of flooding rather than have river walled off.	Y	
5. Option 5 suffers from high costs and high maintenance.	Y	3-5-2
6. Keeping more water in river will makes things worse downstream of White Bridge.	Y	5-2-3
7. What are the timescales for works? Supplementary options of significant importance and felt they were hidden to some extent. Increase channel area at Green Bridge (re-design). Temporary barriers along Carron Terrace. Divert water back into Carron at top of Carron Terrace (Green Bridge end).	Y	5-3-2
8. Complete study of tidal records during last and other historical flood events. Check if spring tides or other surges were occurring during times of flooding.	N	5
9. To reduce impact on town supplementary options A, D and possibly C should be implemented. Priority should be given to leaving bridges as they are.	Y	6-1-2
10. Willing to accept flood risk rather than look at a wall.	Y	4-6-1
11. Rigorous maintenance regime of any channel modifications to ensure continued effectiveness.	Y	3-5-2
12. Upstream storage is best option as land being proposed for development into storage areas isn't really in use.	Y	4-1-6
13. Surprised that drainage and sewerage isn't included in study.	N	5-3
14. What are the funding options?	Y	3-5-6
15. High defence walls look great.	Y	2-4-6
16. The drainage/sewerage system should form part of study. The old mill lade should be a no-brain solution, not just an alternative. The council were warned prior to Braehead being developed that the Carron River was at capacity.	Y	5-4-3
17. Explicit mention of restricted, or no, development upstream in the water run-off zone. Concerned that after planning is approved a cheaper, less attractive option will be constructed. Remember that it is a conservation area.	Y	1-4-6
18. There should be no further building on the high ground along the Carron.	Y	1-5-3
19. High priority to start work and prevent further flooding.	Y	5
20. Open up mill lade as a flood relief drain. Modify rock formation at mouth of Carron. Remove island, don't believe it had no effect on flooding.	Y	1-3-2
21. Keep street drains clear.	Y	5-4-1
22. Option 2 and 3 are equal in effectiveness but 3 looses out on cost.	N	3-2-5
23. Upstream storage could have dual benefits of flood alleviation and community facilities ie. Water sports and other past-times.	Y	5
24. Please give the problem of the mill lade soak-away more thought.	Y	5-2-6

25. Removal of island downstream of Green Bridge.		4
26. Clear more drains on Low Wood Road (2 are presently blocked). Drain Low Wood Road drains into Glaslaw Burn to reduce risk of flooding to Old Town.	N	3-1-2
27. Must follow guidance from experts in the field.	N	5-3-4
28. Live on Carron Terrace and would prefer lower walls. If this was 100 yr flood in my old age would like a view. People enjoy looking at the river.	Y	5
29. If the drains were cleaned regularly problem would not be so bad.	Y	2-4-5
30. Glass walls if possible.	N	5
31. Effects of spring tides on flood defences haven't been considered. In the 2009 flood the high tide seemed to add considerably to the flood damage as water could not escape from the High Street.	N	5-3-4
32. The flood protection scheme is a long way off. In the mean time why not install a trash screen / grid upstream of the Walkers Bridge to catch wooded debris before it reaches the lower parts of the town.	Y	3-2-5
21. Keep street drains clear.	Y	5-4-1
22. Option 2 and 3 are equal in effectiveness but 3 looses out on cost.	N	3-2-5
23. Upstream storage could have dual benefits of flood alleviation and community facilities ie. Water sports and other past-times.	Y	5
24. Please give the problem of the mill lade soak-away more thought.	Y	5-2-6
25. Removal of island downstream of Green Bridge.		4
26. Clear more drains on Low Wood Road (2 are presently blocked). Drain Low Wood Road drains into Glaslaw Burn to reduce risk of flooding to Old Town.	N	3-1-2
27. Must follow guidance from experts in the field.	N	5-3-4
28. Live on Carron Terrace and would prefer lower walls. If this was 100 yr flood in my old age would like a view. People enjoy looking at the river.	Y	5
29. If the drains were cleaned regularly problem would not be so bad.	Y	2-4-5
30. Glass walls if possible.	N	5
31. Effects of spring tides on flood defences haven't been considered. In the 2009 flood the high tide seemed to add considerably to the flood damage as water could not escape from the High Street.	N	5-3-4
32. The flood protection scheme is a long way off. In the mean time why not install a trash screen / grid upstream of the Walkers Bridge to catch wooded debris before it reaches the lower parts of the town.	Y	3-2-5
28. Live on Carron Terrace and would prefer lower walls. If this was 100 yr flood in my old age would like a view. People enjoy looking at the river.	Y	5
29. If the drains were cleaned regularly problem would not be so bad.	Y	2-4-5
30. Glass walls if possible.	N	5
31. Effects of spring tides on flood defences haven't been considered. In the 2009 flood the high tide seemed to add considerably to the flood damage as water could not escape from the High Street.	N	5-3-4

J.2 Score from Questionnaires & Tick List

Option 1: Continuation of maintenance and repairs
Option 2: Construction of direct defences
Option 3: Construction of direct defences with modifications to the channel and bridges
Option 4: Provision of upstream storage
Option 5: Construction of direct defences with upstream storage
Option 6: Provision of increased resilience

SURVEY RESULTS FROM QUESTIONAIRES

RANK	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5	OPTION 6
1	6	6	14	8	25	1
2	9	5	17	8	7	3
3	6	10	5	6	7	6

SURVEY RESULTS FROM TICK SHEET

RANK	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5	OPTION 6
1	5	0	14	4	12	1
2	2	6	11	0	6	3
3	1	3	1	3	3	3

EXHIBITION ATTENDEES (ESTIMATED) = 117
QUSTIONAIRES RETURNED = 60
TICK SHEET NUMBERS = 79 (INDIVIDUAL TICKS)

QUESTIONAIRE RESULTS-POINT SYSTEM

RANK	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5	OPTION 6
1=30pts	180	180	420	240	750	30
2=20pts	180	100	340	160	140	60
3=10pts	60	100	50	60	70	60
TOTAL	420	380	810	460	960	150

TICK SHEET RESULTS-POINT SYSTEM

RANK	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5	OPTION 6
1=30pts	150	0	420	120	360	30
2=20pts	40	120	220	0	120	60
3=10pts	10	30	10	30	30	30
TOTAL	200	150	650	150	510	120

QUESTIONAIRE AND TICK SHEET TOTALS

RANK	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5	OPTION 6
TOTAL	620	530	1460	610	1470	270

J.3 Additional Comments

- requirement for debris control upstream of Walker's Bridge (to prevent it getting caught on the Green Bridge)
- Concern that Council not looking at coastal or drainage flooding
- two Cameron St home owners seemed happy for Council to do the works and take a section of their garden for the floodwall (SMcF didn't recall which two however)
- A number of residents continue to voice their feelings for dredging of the channel.
- Residents claiming lack of gulley cleaning.
- Residents highlighting that the rock island is much larger / higher than the island that used to be there.
- Concern voiced that in their view the embankment on the left bank immediately upstream of the Green Bridge was raised following the Nov 2009 flood and not just re-instated.
- Concerns over tidally influence flood risk / wave pulses passing up the river.
- Resident on Low Wood road immediately to the east of the Glaslaw confluence was concerned that there appeared to be no defence around the rear of his property. He also noted that he was probably more generally concerned about flood risk to his own property from the Glaslaw burn.
- That the flood waters on the High Street dropped quickly after someone came and opened a manhole.
- Discussion with the lady who lives upstream of the Bridgefield bridge on the left bank and whose wall was re-built after the Nov 2009 flood. This caused concern to the owner of the antique carpet shop.
- Upstream of Bridgefield Bridge on the right bank, upstream of antique carpet shop – there is a doorway in the wall.
- Lady with large wall (somewhere between Green Bridge and White Bridge (right bank) has a high garden / boundary wall and voiced concern that new walls would be lower.
- Exclusion of drainage & sewers is a big concern.

K Risk Register

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Aberdeenshire Council
Stonehaven Flood Alleviation Study
PROJECT RISK REGISTER (17th June 2012)

Qualitative Risk Assessment

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H - Likely to prevent project from progressing
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Consequence \ Probability	H	M	L
H	H	H	M
M	H	M	L
L	M	L	L

H - High - Risk stopping viability of scheme
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1. QUALITATIVE ASSESSMENT

A	B	C	D	E	F	G	H	I
			Risk Level					Residual Risk
Item	Risk	Comments	Probability	Consequence	Overall	Mitigation	Action By	
A2 NON-PROJECT SPECIFIC RISKS								
A2.1 Funding								
1	**Scottish Government flood defence budget re-allocated**	Funding allocated for next 3 year, not clear what funding will be available after this.	M	H	H	Monitor, amend scheme to suit if possible.	AC	H
2	**Council unable to allocate funds**		M	H	H	AC to plan adequately for funding requirements.	AC	H
3	**Change in funding rules**		M	H	H	Monitor, amend scheme to suit if possible.	AC	H
4	**Cost of scheme increasing, reducing cost benefit ratio**	Risk allocation added to the project costs in the form of percentage uplift for optima bias.	M	M	M	Regular cost reviews required through out development of scheme. Good project risk management.	AC	M
5	**Submissions to Scottish Government insufficiently finalised.**	Could lead to delays and scheme being unnecessarily constrained.	L	H	M	Allow adequate time and resources to prepare comprehensive scheme.	AC	M
6	**Flood Protection Order approval delayed**		M	M	M	Use procedures of consultations successful for previous FPO's.		M
A2.2 Statutory framework								
7	**Change in policy or legislation**	FRM Act 2009 - beware of transitional guidance. No new legislation currently proposed with respect to flood protection schemes.	L	M	L	Monitor for changes in policy.	AC	L
8	**Change in Regulation**	No new environmental legislation currently proposed.	L	M	L	Monitor for changes in regulation.	AC	L
9	**Changes to structure, local and other management plans**	No large changes currently being considered that will affect works.	L	M	L	Monitor for changes in local plans.	AC	L
10	**FPS approval**	Council will need a process to approve and advertise a FPS.	M	H	H	Consultation to be well planned and designed to enable permission to be gained quickly. Adequate time allowed for in programme.	AC	M
11	**CAR Licensing**	Delays caused by lack of information, poor application and nature of response from SEPA.	M	M	M	SEPA to be adequately consulted prior to application. Adequate time to be allowed for in programme.	AC	M
A2.3 Socio-economic framework								
12	**Objection by residents inside defended area**	The greatest risk to the scheme is that of a formal objection. Objections likely to be minimised as their properties being protected, would be most concerned about loss of space, amenity value, retail opportunities	L	H	M	Well planned, proper consultation and communication. May also lead to FPS that impacts on Environment but minimises objections.		M
13	**Objection by landowners or adjacent developers**	The greatest risk to the scheme is that of a formal objection. Objections likely to be minimised as their properties being protected, would be most concerned about loss of space, amenity value, retail opportunities	L	H	M	Well planned, proper consultation and communication. May also lead to FPS that impacts on Environment but minimises objections.	AC	M
14	**Objection by residents outside defended area**	Objections likely to be most concerned about loss of space, appearance and amenity value.	M	M	M	Well planned, proper consultation and communication. May also lead to FPS that impacts on Environment but minimises objections.	AC	M
15	**Negative impacts on amenity value, recreation & tourism**	Reduction in quality of public spaces e.g. removal of trees, creation of 'dead spaces' and intimidating walls and 'cold' surfaces.	M	M	M	Proposed scheme to be designed and detailed using appropriate materials etc, and maintain/enhance opportunities for recreation etc. Employ Landscape Architect to consult local community and advise on treatment of public spaces.	AC	L
16	**Changes in economic base values, through market change**	Changes to mix of businesses etc can adjust economic analysis. This is unlikely to be significant, although property prices may fall due to general economic downturn.	L	L	L	Main risk would be relocation of commercial properties- but is this at all likely?		L
A3 PROJECT DEVELOPMENT RISKS								
A3.1 Management of Project development								
17	**Lack of staff skills and resources**	Less likely in economic downturn.	L	L	L	Client to ensure adequately skilled designers and project managers working on project.		L
18	**Poor management of the design process, lack of clarity and exchange of information, lack of project planning**	Could lead to delays and poor quality of contract documentation.	M	H	M	Client to set clear brief, formal systems to be set up to enable adequate flow of information, risk management systems and adequate programming and planning takes place. Consider using scheme such as PRINCE supported by CEEQUAL to identify environmental opportunities.	AC	L
19	**Poor management of consultation process**	Could lead to delays.	M	M	M	Stonehaven has consulted widely to date and this has formed good foundation, continue and adopt good practice from previous consultation processes to be used.	AC	L
20	**Competing requirements and lack of communication/understanding between stakeholders**	Could lead to delays & unnecessary additional work.	M	M	M	Adequate consultation required in form of presentations and workshops.	AC	L
21	**Lack of understanding of planning and consent processes**	Could lead to delays.	M	M	M	Advice sought from planners at early stage, early consultation.	AC	L
A3.2 Strategic Risks								
22	**Timing of Scheme**	Scheme being built at same time as other projects in area etc, scheme starting before other projects ending etc.	L	L	L	Consider timing with respect to other flood prevention schemes.		L
23	**Lack of suitable Contractors/Labour etc**	unlikely in current climate.	M	M	M	Consider timing with respect to other flood prevention schemes.		M
24	**Contractors going bankrupt**	More likely in current economic times.	M	M	M	Adequate checks of Contractor's financial status.		L
25	**Scheme restricting Land Use/areas for development etc.**	Unlikely to restrict development as site developed to river bank already, but may be need to demonstrate this to any landowners keen on developing areas to be defended.	L	L	L			L
26	**Risk of secondary flooding**	Risk of surface water flooding identified in JBA's report.	H	M	H	Council to consider looking at additional scheme to relieve surface water flooding, this could be an additional phase of works.		L
27	**Scheme increasing flood risk and erosion elsewhere**	Initial study would indicate this is unlikely.	L	L	L			L
A3.3 Impact of Natural Processes								
28	**Uncertainty in tidal flows & Levels**	Outline studies would suggest that tidal flows and levels would not have significant effect on proposed scheme.	L	L	L			L
29	**Uncertainty in storm frequency, intensity & duration**	Reasonable level of confidence in historic data.	L	L	L			L
30	**Possibility of storm surge**	The risks of storm surge were not studied as part of JBA's brief.	M	H	H	Study required to assess possibility of storm surge.	AC	L
31	**Possibility of waves overtopping**	The risks of wave overtopping were not studied as part of JBA's brief, and there are areas vulnerable to wave and coastal risk.	M	H	H	Study required to assess possibility of wave overtopping.	AC	L
32	**Uncertainty in river flow and levels**	Reasonable level of confidence in modelling flows.	L	L	L	Could be improved by improving gauge record.		L
33	**Correlation between river flow, tides, surges and waves**	The risks of wave overtopping were not studied as part of JBA's brief.	M	M	M	Study required to assess probability of events happening at same time.	AC	L
34	**Bank erosion affecting integrity flood defences**	Morphological changes due to scheme unlikely to be significant.	M	H	H	Defences to be set back from river and or designed with suitable erosion protection and cut off's.		L
35	**Climate change increasing severity and frequency of events, as well as sea level rise**	Allowance for climate change included in fluvial & pluvial modelling.	L	H	M	Monitor research regarding climate change.		M
A3.4 Performance of existing works								
36	**Condition and performance of existing walls between Bridge Street & White Bridge**	Uncertainty over strength of existing walls and foundations.	M	M	M	Adequate Site Investigation required, may need to rebuild walls if strengthening too difficult.		L

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H	H	H	M
M	H	M	L
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1. QUALITATIVE ASSESSMENT

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			Risk Level					Residual Risk
Item	Risk	Comments	Probability	Consequence	Overall	Mitigation	Action By	
37	**Condition and performance of existing bridges**	Existing bridges raised above flood level, except for White Bridge which would appear to be fairly robust. Risk of scour not significantly changed by scheme.	M	M	M	Adequate site investigation, assess bridges for new hydraulic and debris loading, strengthen if required.		L
A3.5 Ecology, heritage and amenity								
38	**Objection by environmental body**	Baseline report carried out by JBA, indicate potential sensitivities and mitigation strategies, consultation with statutory stakeholders is ongoing.	M	M	M	Stakeholder analysis and consultation. Mitigation as appropriate.		M
39	**Risk to removing mature trees. Invasive Non-native species (INNS).**	Are there any TPOs? Any trees removed shall be re planted. INNS Giant Hogweed and Himalayan Balsam may be the principle environmental constraints on any proposed flood alleviation scheme for Stonehaven. Both species are included on Schedule 9 of the Wildlife and Countryside Act 1981 (as amended).	M	M	M	Tree survey and bank re-alignment to minimise impact. Compensatory tree planting, in liaison with planners. Follow appropriate procedures for eradicating INNS.		M
40	**Protected species (otter, bats)**	Baseline environmental survey identified that Bats forage over the channel. Records of Tout & Salmon Nurseries and additional records of European Eel and Lamprey. Further detailed survey required for Otter with respect to chosen option. Further Water Vole surveys should also be carried out during any future Otter survey.	M	M	M	Environmental appraisal. Baseline survey at correct time of year; specific surveys and re-housing ahead of work. Bats - night-time working or obstructing flightlines should be avoided during construction in order to prevent disturbance. Avoid spawning season and periods of migration. Consider artificial holts for minimum of 6 months before works start.		M
41	**Aesthetic requirements change during scheme life as adjacent areas redeveloped**	The main town of Stonehaven is a built heritage conservation area.	M	M	M	Liaise with planners and developers to ensure aesthetics in keeping with development in area.		M
42	**Amenity of area amended altering use by the public.**	The main town of Stonehaven is a built heritage conservation area.	M	M	M	Design to ensure pleasant and secure public spaces encouraging recreation.		M
43	**Damage to or loss of built heritage or archaeological site**	The main town of Stonehaven is a built heritage conservation area. None of the features of cultural heritage interest or archaeology are likely to be affected by any flood alleviation scheme proposals. The C(S) buildings will be afforded additional protection and the grade C(S) bridge and scheduled ancient monument are considerably higher than the watercourses	L	L	L	Review known records (SAMs, Listed Buildings, Conservation Areas, known archaeological sites) including Sites and Monuments Record. Archaeological watching brief if necessary.		L
A3.6 Human Intervention								
44	**New development increasing run-off rate & reducing flood storage**	Flood study does not indicate this is a risk.	L	L	L			L
A3.7 Design Parameters								
45	**Sensitivity to input parameters & design assumptions**	Sensitivity testing carried out on model.	L	L	L	Additional areas of potential sensitivity to be identified.		L
46	**Joint Probability (waves & water levels)**		M	M	M	Additional study to be undertaken.	AC	L
47	**Inadequate knowledge of ground Conditions**	Inadequate SI & geological survey leading to scheme failure through excessive seepage and structural failure of defences.	H	H	H	Adequate design of SI using geotechnical specialist, adequate supervision and quality control of SI Contractor.		L
48	**Poor quality of design data**	Data for catchment considered to be adequate.	L	L	L			L
A3.8 Knowledge of principles/methods								
49	**Poor knowledge/lack of expertise for detailed design and preparation of contract**	Poorly drawn contract leading to compensation events and delays.	L	H	M	Pre-Qualification process to ensure only suitable Designers asked to Tender. Practical knowledge may be augmented by Contractor involvement	AC	L
50	**Poor knowledge of construction methods**	Designer not knowledgeable of latest construction techniques leading to costly design.	M	M	M	Pre-Qualification process to ensure only suitable Designers asked to Tender. Practical knowledge may be augmented by Contractor involvement.	AC	L
	Complexity of Design	Design unlikely to be unusually complex.	L	L	L	Use of standard designs, early Contractor involvement for more complex designs.		L
52	**Inadequate checking procedures**	Inadequate checking procedures leading to fundamental aspects of the design being overlooked.	M	H	H	Robust QA procedures, independent check & review of design and documentation.		L
A3.9 Scheme performance and response								
53	**Impact of events larger than design flood**	Larger events than design event likely to cause defence to be overtopped which can lead to sudden and catastrophic flooding etc.	L	L	L	Use of freeboard and improve flood warning.	AC/ SEPA	L
54	**Risk of failure, due to inadequate maintenance & lack of durability/robustness**	Is a design life of 200 years sufficient, for critical infrastructure? Will the cost of replacement increase greatly e.g. due to oil shocks etc.	M	M	M	Might be worth considering increasing durability criteria. Check incremental benefit cost to higher standard. Draft O & M manual.		L
55	**Failure due to inadequate freeboard/factors of safety**	Design to be based on standard freeboard allowances.	L	H	M	Consider possibility of freeboard being inadequate due to local conditions.		L
56	**Failure due to inadequate tie-in with other structures**		M	H	H	Adequate investigation of existing structures.		L
57	**Change in flood risk probability due to more data**		L	M	L	Review data.		L
58	**Possibility that failure modes of structures could be catastrophic**	Types of structures proposed unlikely to lead to catastrophic failure.	L	H	M			M
A4 Project Implementation Risks								
A4.1 Procurement & Construction								
59	**Risk communication and documentation**	Risks not communicated adequately to the Contractor, leading either to under or overpricing risk.	M	H	H	Adequate Pre-construction information pack, prepared by experienced personnel.		M
60	**Contract terms and conditions**	Unbalanced risk allocation in contract may lead to uncompetitive prices, e.g. loading all the risk onto the Contractor, recommend use of balanced contract risk and contract that encourages 'mutual cooperation'.	M	M	M	Use of well understood contract NEC if possible.		M
61	**Tender costs higher than budget**	Due to 'bespoke' nature of scheme tender costs may be highly variable. Also dependent on which Contractors are available to tender.	M	M	M	Robust cost estimates with adequate allowance for risk. Consider using 'Monte Carlo' type analysis, to evaluate risk & estimate range of costs.		M
62	**Service diversions**	Delays and additional costs due to unforeseen services, and delays/inadequate coordination of service diversions.	M	H	H	Adequate utility survey to be carried out, using scanning techniques and lifting manholes etc. Where possible services to be diverted in advance of works.		M
63	**Increasing construction costs**	Risk of oil shocks, increases in commodity prices, labour shortages etc.	M	M	M	Consider use of 'Monte Carlo' type analysis to consider different scenarios.		M
64	**Inexperienced/Poorly resourced Contractor**	Use of inexperienced Contractor greatly increases risk of project overruns, and increased project management cost	M	H	H	Pre-Qualification process to ensure only suitable Contractors asked to Tender		L
65	**Inadequate working space**	Designer may not be aware of working space required for construction of works.	M	M	M	Works planned & designed with adequate knowledge of plant to be employed. Early Contractor involvement, scope for Contractor to change design.		L
66	**Working on or next to watercourse**	No unusual risks for experienced Contractor.	L	L	L			L
67	**Buildability**	Design may be difficult to build, as designer has limited knowledge of best construction techniques and plant available.	M	M	M	Early Contractor involvement, allow Contractor scope to change design by producing 'specimen' designs.		L

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68	**Access to site**	Difficult access, especially between Bridgefield Bridge and White Bridge. Access route down river.	H	M	H	Compulsory purchase of land may be required. Adequate planning of access routes, storage areas etc.		M
69	**Traffic Management, risk of accidents stopping work etc.**	Most Work may be carried out away from main roads.	M	L	L	Normal traffic management procedures to be followed.		L
70	**Environmental impacts of construction e.g. noise, dust & traffic**	Site close to residential areas, causing disproportionate disruption.	M	M	M	Restrictions on working hours, specifying noise levels and plant used, dust levels to be controlled. Reduction in use of high impact methods of construction.		L
	Environmental impacts of pollution incident(s)	Plant and equipment leaking, inadequate control of surface water runoff.	M	M	M	Employment of adequate site controls, and properly resourced contractor.		L
72	**Flooding of works**	Works flooded setting back project & increasing costs.	M	H	H	Adequate information to be given to the Contractor. Monitoring of weather forecasts. Site Compound, storage of plant and equipment outside 1 in 200 year flood zone.		M
A4.2 Operation and Maintenance								
73	**Lack of maintenance leading to reduction in standard of flood protection**	Works largely passive so less risk of failure, apart from flap valves etc failing.	M	L	L	Draft robust Operations and maintenance plan. Structures to be regularly inspected and repaired, especially White Bridge.		L
74	**Lack of understanding of failure mechanisms, and contingency planning**		L	L	L	Draft O and M manual with contingency plans for extreme events to be prepared in conjunction with emergency services, identifying where breaches most likely to occur and safe access routes.		L
75	**Risks of accidental death and injury to members of the public increasing**	Flood walls restricting access to emergency services etc.	M	M	M	Emergency services to be consulted on design of works and whether any additional risks may be mitigated.		L
76	**Risks of injury and death to maintenance workers increasing**	Flood walls making access unsafe for maintenance workers.	M	M	M	Maintenance authority to be consulted on design of works and whether any additional risks may be mitigated.		L

Note: Above table has been prepared in accordance with Flood Prevention Schemes Guidance for Local Authorities, Chapter 6, Approaches to Risk

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