Almondbank Flood Protection Scheme

Technical Report

July 2013

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List of Abbreviations

1D & 2D	1 Dimensional & 2 Dimensional
BGS	British Geological Survey
CAR	Controlled Activities Regulations
CDM	Construction Design and Management
CES	Conveyance Estimation System
CSO	Combined Sewer Overflow
DEFRA	Department for Environment, Food and Rural Affairs
FEH	Flood Estimation Handbook
FHRC	Flood Hazard Research Council
FRM	Flood Risk Management
HEC-RAS	Hydraulic modelling software capable of one-dimensional steady flow, unsteady flow, sediment transport and water temperature modelling.
ISIS	River modelling software produced by Wallingford Software Ltd & Halcrow Ltd
MCM	Multi-Coloured Manual
NGR	National Grid Reference
OS	Ordnance Survey
PKC	Perth & Kinross Council
Q_{med}	Median annual maxima flood. It has a return period of two years.
RPI	Retail Price Index
SAC	Special Area of Conservation
SEPA	Scottish Environmental Protection Agency
SPP	Scottish Planning Policy
SSSI	Site of Special Scientific Interest
TPI	Tender Price Index
TUFLOW	Hydrological and hydraulic modelling software which includes a two dimensional (2D) component, useful for modelling overland flow
UKCIP	United Kingdom Climate Impact Program
URS	URS Corporated Ltd
WWTW	Waste Water Treatment Works

Contents

List of Figures

List of Tables

1 Executive Summary

Almondbank is at risk of flooding from both the River Almond and the East Pow Burn and has experienced major flooding events in 1909, 1993, and 1999 and more recently in January 2011. SEPA's Indicative Flood Map shows the study area to be at risk of flooding from rivers within the study area.

Mouchel were commissioned by PKC to develop the outline designs for the Almondbank Flood Protection Scheme and have undertaken extensive survey and investigation works alongside the development of a new combined one and two dimensional hydraulic model.

SEPA have confirmed that the input data used and the verified hydraulic model are suitable to develop the flood protection scheme. The design standard of protection for the scheme has been designated for the 1 in 200 year design event plus freeboard allowance. This is consistent with the current SPP (Feb 2010).

An Environmental Impact Assessment has identified a number of measures to be included as mandatory commitments as part of the proposed scheme.

The outline design for the scheme proposes a combination of flood defences which have been tested in the hydraulic model and have been assessed to be the most appropriate for their immediate environment.

The preferred scheme offers the simplest solution in the construction of traditional flood defences (sheet pile walls, reinforced concrete walls and earth embankments) to contain flood waters within the River Almond and East Pow Burn channels, a single flood storage area on the right bank of the River Almond at the Playing Fields, the raising of three bridge structures and the integration of a number of surface water flooding solutions including two pumping stations.

The local community have been formally consulted and recognise the need for the flood scheme and are generally in favour of the proposals. Further to a few small changes to the proposals as a result of feedback received; the outline design for the scheme has been finalised. Continued engagement with the local community must continue throughout the detailed design and construction phases of the scheme.

In total approximately 31 residential properties and 48 non-residential properties (the majority of which are located in Vector Aerospace and Lochty Industrial Estate) will benefit from the final scheme. The benefit-cost ratio for the preferred flood protection scheme is 1.35, therefore the scheme is considered economically viable.

It is recommended that the outline design of the Almondbank Flood Protection Scheme is submitted via the statutory process as defined by the Flood Risk Management (Scotland) Act 2009.

2 Introduction

2.1 General

Mouchel were appointed by Perth & Kinross Council to promote the Almondbank Flood Protection Scheme, further to previous work being undertaken by other consultants.

Almondbank is at risk of flooding from both the River Almond and the East Pow Burn and has experienced major flooding events in 1909, 1993, and 1999 and more recently in 2011 (during the study period).

This report covers the scope of work delivered by Mouchel and also contains a review of the work previously completed by the other consultants.

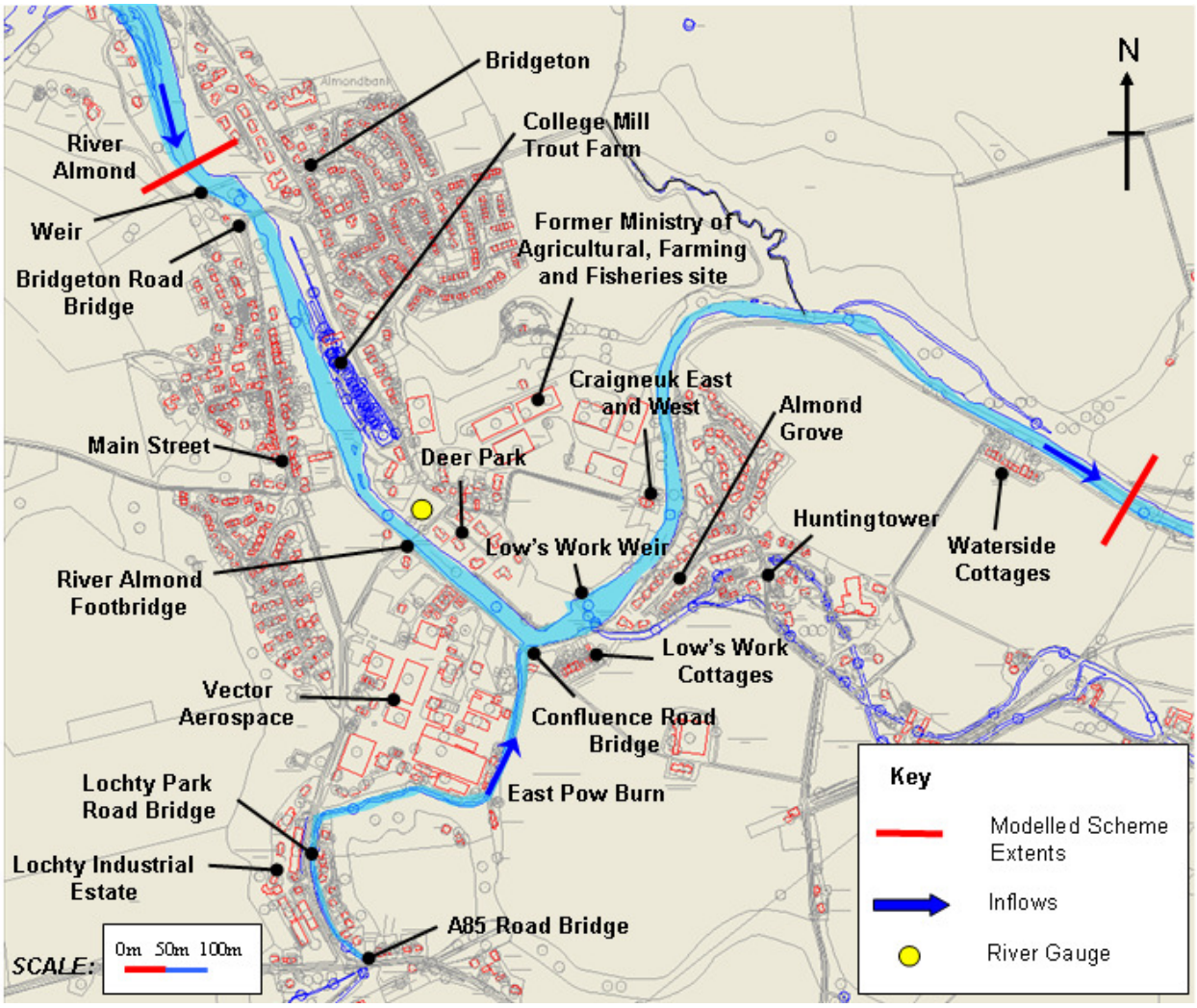

Figure 1 – Modelled scheme extents and key locations in Almondbank

2.2 Study Area

The town of Almondbank is situated 5 miles northwest of Perth, Scotland and has two watercourses; the River Almond and the East Pow Burn, flowing through it. The River Almond flows in a south easterly direction through the town of Almondbank and the East Pow Burn flows in an easterly direction towards the River Almond.

The modelled scheme extents (see Figure 1) follow the boundaries of both of the watercourses within Almondbank. The northern extent of the scheme along the River Almond begins at Bridgeton and continues to downstream of Waterside Cottages, just upstream of the Inveralmond Estate and the River Tay flood defences. Along the East Pow Burn, the A85 Road Bridge marks the upstream extent of the proposed scheme, whilst the downstream extent is marked by its confluence with the River Almond.

The River Almond and East Pow Burn are part of the extensive River Tay Special Area of Conservation (SAC), approximately 9500ha, which is designated for Atlantic salmon *Salmo salar*, river lamprey *Lampetra fluviatilis*, brook lamprey *Lampetra planeri*, otter *Lutra lutra* and oligomesotrophic standing water.

The River Almond supports a high quality salmon population and the Tay is one of the top three Scottish salmon rivers. It is likely that the River Almond supports lamprey species. The SAC supports the European protected species, otter and is also important as it contains oligotrophic and mesotrophic standing-waters that support rare aquatic macrophytes, however the Almondbank area is unconnected with this aspect of the Tay's ecology.

Approximately 1.5 km east of the study area there is a geological SSSI (Almondbank SSSI, NO084262, 0.96 ha in size). The proposed scheme will not have any material direct or indirect impact on this site due to its geological nature and its distance away from the study area.

2.3 Study Area Description

The study area is centred at National Grid Reference (NGR) 306,890E, 725,628N.

The land adjacent to the two watercourses is generally level, low lying land and is occupied by both commercial and residential developments. The banks of the River Almond are generally between 1m and 2m high (with the exception of the bank opposite Waterside Cottages at 5m high), measured from river bed level, with the banks of the East Pow Burn generally between 0.5 and 1.5m high. The width of the River Almond varies between 20m and 60m and the width of the East Pow Burn varies between 3m and 6m.

To the upstream extents of the River Almond, within the study area, there is a combination of residential and commercial developments. Bridgeton Brae and Main Street consist of mainly residential property, with some small commercial premises. The College Mill Trout Farm provides the most northerly commercial development

affected by the flooding. To the left bank of the River Almond, there are small areas of residential development including Deer Park and Craigneuk East and West. The former Ministry of Agricultural, Farming and Fisheries site is a large commercial development consisting of large warehouses behind Druid's House, to the north of Craigneuk East & West.

The bulk of the commercial development can be found on the left bank of the East Pow Burn where Vector Aerospace (formerly the Defence Aviation Repair Agency and before this the Ministry of Defence) and Lochty Industrial Estate are located. Residential development can be found on the right bank of the East Pow Burn at Lochty Park, at the southern end of Main Street towards the A85 Road Bridge.

North of Vector Aerospace and on the right bank of the River Almond a public footbridge and recreational area occupies the space between commercial and residential properties on Main Street. East of the confluence with the East Pow Burn on the right bank of the River Almond, Low's Cottages, Almond Grove and Huntingtower residential developments are located, with agricultural land dominating the landscape further downstream.

2.4 Flooding Background

Almondbank has been subject to a number of extreme fluvial flood events, the first being recorded in January 1909 with two of the more recent and most extensive flood events being recorded in the town in January 1993 and again in September 1999. The most recent notable flood event occurred in January 2011, during the development of the outline design.

The January 1993 flood was estimated at the time to be approximately a 1 in 100 year event and resulted in significant flood damage to many properties. Since then, the Scottish Environmental Protection Agency (SEPA), using 30 years of available flow data, have re-assessed this event to be more in the region of a return period of 1 in 40 years.

The SEPA Indicative Flood Map in Figure 2 shows the areas estimated by SEPA to be at risk of flooding from rivers within the study area if there are no flood defences. This is an estimate of the areas with a 0.5% (1 in 200) or greater probability of being flooded in any given year.

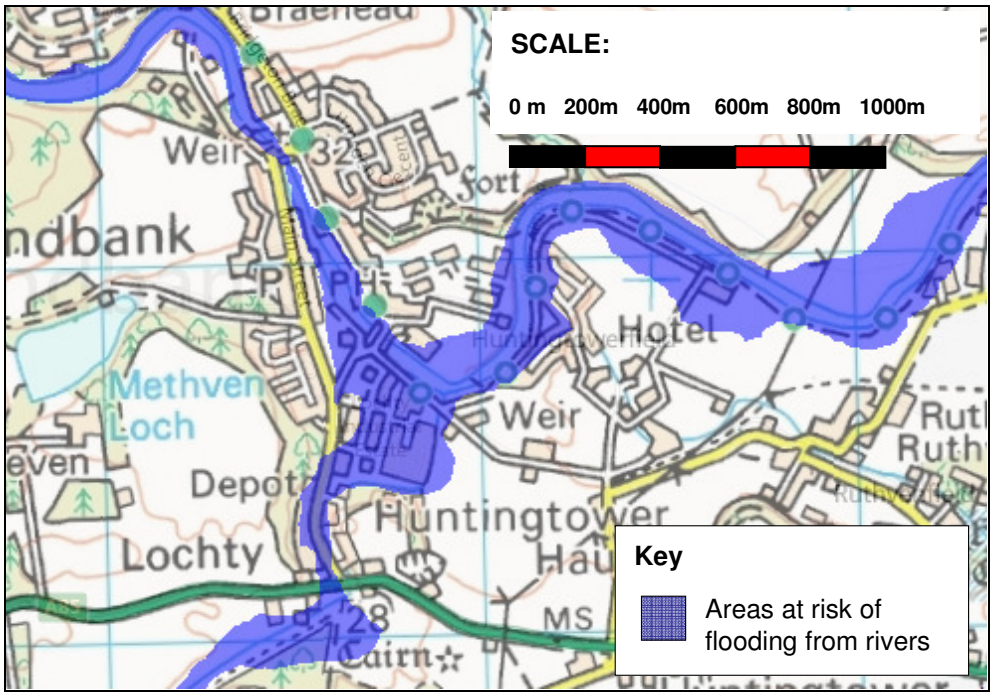

Figure 2 - SEPA's indicative 1 in 200 year undefended flood outline

A more recent flood event was recorded during January 2011. This event was of a much lesser magnitude, but did cause localised damage to the watercourses. Flooding in January 2011 occurred mainly from the East Pow Burn which has no flow or level gauge on it; it is therefore difficult to make an accurate assessment of the return period of this event. However an estimate from anecdotal information was made of between a 1 in 5 year and a 1 in 10 year return period event.

Damages as a result of the 1993 flood event included the inundation of College Mill Trout Farm, the Perth Town Lade intake and the Vector Aerospace site. In addition to the inundation of the commercial premises and lade[1], a number of residential properties (namely Brockhill and some of Low's Work Cottages) were subject to flood waters within their property or within their property boundaries. The Playing Fields just downstream of the College Mill Trout Farm on the opposite bank and an area of land just upstream of Lochty Park Road Bridge on the East Pow Burn were also flooded. The extent of the flood waters on the River Almond was such that the double arched stone road bridge (Black Bridge) located adjacent to the playing field was washed away during the event.

The 1999 flood event is deemed to be of a similar magnitude to the 1993 event (most recently estimated to be between a 1 in 43 year event by SEPA) with damages as a result of flooding noted again at Vector Aerospace, Brockhill and the College Mill Trout Farm, with very high water levels witnessed along the river bank at Deer

[1] The term 'lade' references a man made channel used for conducting water from the watercourse.

Park. The replacement River Almond Footbridge adjacent to the playing field was observed to have had trees located against the upstream side, having been washed down the River Almond from further upstream.

Downstream of the study area, the River Almond feeds into the River Tay, just north of Perth. Further to flood events in 1990 and 1993, works were completed in 2001 on the River Tay flood defences in the centre of Perth. These defences were constructed to protect Perth from a 1 in 200 year fluvial flood event and a coinciding 1 in 100 year high tide. The River Tay defences consist of flood walls and embankments, sluice gates, raised ground levels, outfalls, new drainage ponds, pumping stations and culvert improvements.

The main River Tay defences extend along the River Almond from its confluence with the River Tay to approximately 150 metres downstream of Waterside Cottages (see Figure 3). In addition, a small masonry flood wall was constructed adjacent to the sluice at Low's Work Weir (a grade B listed structure[2]) in Almondbank.

Repairs were completed on The Low's Work Weir in August 2012, reinstating it to full working order, complete with a low flow channel and a fish pass.

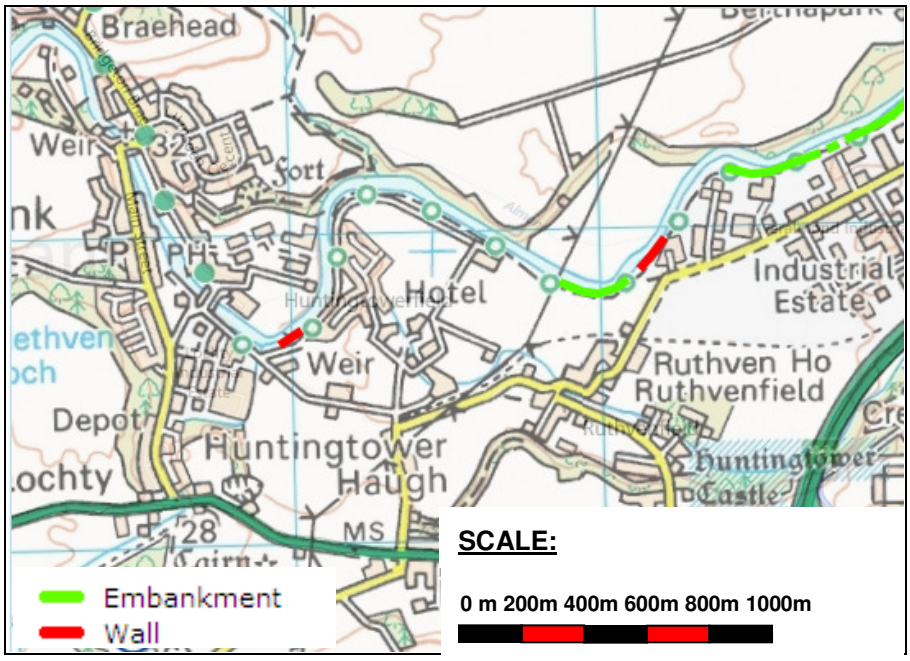

Figure 3 - SEPA map showing the existing Almondbank and River Tay flood defences. [3]

[2] This building is in the Perth And Kinross Council and the Tibbermore Parish. It is a category B building and was listed on 05/10/1971. It's reference is 18304. Mediaeval, rebuilt 1622-4. 80 yards long, unmortared boulder rubble with ashlar groins. Formed to divert water into the King's Lade through Perth.

[3] © 2013 Microsoft Corporation © NAVETQ © AND © 2010 Intermap. Some features of the flooding map are based on digital spatial data licenses from the Centre for Ecology and Hydrology ©CEH, ©MO, ©NSRI, ©MLURI, ©OSNI, ©DARD(NI), ©Defra and includes material based on Ordnance Survey 1:50,000 maps with permission of the controller of Her Majesty's Stationery Office ©Crown Copyright. © SEPA 2010 ALL RIGHTS RESERVED.

The January 2011 flood event was the result of high flows along the River Almond, as a result of snow thaw, causing localised erosion along both banks of the River Almond. Flooding occurred on the East Pow Burn and affected Lochty Park and Vector Aerospace.

2.5 Previous Studies

Prior to Mouchel being appointed, previous studies and investigations have been progressed and delivered by a number of other consultants.

2.5.1 Babtie Group

Following the 1993 flood event, the Babtie Group was appointed to undertake a flood study on the River Almond and East Pow Burn, culminating in the submission of their report in February 1994. The Babtie Group constructed a mathematical model of the River Almond and the flows predicted in the model for the 1 in 200 year event were taken forward to form the basis for the design of a proposed flood scheme. This model was not made available to Mouchel.

2.5.2 Ove Arup and Partners

Further to Babtie Group's report, Ove Arup and Partners were commissioned to produce a cost benefit analysis report which concluded that the cost benefit for the scheme was too small and therefore the scheme could not be justified.

2.5.3 Babtie Group

Following the 1999 flood event, where a similar magnitude of flow to the 1993 event was experienced, the Babtie Group were again appointed to review the previous investigations and re-assess the economic viability of the scheme. Their work further developed the scheme and re-calculated the cost benefit ratios for the River Almond and East Pow Burn and found the developed scheme proposals to be economically viable.

2.5.4 Royal Haskoning

In 2003, further to Babtie Group’s findings, Posford Haskoning (now Royal Haskoning) was appointed to promote a 1 in 200 year flood prevention scheme for Almondbank. The 1 in 200 year standard of protection was adopted to take account of the 1 in 100 year event plus an allowance for the effects of climate change, based on research on climate change published by the Scottish Executive (2001).

As part of Royal Haskoning’s work, a topographical survey was completed in April 2003. A preliminary site investigation (6 boreholes to a maximum depth of 4m) was carried out at the same time to provide initial geotechnical information, including testing for any potential contamination on the site. Royal Haskoning also built a new hydraulic model (for the East Pow Burn), using the HEC-RAS software, that showed that the existing bridge structures crossing the watercourses were causing major flow constraints in flood events and would need to be elevated in order to mitigate this scenario.

In 2004, Royal Haskoning presented a proposed scheme consisting of a combination of flood defence walls and earth embankments to provide flood protection to local business and residential property. Further to calculation of damages and the expected scheme cost, the scheme was shown to be cost beneficial and recommendations were made that the scheme progressed.

In September 2007 Mouchel were appointed to progress this scheme and tested it in their hydraulic model. It was evident that in high flow events that the Royal Haskoning scheme failed at a number of locations and therefore improvements to this scheme needed to take place before it could be progressed.

2.6 Project Brief

The recommendations to progress the scheme made in Royal Haskoning's report of 2004 formed Mouchel's brief for developing the scheme when initial instruction was received by Mouchel to commence in September 2007, from Perth & Kinross Council. The scope of work has developed as the flood protection scheme has progressed and has incorporated;

- A comprehensive review of all available data including the review of all of the previous consultants reports and hydrological and hydraulic models,
- A thorough review to investigate possible alternative options to those already presented,
- Engaging in public and stakeholder consultations during the initial stages of Mouchel's commission and throughout the development of the scheme,
- Development of a 1 and 2 dimensional (1D & 2D) hydrological and hydraulic model, for which, some topographical survey work was required,
- Assessing the proposed scheme in the 1D & 2D model to ensure its robustness,
- Further development of the scheme to protect Almondbank from the risk of fluvial and surface water flooding and making recommendations for the preferred solution,
- Supporting Survey and Investigation Work including;
    - Additional Topographical Surveys
    - Structural Appraisals,
    - Geotechnical Investigations,
    - Surface Water Drainage assessment,
    - Fluvial Geomorphological assessment,

- Screening Opinion and ecological survey work.

- Development of the outline design including the preparation of the scheme drawings,

- Economical Appraisal,

- Preparation of the Environmental Statement,

- Preparation of the Flood Order Submission under the Flood Risk Management (Scotland) Act 2009.

2.7 Project Objectives

In order for the developed scheme to be viable it must;

- Reduce the risk of flooding to the town of Almondbank (for the design event[4]), from the River Almond and the East Pow Burn, to the people, property and local infrastructure of the town,

- Provide an economically viable solution, by comparing the total expected benefits with the total expected costs and determining if the benefits outweigh the costs and by how much,

- Provide a technically sound and sustainable flood protection scheme that can be constructed, maintained and operated, ensuring the health and safety of the people it protects, whilst having minimal impact on its immediate environment both during construction and also on completion and throughout its operational life.

[4] Derivation of the Design Standard of Protection is referenced in Section 5.5.1 of this report.

3 Flood Management Options Review

A comprehensive document review of the all the previous studies was completed by Mouchel. All available documentation was provided to Mouchel by Perth & Kinross Council. A comprehensive list of these documents can be referred to in Appendix A.

Further to the review of the existing documentation, Mouchel undertook to investigate possible alternative options to those already presented. Up to this point, no alternative options other than traditional flood defences (i.e. permanent engineered flood walls or embankments) had been assessed.

3.1 Alternative Options Appraisal

The options appraisal considered the information presented in the previous reports together with observations made on site, to investigate the feasibility of alternative flood defence options. The assessment of these alternatives included reference to site topography, flow regimes, observed features both within and adjacent to the watercourses, environmental impact of proposed solutions and financial implications. Where required these alternative proposals were confirmed with simple calculations and hydraulic modelling.

The flood management options considered are summarised below and can be found in more detail in Mouchel's report[5].

3.2 River Almond Flood Management Options

3.2.1 River Almond Flood Diversion Channel

The possibility of using a diversion channel was investigated, to avoid the peak river flood flows passing directly through the centre of Almondbank. The route that appeared possible was a diversion from downstream of Cromwell Park, to upstream of the centre of Almondbank, diverting via a channel to a smaller, un-named water course that flows around the north-east of Almondbank, discharging into the River Almond downstream of the Almond Valley Village Development.

This option presented some major difficulties as a result of a difference in ground level between the two watercourses of between 10 and 20m and the requirement for some sizeable excavations. To overcome this would require costly engineering works to be undertaken. The capacity of the receiving water course in the discharge location would need to be sufficient to accommodate the flows and without significant

[5] "Almondbank Flood Management Options Report," produced by Mouchel Parkman on behalf of Perth & Kinross Council in March 2006

works to improve this, the small village of Pitcairngreen would be put at risk from flooding.

3.2.2 River Almond Online Storage

Online storage could be provided by the creation of a restriction in the river channel, forcing flow to back up into a suitable 'engineered' feature. It was estimated that any online storage scheme would need to have a very large capacity resulting in a significant plan area in order that flooding downstream could be eliminated.

The online storage scheme would need to be controlled by a water retaining structure built across the valley floor, allowing a safe flow to be passed forward whilst retaining any excess flows. It was recommended that this option should be discounted on the grounds of cost; as such a structure would need to be capable of retaining a depth of water in the order of 20m, whilst still passing forward a significant flow.

3.2.3 River Almond Offline Storage

The topography of the River Almond catchment does not present many sites suitable for offline storage schemes within the study extents. The most obvious sites are at the downstream end of Almondbank, where the valley begins to open out. Unfortunately these sites have either been developed already or are too far downstream to prevent flooding in Almondbank itself. A viable storage area has been identified in the upstream section of the scheme extents at the Playing Fields on the right bank of the River Almond. This option is further pursued in Section 6, Flood Protection Options.

3.2.4 River Almond Flood Embankments and Walls

A simple solution to the flooding problems was to study the flood paths and build appropriate defences to prevent these paths being operated (this is the approach taken by Babtie Group in previous studies). Through hydraulic modelling of the catchment, it was possible to see the extents of the required flood defence walls and this solution represents a viable option to provide flood defences to the centre of Almondbank.

3.3 East Pow Burn Flood Management Options

3.3.1 East Pow Burn Diversion Channel

As the East Pow Burn flows into the River Almond through Almondbank, the options for a flood diversion channel are limited. One consideration was to divert flow around the Low's Work Weir and avoid some of the problems associated with flow backing up in the East Pow Burn, however, the line of the Perth Town Lade (the small channel running off from Low's Work Weir), inhibits this option. Hydraulic modelling also confirms that the diversion channel at this location does not considerably reduce river levels. Refer to 6.2.2 for option details.

3.3.2 East Pow Burn Online Storage

The geometry of the East Pow Burn lends itself to small online storage options being implemented along the channel and it would be possible to build small constrictions to allow flows to back up within the channel. The feasibility of this proposal was tested by Mouchel using Royal Haskoning's HEC-RAS model to establish how effective such a scheme would be.

As the River Almond yields the predominant flows, flooding along the main river channel will not be alleviated by a storage scheme on the East Pow Burn, but it was necessary to establish whether the flooding at the downstream end of East Pow Burn would be eased by reducing flows with an online storage scheme.

The minimal reduction in the flood defence extents as a result of introducing the online storage identified that this option would be unjustifiable. Regardless of any upstream storage on the East Pow Burn, the River Almond flood flows will govern flood depths to the downstream section of the East Pow Burn.

As there remains the requirement to construct separate flood defences at the downstream end of the East Pow Burn, adjacent to the confluence with the River Almond, by inspection it was apparent that online storage option on the East Pow Burn would not be prove to be economically viable.

3.3.3 East Pow Burn Offline Storage

The most obvious location for an offline storage area, within the study area, is the agricultural land on the right bank towards the downstream end of the East Pow Burn. This option is included in Royal Haskoning's proposals although the area identified for the flood storage area requires significant land take and was later discounted by Mouchel. As with the online storage option for the East Pow Burn, in addition to the offline storage area investigated, there is still the requirement to construct flood defences at the downstream end of the East Pow Burn, as flood levels in this section of the East Pow Burn are governed by flows in the River Almond.

3.3.4 East Pow Burn Flood Embankments and Flood Walls

Due to the backing up of flow at the downstream end of the East Pow Burn, the construction of flood embankments and flood walls are, on balance, the best course of action for the East Pow Burn. This would allow flows to be retained within the channel and presents a viable option to provide flood defences to the town of Almondbank.

3.4 Recommendations

Mouchel's Flood Management Options Report concluded that the recommendations of Royal Haskoning's latest work, presented an appropriate and economically viable scheme to protect the risk of flooding to the town of Almondbank. Mouchel

recommended a single off line storage area on the upstream section of the River Almond (rather than the two proposed by Royal Haskoning) and a combination of flood embankments and flood walls along the banks of the River Almond and the East Pow Burn be carried forward to outline design.

Further to this recommendation, it was concluded with Perth & Kinross Council that it was an appropriate stage in the project to formally consult with the local community on the scheme proposals and therefore a Public Consultation exercise was carried out, this is reported in the following section of the report.

4 Public Consultation (2008)

Previous consultants involved with the scheme had carried out some individual consultation with local residents at risk of fluvial flooding. Following Mouchel's review of the existing documentation and the potential scheme options, Mouchel were asked by Perth & Kinross Council to consult more widely on the proposed scheme.

4.1 Residents Meeting and Public Exhibition (2008)

Further to the conclusions of Mouchel's Flood Management Options Report the flood protection scheme, as developed by Royal Haskoning, was formally presented to the local community.

A Resident's Association meeting was held in St Serf's Church, Almondbank on 23rd January 2008 and this was followed by a public exhibition that took place on 30th January 2008 at the Bowling Club in Almondbank. These events allowed the public to view and comment on the proposed Flood Protection Scheme, with approximately 100 members of the Almondbank community in attendance during these 2 events.

The local community recognised the need for the flood scheme and were generally in favour of the proposals.

4.2 Local Community Feedback (2008)

Mouchel's Public Consultation Report[6] documents the details of these consultations and presents all of the feedback received. The major concerns from the local community were focused on the following key issues presented in Figure 4 below.

- A number of consultees were concerned that areas beyond the extents of the presented scheme may be worse affected by flood waters once the scheme was implemented,
- Concerns were expressed regarding the height, extent and potential impact of the proposed defences,
- A number of comments were received concerning the current level of erosion along the watercourses, particularly the section of the River Almond adjacent to the Bowling Club,
- There were some concerns regarding the extent of tree loss in order to accommodate the proposed scheme,

[6] "Almondbank Flood Mitigation Scheme, Public Consultation Report," produced by Mouchel on behalf of Perth & Kinross Council in May 2008

- Some consultees stated that the Royal Haskoning modelled extents of the flood water presented at the consultation were inaccurate.

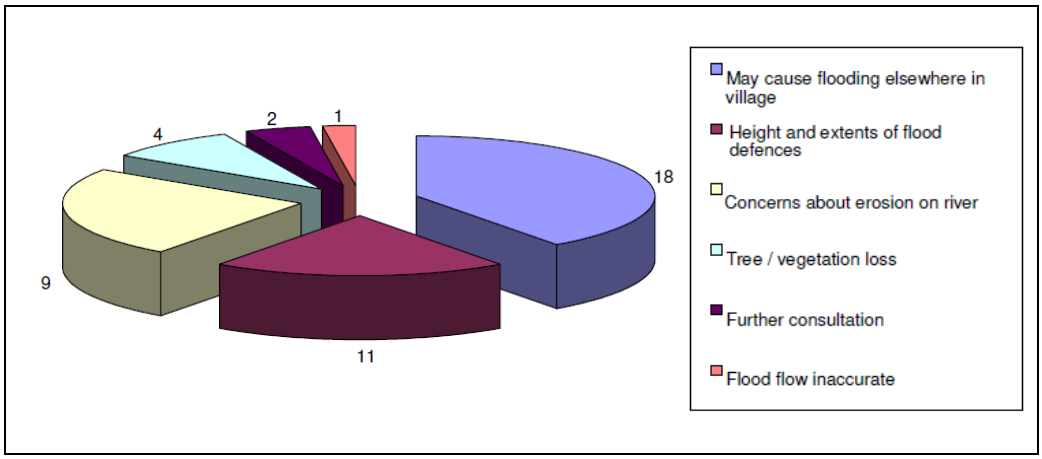

Figure 4 – Local community concerns (2008)

4.3 Post Consultation Actions (2008)

All feedback received during the consultation process was reviewed by Mouchel with Perth & Kinross Council and a response prepared and presented in Mouchel's Consultation report.

With reference to the key issues listed above, the following key actions were identified in order to develop the flood protection scheme;

- Perth & Kinross Council instructed Mouchel to carry out a complete hydraulic river modelling exercise, to more accurately assess the flood water extents, both within and adjacent to the watercourses,

- On completion of the hydraulic model build, Mouchel were to assess the suitability of the proposed scheme, as presented to the local community during the public consultation,

- Mouchel were to progress any additional works (surveys, investigations, assessments, calculations) and any further consultations required to develop the outline design to a suitable level of detail for submission under the Flood Management (Scotland) Act 2009.

5 Fluvial Hydrological and Hydraulic Modelling

5.1 Previous Work

Earlier studies undertaken by other consultants had produced hydraulic models in differing versions of software. Babtie Group had undertaken modelling on the River Almond, using their in-house software "Floodtide" ("Floodtide," software was not available to Mouchel as it is generally only used in-house by the Babtie Group, who were bought by consultants Jacobs in 2004). Royal Haskoning adopted these results and developed a hydraulic model for the East Pow Burn, in Hec-Ras software.

As the previous modelling work was in different forms and were not all available for interrogation during this study, Mouchel developed a new combined hydraulic model in ISIS one dimensional (1D) and TUFLOW two dimensional (2D) software.

5.2 Data Collection

A number of site visits were made to the study area to gain a better understanding of the flooding mechanisms and locations. A review of historic flood events was undertaken using documented evidence and photographs, in conjunction with speaking to members of the local community and Perth & Kinross Council.

In order to develop a more comprehensive hydraulic model, Mouchel undertook a more detailed topographical survey of the floodplain and property threshold levels and a river cross section survey.

Hydrometric data was collected from SEPA, including;

- Peak flows measured at SEPA's river gauge located immediately upstream of the River Almond Footbridge. This data was used in the hydrological model,
- Flow and level data and a rating curve for the River Almond gauge, measured at SEPA's river gauge. This data was used to verify the hydraulic model.

5.3 Hydrological Analysis

Mouchel undertook a hydrological assessment to determine the inflows for the hydraulic model. Four watercourses relevant to this study were identified from the Ordnance Survey (OS) map and the Flood Estimation Handbook (FEH) CD-ROM 2; the River Almond, the East Pow Burn, Methven Loch and Gelly Burn.

The River Almond at Almondbank has a catchment area of 172km^2, just upstream of the Bridgeton Road Bridge along Main Street in Almondbank. The catchment is mainly rural, and starts from the mountains of Ben Chonzie, west of Almondbank. The East Pow Burn has a catchment area of 48.4km^2, located to the southwest of Almondbank. The catchment is more urbanised than the River Almond.

The River Almond is the watercourse with the highest flow and the East Pow Burn has the second largest flow. The Gelly burn is a small watercourse which discharges into the River Almond whilst the Methven Loch is a catchment area, from which surface water will flow into the River Almond. The latter two catchments are significantly smaller than the catchments of the River Almond and the East Pow Burn and flows coming from these have simply been modelled as point inflows into the River Almond.

In agreement with SEPA, two methods were used by Mouchel for the hydrological analysis of the two major watercourses (the River Almond and the East Pow Burn), the FEH rainfall runoff method and the FEH statistical method. Both of these methods are suitable for large to medium size catchments and are widely used in Scotland.

During the study period, consultation with SEPA has resulted in a conservative approach to the hydrology. Further details relating to this consultation and details of Mouchel's hydrological calculations are documented in Mouchel's Hydraulic Modelling Report.[7]

5.3.1 FEH Rainfall Runoff Method

The FEH rainfall runoff peak flows and hydrographs were generated using ISIS software and the FEH catchment descriptors from the FEH CD-ROM 2. The FEH rainfall runoff flows at each respective inflow to the hydraulic model are presented in Table 1.

Return period (years)	River Almond (m^3/s)	East Pow Burn (m^3/s)	Gelly Burn (m^3/s)	Methven Loch (m^3/s)
10	134	25.5	1.56	0.50
50	190	36.9	2.30	0.70
100	215	42.0	2.58	0.84
200	245	47.9	2.95	0.97

Table 1 - Peak flows derived using FEH rainfall runoff method for the four catchments

Due to the minor flows from the smaller catchments of Gelly Burn and Methven Loch, it was considered that the figures derived using the FEH rainfall runoff method provided a sufficiently accurate assessment of flows for theses catchments and it was not necessary to apply the FEH statistical method.

[7] "Almondbank Flood Mitigation Scheme, Hydraulic Modelling and Option Assessment Report," produced by Mouchel for Perth & Kinross Council in April 2012.

5.3.2 *FEH Statistical Method*

The two largest catchments of the River Almond and the East Pow Burn contribute the vast majority of flows in Almondbank and their flows were also assessed using the FEH statistical method.

The FEH statistical method calculated Q_{med}, (Median annual maxima flood; it has a return period of two years) from the AMAX series (annual maximum gauged flow) from SEPA's gauge located upstream of the River Almond Footbridge, for the River Almond catchment. The River Almond flows derived by Mouchel and the flows derived by SEPA, and provided to Mouchel, for the purpose of this study, are compared in Table 2.

Return Period (years)	SEPA Flow (m^3/s)	Mouchel Flow (m^3/s)	% Difference
10	174	182.3	-4.6
50	240	230.8	4.0
100	273	250.0	9.2
200	311	268.4	15.9

Table 2 - Comparison of River Almond flows derived using the FEH statistical method by Mouchel and SEPA

Mouchel were provided with Q_{med} values during the ongoing liaisons with SEPA. Detailed calculations were not made available and no review of the methods used to derive these figures was undertaken.

The differences in the flows calculated by SEPA and Mouchel, as presented in Table 2, could be as a result of there being a number of methodologies available to derive Q_{med} values. Mouchel used the gauge data provided by SEPA to calculate their Q_{med} values although these values can also be calculated from the FEH catchment descriptors or taking an estimate of channel capacity.

Differences in the catchments used as part of the pooling group could account for the difference between Mouchel's and SEPA's flow values. Catchments which can be incorporated into the pooling group can vary as long as they fall within the required criteria for the pooling group analysis. These different growth curve values result in the different flows shown above. The difference in Mouchel's and SEPA's flow values can be shown to increase as the return period event increases.

Mouchel calculated the FEH statistical flows for the East Pow Burn using a donor gauge, matching the relevant criteria in order to estimate flows for a range of return period flows, these are presented in Table 3.

Return Period (years)	Mouchel Flow (m^3/s)
10	21.0
50	30.7
100	35.8
200	41.5

Table 3 - East Pow Burn flows derived using the FEH statistical method by Mouchel

5.3.3 Summary of Hydrological Analysis

The estimated flows for the 1 in 200 year flood return period event (as these flows are critical for the proposed flood protection solutions) are summarised in Table 4.

Watercourse	Catchment area (km^2)	FEH Rainfall Runoff (m^3/s)	FEH Statistical (m^3/s)		Flows adopted (m^3/s)
			SEPA	Mouchel	
River Almond	172.2	245	311	268.4	311
East Pow Burn	48.4	47.9	-	41.51	41.51
Methven Loch	0.6	0.97	-	-	-
Gelly Burn	1.8	2.95	-	-	-

Table 4 – Estimated flows for the 1 in 200 year flood event

5.3.4 SEPA Consultation

As a conservative approach is preferred when assessing potential flood protection solutions, it was agreed with SEPA that Mouchel would adopt and take forward SEPA's statistical flow estimates for the River Almond ($311m^3/s$) as the design flow. In consideration of the East Pow Burn flows, based on comparison with flows estimated in previous studies and further to consultation with SEPA, the estimated FEH Rainfall Runoff flows were considered overly conservative and the FEH Statistical flows estimated by Mouchel were adopted ($41.51m^3/s$) as the design flow.

5.4 Hydraulic Model Development

5.4.1 Hydraulic Model Software

The combined hydraulic model was developed using the two software packages ISIS and TUFLOW.

ISIS (version 3.0.0.27) provides the one dimensional element of the model and can be linked with TUFLOW. The one dimensional element of the model (ISIS) includes the river in channel cross sections and also the hydrological inputs. The one dimensional hydraulic river model of the two main watercourses was built in order to accurately assess the water levels in these watercourses.

TUFLOW (version 2007-07-BF) provides the two dimensional element to the model to simulate overland flow and incorporates ground levels and features. A two dimensional hydraulic model of Almondbank was built by Mouchel in order to simulate flow paths, depths and velocities of flood water once they over top the river banks. In addition it has also been used to determine the effect on river levels which would be caused by the proposed flood protection measures in Almondbank.

5.4.2 Hydraulic Model Extents

The one dimensional component of the combined hydraulic model developed by Mouchel commences at Braehead Cottage (sufficiently upstream of the study area to be able to model the impact on upstream water levels) and extends 2940 metres along the River Almond to approximately 500m downstream of Waterside Cottages (sufficiently downstream of the study area to be able to model the impact on downstream water levels). Included in the same model is the East Pow Burn, extending 50 metres upstream of the A85 Road Bridge at Lochty Park to it's confluence with the River Almond.

The two dimensional components of the combined hydraulic model are reduced (by 350 and 400 metres up and downstream respectively on the River Almond and 50m upstream on the East Pow Burn), as the main purpose of the two dimensional model is to model flow paths and flood depths through the town and did not need to include reaches along the watercourses which extend outside of the town.

5.4.3 Hydraulic Structures

There are two bridges and two weirs on the River Almond and there are five bridges on the East Pow Burn within the extents of the combined hydraulic model. All of these structures have a hydraulic impact on the water levels of the watercourses and have been incorporated in the hydraulic model. The location of hydraulic structures and direct inflows to the model are shown in Figure 5.

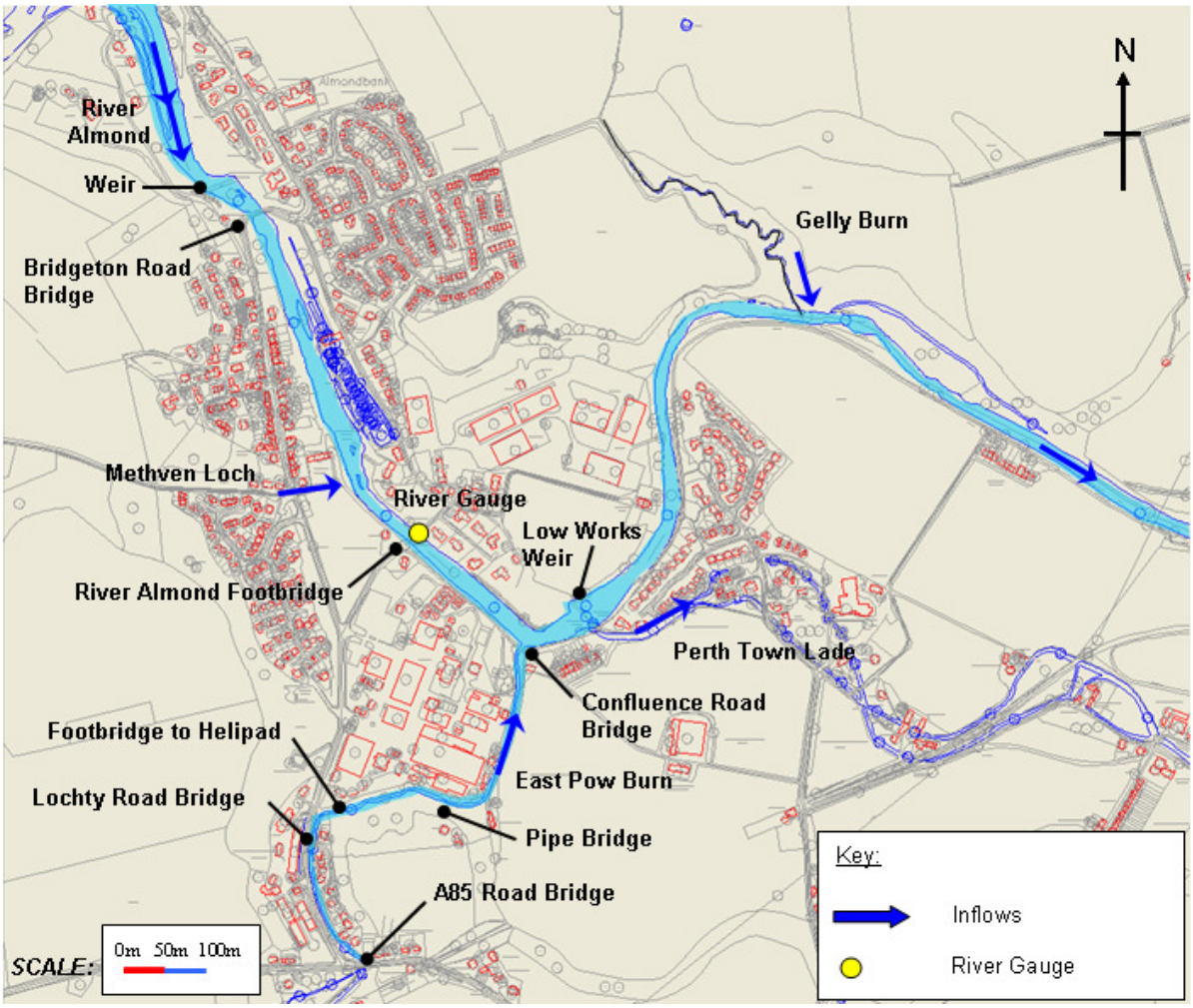

Figure 5 - Location of hydraulic structures and direct inflows to the model

5.4.4 *Manning's Roughness Values*

Manning's roughness is the parameter that affects water velocity and water levels in a river channel and defines the roughness of a river channel and floodplain. Its value depends on the surface material and is subject to seasonal variations. Manning's roughness values are often subjective and fall within an acceptable upper and lower range for a given section of watercourse based on its physical characteristics.

The Manning's roughness values in the River Almond and the East Pow Burn were initially estimated using the CES (Conveyance Estimation System). This approach takes into account the river profile and provides estimated roughness values for the river bed and river sides. The Manning's values were reasonably uniform along the respective study reaches of both the River Almond and the East Pow Burn.

Manning's values along the study reaches of the River Almond channel were initially assessed to fall within a range of 0.031 and 0.049 as these are typical of the characteristics of the River Almond;

- An average value of 0.040 was selected for the length of the River Almond channel downstream of the Bowling Green,

- A higher value of 0.055 was initially used for the length of the River Almond channel upstream of the Bowling Green as this river reach has more vegetation and irregularities (including larger than average stones) in the river channel,

- A value of 0.08 was used for the River Almond island cross sections (located adjacent to the College Mill Trout Farm, the Playing Field and next to the Gelly Burn outfall), as these localised islands constitute a build up of gravel, shingle and silt and act as obstructions to flow. The same value of 0.08 was also used for the banks of the River Almond.

Further to assigning the initial Manning's values, the hydraulic model's flow / stage relationship was compared with SEPA's rating curve at the location of the River Almond Footbridge. This comparison indicated that some of the estimates using the CES were too high and were therefore two were reduced accordingly to provide a closer match with SEPA's rating curve;

- A reduced value of 0.035 was selected for the length of the River Almond channel downstream of the Bowling Green,

- A reduced value of 0.045 was selected for the length of the River Almond channel upstream of the Bowling Green,

- A value of 0.08 was maintained for the River Almond islands and the banks.

After reducing the Manning's roughness values, the hydraulic model's time / stage relationship was also compared with two large events recorded at the gauge (January 1993 and September 1999). The comparison showed that the hydraulic model produced a good match with the recorded data at the SEPA gauge for both events.

As no gauge data is available for the East Pow Burn, the Manning's values were estimated using the CES method. Without gauge data or other reliable anecdotal flooding information available for the East Pow Burn to verify this model reach, these values are assessed to be conservative, including an allowance for seasonal variations.

The estimated values for the main channel fell within a range of 0.026 and 0.042 and the estimated values for the river banks fell within a range of 0.045 and 0.057;

- A value of 0.042 was selected for the channel of the East Pow Burn,

- A value of 0.057 was selected for the banks of the East Pow Burn.

The reduced Manning's values were used for the 'Do Minimum' and 'final outline design' model scenario's, with accordingly adjusted (increased by 20%) values used for the 'Do Nothing' model scenario. The 'Do Minimum' scenario assumes that maintenance is carried out to maintain the current condition of the watercourses. The 'Do Nothing' scenario assumes that no maintenance is carried out on the watercourses and that vegetation is allowed to flourish and any structures are allowed to deteriorate.

5.4.5 Critical Storm Durations

The critical storm duration is the duration of a rainfall event in a particular catchment resulting in the highest peak flow in the response hydrograph producing maximum water levels. For any given storm the duration is unlikely to coincide exactly with the critical storm durations of each catchment and water levels would not be as high as the water levels which have been modelled, thus this is a conservative assessment.

Critical storm durations have been modelled in both the River Almond and the East Pow Burn; the critical storm duration for the River Almond Catchment is modelled at 17.25 hours and the critical storm duration for the East Pow Burn catchment is modelled at 15.25 hours.

For the Gelly Burn and Methven Loch catchments, the same storm duration as the River Almond catchment (17.25 hours) has been used to ensure their contributing peak flows coincide with the peak flows in the River Almond as a conservative approach.

5.4.6 Downstream Boundary

At the downstream end of the 1D component of the hydraulic model, the downstream boundary has been based upon a normal depth curve derived from the gradient and cross sectional data at this location.

A sensitivity analysis was undertaken on the level of the downstream boundary to assess potential effects on the upstream water levels. The levels in the downstream boundary normal depth curve were increased and decreased by 0.5 metres to assess what effect this would have on modelled water levels upstream. Results show local variations at the downstream boundary but no propagation into the study area upstream.

The highest water levels recorded at the River Tay were checked from previous studies to assess their potential influence on water levels along the River Almond in the study area. Based on the 1 in 500 year level in the River Tay (estimated to be 9.06 mAOD), the influence of the River Tay on levels upstream in the River Almond were found to be negligible[8].

[8] Report on Investigation of Flooding from River Almond Perth Flood Study by Babtie Group in Feb. 1994 for Perth & Kinross Council.

5.4.7 Verification

Mouchel have used a number of techniques to ensure the models accurately represent the flooding which occurs in the town. The 'Do Minimum' hydraulic model was used for the verification as this assumes the current condition of the watercourses is maintained.

5.4.7.1 Verification Events

The January 1993 and September 1999 events were used as verification events, as both events resulted in out of bank flooding of the town. The water levels recorded at SEPA's gauge on the River Almond were compared with model results and for both events, the modelled water levels compared favourably with the historical levels recorded at the gauge. Figure 6 shows the flood outline generated for the January 1993 verification event.

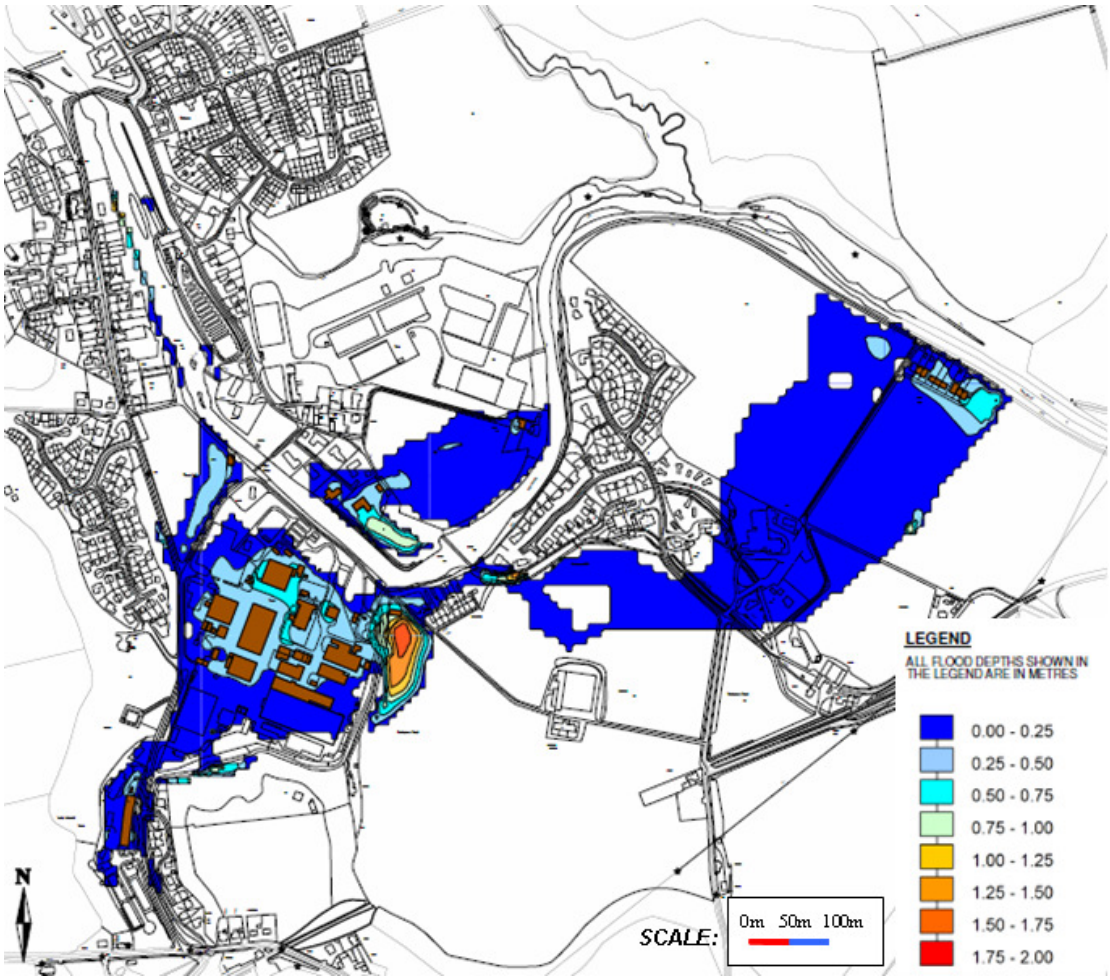

Figure 6 - Flood outline generated for the January 1993 verification event

During the January 1993 flood event, the River Almond Footbridge collapsed and obstructed the flows, resulting in a localised increase in water levels. This obstruction to the flows is likely to contribute to the slight under prediction (approximately 200mm) by the hydraulic model of the peak water level for that event. Figure 7 shows the flood outline generated for the January 1999 verification event.

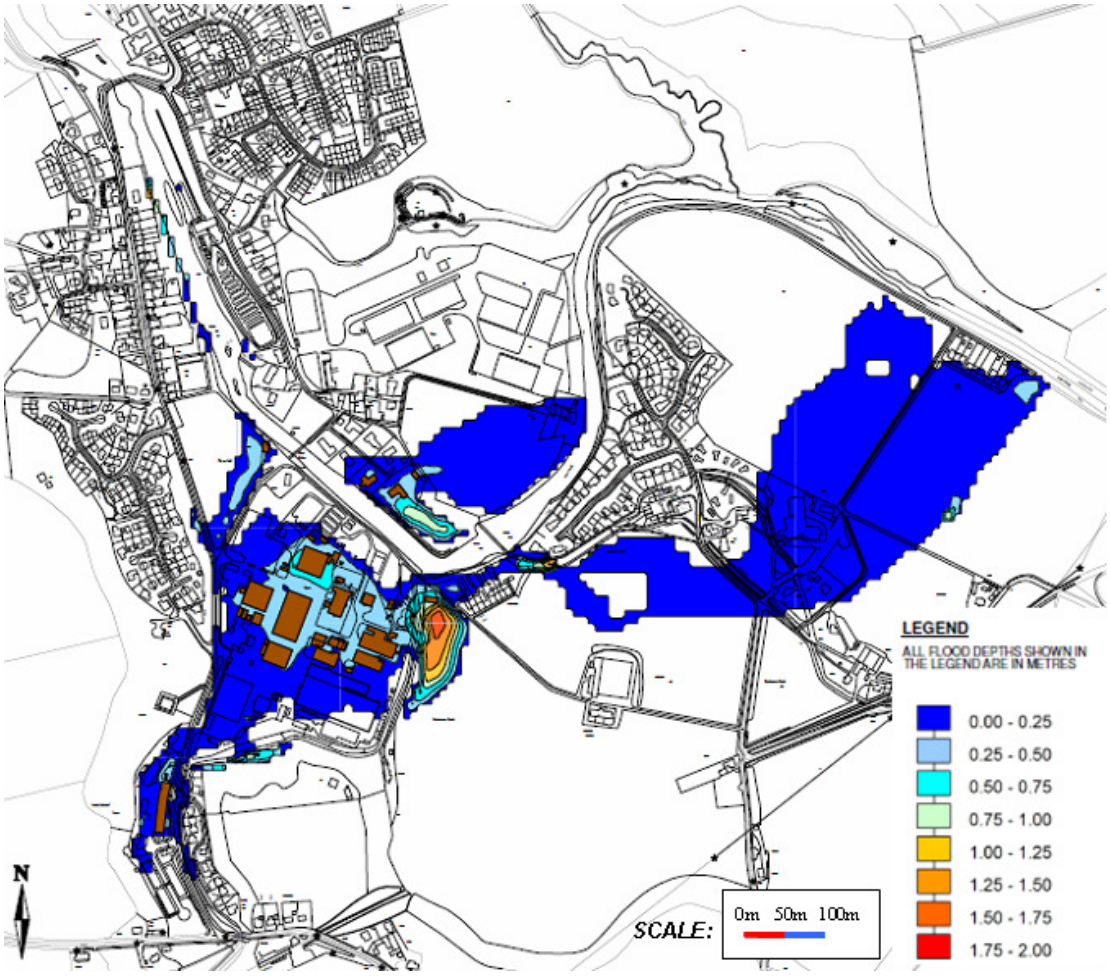

Figure 7 - Flood outline generated for the September 1999 verification event

5.4.7.2 Rating Curve of the SEPA Gauging Station

The only river gauging station within the study reach is located upstream of the River Almond Footbridge on the River Almond. As part of the model verification a comparison was undertaken of the modelled results and SEPA's rating curve.

To achieve a close match, the roughness values in the one dimensional component of the model were adjusted (as referenced in Section 5.4.4 of this report). The final Manning's values used were within a range which is realistic based on the physical characteristics of the river channels. As the adjusted roughness values provided a good match with SEPA's rating curve at the gauge, the same values were then applied upstream as far as the Bowling Green and also in the downstream reach of the model as the physical characteristics of the river channels were considered to be similar.

The highest water level from Mouchel's hydraulic model for the 1 in 200 year event differs from the SEPA rating curve by being approximately 300mm (7.9 %) higher. For high flow values, water levels calculated by the model tended to be conservative when compared to the SEPA rating curve.

5.4.7.3 Flooding Mechanisms

To support the verification of the hydraulic model, comparisons have been made between the model results and anecdotal evidence received from the local community in relation to flooding mechanisms within the study area.

One example of this verification confirms that flood water coming from the River Almond over the Playing Fields, flows into the Vector Aerospace site. At this point, the model also confirms that the onset of flooding at the College Mill Trout Farm is at the same point at which the Playing Field and Bowling Green begin to flood.

The flooding mechanisms produced by the hydraulic model matched the anecdotal information received from the local community, providing a good verification and confidence in the results of the hydraulic model.

5.4.7.4 SEPA Flood Extents

The flood outline generated with Mouchel's model for the 1 in 200 year event has been compared to the SEPA flood extents for the same design event as illustrated in Figure 8.

Mouchel's 'Do Minimum' modelled flood extents can be compared to SEPA's as they have both been modelled as an undefended scenario.

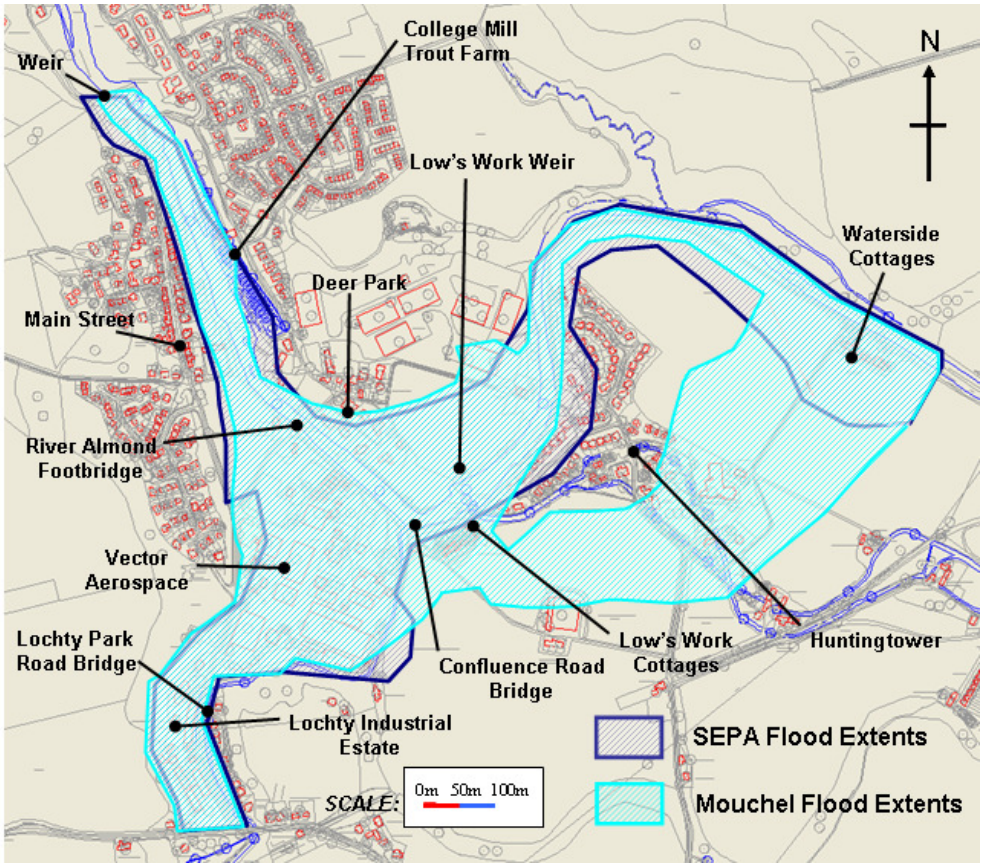

Figure 8 – Comparison of the SEPA and Mouchel undefended 1 in 200 year flood outlines

The two flood outlines are similar however, the flood outline produced by Mouchel will be a more accurate representation of the 1 in 200 year event than SEPA's strategic outline due to the enhanced accuracy of the ground levels and hydrological and hydraulic models used by Mouchel in this study.

5.4.7.5 Summary of Model Verification

Using the best available data, the model verification highlighted that the model provided a good representation of water levels and flood extents within the town of Almondbank. It was confirmed with SEPA (please refer to email in Appendix B) that the data used and the model verifications were suitable to develop the flood protection scheme, to test flood protection proposals and derive flood defence heights and volumes of storage and has been used to develop the flood protection solutions.

5.4.8 Sensitivity Analysis

A sensitivity analysis was undertaken using the verified model to assess potential changes in water levels occurring from changes in a number of model parameters (Roughness, Flow and the Downstream Boundary).

The sensitivity of the water levels along the River Almond to changes both in roughness and flow are moderate whilst sensitivity to these parameters along the East Pow Burn is low. Alterations to the levels of the downstream boundary have only a localised effect along 400 metres of the most downstream extent of the model and changes in water level further upstream of this point were negligible. The sensitivity analysis results are presented in Table 5.

		Typical Change in Water Level (mm) for the 1 in 200 year event					
		East Pow Burn			River Almond		
Parameter	Change	Level Change	% Change	Cross Section	Level Change	% Change	Cross Section
Roughness	+20%	+90	4.0%	02_0233	+400	11.1%	01_1509
	- 20%	-100	-4.5%	02_0233	-320	-8.8%	01_1509
Flow	+20%	+40	1.2%	02_0064	+500	13.8%	01_1509
	- 20%	-200	-5.6%	02_0064	-370	-10.2%	01_1509
Down stream boundary	+0.5 m	0	0%	02_0004	+500	13.7%	01_0000
	- 0.5 m	0	0%	02_0004	-500	-13.7%	01_0000

Table 5 – Sensitivity Analysis of the Hydraulic Model, Showing Typical Changes in Water Level

As the hydraulic model is moderately sensitive to changes in roughness and flow along the River Almond, it is important that the 1 in 200 year flows and model roughness values account for this uncertainty.

The model roughness values used along the River Almond have been verified using the two highest flow events recorded at the SEPA river gauge station. This gives confidence that the hydraulic model is a good representation of the River Almond water levels during high flow events.

The 1 in 200 year flows agreed with SEPA and used in the hydraulic model are conservative, using these flows gives a robust 1 in 200 year standard of protection.

5.5 Hydraulic Design Parameters

Prior to developing the scheme outline designs, it was necessary to confirm the key fundamental hydraulic parameters.

5.5.1 Design Standard of Protection

Scottish Planning Policy (SPP)7; Planning and Flooding, states that a Medium to High risk area is characterised to have a 1 in 200 year (or 0.5%) annual probability of flooding. (SPP)7 was superseded by the consolidated SPP in February 2010 to give a more focused statement of Scotland's national planning policy although the general principals and the Risk Framework definitions of (SPP)7 are consistent.

In accordance with DEFRA research, SEPA recommend that a climate change allowance of +20% on the estimated peak flows be made over and above any freeboard allowances.[9] and recommends that Local Authorities consider and determine if a climate change allowance can be justified.

Further to consultation with SEPA and confirmation of the hydrology values for use in the hydraulic model, it was considered that a 200 year standard of protection with an allowance for climate change (20% addition on peak flows) would provide an appropriate standard of protection for the scheme. In additional to the consideration of climate change, freeboard values were added to the modelled top water levels to define the scheme flood defence levels.

Assessment of the resulting flood defence levels, for the 1 in 200 plus climate change event, and review of the scheme extents by Mouchel and Perth & Kinross Council identified that some of the required flood defence heights were in excess of those that would be deemed acceptable by the local community, (particularly those residents in close proximity to the proposed defences) and the local Planning Authority. In addition to the perceived impact to the local community, it was considered that construction of defences to these heights may be impractical and could impact on the cost benefit of the scheme.

It was concluded that the incorporation of climate change for the 1 in 200 year design event was not practical and the level of protection for the scheme was confirmed at the 1 in 200 year design event plus freeboard allowance. This is

[9] Technical Flood Risk Guidance for Stakeholders, prepared by SEPA

consistent with the current SPP (Feb 2010). This standard of protection reduced the heights of the flood defences but still provided a good level of flood protection for the town.

Providing differing levels of protection for the River Almond and the East Pow Burn was considered as a possibility as the probability of a 1 in 200 year event occurring on both watercourses is very small. In order to provide an equal standard of protection throughout the town this approach was not taken any further.

5.5.2 Freeboard

Freeboard allowance can be determined as 'a height added to the predicted level of a flood to take account of the height of any waves or turbulence and the uncertainty in estimating the probability of flooding'.[10]

A minimum freeboard of 500mm is recommended by SEPA[11] to account for the uncertainties in flood design and also allowance for post construction settlement or wave action. CIRIA[12] recommends a freeboard allowance of 600mm.

In addition to the top water levels generated by Mouchel's hydraulic model, an allowance for freeboard to determine the scheme flood defence levels was incorporated and typically;

- The flood defence levels calculated for the reinforced concrete and sheet pile flood walls and raised bridge structures incorporate 300mm freeboard above modelled top water levels,

- The flood defence levels calculated for the earth embankments incorporate a 600mm freeboard above modelled top water levels (allowing for settlement of these embankments over time).

As flow values incorporated into the model are deemed to be conservative, it was assessed that a lower value of 300mm was an appropriate value for determining freeboard allowance for the sheet pile and reinforced concrete flood walls and to the underside of the bridge structures.

Whilst these values are typically used across the scheme, it has been necessary to increase these values at some locations. These are detailed in Table 6.

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[10] Scottish Planning Policy (SPP) February 2010

[11] Technical Flood Risk Guidance for Stakeholders

[12] CIRIA Report C624

Flood Defence Location	Freeboard	Note
River Almond Left Bank (Upstream of River Almond Footbridge)	400mm	Minimum defence height has been set at 500mm. At this location, freeboard has been increased to maintain minimum defence height.
River Almond Right Bank (Along Vector Aerospace north east boundary)	400mm	Minimum defence height has been set at 500mm. At this location, freeboard has been increased to maintain minimum defence height.
River Almond (At and adjacent to the confluence)	600 - 800mm	Increased freeboard at this location to allow for increased flow velocities at this location (bend in the watercourse) and to tie into adjacent road and bridge parapet levels.
River Almond Footbridge	300mm	The finished footbridge deck level is to be raised by 0.96m, with 300mm freeboard allowance to the underside of the supporting beam.
Confluence Road Bridge	210mm	Due to constraints associated with the geometry of the adjacent raised road levels, it has not been possible to achieve 300mm freeboard to the underside of the Confluence Road Bridge and therefore the bridge structure and adjacent flood defences will be designed to contain the corresponding depth of surcharge.
Lochty Park Road Bridge	-720mm	Due to constraints associated with the geometry of the adjacent raised road levels, it has not been possible to achieve any freeboard to the underside of Lochty Park Road Bridge. This will not result in the bridge being allowed to flood as the bridge structure and adjacent flood defences will be designed to contain the corresponding depth of surcharge.

Table 6 – Deviations from typical freeboard levels

6 Flood Protection Options

6.1 Modelling the Royal Haskoning Flood Protection Scheme (2003)

Further to verification of Mouchel's hydraulic model, the outline scheme developed by Royal Haskoning was tested in the two dimensional model. Royal Haskoning's scheme was developed for the 1 in 100 year plus climate change flood event (as agreed with Perth & Kinross Council to be the required standard of protection at the time), which is equivalent to the 1 in 200 year standard of protection. The outline scheme was tested using Mouchel's calculated hydrology.

The Royal Haskoning proposed scheme consisted of flood walls, embankments and two offline flood storage areas, as presented in Figure 9.

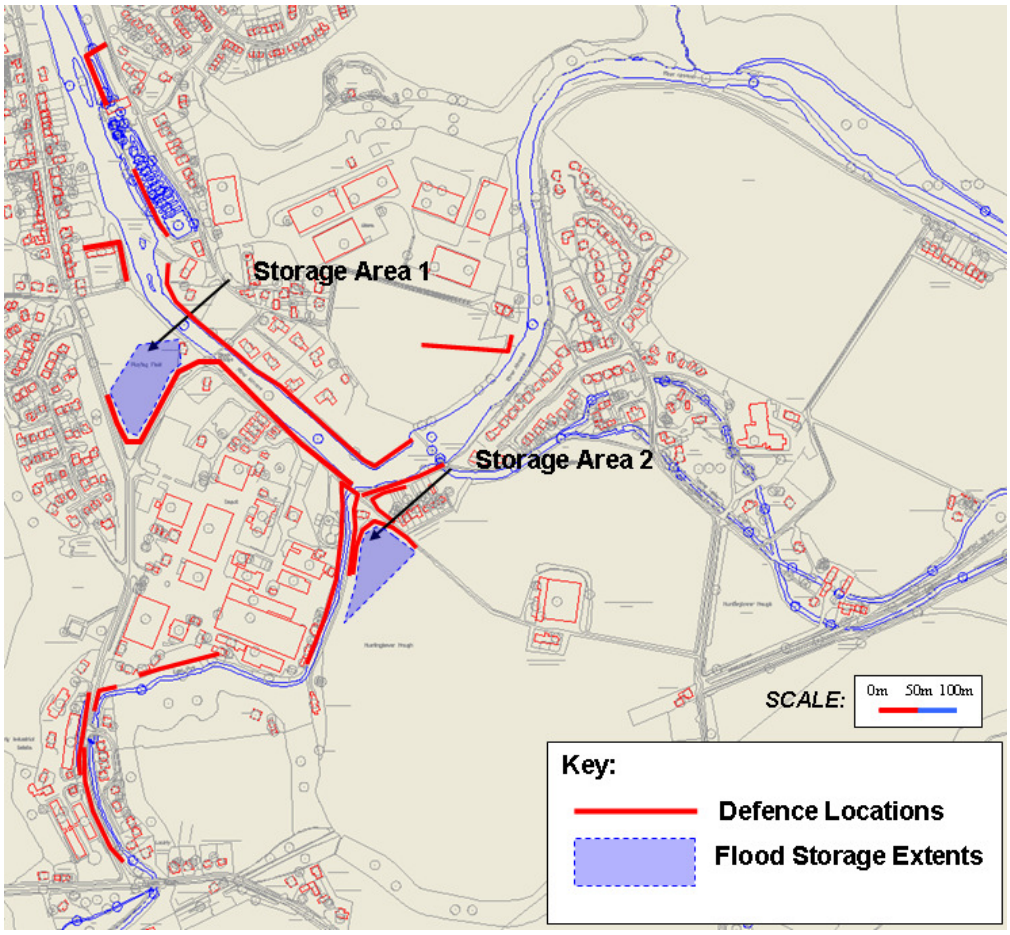

Figure 9 - Flood defence scheme proposed by Royal Haskoning in 2003

Based on Mouchel's hydraulic assessment, the Royal Haskoning proposed scheme was found not to fully contain flood waters within the River Almond and the East Pow Burn and therefore would not fully protect the town from the 1 in 200 year flood return period event. This was assessed to be for a number of reasons;

- Babtie Group's hydraulic model used different flows than those calculated by Mouchel,

- Babtie Group's hydraulic model, with which the flood defence levels were derived for the 'Royal Haskoning proposed scheme', did not benefit from a two dimensional hydraulic component to better assess overland flow.

Initial review of the model outputs identified that it would be necessary to raise some of the proposed walls and embankments along with lengthening the defences in some locations in order to prevent flood waters from overtopping and bypassing the defences.

The locations where the 'Royal Haskoning proposed scheme' was modelled by Mouchel to first 'breach' are shown in Figure 10.

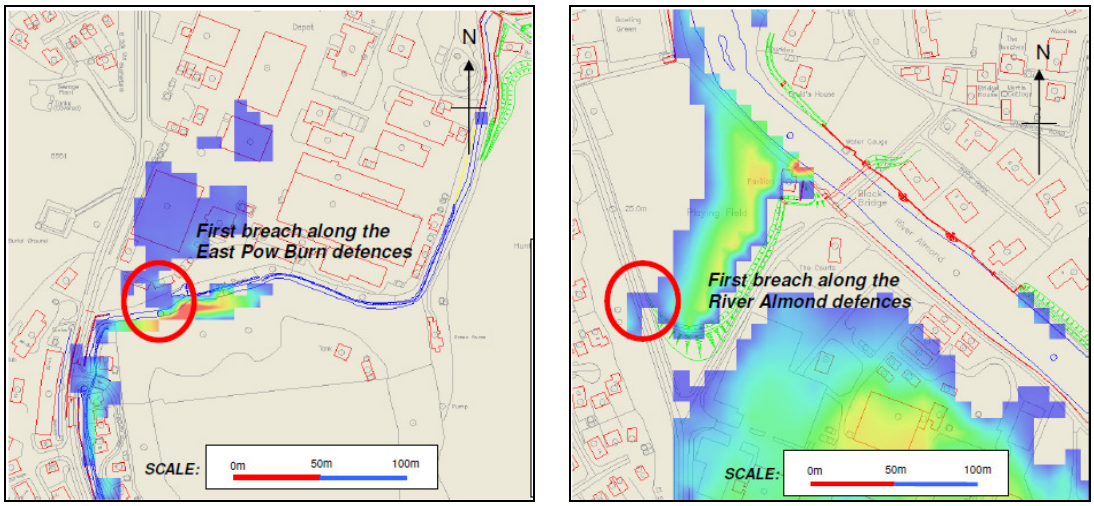

Figure 10 - First locations of modelled breaches for the Royal Haskoning proposed scheme.

For the East Pow Burn, the first breach is shown to occur approximately 100 metres downstream of the Lochty Park Road Bridge when the flow in the East Pow Burn reaches 26 m^3/s (estimated by Mouchel to be approximately the 1 in 25 year return period event).

For the River Almond, the first breach is shown to occur at the proposed Playing Field flood storage area, when the flow in the River Almond reaches 250m^3/s (estimated by Mouchel to be approximately a 1 in 60 year return period event).

6.2 Flood Protection Options

Mouchel investigated a number of variations to the 'Royal Haskoning proposed scheme' and identified improvements to protect the town of Almondbank.

6.2.1 *Option 1*

Option 1 is presented in Figure 11 and was based on the Royal Haskoning proposed scheme (2003), incorporating two flood storage areas, raising of three bridge structures and increases in the height and length of the proposed flood walls and embankments along the East Pow Burn and the River Almond.

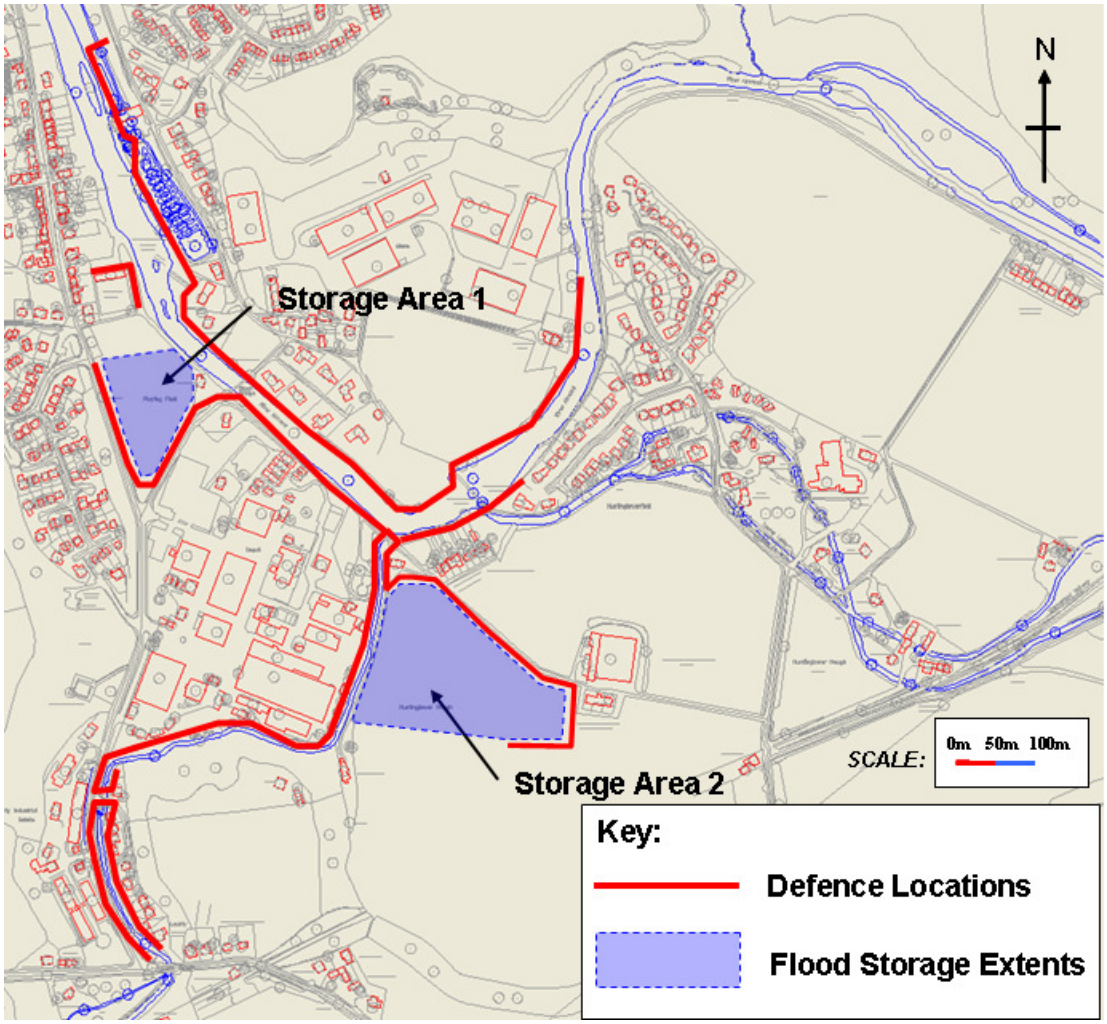

Figure 11 - Option 1

6.2.2 *Option 2*

Option 2 is presented in Figure 12 and is based on Option 1, removing Storage Area 2, replacing it with a diversion channel to carry excess flood water from upstream of the confluence on the East Pow Burn and discharges at a point downstream of the confluence into the River Almond.

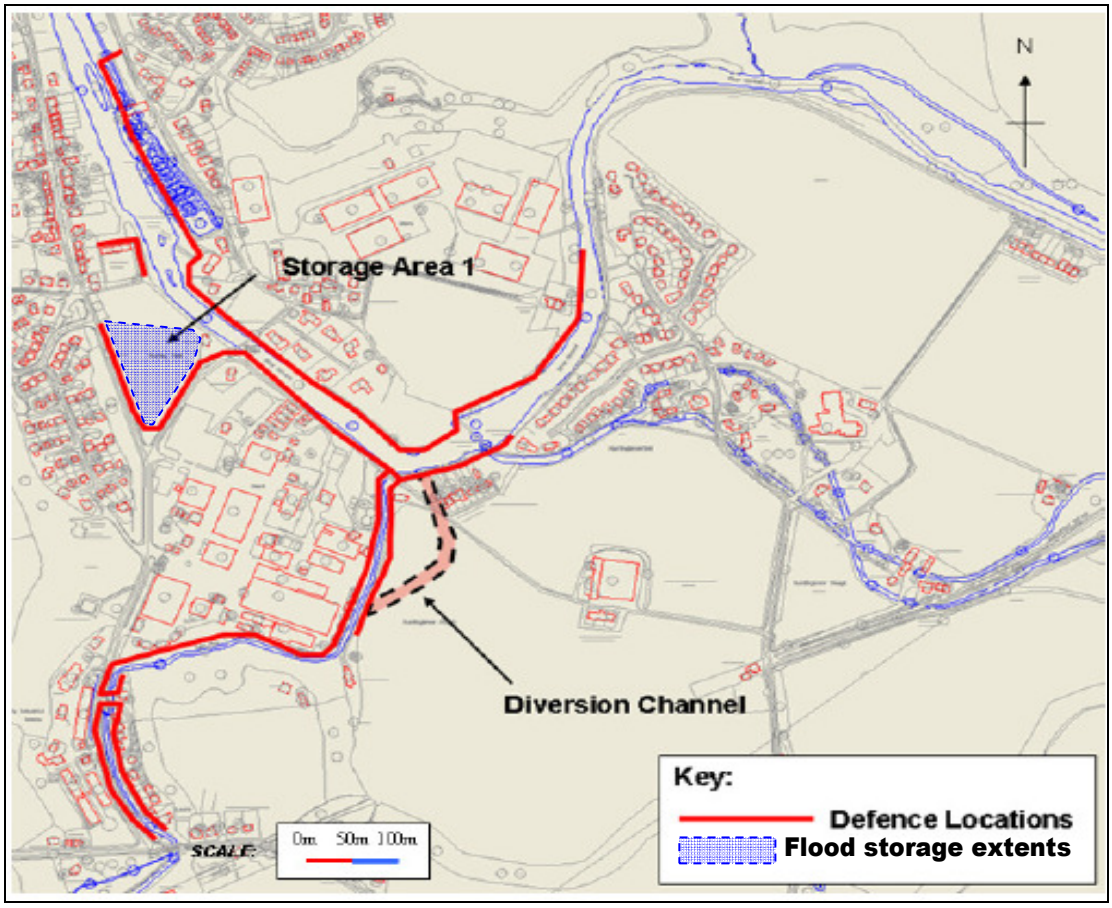

Figure 12 - Option 2

6.2.3 *Option 3*

Option 3 is presented in Figure 13 and is based on Option 1, removing Storage Area 2 and leaving Flood Storage Area 1 at the Playing Fields along with raising of three bridge structures and the required increases in height and length of the proposed flood walls and embankments along the East Pow Burn and the River Almond.

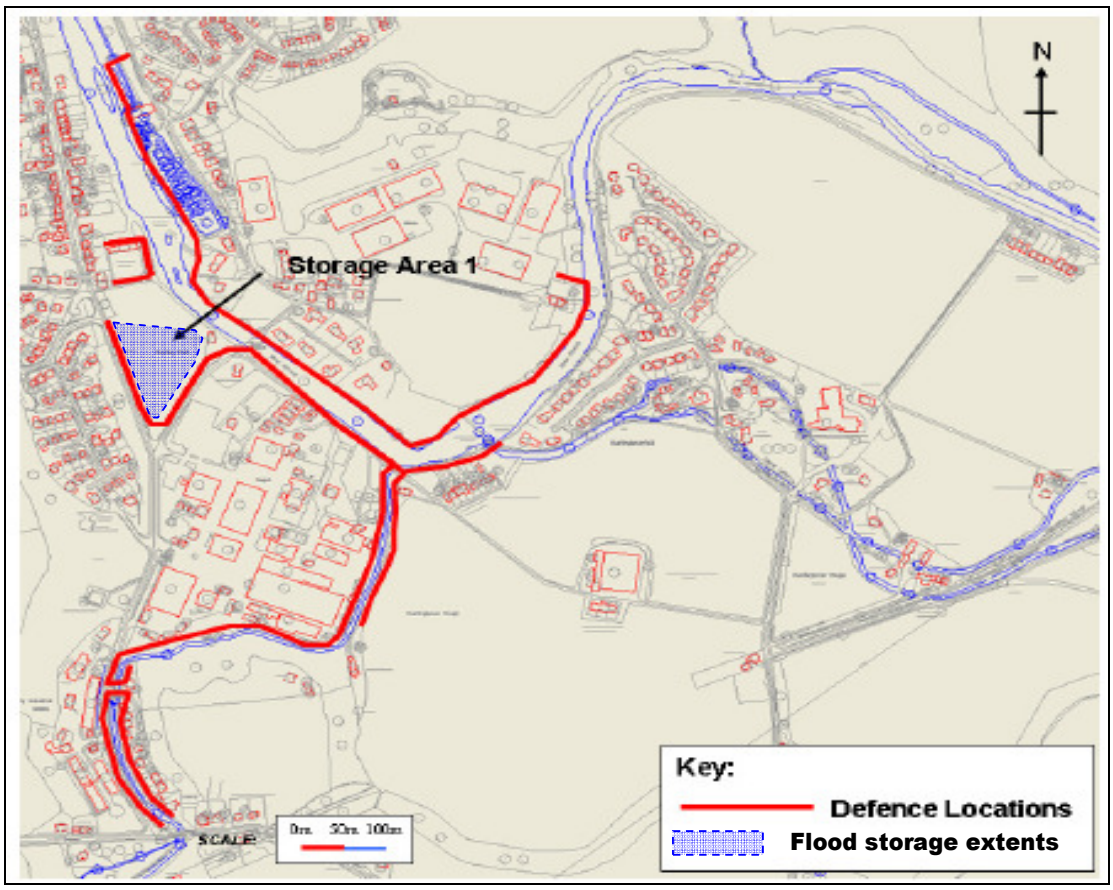

Figure 13 - Option 3

6.3 Flood Protection Options Assessment

6.3.1 *Option 1*

Assessment of the effectiveness of the proposed flood storage areas highlighted;

- Flood Storage Area No.1 is part of the natural floodplain and that enhancement of the existing landscape will allow for the offline storage of approximately 11,000m³ on the right bank of the River Almond, during the design event,

- Flood Storage Area No. 2 would require significant land take on the right bank of the East Pow Burn in order to provide a flood storage area without the need for extensive engineering works to direct and contain flood waters.

The hydraulic model highlighted that the flood defences required at the downstream extent of the East Pow Burn immediately upstream of the confluence are governed by the flood levels arising in the River Almond. The introduction of Flood Storage Area No. 2 will result in a negligible increase (approximately 20mm) of the required flood defence heights further upstream on the East Pow Burn, but as the need for the defence structures at the downstream of the East Pow Burn remains, this is assessed to be an un-effective solution.

Flood storage area No. 2 is estimated to store approximately 40,000m³ of flood water and would be defined under the Reservoirs Act (1975) and more recently the Reservoirs (Scotland) 2011 Act. If defined under these Acts, the flood storage area would require mandatory regular inspection and maintenance over the life of the scheme. The consequences of failure of this flood storage area would pose severe risks to the commercial and residential community in the south west of Almondbank.

The much lesser storage volume of Flood storage Area No. 1 will also now be defined under the Reservoirs (Scotland) 2011 Act, although the consequence of failure is assessed to have a much lesser impact.

6.3.2 Option 2

Assessment of the effectiveness of the proposed flood storage area and diversion channel highlighted;

- The same observations with regards to Flood Storage Area No 1 in Option 1,
- A diversion channel to carry excess flow from the East Pow Burn and discharge this to a point downstream on the River Almond would require significant engineering works.

As with Option 1, the downstream flood defence levels required on the East Pow Burn are governed by the flood levels arising in the River Almond and the diversion channel would again give negligible reductions in the height of the flood defences further upstream of the diversion channel on the East Pow Burn.

The costs and practicalities associated with constructing and safely operating the diversion channel were estimated to be un-economically viable when compared to the estimated difference in flood defence level of the walls and embankments along the East Pow Burn.

6.3.3 Option 3

Assessment of the effectiveness of the proposed flood storage area and the increased extents and heights of the flood defences highlighted;

- The same observations with regards to Flood Storage Area No 1 in Option 1,

- Increasing the extents and heights of the flood defences along the banks of the watercourses was the simplest solution to contain flood waters within the watercourses during the design event.

6.3.4 Recommendation of Preferred Option

The magnitude of Storage Area 2 presented in Option 1 is onerous when compared to the relatively simple solution of Option 3. The storage of such a significant volume of flood water at this location identified un-acceptable risks to the community of Almondbank should this element of the scheme fail.

The diversion channel solution presented in Option 2 was assessed to be inefficient and costly, considering the negligible reduction of flood defence height of 100mm along the East Pow Burn. There was no tangible benefit in the construction of a diversion channel when compared to the relatively simple solution of Option 3.

Option 3 was therefore recommended by Mouchel to Perth & Kinross Council as the preferred Scheme to take forward to outline design to protect the town of Almondbank against the design event.

6.4 Model Scenarios

In conjunction with using the hydraulic model [13]to develop the flood protection scheme, a number of scenarios such as the 'Do Nothing' and 'Do Minimum' have been used to determine flood damages in the town, in order to assess benefit cost ratios of the scheme proposals.

6.4.1 'Do Minimum' Scenario

The 'Do Minimum' scenario assumes that the river channels and hydraulic structures remain in good condition over time and do not fall into disrepair. This scenario is used to assess flood damages for a range of return periods and assumes that no blockages will occur at any of the hydraulic structures. In reality however it is likely that at least some blockage would occur at some of the structures in high flow events. For assessment of flood damages, the Do Minimum scenario however is modelled to give the best case scenario for various return period events.

6.4.2 'Do Nothing' Scenario

The 'Do Nothing' scenario assumes that the river channels and hydraulic structures do not remain in good condition over time and fall into disrepair. This scenario is used to assess flood damages for a range of return periods and assumes that blockages of up to 70% will occur at some of the bridge structures. Low's Work Weir is assumed to have fallen into disrepair.

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[13] "Almondbank Flood Mitigation Scheme, Hydraulic Modelling and Option Assessment Report," produced by Mouchel for Perth & Kinross Council in April 2012.

6.4.3 *'Do Something' (Final Outline Design) Scenario*

The 'Do Something (final outline design)' scenario represents the scheme for the 1 in 200 year level of protection, with river banks and hydraulic structures remaining in good condition. No blockages are modelled to occur, a number of the bridge structures are raised to allow more free flow of flood water, Low's Work Weir has been reinstated to its former condition and the Perth Town Lade remains closed.

Purely for assessment of flood damages, the 'Do Something (final outline design)' scenario is modelled to give the best case scenario for various return period events. In reality however it is likely that at some blockage would occur at some of the structures in high flow events. Breach Analysis has been undertaken as a separate exercise.

Table 7 references modelled top water levels for the design event for the Do Nothing, Do Minimum and 'Do Something (final outline design)'scenarios.

Cross Section Label	Do Minimum	Do Nothing	'Do Something (final outline design)'
River Almond, College Mill Trout Farm Hatchery (01_2357a).	25.570	25.728	25.590
River Almond, Playing Field (01_2010).	24.044	24.158	24.140
River Almond, East Pow Burn Confluence (01_1732).	23.138	23.175	23.200
River Almond, Craigneuk (01_1382).	19.970	20.342	19.940
East Pow Burn, Upstream of Lochty Park Road Bridge (02_0562).	25.626	25.722	25.820
East Pow Burn, Helipad Footbridge (02_0435).	25.042	25.038	25.790
East Pow Burn, Huntingtontower Haugh (02_0233).	23.866	23.977	24.250

Table 7 - Top water levels for the design event

7 Surveys and Investigations

Mouchel identified that further surveys and investigation would be required to develop the Scheme to outline design. These are as follows;

- Additional topographical survey,
- Structural appraisal and highway assessment,
- Geotechnical desk study and preliminary site investigations,
- Surface water drainage investigations,
- Environmental survey and reporting,
- Fluvial geomorphological assessment,
- Assessment of College Mill Trout Farm operations,
- Review of existing services with Statutory Authorities,
- Contractor's scheme review,
- Model Scenarios.

Details of these surveys and investigations are documented below.

7.1 Topographical Survey

In 2003 Royal Haskoning commissioned a topographic survey of the East Pow Burn, the River Almond and adjacent residential and commercial areas. This included spot levels, threshold levels and riverbed cross sectional data, all provided in AutoCAD format. This data set was combined with Perth & Kinross Council's OS mapping to provide a topographic survey of the area.

In order to develop the one and two dimensional hydraulic model, Mouchel commissioned a supplementary topographical survey. The additional survey information was required to enable mapping of the flood extents and included the survey of additional river cross-sections, spot level data and threshold levels along and adjacent to the River Almond and East Pow Burn. This topographical data has also been provided to Perth & Kinross Council.

7.2 Bridge Structural Appraisal and Highway Assessment

Within the extents of Mouchel's hydraulic model there are a number of structures, including two bridge structures on the River Almond and three bridge structures on the East Pow Burn. Of these structures, three were assessed to have a hydraulic impact on the Scheme and works to raise the underside levels of the three structures to mitigate against these impacts are proposed.

7.2.1 Structural Appraisal of Bridge Structures

To ascertain if the existing bridge abutments could be used to facilitate the proposed raising works, Mouchel undertook a visual structural appraisal, in December 2009, of

the condition of the existing bridge abutments and made recommendations as to their suitability for the scheme proposals.[14].

The bridge structures appraised are referred as;

Structure No. 1; **River Almond Footbridge**

Structure No. 2; **Confluence Road Bridge** (Road bridge across the East Pow Burn at its confluence with the River Almond)

Structure No. 3; **Lochty Park Road Bridge** (Road bridge providing access to Lochty Park residential estate from Main Street)

The locations of these structures are identified in Figure 14 below.

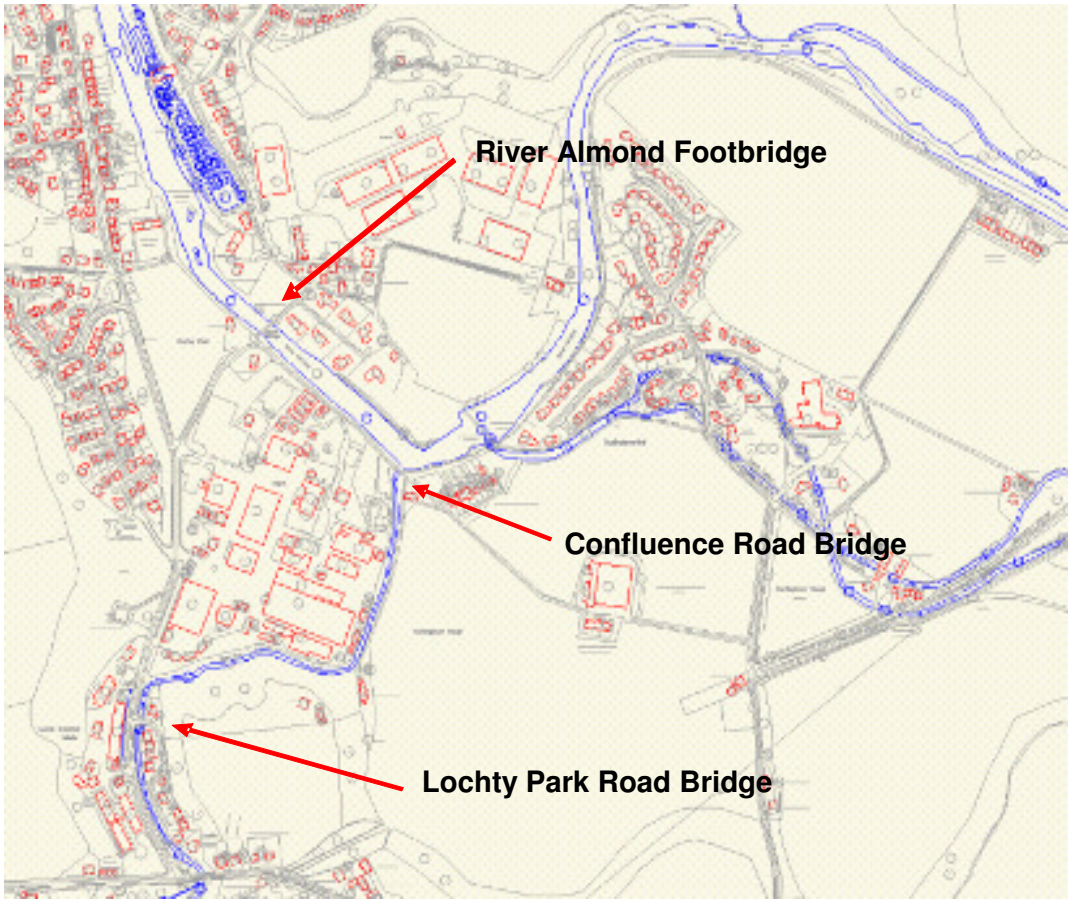

Figure 14 – Location of Bridge Structures

[14] "Almondbank Flood Mitigation Scheme, Structural Appraisal Report," produced by Mouchel on behalf of Perth & Kinross Council in January 2010

7.2.1.1 River Almond Footbridge

Figure 15 – River Almond Footbridge

As shown in Figure 15 the structure consists of a 30m single span bailey bridge, constructed in steel, which carries a footpath of approximately 1.5m wide over the River Almond between Deer Park and Main Street. The bridge replaced the former Black Bridge which was destroyed during the January 1993 flood event.

It was identified, as part of Mouchel's hydraulic modelling exercise, that in conjunction with the proposed flood defences, the footbridge would need to be raised by approximately 1000mm to protect against flooding of the local area and maintain pedestrian access across the River Almond at this location during the design event.

The existing footbridge abutments consist of concrete bank seats which are believed to be bearing on the general embankment fill material and appear to be in good condition. Whilst these abutments are thought to be in a good condition it is recommended that if the structure is to be raised then the existing abutments are not retained for use as it is thought that they would not be robust enough to resist the additional forces and moments associated with an increase in deck level. The existing abutments support the deck and also act as retaining structures. The sliding forces, bearing pressures and overturning moments will be increased as a result of the increased retained height if the deck is raised.

For structural reasons and in order to provide suitable access to the footbridge without significantly impacting on the current views of adjacent residents, it was recommended that consideration be given to the re-location of this footbridge slightly upstream of its existing location.

This recommendation is incorporated into the scheme and it is proposed to re-locate the existing footbridge approximately 12m upstream (north west) of its current location. It is assumed that the current footbridge is suitable for relocation upstream although this will be subject to a structural assessment during detail design to confirm its suitability for re-use. The new footbridge access ramps and abutments will be incorporated into the scheme defences along the adjacent riverbanks.

7.2.1.2 Confluence Road Bridge

Figure 16 – Confluence Road Bridge

The Confluence Road Bridge shown in Figure 16 carries a road bridge spanning approximately 5m across the East Pow Burn, at its confluence with the River Almond. The structure consists of 4 steel I-beams with concrete infill and carries an un-named private road from Main Street to Low's Cottages, Almondbank. The deck of the structure is approximately 4.36m wide incorporating some edge protection although this is badly damaged.

At the time of the structural appraisal, it was identified as part of Mouchel's hydraulic modelling exercise that, in conjunction with adjacent flood defences, the finished road level would need to be raised by approximately 1300mm from its current level to protect against flooding of the adjacent area (putting aside any highway elevation constraints that may arise).

The structure is supported by coursed masonry abutments that appear to be in an acceptable condition. The training walls are of random rubble construction and show indications of missing blockwork whilst the existing edge protection has become very badly damaged.

Although these abutments are assessed to be in an acceptable condition, it is not recommended to reuse them in order to accommodate the required raised bridge

deck. It is thought that increasing the height of the existing abutments will increase the forces and moments applied to these foundations and they may not have sufficient capacity to resist them. The existing abutments support the deck and also act as retaining structures. The sliding forces, bearing pressures and overturning moments will be increased as a result of the increased retained height if the deck is raised.

The outline scheme proposals include the removal of both the existing bridge and its abutments and the construction of new abutments to support a raised road bridge and safety barriers, to be incorporated into the flood protection scheme defences along the adjacent East Pow Burn and River Almond river banks.

7.2.1.3 Lochty Park Road Bridge

Figure 17 – Lochty Park Road Bridge

As shown in Figure 17, the road bridge structure consists of 3 box culverts of differing sizes, located within the river bed, acting as support to the road that serves as the only access to Lochty Housing Estate at its junction with Main Street, Almondbank.

At the time of the structural appraisal, it was identified as part of Mouchel's hydraulic modelling exercise that, in conjunction with adjacent flood defences, the cross sectional area at this location would need to be increased, and the finished road level would need to be raised by approximately 1300mm from its current level to protect against flooding of the adjacent area (putting aside any highway elevation constraints that may arise).

The box culverts are generally in good condition with no signs of deterioration. Whilst these are thought to be in good condition, in order to increase the flow conveyance at this point it is recommended that the 3 box culverts are removed and a single

span structure and supporting abutments for the required clearance are constructed in their place.

7.2.2 Highway Assessment

Further to the structural appraisal and recommendations for the replacement bridge structures, a desk study was completed and included in the Structural Appraisal Report[15]. The desk study briefly assessed the impact of the proposals, to raise the soffit levels of the three bridge structures, on the surrounding road network and residential properties.

7.2.2.1 River Almond Footbridge

The desk study assessed that raising the level of the footbridge and relocating the structure upstream of its existing location will require that the approaches are also suitably raised such that the existing at grade facility would be maintained. In accordance with Transport Scotland's 2009 publication Disability Discrimination Act; Good Practice for Roads, it is proposed that this can be achieved by providing approach ramps to each side of the proposed raised structure. The recommendations in Transport Scotland's document were incorporated into the outline design for the proposed works to the footbridge. In order to construct the required access ramps, there is the need for minimal land take on the eastern bank of the river.

Further to community feedback during the 2011 Public Consultation, small changes were made to the outline design in accordance with 'Cycling by Design 2010 (Rev1, Jun11), Published by Transport Scotland and Cycling Infrastructure, Design Guidance and Best Practice.)

7.2.2.2 Confluence Road Bridge

The desk study assessed that the existing road is generally at grade on the approach to and over the bridge. Raising the level of the road by 1300mm at this location will require that the approaches to this structure are also raised such that a suitable access could be maintained.

In accordance with 'Perth & Kinross Road Development Guidelines', in order to raise the road by 1300mm whilst complying with their minimum vertical geometry standard (6000m radius curve), the road would have to be re-profiled over a length of approximately 275m on either side of the bridge structure.

It is recognised that in order to re-profile the road along this length there will be impacts on the entrances to residential and commercial properties in the vicinity of the bridge. The entrance to the Waste Water Treatment Works will be affected, as

[15] "Almondbank Flood Mitigation Scheme, Structural Appraisal Report," produced by Mouchel on behalf of Perth & Kinross Council in January 2010

well as access to the properties at Brockhill, Puddledub and Low's Work Cottages. These accesses would be subject to re-profiling and may require land take outside of the existing highway boundary.

As the existing site layout is significantly below standard for 'new developments', it is recommended that a non-standard geometry (subject to Perth & Kinross Council approval) is adopted at this location, to be offset against the potential benefits of the proposed flood protection scheme.

Further to submission of the structural assessment and development of the scheme, in conjunction with Perth & Kinross Council, the outline design proposes the re-profiling of the road over a length of approximately 15m to the north-west and 30m to the south east.

7.2.2.3 Lochty Park Road Bridge

The desk study assessed that the existing access roads are between 1% and 2% grade. Raising the level of the road by 1300mm at this location would require that the approaches to the structure are also suitably raised such that an at grade junction would be maintained.

In accordance with 'Perth & Kinross Road Development Guidelines', in order to raise the road by 1300mm whilst complying with their minimum vertical geometry standard (6000m radius curve), the road would have to be re-profiled over a length of approximately 275m on either side of the bridge structure.

It is recognised that in order to re-profile the road along this length there will be impacts on the entrances to residential and commercial properties in the vicinity of the bridge. The access route from Main Street to the Waste Water Treatment Works and access to Lochty Industrial Estate will be affected, as well as access to the properties on Lochty Park. These accesses would be subject to re-profiling and may require land take outside of the existing highway boundary.

The existing site layout is assessed to comply with the Councils requirements, although it is recommended that a non-standard geometry (subject to Perth & Kinross Council approval) is adopted at this location, to be offset against the potential benefits of the proposed flood protection scheme.

Further to submission of the structural assessment and development of the scheme, in conjunction with Perth & Kinross Council, the outline design reduced the height to which the bridge will be raised to 750mm and proposes the re-profiling of the road over a length of approximately 35m to the north and 35m to the south. This will not result in the bridge being allowed to flood during the design event, the bridge structure will tie into the adjacent flood defence structures and be designed to contain the flood waters.

7.3 Geotechnical Investigations

Some ground investigation had been carried out prior to Mouchel being commissioned on the flood protection scheme. Further to initial review of this data, Mouchel undertook a Geotechnical Desk Study[16].

7.3.1 Geotechnical Desk Study

The desk study reviewed all available documentation in relation to the extents of the flood protection scheme, to determine the likely ground conditions and outline any pertinent issues to enable the design of a preliminary ground investigation. The key elements from this study are summarised below;

7.3.1.1 Site History

A review of historical maps dating between 1881 and 1997 was undertaken;

- The 1881 map shows a largely industrial area (gas and bleach works), with residential areas in the town of Almondbank and at Waterside Cottages,
- The 1901 map has the reference to the gas works removed and shows an extension to Pitcairnfield (more currently referred to as Bridgeton) bleach works and reference to Huntingtower bleachfield,
- The 1932 map shows an increase in the industrial areas and the addition of a number of railways,
- The 1968 map shows the Royal Naval Depot, College Mill Trout Farm, the Waste Water Treatment Works at the confluence of the watercourses and a decrease in size of the bleach works,
- The 1994 and 1997 maps show a continued increase in the areas now shown to be residential, including the demolition of former industrial buildings to provide space for these developments.

7.3.1.2 Geology

The British Geological Survey map sheets were obtained and reviewed. The drift geology indicates the site to be underlain by alluvium and the solid geology is undivided mainly cross-bedded sandstone of the Lower Devonian period.

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[16] Almondbank Flood Mitigation Scheme, Geotechnical Desk Study, April 2010, prepared by Mouchel – *(**Note**; This report makes reference to a design event of 1 in 200 year event plus an allowance for climate change, the design event has since been revised to a 1 in 200 year event)*

7.3.1.3 Hydrology

The River Almond flows in a southerly direction through the village of Almondbank and the East Pow Burn flows in an easterly direction towards the River Almond.

The Envirocheck report indicates the river quality grade for the River Almond to be Grade A (excellent). No river quality data is available for East Pow Burn. Seven discharge consents are recorded in the Envirocheck report within 250m of the scheme boundaries. The current status of these consents has not been supplied.

Information obtained from the site centred Envirocheck report (Data source; Scottish Executive, Geographic Information Service) suggests that the site is located within a Nitrate Vulnerable Zone indicating that the area is at risk of nitrate losses from agriculture to groundwater.

7.3.1.4 Hydrogeology

The Envirocheck report indicates the underlying rock to be a major or highly permeable aquifer. The soil is identified as having high leaching potential.

Groundwater has been encountered in historical ground investigations at shallow depths, standing between 1.4m and 1.68m below ground. Beneath the site, groundwater is likely to be in hydraulic continuity with the River Almond.

7.3.1.5 Ground Conditions

Relevant historical borehole logs for the site and surrounding area were sourced from the British Geological Society. The logs generally indicate the ground conditions to comprise medium dense to dense sand and gravel overlying firm and stiff clay. Made ground is present in most locations at the ground surface.

Sand and gravel was encountered in all historical exploratory holes within the study area and generally described as medium dense and dense silty fine to coarse sand and fine to coarse sub angular to sub-rounded gravel with occasional cobbles and boulders.

Glacial clay was encountered in a few historical boreholes beneath the sand and gravel. The clay was generally described as firm and stiff brown silty sandy clay with fine to coarse sub-angular to sub-rounded gravel and occasional cobbles.

Made ground was encountered in most locations above the sand and gravel with an average thickness of 1m. This generally consisted of ash and rubble fill with some areas of soft to firm clay with brick fragments.

7.3.2 Preliminary Engineering Assessment

7.3.2.1 Earthworks

Any proposed flood retaining earth embankments are likely to require an impermeable core to reduce the flow of any water through the structure and a deeper cut off or suitable toe drainage may also be required to prevent seepage of water beneath the embankments. Any fill material required would need to be imported as it is not anticipated that any suitable surplus material will arise from other site works.

7.3.2.2 Structures

Flood walls could be constructed using sheet piles with facing and capping material or traditional concrete walls with strip foundations. Sheet piles are considered more sustainable, as they require less material to be imported and can be removed and recycled if necessary. However, there is a risk that they may refuse to be driven in some soils such as dense sand and gravel and in the glacial clays there is a risk that cobbles and boulders will be struck. The driving of sheet piles can be very noisy and can cause vibrations, therefore wherever possible, steel sheet piles should be avoided near to residential areas and any structures sensitive to vibration.

Any reinforced concrete flood walls would need to be founded on competent material, the presence of which was investigated during the preliminary ground investigation.

7.3.2.3 Risk Register

A risk assessment was carried out which considered the geotechnical risks identified during the desk study, their possible impacts and their likely effects. It also identified control measures to reduce the risks; principally the need for appropriate design to minimise the identified risks. The residual risks inherent during construction and operation were then assessed.

The complete Risk Register incorporated into Mouchel's report[17] can be referenced in Appendix C, the moderate to high residual risks are summarised in Table 8 below.

[17] Almondbank Flood Mitigation Scheme, Geotechnical Desk Study, April 2010, prepared by Mouchel – *(**Not**e; This report makes reference to a design event of 1 in 200 year event plus an allowance for climate change, the design event has since been revised to a 1 in 200 year event)*

Hazard	Consequence	Risk Control Measure
Design changes following completion of GI.	Structures designed on inadequate information and subsequently fail.	Undertake comprehensive GI. Minimise changes following GI. Undertake additional GI if required.
Soft ground beneath proposed earth bunds.	Subsidence and cracking of bunds due to failure of soft ground, difficulty placing earthworks materials.	Undertake comprehensive GI. Remove or treat soft material if required.
Deep seated slip surfaces below bund.	Failure of bund side slopes	Undertake comprehensive GI. Undertake slope stability analysis once suitable fill source is identified.
Installation of steel sheet piles causes vibration.	Vibration damage to adjacent buildings and services.	Locate sheet piles away from residential areas and structure sensitive to vibration where possible. Consider specialist measures to reduce piling vibrations. Carry out property surveys before and after pile installation.
Adverse weather conditions during earthworks season.	Deterioration of otherwise acceptable materials. Decreased stability. Difficulty placing earthworks materials.	Plan works for spring or summer if possible. Limit earthworks in wet weather

Table 8 – Summary of residual moderate to high geotechnical risk factors

7.3.2.4 Contamination

The desk study assessment identified the potential for contamination within soils to exist at several locations across the study area due to previous industrial uses (gas works, bleach works, saw mill, bleachfield, railway line and waste water treatment works). As the potential exists for contamination to affect the proposed works, it was recommended that during any ground investigations, a chemical analysis is carried out in the vicinity of the proposed excavations. Analysis needs to consider the risks to site users, structures and water courses, in addition to requirements for waste disposal or re-use of excavated soils.

7.3.3 Ground Investigations

Mouchel's geotechnical desk study concluded that there was insufficient information available on the ground conditions to facilitate design of the scheme and it was recommended that a phased ground investigation was undertaken comprising a preliminary investigation to inform the outline design of the scheme, followed by a detailed investigation to assist with detailed design of the structural elements.

The preliminary investigation was not designed to provide a level of information sufficient to support detailed design. The preliminary ground investigation aimed to;

- determine the nature and thickness of the material at points along the scheme,

- determine the outline geotechnical properties of the materials underlying the scheme area,
- determine an estimate of the levels of sulphate and pH in the soils and groundwater across the scheme area,
- determine the absence / presence of contamination in the area of the exploratory holes,
- determine the level of chemical contamination within the soils and groundwater at the location of the exploratory holes.

Mouchel recommended that the ground investigation should include approximately fifteen cable percussive boreholes to depths of between 10m and 15m below existing ground levels with window sample holes or trial pits to confirm the geological sequence between the cable percussive boreholes.

Standpipe piezometers with porous tips were recommended to be used in several boreholes to determine the groundwater regime across the site.

It was recommended that geotechnical testing be undertaken on samples recovered to include; classification, strength and consolidation testing, chemical and leachability testing. Samples taken in the vicinity of the former bleach works to be scheduled for volatile and semi-volatile organic compounds.

The ground investigation should be undertaken in accordance with Eurocode 7 – Geotechnical Design, Part 2 – Ground Investigation and Testing, BS5930; 1999 including amendment 1 and BS1377; 1990 (Parts 1 to 9) including subsequent amendments.

7.3.3.1 Preliminary Ground Investigation

Following recommendations made in Mouchel's Desk study, a Preliminary Ground Investigation was undertaken.

The geotechnical and geo-environmental investigation was undertaken by Geotechnics Ltd during September 2010 and consisted of 15 cable percussive boreholes (the locations of which are referenced in Figure 18), to depths varying between 2.15m and 12.45m deep with associated sampling and in situ testing; stand pipe piezometers were installed in a number of locations for groundwater and gas monitoring purposes. A full plan showing borehole locations is included in Appendix D.

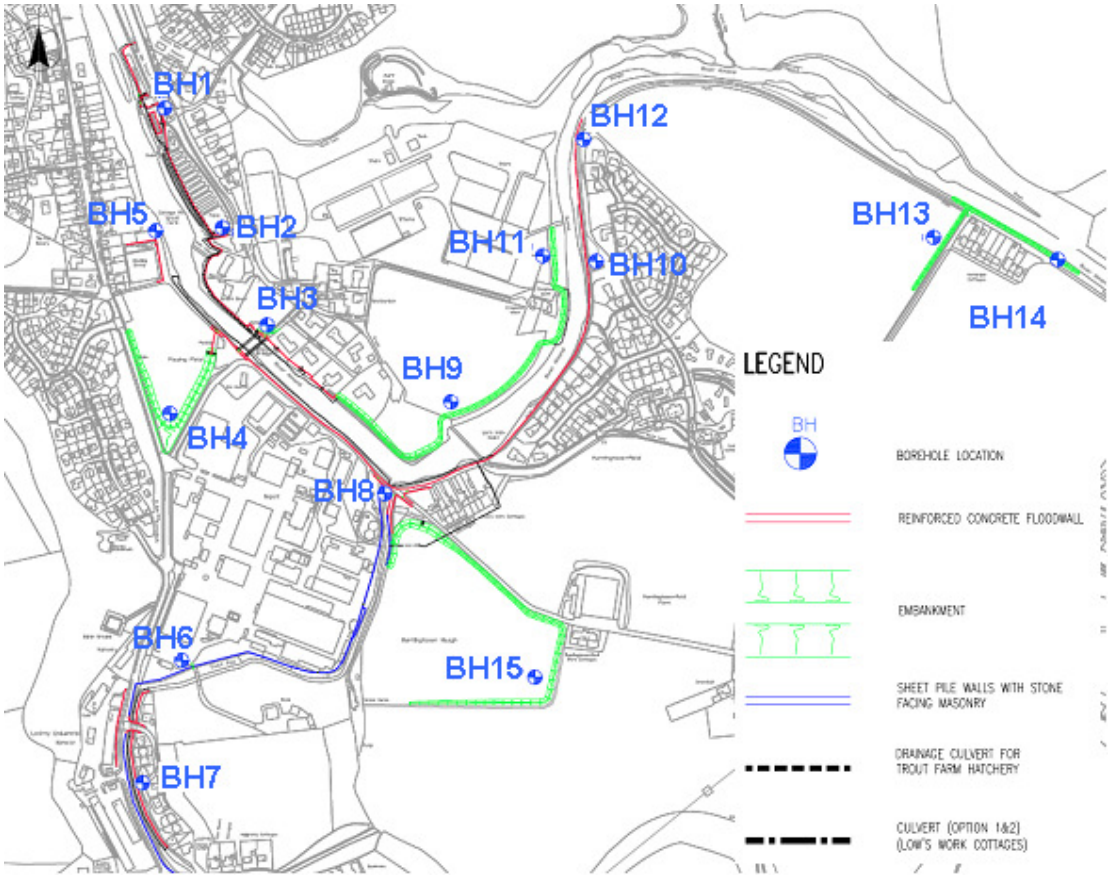

Figure 18 - Preliminary Ground Investigation, Exploratory Hole Location Plan

The investigation also included in situ and laboratory testing and reporting. A geotechnical and geo-environmental interpretation and evaluation of the data obtained was not commissioned.

7.3.4 Review of Factual Report

Geotechnics Limited submitted their factual report to Mouchel in November 2010[18]. Further to completion of the preliminary ground investigation and submission of the Factual Report by Geotechnics Ltd, Mouchel undertook a review of the document in line with the proposed outline designs for the scheme. The following summary is therefore an initial appraisal of the outline design of the scheme on this basis.

7.3.4.1 Ground Conditions

The BGS map (Sheet 48W, Perth) indicated that the site was underlain by alluvium, which is noted to have 'back-features' of river terraces in places. This ties in with the material encountered during the ground investigation which generally comprised a medium dense to dense sand or gravel. The fines content varied from 2% to 43% where a localised pocket of silt was encountered but was generally found to be less

[18] 'Almondbank Flood Mitigation Scheme, Factual Report prepared for Perth & Kinross Council by Geotechnics Limited, November 2010

than 15%. There was a low to medium cobble content throughout although a thin (0.30m thick) layer of cobbles was encountered in BH11/11A. Generally this alluvium showed very little lateral variability.

The BGS map also indicated that the alluvium was underlain by glacial till sitting on top of bedrock although the investigation did not penetrate the base of the alluvium. Made ground was encountered in 7 of the 13 locations although in the majority of places the thickness was not substantial (less than 0.50m). Exceptions to this were localised in the northwest area of the scheme in BH1 (north of the College Mill Trout Farm), BH3 (adjacent to the River Almond Footbridge) and BH5 (the Bowling Green). In particular BH5 encountered made ground containing man made detritus such as concrete, metal and brick down to a depth of 3.40m and anecdotal evidence would suggest that a significant area west of the river is reclaimed land. No visible signs of contamination were noted.

7.3.4.2 Groundwater Conditions

Groundwater observations were made during the investigation and are presented in Table 9.

Groundwater monitoring was undertaken over a period of two months at seven of the borehole locations. The results indicated a site wide groundwater high of 0.95m bgl in BH6 (Vector Aerospace) and a groundwater low of 2.67m bgl in BH8 (close to the Confluence Road Bridge). Groundwater levels at BH15 (Huntingtowerfield), BH1A (College Mill Trout Farm), BH11A (Craigneuk), BH5 (Bowling Green) & BH3 (Deer Park) ranged between 1.46 & 2.3m bgl.

Exploratory Position	Groundwater Strike Depth (mbgl)	Rose to (mbgl)	Comments	Lithology
BH2	3.40	3.10	Moderate flow	Very sandy, slightly silty GRAVEL
BH3	5.40	4.90	Moderate flow	Gravely clayey SAND
BH4	4.30	3.95	Slow flow	Silty SAND and GRAVEL
BH5	3.50	3.30		Silty sandy GRAVEL
BH6	1.50	1.25	Slow flow	Sandy slightly silty GRAVEL
BH8	3.30	3.00	Slow flow	Very sandy silty GRAVEL
BH9	2.90	2.60		Silty SANDY and GRAVEL
BH10	5.00	5.00	Damp	Very gravely, very silty SAND
BH13	5.10	4.70		Slightly silty, very sandy GRAVEL
BH15	3.20	2.90		Very sandy silty GRAVEL

Table 9 - Groundwater observations made during the preliminary site investigation (where the borehole is omitted no groundwater was encountered).

7.3.5 Preliminary Seepage Analysis

Seepage through and beneath the proposed earth embankments was evaluated using GEOstudio's SEEP/W 2007 software. The analysis was based on a typical cross section through an earth embankment taken from the outline design drawings and used modelled top water levels and flood event durations for the 1 in 200 year event. The analysis was completed using parameters derived from the data obtained during the preliminary site investigations.

The purpose of the analysis was to determine the permeability of the proposed earth embankments and whether, and to what extent, control measures would be required to avoid significant seepage through them.

The SEEP/W software program allows two fundamental types of finite seepage analysis; Steady-state (water pressures and flow rates have reached a steady value) and Transient (water pressures and flow rates are always changing). In order to carry out the design calculations efficiently and with the limited information from the preliminary site investigations, for this analysis, Transient was chosen.

The analysis was carried out on the embankment section assuming the embankment fill as a cohesive material;

1. With no core,
2. With a 5m sheet pile core,
3. With an 8m sheet pile core.

Figure 19 shows the results for the analysis assuming an 8m deep sheet pile core.

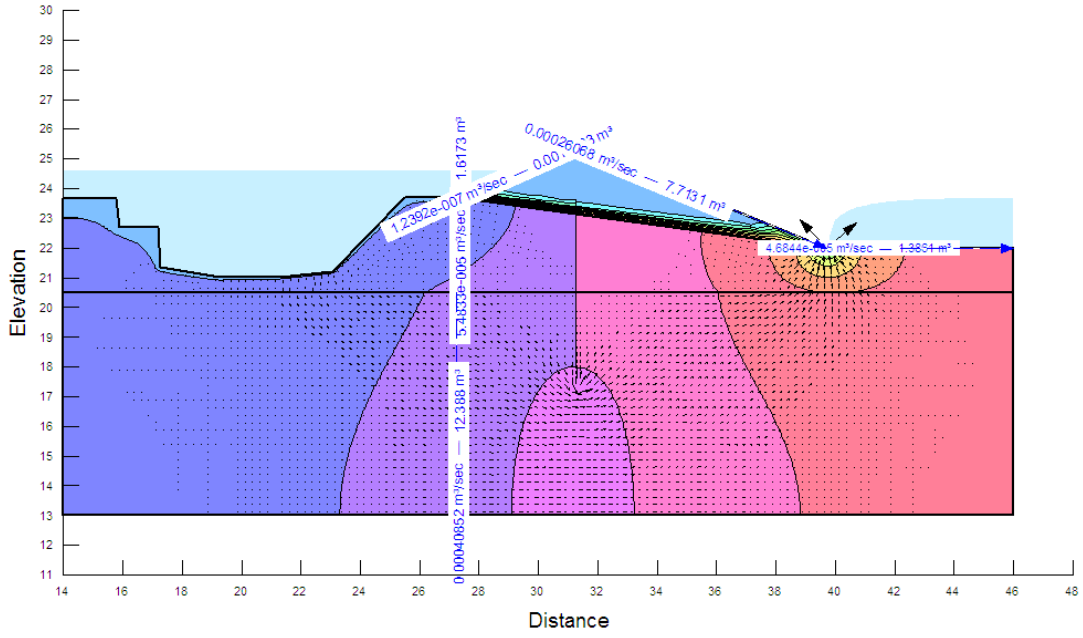

Figure 19 - SEEP/W results for the earth embankment with cohesive fill with an 8m sheet pile core.

A sensitivity analysis was carried out to determine the seepage flow by increasing the permeability value of the fill material and assuming a granular fill with;

1. With no core,
2. With an 8m sheet pile core.

Figure 20 shows the results for the sensitivity analysis assuming an 8m deep sheet pile core.

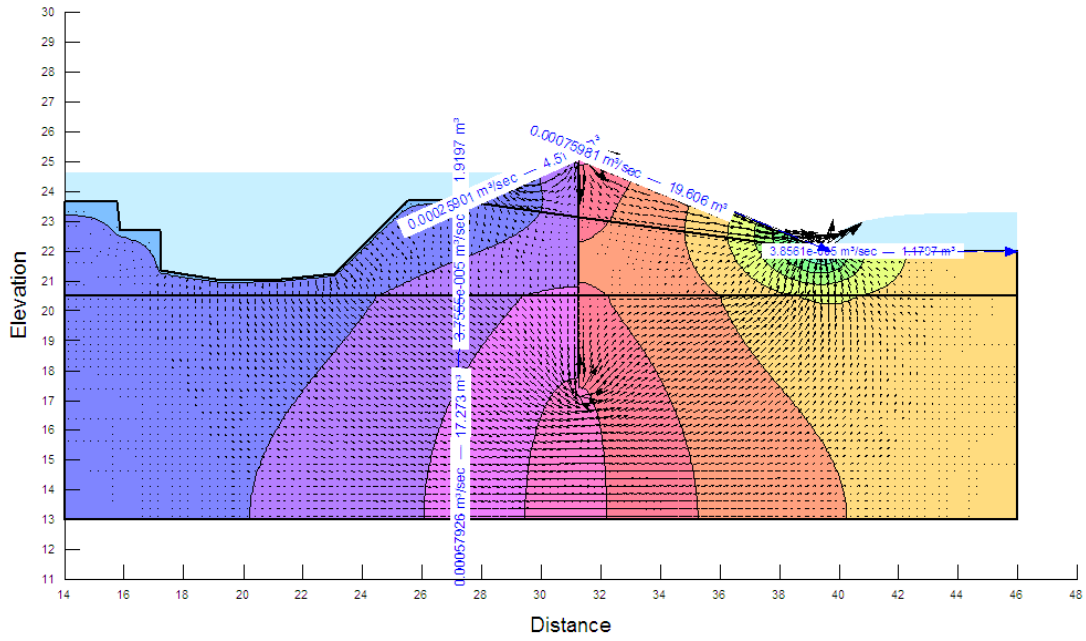

Figure 20 - SEEP/W results for the earth embankment with granular fill with an 8m sheet pile core.

The analysis identified that when the maximum flooding period is modelled, there is always a degree of groundwater to the dry side of the embankment and therefore drainage will be required to collect these seepage flows. Whilst further analysis would be required to determine the extents of these flows it is thought that typical highway drainage systems would be of sufficient magnitude to accommodate the flows.

Due to the granular nature of the subsoils and lack of impermeable boundary layer identified at the base, the sheet pile depths analysed (up to 8m) do not have a significant effect on reducing seepage. The use of piles may mean that drainage measures could be scaled back although the extent of this should be assessed with regard to cost efficiencies.

Where topography does not allow removal of such flow from the toe of the embankments through drainage, the only economical solution would be to install cut-off piles extending into an effectively impermeable stratum at depth. Such a stratum was not identified during the preliminary ground investigation.

Class 2 cohesive, clay based fill would be more beneficial in terms of seepage, although the slopes would not be stable at 1(v);2(h) once saturated. Shallower slopes could be used but the increase in plan footprint may be problematic in terms of land take. Alternatively clay cores / granular shoulders or wholly granular (Class 1) earth dams could be used but these would result in more onerous drainage requirements.

Assessment of the flood wall structures (reinforced concrete and sheet piles) was not undertaken during this analysis although recommendations for the drainage at the

toe of the embankments is also applied to the outline designs for the flood wall structures. Further assessment of their required depths below ground level and the specific drainage arrangements for these structures will need to be undertaken during detailed design of the scheme.

7.3.6 Outline Design Review

The ground investigation broadly confirmed the findings of the desk study and indicated that the subsoils encountered in the scheme are likely to be broadly medium dense to dense gravels with varying proportions of cobbles sand and silt / clay.

Based on the Ground Investigations undertaken to date, the design proposals were assessed to be appropriate for the ground conditions in terms of bearing capacity and settlement. The following geotechnical risks were noted;

- There is the potential for groundwater to be shallow in places and therefore allowance should be made for dewatering measures within excavations,
- Cobbles within the boreholes were noted which may impact on the ability to drive sheet piles at the site,
- Although no visibly contaminated material was encountered during the Ground Investigation, there is potential for pockets of contaminated material to be present within the areas of made ground.

Review of the historical data available and the more recent data obtained during the preliminary ground investigation gave consistent indication of the expected ground conditions within the study area. This information has been used to inform the outline design and preliminary analysis that have been completed.

It has previously been stated that the preliminary ground investigations and subsequent analyses are not sufficient on which to base a detailed design. It is therefore recommended that during the next phase of the scheme further ground investigations are carried out, using the results of these investigations to complete the appropriate analysis to determine the design parameters and develop the detailed designs.

7.4 Surface Water Drainage Investigations

In order to deliver an integrated solution to the fluvial flooding problems experienced in Almondbank, it was necessary to consider the impact of the outline design proposals on the adjacent surface water drainage systems. This was considered necessary in order to assess the potential of surface water ponding on the ‘dry side’ of the flood defences, which could be perceived as failure of the flood protection scheme.

Initial investigations were carried out to investigate the relationship between fluvial and surface water flooding and further to recommendations made in the report[19] produced, Mouchel went on to further investigate and recommend a number of surface water flooding solutions[20].

7.4.1 Impacts on Drainage Infrastructure

For the existing scenario, with no fluvial flood scheme in place, the modelled 1 in 200 year flood levels will rise above ground level at a number of CSO's within the study area, identifying the risk of backwater effects. On completion of the fluvial flood scheme, floodwaters will be contained within the watercourses and may therefore exacerbate the backwater effects.

7.4.1.1 Desk Study

A desk study to investigate the relationship between fluvial and surface water risk was carried out by Mouchel during December 2009.

The study area was assessed and categorised into High, Margin and Low Areas;

[19] 'Impacts on Drainage Infrastructure, Desktop Study & Further Investigations prepared by Mouchel for Perth & Kinross Council (April 2010). *(**Not**e; This report makes reference to a design event of 1 in 200 year event plus an allowance for climate change, the design event has since been revised to a 1 in 200 year event)*

[20] 'Surface Water Flooding Solutions' prepared by Mouchel for Perth & Kinross Council (June 2012)

High Areas	Areas assessed to be 10m or more above the 'Do Minimum' 200 year event top water level. *(Bridgeton, Pitcairngreen)* Where ground levels are sufficiently above the 'Do Minimum' 200 year event top water levels, the areas served by separate surface water sewers appear to be at little risk from surface water flooding from sewer overflows and therefore excluded from further investigation.
Margin Areas	Areas assessed to be between 0m and 10m above the 'Do Minimum' 200 year event top water level. *(Main St, Admiralty Wood, College Mill Road and the Ministry of Agriculture site)* Margin areas that may be affected by the 'Do Minimum' 200 year event top water levels were further investigated to determine their risk of flooding.
Low Areas	Areas assessed to be below the 'Do Minimum' 200 year event top water level. *(Vector Aerospace, Waste Water Treatment Plant, Low's Work Cottages, Lochty Industrial Estate, Huntingtowerfield, Deer Park and properties south of College Mill Trout Farm)* Ground levels at or below the 'Do Minimum' 200 year event top water levels may not be able to drain effectively during such an event and these areas are likely to require protection solutions.

Table 10 – Desk study undertaken by Mouchel to investigate the relationship between fluvial and surface water risk

The fluvial flood protection scheme is designed to provide a level of service of 1 in 200 years. The industry standard publication ' Sewers for Scotland, 2nd Edition (2007)' requires that *new* surface water sewers are designed not to overflow in a 1 in 30 year event, with checks being made for the 1 in 100 and 1 in 200 year events. Mouchel understand this to mean that the system may overflow in an event beyond 1 in 30 years, provided that secondary flow paths and storage can be utilised such that no property is at risk of internal flooding from the higher events.

Backwater calculations were carried out using steady state 'peak flow' to assess the performance of critical areas of the drainage network. Rainfall intensities for the 30yr event were derived from the Wallingford Procedure (Design and Analysis of Urban Storm Drainage, Volume 4, The Modified Rational Method.) and compared against peak rainfall intensities derived from the River Almond catchment critical duration 25yr, 50yr, 100yr & 200yr events.

The calculations for the combined sewer system that serves the majority of properties in the study area indicated that the sewer system suffers from a lack of capacity and presents a surface flooding risk. This is as a result of the sewer being undersized, with the predicted fluvial flood levels having a minimal effect in comparison. Nevertheless, if the system continues to overflow or surface water flooding is occurring following completion of the flood protection scheme, public perception of the scheme may be unfavourable.

7.4.1.2 Site Visit and Verification Exercise

Further to recommendations of the desk study, a site visit was undertaken during February 2010. A verification exercise was then undertaken to investigate further the areas highlighted at risk during the desk study and refine any assumptions made.

Data gathered during the site visit and its use in the verification exercise included;

- Information on contributing roof and hardstanding areas, other surface types, surface flowpaths, soakage potential and natural watercourses (used to refine estimates of sewer flows),
- Anecdotal information as a result of discussions with residents (used to assess the extent and nature of any failure of the sewer system),
- Rainfall records (these were compared with storm events recalled by residents),
- General observations of the system were also conducted, including observations of the CSO's at Bridgeton, the Bowling Green and the WWTW.

In refining the assumptions made in the desk study, particular attention was given to assessment of the capacity of the combined sewer system. It was concluded that a capacity issue does exist in terms of the modern design standard of a 1 in 30 year level of service. It was estimated that the combined sewer only has the capacity to handle approximately 22% of the connected roof area before spilling to the street.

The performance of the CSO's was assessed and it was observed that;

- The CSO at Bridgeton appeared to be malfunctioning at the time of the site visit,
- The CSO at the Bowling Green appeared to be jammed and blocked,
- The CSO at the Waste Water Treatment Works was partially buried by sediment.

It was concluded that whilst it is assessed that the flood protection scheme will have a negligible effect on the capacity of the combined sewer system, the sewer system itself may present a risk of flooding due to lack of capacity.

In consideration of the delivery of an integrated solution to the fluvial flooding issues, it was Mouchel's recommendation that the scheme considered measures by which surface water flooding can be managed alongside fluvial flooding. These recommendations were discussed with Scottish Water further to confirmation of those areas assessed to require surface water flooding solutions. (Discussions with Scottish Water are detailed in Section 7.5.3.)

7.5 Surface Water Flooding Solutions

An assessment of the effect of the proposed scheme on the existing drainage infrastructure found that fluvial floodwater could backflow up the system from some drainage outfalls and pond on the 'dry' side of the proposed defences. Backflow protection such as non return valves could prevent this but would also prevent any surface water runoff from reaching the river, resulting in a residual risk of surface water flooding on the 'dry' side of the defences.

7.5.1 Methodology

The Low and Margin areas (as previously determined) were analysed to;

- Determine the likelihood of spills from the existing drainage infrastructure resulting from incapacity,
- Assess the areas and extents of resulting surface water flooding.

Sewer capacity and the likelihood and location of spills were estimated from steady state backwater calculations. Surface water flooding extents were estimated by calculating the 1 in 30 year design event runoff volume from each contributing catchment, and applying this to a contour map of the catchment.

Surface water flow paths were assessed from the contour map and determined to be either 'safe' (freely draining to the river without significant risk of internal flooding) or 'unsafe' (not freely draining, or at risk of causing internal flooding).

Mouchel assessed the extent of predicted surface water drainage problems in nine areas;

- Bridgeton Brae,
- Main Street,
- Vector Aerospace Site,
- Huntingtowerfield,
- Ministry of Agriculture Site,
- Deer Park,
- Low's Work Cottages,
- Lochty Industrial Estate,
- Waterside Cottages.

The analysis confirmed that in terms of the modern design standard of a 1 in 30yr level of service, the combined sewer serving the majority of Almondbank does suffer from a lack of capacity to handle the potential runoff from the areas it serves, regardless of water levels in the river (i.e. 'free outfall' conditions).

Of the nine areas assessed, solutions were recommended for Bridgeton Brae, Main Street and the Vector Aerospace site. The remaining six areas were assessed at 'Low Risk' and therefore no solutions are recommended.

Figure 21 presents the excess surface runoff flowpaths and identifies the 'at risk' areas where solutions are assessed to be required.

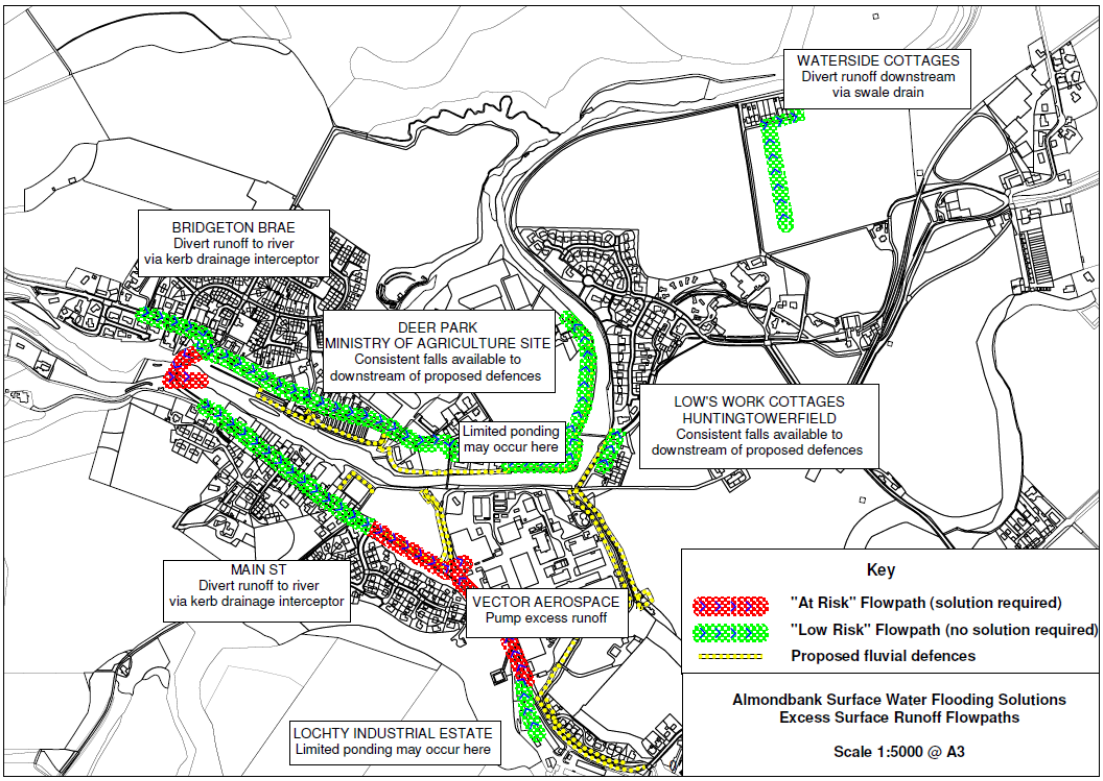

Figure 21 - Plan showing excess surface runoff flow-paths

7.5.2 Analysis of Low Risk Areas

7.5.2.1 Huntingtowerfield and Ministry of Agriculture Site

Flap valves or other methods of backflow prevention are recommended to be installed on storm water outlets from Huntingtowerfield and the Ministry of Agriculture site. Ground levels behind the defences are lower that the design flood level, so a risk of backflow from the river exists.

7.5.2.2 Deer Park and Low's Work Cottages

An analysis of the surface flow paths in these areas, demonstrates that surface runoff can escape downstream along the line of the proposed flood defences, with minimal ponding. The identified flowpaths will be further assisted by drains along the foot of the proposed defences.

7.5.2.3 Lochty Industrial Estate

An analysis of the contributing area; existing drainage infrastructure; existing ground levels and the proposed re-grading of Main Street along the East Pow Burn; and the

resulting surface flow paths indicates that surface water ponding in this site will be minor.

7.5.2.4 Waterside Cottages

As this location is not at risk of fluvial flooding and the surface water flooding is not exacerbated by the modelled water levels for the fluvial design event, it is not recommended that any works to the surface water drainage are included in the flood protection scheme.

7.5.3 Scottish Water

A telephone meeting was held with Scottish Water in June 2010 to discuss Mouchel's analysis of the areas investigated, inviting comment from Scottish Water (SW). SW stated that they had no records of sewer flooding incidents in Almondbank and would be unable to justify investment in improving the performance of their assets, but accepted that Mouchel's analysis was reasonable. It was agreed that 'off-line' solutions, which would work independently of the combined sewer network, would be developed by Perth & Kinross Council within the remit of the proposed flood protection scheme.

7.5.4 Analysis of 'At Risk' Areas

7.5.4.1 Bridgeton Brae

The existing combined sewer system serving the Bridgeton catchment is assessed to have insufficient capacity to meet the Sewers for Scotland, 2nd Edition (2007) standard.

Excess runoff will flow down the kerb and channel of Bridgeton Brae and across the Bridgeton Road Bridge, where analysis determines it will collect on its west side at a low point in the road. The flooding described will eventually spill across the pavement into the river (Indicative extents are shown in Figure 22).

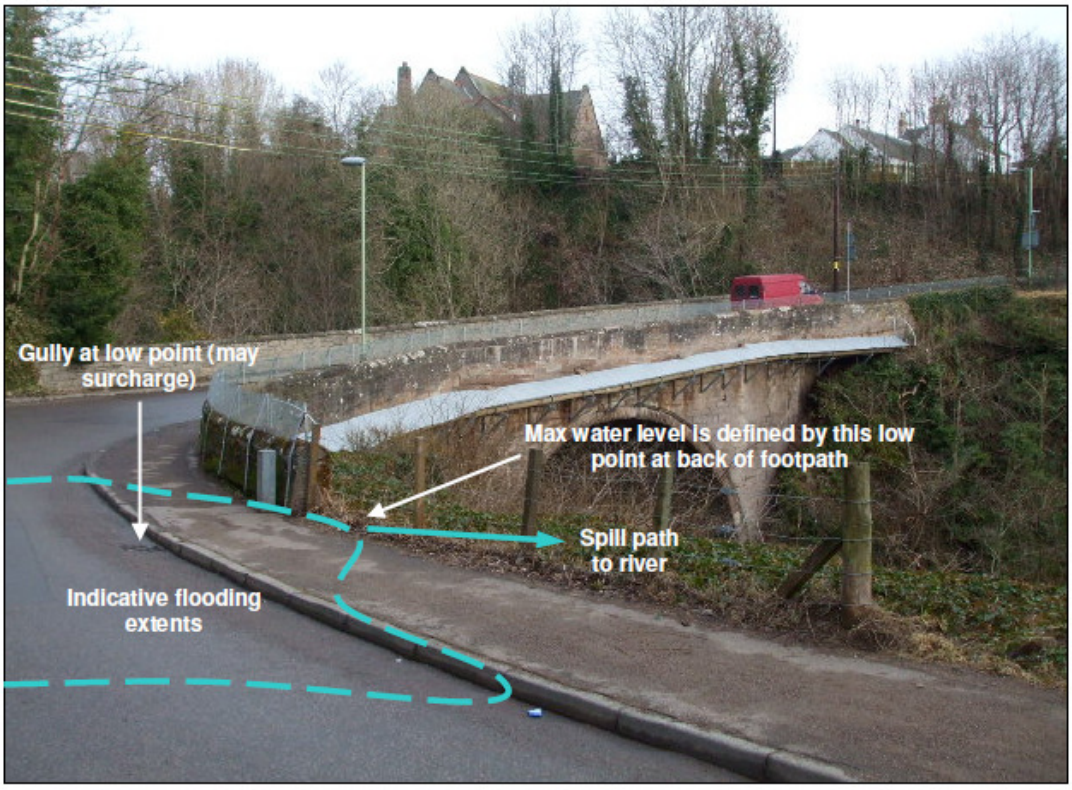

Figure 22 - Indicative flooding extents from surface runoff across Almond Bridge

The flooding on the west side of the bridge (approximately 200-300mm deep before spilling), is likely to impede pedestrians and vehicles. The ponding will occur on a 'semi-blind' corner, where it may not be seen by drivers crossing from Bridgeton. The road has a significant slope across the bridge, meaning that runoff velocity would be fairly high.

A number of options were considered to mitigate any ponding on the highway;

- Installation of a drop kerb and works to locally reduce the footpath at the low point of the carriageway to direct flood water down the bank to the river. This would reduce the surface water ponding on the road at this point but would mean that flows are directed across the footpath. Surface water will continue to flow with high velocities along Bridgeton Brae and over the bridge, with no improvement across the bridge for either pedestrians or vehicles.

- Installation of a combined kerb and drainage system in Bridgeton Brae and immediately above the bridge, to collect surface runoff and overflows from the highway and discharge it via an outfall to the river before it can flow across the bridge. This would reduce the surface water ponding on the road whilst improving safe passage across the bridge for both pedestrians and vehicles. Utility diversions (including existing sewers) may be required. The proposed outfall is in a steep bank and consideration will need to be given to its design and construction (a similar CSO outfall has been successfully installed in similar conditions downstream of the bridge).

The flooding at this location does not directly pose a threat to property, however it does impede access across the bridge and being on a partially blind corner potentially introduces dangerous conditions to traffic and pedestrians. It is recommended by Mouchel that the installation of a combined kerb and drainage system is incorporated into the scheme proposals.

7.5.5 Main Street

The existing combined sewer system serving Main Street and adjacent residential areas is assessed to have insufficient capacity to meet the Sewers for Scotland, 2nd Edition (2007) standard. Excess runoff will flow down the kerb and channel of Main Street towards the bottom of the catchment towards the entrance to the Vector Aerospace site.

A single option was considered to mitigate excess runoff and ponding on the highway;

- Installation of a kerb drainage system on Main Street (between east Drive and McKenzie Drive) to collect surface runoff and overflows from the highway. Flows that are intercepted will be piped beneath the Playing Fields and discharge into the River Almond at a suitable location. Interception of these flows will improve safe passage for both pedestrians and vehicles along Main Street and reduce the surface runoff catchment area flowing into Vector Aerospace, reducing the extent of flooding within the site. Some utility diversions may be required.

7.5.6 Vector Aerospace

The Vector Aerospace site is vulnerable to fluvial and surface water flooding. During a sufficiently high flood event, the water levels in the adjacent watercourses will prevent the surface water drains in Vector Aerospace from functioning, and surface water will collect within the site.

The extents of surface water flooding from the 200yr design event (approx 100mm of rainfall) with the proposed flood defences in place have been estimated, assuming that the Main Street interceptor has been installed. The extents of these are shown in Figure 23 below (Approximate flooding volume of 7,100m^3). The negligible storage available in the existing drainage system (circa 50-100m^3) is not taken into account.

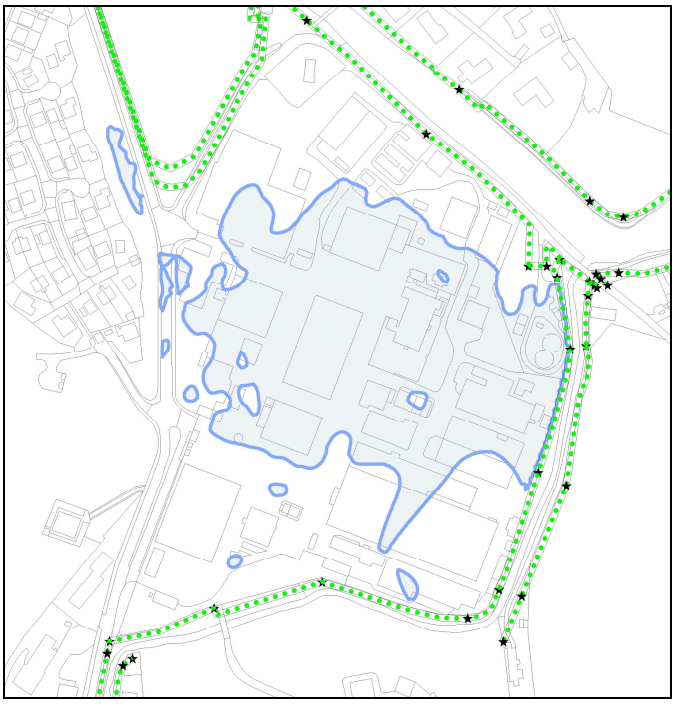

Figure 23 - 1 in 200yr surface water flooding extent, Vector Aerospace

External flooding may be such that manufacturing work can continue, but Mouchel's analysis suggests that the best case scenario is one where surface water flooding will pond around buildings, preventing or hindering access to a significant proportion of the site.

A number of options (in addition to the interception of excess surface water from Main Street) were considered to mitigate surface water flooding on the site.

7.5.6.1 Underground Storage Tank

The installation of an underground storage tank as an overspill facility to the sites existing drainage system. This would operate when raised river levels prevent runoff in the existing system from discharging to the river and water would spill into the storage tank. The stored water will be released when the fluvial flood passes and the river levels reduce, allowing the system to drain freely again.

This proposed solution will reduce the risk of external flooding in the Vector Aerospace site, further to the fluvial flood protection structures being installed. Operating costs will be relatively low and the storage system will have a lower risk of failure (when compared to a surface water pumping station). A storage system will require a large footprint with regular maintenance and checking requirements. The volume of the storage tank will be constrained by the available area, groundwater levels, outfall levels and the depth of the existing sewers.

The available storage may not be sufficient to contain the estimated flood volume of 7,100m^3. The capacity of the tank is dependent on the tank being able to drain between storm events and have sufficient capacity for the critical events. New or extended surface collection systems may be required.

7.5.6.2 Surface Water Pumping System

Installation of a surface water pumping system to remove the risk of flooding. This would intercept the surface water from the existing outfall to the site, collect the water within a wet well and pump it directly into the river.

The pumps would be designed to mimic the current outfall system; the flows above the pipe surcharge level would spill into a new drainage network to the pumping station. The pumps would be sized at the same flow rate to discharge against the top river level and as such they would have no negative impact on the network.

Improvements to the existing site drainage have not been considered as part of this scheme. If the existing system is insufficient due to hydraulic or operational issues, new site specific drainage systems may be required.

This proposed solution will reduce the risk of external flooding in the Vector Aerospace site, further to the fluvial flood protection measures being installed. It will require a smaller footprint than the storage solution that would not be constrained by the depths of existing sewers. This solution would attract higher operating expenditure than a storage solution with a higher risk of failure and would also require regular maintenance and testing.

7.5.6.3 Combined Storage and Pumping

In addition to the proposed Main St surface runoff interceptor, a combined or 'balanced' solution was considered with both a storage facility and a pumping station constructed, but each is smaller than its standalone alternative.

This solution balances the risks between the initial expense and large footprint of a storage tank, and the higher cost and operation & maintenance expense of a pumping station. Although having the benefits of each system it also has both sets of risks too.

7.5.6.4 Required Level of Service

Sewers for Scotland, 2nd Edition (2007) is primarily a design guide for new developments. Development on floodplain is now much more constrained than in the past, to the extent that an application made now to build Vector Aerospace on its current site would probably be declined.

Mouchel's opinion is that a surface water solution designed to a 1 in 30 year level of service is reasonable, achievable, practical and appropriate for integration into the proposed fluvial flood scheme.

7.5.6.5 Preferred Option for Vector Aerospace

Of the three options proposed, the standalone surface water pumping station is the preferred option as it can be designed to be independent of the need for storage. Storage cannot be guaranteed (of our estimate of the 200yr event flood volume, only

half can be stored within the footprint of the car park, assuming a 1m depth) and the consequence of not having sufficient storage is considerable in this site.

7.6 Environmental Surveys

In order to evaluate information regarding the existing environment, against which impacts of the scheme could be assessed, a range of environmental surveys were undertaken. Surveys followed standard guidelines and best practice as indicated in the Environmental Statement[21]. Further details regarding the Environmental Statement are provided in Section 8 of this technical report.

7.6.1 Landscape and Visual

Landscape and visual site survey and analysis was undertaken with a study area 1 km each side of the centreline of the River Almond and East Pow Burn. The purpose of the survey was to; confirm the information obtained during the desk study; to become familiar with site conditions; and to assess views to and from the River Almond and the East Pow Burn. The study area was visited during March 2005, September 2009 and June 2011.

7.6.2 Ecology

Site surveys for particular habitats and species were undertaken as indicated in Table 11. The ecological survey study area was defined as the sections of the River Almond and the East Pow Burn and adjacent habitats that will be directly affected by the proposed flood protection scheme. In general the margin of the ecological survey area is formed where the built environment of Almondbank (and to a lesser extent farmland) borders the wildlife habitats of the River Almond and East Pow Burn.

Species	Type of Survey	Timing
Habitats		
Phase 1 habitat survey	Standard Phase 1 habitat survey (JNCC, 2007)	July 2005
	Updated Phase 1 habitat survey	September 2009 February 2010 May 2011 April 2012
River Corridor Survey	Standard River Corridor Survey methods (NRA, 1992)	July 2005
Protected species		
Otter	Survey as part of extended Phase 1 Habitat Survey	July 2005

[21] Almondbank Flood Protection Scheme, Environmental Statement, Volumes One and Two, prepared by Mouchel for Perth & Kinross Council (2013.

Species	Type of Survey	Timing
	Specific update survey	October 2007
	Specific update survey of otter holt on East Pow Burn only	July 2010
	Specific update survey	April 2012
Water vole	Survey as part of extended Phase 1 Habitat Survey	July 2005
Bat	Habitat based appraisal	October 2007 September 2009 April 2012
Red squirrel	Habitat based appraisal	October 2007 September 2009
Badger	Survey as part of extended Phase 1 Habitat Survey	July 2005
Lamprey	Specific survey	September 2008
Fresh Water Pearl Mussel	Specific survey	October 2007

Table 11 - Ecology surveys undertaken

7.6.3 General Walkover Surveys

Other more general environmental walkover surveys were undertaken during the course of the assessment to help identify and evaluate land use, water features, recreational access routes / features and potential construction noise and air quality receptors.

7.7 Fluvial Geomorphological Assessment

A fluvial geomorphological study of the River Almond and East Pow Burn has been undertaken that examined morphological features in the river channels and anthropogenic changes to the watercourses[22]. The study also examined the proposed scheme designs to determine if they would have an impact on the present morphology of the watercourses.

7.7.1 Assessment of the River Almond and the East Pow Burn

The River Almond is a large, dynamic gravel bed river with its headwaters extending into the Grampian mountain range. The East Pow Burn is a heavily engineered watercourse with a much smaller catchment, which feeds into the River Almond. Both watercourses display characteristics of having a flashy response to changing hydrological conditions.

[22] River Almond & East Pow Burn Fluvial Geomorphological Assessment, prepared by Mouchel for Perth & Kinross Council, April 2011.

The River Almond has carved a channel through glacial deposits from the late Devensian ice-sheet and re-worked past alluvial deposits. The River Almond from the Bridgeton Road Bridge to the bridge pier at Craigneuk has been artificially engineered for various industries over the last 200 years. The East Pow Burn meanders through glacial outwash and alluvial gravels, which has been modified with rock armour for industry. Flood plains associated with both watercourses have been mostly developed upon, with residential, agricultural and commercial uses.

The study has identified significant areas of erosion and deposition are occurring on the river bed and banks at the Playing Fields, upstream of Low's Works Weir and upstream of the bridge pier on the River Almond. This morphological episode is a result of anthropogenic changes to the River Almond resulting in a reduction in the cross-sectional area of the river channel, damage to two weir structures and the development of a large island in the channel. Photographic and anecdotal evidence identifies that major morphological change has occurred since 2005.

In contrast the East Pow Burn morphology appeared relatively stable There was no evidence of significant erosion or deposition of the riverbank and river bed. Rock armour has been extensively used at the toe of the riverbanks along the watercourse. The confluence has been heavily engineered with a concrete bed and masonry channel sides to support the Confluence Road Bridge.

The hydraulic modelling has highlighted that for the 1 in 200 year flood event, the velocities along the watercourses will see a small increase in some areas and decrease in others. It is anticipated that these velocity fluctuations should not greatly increase river bed and riverbank shear stresses.

7.7.2 Study Recommendations

The scheme will need to addresses the current erosion occurring on the River Almond within the study area, reducing the over supply of sediment to the river channel. Low's Works Weir is a grade B listed building and has been restored to its original condition under a separate commission prior to construction of the scheme. The restoration of the weir was completed in August 2012.

The scheme should include erosion protection measures at the exposed sections of riverbank. Care should be taken not to increase river bed and riverbank shear stresses, this will provide long-term stability to the riverbank, which is ultimately protecting the flood defence structures. The scheme should not significantly decrease existing cross-sectional areas in the watercourses.

The riverbed on both watercourses is well armoured. Construction techniques need to minimise unnecessary disturbance of the riverbed to prevent erosion post construction. Care should be taken to minimise sediment movement during construction works in the river channel.

The exposed escarpment upstream of Waterside Cottages is being eroded. With the increased in flow and velocity of the scheme it is recommended that the escarpment should be monitored for future instability.

7.7.3 January 2011 Event

Further to the original study, high river levels in January 2011 caused significant erosion downstream of Low's Work Weir on the River Almond. Approximately 55 metres of the right riverbank was lost at the boundaries of residential properties at Huntingtower, with extensive erosion also occurring at the agricultural field on the opposite bank. Shortly after the erosion occurring, emergency works were undertaken to reconstruct and stabilise the affected riverbanks.

Significant erosion of the riverbank also occurred along the East Pow Burn adjacent to Main Street. Perth & Kinross Council propose works at this location to mitigate against further collapse and scour of the riverbank.

Mouchel recommend post construction monitoring at both of these locations to ensure the stability of the works and to capture any further morphological changes that may occur.

7.8 College Mill Trout Farm

The College Mill Trout Farm is situated on the left bank of the River Almond at the uppermost reach of the study area. Mouchel has worked extensively with the landowner to understand the operational requirements of the trout farm. The landowner has provided information to enable Mouchel to develop the outline design to ensure the continued operation of the site during the design event.

The shallow depth of water and siltation in the lade and associated channels means standard flow monitoring equipment will not provide sufficiently accurate readings. In the absence of current flow data, Mouchel have used historic flow data and taken guidance from the landowner to develop the outline design. A bespoke flow monitoring methodology will need to be developed and a more detailed assessment will need to be undertaken at detail design, to provide more accurate parameters for the design of the pumping station and the hatchery sluice.

It has been witnessed in previous flood events and identified in the hydraulic model that the hatchery area, barn, raceways and the lower ponds become inundated with flood waters. Firstly, internal flooding of the site occurs from excess flows in the lade channel and flood waters from the River Almond backing up the hatchery outfall pipe and flooding the hatchery area. Secondly the River Almond overtops the riverbank along the length of the site, flooding the hatchery, barn area, raceways and the lower ponds.

There are two key elements of the trout farm design; firstly to defend the key operational areas and secondly to allow continued operation of the trout farm for the design event.

7.8.1 College Mill Trout Farm Operations

The trout farm is a natural gravity fish farm and is fed by a single source of water via the College Mill Lade, which runs the entire length of the trout farm providing flow for various operations. An old masonry weir and a large sluice gate extract flow upstream from the River Almond and diverts it into the lade. A smaller secondary sluice is located 15m downstream of the large sluice to discharge excess flows from the lade back into the River Almond when the river is in spate.

The College Mill Lade channel feeds the hatchery tanks, the upper ponds, the lower pond and the raceways. The water levels are controlled by a series of sluices along the lade. A large sluice arrangement controls flows in the lade downstream of the hatchery before the lade runs under the barn. Upstream of the upper ponds two smaller sluices can extract flow back to the River Almond and to the raceways. A final sluice is located at the end of the lade channel downstream of the upper ponds to provide additional flow control in the lade and upper ponds.

The hatchery area is where fish are grown from eggs to juvenile fish. A loss of fish stocks in the hatchery can result in a significant disruption to fish supply and financial costs to the trout farm owner.

The hatchery tanks that are sited lower than the level of the lade channel are fitted with small drainage pipes that take flow from the lade channel. To regulate flow in the hatchery tanks an outfall pipe discharges flows to an open gully running the length of the hatchery, which discharges into the River Almond.

The trout farm ponds are where the fish are grown. The upper ponds are fitted with small sluices and drainage pipes taking flows from the lade channel into the ponds. At the opposite end adjacent to the lower pond a set of sluices takes flows from the upper pond through the existing embankment and access track and discharges into the lower pond. The lower pond is positioned parallel to the riverbank along the length of the upper pond area. The outfall for the lower pond, fitted with fish netting and revolving sluice gate, is situated downstream of the raceways area and discharges water back to the River Almond.

The raceways is a holding area for selecting fish, situated upstream of the lower pond. A series of sluices and portable pipes are used to move fish from the upper and lower pond to the raceways.

7.8.2 Fluvial Flood Protection

To provide fluvial flood protection to the entire trout farm would require flood defences to be located along the river bank. This would require extensive removal of the riverbank and tree line and flood defences 3 metres high, from the hatchery to the downstream extent of the site. This option was not viable from an engineering, economic and environmental view point and therefore this option was discounted.

As an alternative to providing fluvial flood protection along the entire length of the riverbank, the trout farm operations were assessed and it was concluded that the

hatchery tanks, raceways and the ponds needed to be protected against fluvial flooding. Fluvial flooding of the area to the south of raceways and the access track running to the west of the ponds has been deemed not to interfere with the safe operation of the trout farm during high flows and will not be protected. The access track will need to be reinforced to protect against scour during a flood event.

An investigation into the main sluice arrangement at the entrance to the College Mill Lade and the secondary sluice 10 metres downstream, showed the structures to be ineffective during flood events allowing increased volumes of flood water to flow along the lade. It was assessed that restoring the main sluice gate would not be sufficient to protect the trout farm from flooding and a new sluice gate arrangement will be required upstream of the hatchery on the existing lade.

The hydraulic model and anecdotal evidence identifies that excessive flows enter the lade before the River Almond spills over bank top, immediately upstream of the hatchery tanks. As excess flows enter the lade the new sluice gate will control these flows however it will cause a head of water upstream of the sluice, increasing turbulence and high velocities locally and spilling back to the River Almond. A simple side weir arrangement will be required immediately upstream of the new sluice gate, to allow the excess water to spill back to the River Almond.

Flood flows contain large amounts of debris in the lade channel therefore a fish screen will need to be constructed in the lade channel between the proposed sluice and hatchery tanks to trap the debris. The screen will only need to be in operation during high water levels and will need to be monitored for blockages during use.

7.8.3 Operational Flood Protection

During flood events the hatchery operation cannot discharge water back into the River Almond, resulting in water backing up the existing drainage system and flooding the internal working areas. Therefore non return valves will be required on the existing outlet pipes to prevent internal flooding. The hatchery still needs to remain operational during a flood event therefore a spill off system will be required to include new pipe work to the rear of the hatchery tanks. A pump station was considered however this option was discounted because of the limited space available. A spill off system will allow drainage of the tanks at grade into either the open channel adjacent to the barn or adjacent to the raceways. The final discharge point will be determined at detailed design.

The open channel between the barn and the hatchery is the location for the first main outfall for river water from the lade back to the River Almond. If the perimeter of the trout farm at this location is protected from fluvial flooding then it will be necessary to strengthen and increase the height of the open channel to contain excess flows prior to discharge. The vehicle access crossing the outfall channel will need to be replaced in line with these works.

As with the hatchery tanks, if the ponds are protected from fluvial flooding then all outfalls on the fish ponds will need to be fitted with non return valves. Any surface

water collecting in this area will need to be diverted into a suitable drainage system and allowed to spill back to the River Almond. It is assessed that the most efficient way of ensuring excess surface waters do not collect on the dry side of the defences is that they are discharged back to the River Almond via a pumping station located at the southern extent of the site.

Currently during high flows excessive river water enters the lade and flows the entire length of the lade channel. At the southerly extent of the lade a sluice is sited to prevent the fish ponds from flooding internally. The sluice then outfalls back to the River Almond; however during a flood event river water will back up the drainage outfall and prevent excess river water in the lade from escaping. It will be necessary to install a non return valve, retention well and pump station at the outfall to pump the excess river water from the Lade back to the River Almond.

7.9 Statutory Undertakers

During the development of the outline design, requests were made to the Statutory Undertakers for information regarding their services within the scheme extents. Information received in response to these requests was collated and incorporated into the outline design drawings.

The outline designs were progressed in line with the data received and where possible, the designs were developed to minimise conflict between services and flood defence structures. There still remain a number of locations where it has not been possible to avoid conflict between existing services and proposed flood defence works.

At the time of the Public Consultation in 2011, all of the Statutory Undertakers were notified of the Public Exhibition and asked for feedback in relation to the scheme proposals and any impact these may have on their apparatus. Minimal feedback was received at this time (a number of confirmations of receipt of the project information, none of the Statutory Undertakers attended the Public Exhibition).

Mouchel completed an exercise to accurately determine the extents of the potential disruption to the affected services. Consideration was given to both the temporary and permanent works associated with the scheme and the extent of any disruption to the affected services.

Details of the all of the affected services and their locations can be referenced in the full schedule[23] contained in Appendix E. The schedule was provided separately to each of the relevant Statutory Undertakers in order that they were able to provide a preliminary estimate for any costs associated with the protection and diversion of their services.

[23] Schedule for affected services', prepared by Mouchel for Perth & Kinross Council, October 2011

Some of the more significantly affected locations are;

- Adjacent to the confluence of the River Almond and the East Pow Burn,
- Lochty Park Road Bridge,
- Adjacent to the Playing Fields and the River Almond Footbridge.

Preliminary cost estimates were received from all of the Statutory Undertakers contacted and included in the Economic Assessment;

- Openreach BT (a BT Group Business),
- Scottish & Southern Energy (Power Distribution),
- Scotland Gas Networks,
- Scottish Water.

Details of the responses received from each of the Statutory Undertakers, including the preliminary cost estimates can be referenced in Appendix F.

7.10 Early Contractor Involvement

In February 2010 a contractor was invited to review the proposed outline design with regards to the buildability of the proposed scheme and the suitability of the proposed flood defence structures. The contractor reviewed the proposed scheme drawings and further met with members of Mouchel's project team and Perth & Kinross Council on site to assess the suitability of the proposed scheme.

The result of the consultation highlighted that the proposed scheme does not propose any obvious difficulties with construction. Some of the particular issues raised are as follows.

7.10.1 College Mill Trout Farm

The College Mill Trout Farm may present some challenges, mainly with regards to access to the site and minimising the impact on the operation of the trout farm during construction. Access could be gained from the north however the structural integrity of the Town Lade would need to be considered. Alternatively access could be gained via the main access to the south; this would require the proposed bridge downstream of the hatching tanks to be built first to gain access to the north of the site.

Timing of the proposed works to the south west of the ponds to the south of the trout farm would need to consider the seasonal nature of the use of the ponds. The anti-heron netting would need to be raised locally to accommodate the works. The existing gate at the southern end of the site will need to be re-opened to allow access to construct the southern defences.

7.10.2 College Mill Road Properties

It is envisaged that the construction of the reinforced concrete flood walls to the boundaries of the properties located on College Mill Road (Druids House, Rhourkton House and Rhencullew) will require construction equipment to track onto the river terrace rather than through the properties. Access from the rear of these properties is limited and would cause substantial disruption to residents. Some trees would need to be removed but landscaping proposals would ensure that these are replaced.

Further downstream, there is also limited access to the riverbank around Deer Park, similar arrangements will be required and access will be required to the gardens of the properties.

7.10.3 River Almond Footbridge

There are a significant number of buried and overhead utility services adjacent to the existing River Almond Footbridge structure that may require diverting as a result of both the temporary and permanent proposed bridge raising works. Consideration should be given to replacing the bridge entirely. This would limit the disruption to users as the existing bridge could remain in position until the new one was commissioned and the cost of a new bridge could be partially offset by the reduction in the costs of the utilities diversions.

The deck of the existing bridge has an unknown lifespan as this was originally installed as a temporary replacement, whilst a new structure would have a defined lifespan. Moving the existing bridge deck would require a large crane to transport the entire section or could be dismantled and rebuilt in sections.

7.10.4 Confluence Road Bridge

At the confluence with the River Almond and East Pow Burn the existing road bridge will need to be removed and the new approach roads and abutments will need to be constructed before the new bridge deck is placed. Any vibration from construction of these works and the nearby sheet pile walls would need to be monitored due to the close proximity of the waste water treatment works and residential properties.

Alternative access provisions will need to be made during the works. This should be possible from the south for properties to the south of the new bridge crossing (Low's Work Cottages, Brockhill and Puddledub). This access could be gained during the works via the existing farm track for these properties.

7.10.5 Sheet Piling Operations

There are a few locations where due to the proximity of existing buildings and utility services, sheet piling operations may prove difficult due to limited space or lack of access;

- The proposed sheet pile wall to the eastern boundary of Vector Aerospace on the left bank of the East Pow Burn could be installed from the opposite bank along Huntingtontower Haugh,

- Access to the riverbank along the southern boundary of Vector Aerospace could be gained from the Vector Aerospace site, negotiation and agreement for this access will need to be concluded during detailed design. Vibration from installation of the sheet piles would need to be monitored due to the close proximity of utility services and buildings,

- In some locations the line of the sheet pile wall will need to be installed at minimum distances from commercial structures and residential properties, both for ease of access and disruption and in order to minimise disruption to the occupants.

7.10.6 Lochty Park Road Bridge

At Lochty Park residential estate, the only access across the East Pow Burn is the Lochty Park Road Bridge that will need to be removed and replaced as part of the outline design.

It is considered possible to sequence the removal of the existing culvert structures and construct the replacement bridge one half at a time in order to maintain access. Alternatively a temporary bridge could be erected upstream adjacent to No.6 Lochty Park.

The reinforced concrete floodwall along the right bank of the East Pow Burn in this location will need to be carefully phased in order to maintain access to properties. At some key locations, construction access will need to be from the East Pow Burn. Access to track into the watercourse (bearing in mind constraints associated with this being a SAC) may be gained from the A85 Road Bridge turning into Main Street.

It is recommended that all three bridge structures for the proposed scheme are replaced in the initial phase of construction.

8 Environmental Assessment

8.1 Environmental Assessment

In tandem with the development of the outline design, an Environmental Impact Assessment (EIA) of the scheme was undertaken in accordance with the Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011 (the EIA Regulations), which implement European Union Directive 85/337/EEC (as amended by Council Directive 97/11/EC and 2003/35/EC) on the assessment of the effects of certain public and private projects on the environment.

The EIA Regulations require that an Environmental Statement (ES)[24] is prepared for specific types of development before they can be given development consent. The requirement to prepare an ES was confirmed by Perth & Kinross Council in their response to a request for a screening opinion under the EIA regulations.

The aims of EIA are to;

- Gather information about the existing environmental conditions in the study area and identify environmental constraints and opportunities which may influence, or be affected by the proposed scheme,
- Identify and assess potential environmental impacts that may arise from the construction and/or operation of the scheme,
- Identify and incorporate into scheme design and operation, features and measures to avoid or mitigate adverse impacts.

8.1.1 Existing Environment

Almondbank comprises several groups of houses (some of which are classed as listed buildings), the Vector Aerospace site, College Mill Trout Farm, the Playing Field and a Bowling Club. The River Almond and its tributary the East Pow Burn are the main watercourses in the village and are part of the River Tay Special Area of Conservation. Other features associated with these watercourses include Low's Work Weir (a listed building), the Waste Water Treatment Works, Perth Town Lade and a number of surface water outfalls. The banks of both the River Almond and the East Pow Burn are tree lined and this links with woodland in the wider area. Beyond the river lie areas of amenity grassland, agricultural land and the gardens of residential properties. The River Almond and East Pow Burn and associated

[24] Almondbank Flood Protection Scheme Environmental Statement - Volume One, Almondbank Flood Protection Scheme Environmental Statement - Volume Two, Almondbank Flood Protection Scheme Environmental Statement - Non-technical Summary.

bankside trees provide suitable habitat for wildlife, including fish, otter, bats and birds.

The main commercial premises comprise the Vector Aerospace site, situated at the confluence of the River Almond and East Pow Burn adjacent to both watercourses and the College Mill Trout Farm on the left bank of the River Almond further north. There are a number of public access routes close to the River Almond and these are heavily used for recreational purposes, particularly dog walking by local residents.

Some sections of the banks of the River Almond and the East Pow Burn have been protected from erosion in the past, including adjacent to the Bowling Green and along the banks of East Pow Burn at Vector Aerospace. In response to flood events in 2011, temporary erosion protection has been installed along the River Almond downstream of Low's Work Weir and on the East Pow Burn at Lochty Park.

8.1.2 Environmental Impacts and Mitigation

The proposed scheme and associated protection measures have been designed to minimise adverse environmental effects wherever possible. Nonetheless some impacts will arise from the proposals, these are summarised below.

8.1.2.1 Land Take

There will some permanent loss of land as a result of the construction of flood walls and embankments and also some additional temporary land take during the construction period, to allow for access to the works area. Land temporarily affected will be reinstated following scheme completion. The siting of the flood protection proposals has been chosen to reduce tree loss as much as possible, although some tree removal and thinning along the river banks will be necessary to accommodate the works.

A number of private residential properties adjacent to the River Almond and East Pow Burn will be affected by the proposals, primarily through the construction of flood defences along the perimeter of private gardens. Other properties may be affected through temporary land take within gardens during the construction period however this land will be reinstated on completion of the works.

8.1.2.2 Landscape and Visual

The main landscape and visual impact due to the scheme will be the removal of trees and other vegetation from various points along the River Almond and the East Pow Burn to enable the installation of the sheet piling, flood walls, earth embankments and erosion protection. Appropriate landscaping, including tree planting, will be implemented as mitigation. The precise location of the erosion protection on the embankments and the flood walls will be designed to reduce the need for removal of high-quality mature trees and tree condition surveys will be undertaken.

Views of the proposed flood protection measures from residential, recreational and commercial receptors are constrained to a relatively narrow area due to a combination of existing belts of woodland, steep banks and twisting roads and tracks. The flood defence structures would be relatively inert in that they would be motionless, emit no light or noise (except for the occasional use of the pumping stations at the trout farm and the Vector Aerospace site) and, with replanting and vegetation re-growth, will blend into the surrounding area.

8.1.2.3 Water Quality and Hydrology

During the construction period there is potential for sediments and other pollutants (such as chemicals, fuels, oils, concrete) to enter the watercourses as a result of vehicle movements, earth moving, construction activities or accidental spillage. There is also the potential for sediment release due to physical disturbance of existing riverbanks and riverbed, particularly through the installation of sheet piles and erosion protection.

Water quality will be protected by the implementation of appropriate pollution control measures throughout the construction period.

8.1.2.4 Ecology

The location and design of the flood protection works has been developed to minimise tree removal, however there will be disturbance to and loss of habitat as a result of the creation of flood walls and embankments and the need to access the river bank for these works. This will mainly involve removal of areas of bankside woodland, including some mature trees with bird breeding habitat and, possibly, bat roosts. Where possible mature trees will be retained and appropriate landscaping including the planting of additional native broad-leaved trees will be carried out as part of site restoration. All site clearance works will be undertaken in accordance with good practice construction guidelines.

Any otter breeding sites that will be affected will be closed off and alternative sites provided elsewhere. Trees/groups of trees that will be affected will be inspected for signs of bats and relevant licences obtained if any bat roost were to be disturbed. Vegetation/tree removal will either be undertaken outside the bird breeding season or trees and scrub checked for the presence of breeding birds/active nests prior to site clearance. Bird and bat boxes will be erected on completion of the works.

Any works within watercourses will be undertaken to avoid sensitive periods for fish and water quality will be protected by the implementation of appropriate pollution control measures during the construction period.

Careful reinstatement, replacement and, where possible, enhancement will ensure that river banks are recreated so as to allow vegetation to re-establish. In addition, similar riverbed characteristics will be restored where appropriate to enable colonisation by aquatic vegetation

As the River Almond and the East Pow Burn form part of a SAC, the Habitats Regulations (The Conservation (Natural Habitats & c.) Regulations 1994 (as amended)) are applicable and as such a Habitats Regulations Appraisal has been undertaken in parallel with the production of the ES to identify the need for any further mitigation.

8.1.2.5 Cultural Heritage

Potential adverse impacts on known features of cultural heritage interest have been avoided by careful design. If significant cultural heritage assets / archaeological features are encountered during construction appropriate mitigation will be put in place.

8.1.2.6 Geology, Soils and Contaminated Land

Potential impacts during construction include compaction of soils (through the use of heavy plant and equipment) and this may result in increased erosion with the risk of pollution to surface waters. Inappropriate soil stripping, storage, handling and reinstatement of soils can also result in degraded soil condition. Site works will be undertaken in accordance with good practice construction guidelines to minimise the potential impacts on soils. All material to be used or reused during construction will be stockpiled in designated areas, with appropriate containment and protective measures in place, and will be carefully transported and handled.

8.1.2.7 Air Quality and Noise

There will be elevated dust, vehicle emissions, noise and vibration during the construction of the flood protection works. However, this will be localised and of short term duration as construction activities will be phased and works will be split so as not to occur continuously in all areas, thereby controlling the potential level of dust emission and noise/vibration. All construction activities will be undertaken in accordance with standard best practice to minimise disturbance or nuisance and construction works will only be carried out during agreed working hours.

8.1.2.8 Traffic and Access

All construction traffic is expected to travel along the A85 and enter Main Street at Lochty. Traffic flow along the A85 as well as traffic exiting and entering the Lochty junction may be affected during the construction period due to the presence of site vehicles.

It is assessed that;

- Access to Bridgeton Brae, the Playing Fields, the Bowling Green and Lochty (including Lochty Park Road Bridge) will be required from Main Street,
- Access to College Mill Trout Farm, College Mill Road, Deer Park and Craigneuk will be required from College Mill Road via Main Street,

- Access to the Vector Aerospace site will be required from Main Street,
- Access to the River Almond Footbridge will be required from Main Street to the south west and College Mill Road via Main Street to the north east,
- Access to the Confluence Road Bridge will be required from Main Street and the access road to the north west and the south east.

Traffic management measures will be implemented to minimise disruption to the use of public roads and to existing access arrangements.

Some public access routes in the locality of the flood protection scheme will be temporarily affected, however, a staged approach to construction should ensure that routes are accessible throughout the construction period. If accesses are to be restricted then residents will be consulted prior to the works. New access to specific properties will be provided where required. A new section of access road will be constructed across the flood embankment at the Playing Fields and the existing pavilion removed and rebuilt in a similar position to its current location.

8.1.3 Environmental Commitments

The EIA has identified the following key measures to be included as mandatory commitments as part of the proposed scheme, with a view to reducing potentially significant impacts identified during the assessment;

- Maintain existing access arrangements or provide alternative access arrangements during the construction period and limit any closures to off-peak periods,
- Careful consideration to tree removal during the detailed design to reduce tree loss,
- Good construction site practices to be implemented to control noise, dust and the risk of pollution,
- Restoration of areas temporarily disturbed during construction,
- Re-use of excavated materials, where possible, in earth embankments and landscaping,
- Appropriate handling, storage, re-use and disposal of excavated materials, as applicable,
- Tree planting where space allows,
- Screening at the location of the new footbridge to match the existing planting,
- The existing hedge on the approach to the Playing Field car park will be supplemented by landscape planting. In addition an area at the entrance to the Playing Field car park off Main Street will be landscaped,

- Use of materials that will blend the replacement road bridge at the confluence of the River Almond and the East Pow Burn more easily into the surrounding landscape and also reduce its visual intrusion. Compensation planting will be provided to mitigate for loss of trees in this area,
- Appropriate pollution control procedures to reduce the risk of sediment entering watercourses,
- Measures to deal with fuel and oil transport and storage, such as the inclusion of appropriately bunded areas and spillage trays,
- Emergency/contingency procedures to deal with any accidental spillages,
- Careful bank/watercourse restoration to include; landscaping (seeding and planting); facing of structures with local stonework (or similar finish); carefully designed bank re-profiling,
- Biodegradable materials will be considered to aid the regeneration of bank-side vegetation and to protect tree roots,
- Tree condition survey and check for bat roosts,
- Replacement of otter breeding sites,
- Structural building surveys before, during and after construction for properties within 40m of piling works areas,
- Monitor dust emissions and measure noise levels where necessary,
- Traffic management.

9 Flood Protection Proposals

The recommended flood protection proposals have been developed to outline design and presented in the final outline design scheme drawings. A complete set of the final Flood Protection Order Drawings can be found in Appendix G.

9.1 Scheme Elements

The outline design for the scheme proposes a combination of proven flood defences that have been assessed to be the most appropriate for their immediate environment. Further to a more detailed analysis, detail designs for the specific type of each of these structures will be confirmed in line with the considerations below.

9.1.1 Sheet Piled Flood Walls

Sheet pile walls offer a robust flood defence solution that can provide erosion protection and flood defence within a limited amount of space; this is of benefit where flood defences are required in close proximity to buildings and property boundaries. Dependant upon the location and surroundings, the sheet pile walls can be left as installed, painted or finished with a cladding, sympathetic to the local environment.

9.1.2 Reinforced Concrete Flood Walls

Reinforced concrete walls also offer a robust flood defence solution and are more suitable where sufficient space exists for excavation of footings and the operation of construction plant. This solution is largely more cost efficient per metre of installation than the installation of sheet pile walls.

This type of construction lends itself to the provision of a more aesthetic finish with an increased flexibility in the choice of finish and is therefore ideally suited to the sections proposed along the banks of the River Almond where the flood defences must blend in with the river corridor, which is designated a Special Area of Conservation.

9.1.3 Earth Embankments

In locations where sufficient land is available, the outline design proposes earth embankments; constructed with imported materials with an impermeable core, to contain flood waters and manage seepage. The footprint of these structures requires more land take and is only suitable where the surroundings allow.

In certain locations along the River Almond, existing earth embankments have been constructed along the banks to provide local flood protection and in some locations these will be reduced to existing ground level and re-built to increased levels to ensure continuity of flood water retention within the watercourse.

9.1.4 Erosion Protection

Each of the proposed flood defence structures will require some form of erosion protection to ensure its long term stability during normal and flood conditions.

Designs for the erosion protection will have to adhere to the SEPA Good Practice Guide for Bank Protection, in line with the requirements of the Water Environment (Controlled Activities) (Scotland) Regulations 2006 (CAR). SEPA has defined two classes of bank protection measures; Green (soft) and Grey (hard) which are;

9.1.4.1 Green Bank (Soft) Protection

Green bank protection measures includes; engineering with biodegradable geotextiles (meshes or rolls of natural fibre used to protect and stabilise the river bank), un-mortared rip rap at bank toe (anchored at the foot of the bank to protect against toe scour), re-profiling of the existing bank using local natural materials.

9.1.4.2 Grey Bank (Hard) Protection

Grey bank protection measures include; major bank modification using artificial materials, reinforced concrete and sheet piled walls, gabion mesh baskets or mattresses filled with stone, reinforced earth (compacted soil between layers of geotextile), stone revetments (large pieces of rock armour placed on the river banks,), grouted revetments, non biodegradable geotextiles (fabrics made from synthetic material).

The type of erosion protection proposed during detailed design will be that which minimises any negative environmental impact (as far as practical), is cost effective and achievable, whilst considering the existing river channel characteristics and any future access and maintenance requirements.

9.1.5 Maintenance Access Points

Consideration has been given to maintenance access points, for routine and emergency maintenance operations, at suitable locations along the watercourses. These maintenance points will be incorporated into the existing river banks and designed to withstand vehicle loadings at a suitable gradient to allow safe access and egress. Erosion protection will be incorporated and detailed designs will be sympathetic to their environment.

9.2 River Almond Flood Protection Proposals

The River Almond flood protection proposals are referenced by the property or land that they are designed to protect and referenced to the relevant scheme drawings;

9.2.1 Bridgeton Road Bridge

(Drawing Ref; 716516_OPT_200)

The outline design proposes a combined kerb and drainage system in Bridgeton Brae immediately above the bridge, to collect surface runoff and overflows from the road and discharge it to the river before it can flow across the bridge.

The kerb drainage system will intercept surface water flows from this section of Main Street, (extending from No.21, heading south eastwards towards College Mill Road, continuing westward towards the road bridge). Prior to reaching the bridge, the intercepted flow will discharge via a buried outfall pipe into the River Almond at a location upstream of the road bridge.

9.2.2 College Mill Trout Farm

(Drawing Ref; 716516_OPT_201, 202, 203, 204, 301 & 302)

The outline design proposes to mitigate the risk of fluvial flooding and maintain operation of the trout farm during the design event, with a combination of sheet pile flood walls (with cladding), reinforced concrete flood walls a demountable defence, a pumping station, drainage infrastructure works and the upgrading and replacement of access routes and sluices.

At the northern perimeter of the trout farm, a new sluice gate and side weir arrangement will be installed on the College Mill Lade intake to prevent excess flows entering the trout farm. Any excess flows will discharge via a spillway back into the River Almond. A demountable defence or flood gate will be incorporated adjacent to the new sluice gate arrangement to maintain vehicle access to the College Mill Lade entrance approximately 50m further upstream.

A sheet pile flood wall (with cladding) to the northern perimeter of the site incorporates the demountable defence or flood gate and sluice gate and will be clad in a suitable material and be protected from erosion at the toe on the river side. The sheet pile wall (with cladding) will continue south along the boundary of the trout farm, following the line of the river bank to the access ramp immediately upstream of the existing main trout farm outfall.

A secondary spill off system will be installed to ensure that the nine hatchery tanks are able to continue operation during the design flood event. The spill off system will allow continued discharge from the hatchery tanks via a separate pipe, under the barn and discharge adjacent to the raceways, through the proposed reinforced concrete flood wall.

In order to maintain the safe operation of the trout farm it will be necessary to make improvements to the existing access routes including local changes in elevation and finished levels to tie in with flood defence levels. This will allow the landowner to maintain access and operation during the design flood event. Structural retaining

walls will be constructed, where needed, to support increases in elevation to existing access routes.

The existing single vehicle access bridge will be replaced to maintain vehicle access for continued operation and maintenance of the trout farm. A reinforced concrete flood wall is proposed across the western extent of the bridge to tie into the sheet pile wall upstream and downstream of the bridge. A reinforced concrete flood wall will be constructed along the eastern boundary of the bridge to tie into the barn to prevent internal flooding from the River Almond.

A reinforced concrete flood wall will protect the internal area of the 'raceways', north of the ponds, allowing flood water to occupy the area between this and the river. The existing sluice gate east of the raceways will be replaced to tie in to the flood defence wall height. The riverside of the wall will be protected from river erosion. From the sluice, the reinforced concrete flood wall will continue to follow the existing access track southward alongside the ponds, allowing the existing vehicle access to flood during the design flood event. The vehicle access to the very south of the trout farm will be raised to tie in with flood defence levels

Pedestrian access to the river bank will be maintained along this stretch with the incorporation of permanent access steps over the reinforced concrete flood wall.

The existing trout farm drainage outfall to the south of the site will be modified to flow into a new pumping station and retention well, located at the current outfall. This will maintain continuous operation of the ponds during design flood events.

All outfalls from the trout farm ponds and the hatchery will be fitted with non return valves to inhibit the backflow of water from the river during flood events.

A maintenance access point will be incorporated at the south east extent of the trout farm on the left bank of the River Almond, to gain access to the upstream extents of the scheme and downstream towards the confluence.

9.2.3 Bowling Green

(Drawing Ref; 716516_OPT_ 204, 205 & 308)

The Bowling Green is at risk of flooding for the design event. In order to mitigate this risk, it is proposed to remove the eastern length and some of the northern section of the existing masonry perimeter wall and replace this with a reinforced concrete flood wall. The existing pedestrian access gates will be re-located from their current location in the north east corner to the eastern end of the northern perimeter wall with a new pedestrian access adjacent to the northern perimeter wall to a point where existing ground levels are sufficient to be outside of the flood risk area. Finished ground levels of the area currently used for car parking to the north of the perimeter wall will need to be re-graded to prevent ponding of flood water. The existing hedge to the southern boundary of the Bowling Green will be removed and replaced with a reinforced concrete flood wall.

A maintenance access point will be incorporated adjacent to the Bowling Green on the right bank of the River Almond, to gain access to the upstream extents of the scheme and downstream towards the confluence.

9.2.4 Playing Fields

(Drawing Ref; 716516_OPT_ 204, 205, 206, 207, 308 & 309)

It is proposed that the grassed area forming the Playing Fields off Main Street, on the right bank of the River Almond is designed to work as a flood storage area for excess flood waters spilling from the River Almond during a flood event. It is proposed to construct an earth embankment, with an impermeable core, to the south west and south east perimeters of the Playing Fields to ensure that water will be contained within this area during a flood event and allowed to discharge back into the River Almond as water levels begin to reduce.

A surface water drainage channel has been incorporated along the 'wet side' of the embankment to channel flows as flood water recedes. These will discharge through a piped outfall passing beneath the earth embankment in to the River Almond at the eastern extent of the embankment. The earth embankment will also incorporate erosion protection.

Vehicle and pedestrian access to the playing field is to be maintained with the incorporation of a series of access points over the embankment and a single vehicle access track over the embankment. The access track will tie into the existing track along the right river bank and be accessed from the existing Playing Fields car park off Main Street.

When the flood storage area is in use during a flood event, several measures are proposed to protect members of the public. A permanent continuous fence with gated access points is to be constructed along the length of the top of the embankment, with similar measures adopted to prevent vehicle access over the embankment and on towards the Bowling Green.

Extensive warning signage will be erected around the flood storage area, along with access and egress points along the embankment construction. Life buoys will be placed at intervals around the flood storage area in case of an emergency.

The current location of the pavilion puts it at risk of flooding during the design event and as a result of its current condition it will be removed and a new structure built as close to its existing location as possible, protected by the adjacent flood defence structures.

The river bank section along the length of the Playing Fields will be stabilised and protected from erosion.

9.2.5 Main Street

(Drawing Ref; 716516_OPT_ 204, 205 & 309)

The outline design proposes to mitigate against overflow from the combined sewer along the lower section of Main Street flowing southwards towards Vector Aerospace, through the use of a combined kerb and drainage system on Main Street.

The kerb drainage system will intercept surface water flows from a section of Main Street, from just north of East Drive to just south of Mackenzie Drive. Intercepted flows will discharge, via a buried outfall pipe beneath the Playing Fields, into the River Almond at a location upstream of the River Almond footbridge.

9.2.6 College Mill Road Properties

(Drawing Ref; 716516_OPT_ 204, 205 & 302)

The properties to the south of College Mill Trout Farm located on College Mill Road (Rhencullew, Rhourkton House and Druids House), will be protected from flooding by the construction of a reinforced concrete flood wall with associated erosion protection, in line with their property boundaries along the left river bank.

9.2.7 SEPA Gauge

(Drawing Ref; 716516_OPT_ 204 & 303)

Access to the existing SEPA flow gauge and apparatus will be maintained with the provision of access steps over the reinforced concrete flood wall. There have been no changes to the location of the gauge station as part of the flood protection scheme. The gauge and apparatus will need to be protected and the power supply maintained during and on completion of the construction works.

9.2.8 River Almond Footbridge

(Drawing Ref; 716516_OPT_ 204, 206, 207 & 303)

In order to mitigate the risk of flooding at this location it is proposed to increase the height of the footbridge relative to the design event flood levels. It is proposed that the existing footbridge is relocated approximately 12m upstream and placed on newly constructed bridge abutments.

The footbridge will be relocated upstream due to its close proximity to the properties at Deer Park (raising the bridge would result in their properties being overlooked by pedestrians using the footbridge). Relocating the footbridge will ensure that the newly constructed abutments are designed to withstand the increase in height and will ensure the minimal of disruption to pedestrians during the construction period.

As a result of the increase in footbridge height it will also be necessary to build new access ramps to the footbridge, these will tie into the adjacent reinforced concrete

flood wall structures running along the left (north east) and right (south west) banks of the River Almond. The land take for these access ramps is also more suited to the proposals to relocate the footbridge upstream of its current location.

The reinforced concrete flood wall on the right bank (south west) in this location will tie into the earth embankment at the perimeter of the Playing Fields, tie into the footbridge access ramp and continue for a short distance south eastwards along the access road to Low's Work Cottages. The river side of the reinforced concrete flood wall will be protected against erosion.

The reinforced concrete flood wall on the left (north east) bank at this location is the continuation of the reinforced concrete flood wall protecting the properties on College Mill Road which will tie into the footbridge ramp access, continuing south eastwards towards the properties at Deer Park. The river side of the reinforced concrete flood wall will be protected from erosion.

9.2.9 Deer Park

(Drawing Ref; 716516_OPT_ 207, 208, 303 & 304)

The properties adjacent to the left (north east) bank of the River Almond, located on Deer Park (No's 1, 2 & 3), will be protected from flood waters by the continuation of the reinforced concrete flood wall with associated erosion protection, to follow the extent of their property boundaries.

At the boundary between No 3 & 4 Deer Park, the reinforced concrete flood wall will tie into an earth embankment that will follow the line of the top of the left river bank from this point. The earth embankment will be constructed with an impermeable core to contain flood water within the River Almond. This embankment continues along the left riverbank to just upstream of Low's Work Weir, where it ties into high ground.

Any existing earth embankment along this length will be reduced back to original ground levels prior to the formation of the higher earth embankment.

Any surface waters collecting on the 'dry' side of the reinforced concrete wall and embankment will drain to a surface water drainage channel and discharge to the River Almond via pipes through the structures, a non return valve will be required on each pipe to prevent flood water from the River Almond from flowing back into the 'dry' area.

9.2.10 Access Road along the North East Boundary of Vector Aerospace Site

(Drawing Ref; 716516_OPT_206, 207, 208, 212, 213, 303 & 304

It is proposed to contain flood waters, spilling from the right bank of the River Almond, along this length of road. This will be achieved by slightly increasing the finished road level at the north west end to tie in with the flood defence level of the reinforced concrete flood wall.

From this point, the reinforced concrete flood wall will follow the south west side of the access road and the boundary of the land owned by Vector Aerospace, the finished road level will decrease to tie in with existing levels. This will allow flood water to flow onto the access road and contained there before being allowed to discharge back to the River Almond as flood levels recede.

The length of the access road subject to flood waters will be designed to withstand the flows and also protected against scour. The elevation of the access road at the entrance to the Waste Water Treatment Works will be raised in line with the adjacent flood defence heights, to prevent any flood water from entering the works. It is proposed that an alternative access to the treatment works will be provided to the rear of the works through the Vector Aerospace site.

The reinforced concrete flood wall will continue to the south east of the Waste Water Treatment Works entrance and tie in with the sheet pile flood wall to the southern perimeter of the Vector Aerospace site.

9.2.11 Vector Aerospace Site

(Drawing Ref; 716516_OPT_ 206, 207, 208, 212, 214, 215, 303, 304, 310 & 311)

The Vector Aerospace site will be protected from fluvial flooding with the construction of reinforced concrete flood walls to the north eastern perimeter and sheet piled flood walls to the south east and south western perimeter.

A surface water pumping system will be installed on site. A weir chamber will be constructed at the existing site outfall to intercept excess flows and pass them forward through a gravity pipeline to the surface water pumping station and wet well. Excess flows will then be pumped directly into the River Almond via a new outfall that will be integrated into the reinforced concrete flood wall at this location.

9.2.12 Craigneuk East and West

(Drawing Ref; 716516_OPT_ 209, 305 & 306)

The agricultural field to the south west of the Craigneuk properties will be protected with an earth embankment that will commence in the south west corner of the field and follow the boundary of the field in a north easterly direction towards Craigneuk. The earth embankment will be constructed with an impermeable core to ensure that flood water is contained within the River Almond.

Maintenance access to the River Almond will be incorporated in the south west corner of the field at the start of the embankment, to gain access to the downstream extents of the scheme and upstream towards the confluence.

Any surface water collecting on the ‘dry’ side of the embankment will drain to a surface water drainage channel and discharge to the River Almond via pipes through the structures. A non return valve will be required on each pipe to prevent flood water from the River Almond from flowing back into the ‘dry’ area.

The embankment ties into a reinforced concrete flood wall that is proposed to protect the properties at Craigneuk. The length of earth embankment and wall protecting the field and properties at Craigneuk will be well protected from erosion on the river side of the embankment. This is recommended due to the nature of the river at this point

The reinforced concrete wall to the boundary of the properties follows the river bank past Craigneuk until it reaches a point where it ties into existing higher ground levels to the north of the properties; this location ensures continuity of protection against the design event flood water levels. There will be some accommodation works to the garden of the property at Craigneuk East to ensure the desired line of the defences is achieved.

Any surface water collecting on the 'dry' side of the flood defences will drain to a surface water drainage channel and discharge to the River Almond via pipes through the wall. A non return valve will be required on each pipe to prevent flood water from the River Almond from flowing back into the 'dry' area.

9.2.13 Low's Work Cottages

(Drawing Ref; 716516_OPT_212, 213, 304 & 305)

It is proposed that Low's Work Cottages will be protected from flooding by a reinforced concrete wall constructed along the top of the right river bank. , The flood wall will be an integral part of the proposals to increase the bridge height at the confluence of the River Almond, following the line of the river bank along the front of the properties and tying into the existing masonry wall beyond the most eastern cottage.

The road access in front of the cottages will undergo works to increase the elevation in order to tie in with the proposals to raise the road bridge level at the confluence of East Pow Burn with the Almond. The property side of the access track will be supported with a structural retaining wall where necessary, until the change in elevation required ties back into the existing road levels.

9.3 East Pow Burn Flood Protection Proposals

The East Pow Burn flood protection proposals are summarised by the property or land that they are designed to protect and are described and referenced to the relevant scheme drawings below;

9.3.1 Lochty Park Road Bridge

(Drawing Ref; 716516_OPT_ 215, 311 & 312)

In order to mitigate the risk of flooding in this area and to contain the flood water within the East Pow Burn, it is proposed to remove the existing culverted road bridge structure and replace it with a single span road bridge with an increased elevation to allow more water to pass through during a flood event. The bridge structure will be designed to surcharge for the design event as it was not possible to provide

freeboard at this location due to the limitations of tying in the raised bridge structure with the adjacent Main Street road elevations.

As a result of increasing the level of the Lochty Park Road Bridge, the adjoining roads will also be subject to works to tie into the new elevations. Main Street to the north and south of the junction will be re-graded to tie in with the new bridge structure with structural retaining walls being constructed to support the elevated sections of road. Lochty Park Road will also be subject to some re-grading with the need to make some alignment and elevation changes to existing residential accesses.

9.3.2 Lochty Park

(Drawing Ref; 716516_OPT_ 215, 216, 311 & 312)

In conjunction with the raised road bridge, the Lochty Park properties upstream and downstream of the bridge crossing will be protected on the right bank by a reinforced concrete flood wall along the property boundaries, tying into the Lochty Park Road Bridge. Erosion protection will be introduced along the length of the toe of the flood walls. On the opposite bank of the watercourse it is proposed to construct a sheet pile flood wall (with cladding) to ensure that flood water is contained within the East Pow Burn at this location and passed forward as design event water levels recede.

The upstream extent of the reinforced concrete floodwall on the right bank (from the Lochty Park Road Bridge towards the A85) ties into the existing stone retaining wall at the junction of Main Street with the A85. The upstream extent of the sheet pile flood wall (with cladding) on the opposite bank ties into existing ground levels approximately 25m north of the junction.

A maintenance access point will be incorporated from the left bank of the East Pow Burn at the most upstream extent of the scheme close to the A85 road bridge, to gain access to the East Pow Burn towards Lochty Park road bridge.

The downstream extent of reinforced concrete flood wall on the right bank to the boundary of No1 Lochty Park will continue, turning eastwards to follow the bank of the East Pow Burn, tying in to higher ground levels. The downstream sheet pile flood wall (with cladding) on the left bank will continue to follow the bank of the East Pow Burn, heading eastwards to the perimeter of the Vector Aerospace site.

9.3.3 Vector Aerospace

(Drawing Ref; 716516_OPT_ 206, 207, 208, 212, 214, 215, 303, 304, 310 & 311)

The sheet pile flood wall running along the left bank of the East Pow Burn at Lochty Park will continue to follow the river bank to the south and south east boundary of Vector Aerospace, to provide continued protection to the site from fluvial flooding. The sheet pile wall will tie into the Confluence Road Bridge at the confluence of the East Pow Burn with the River Almond.

Any existing access points to the river bank along this length will be maintained with the provision of appropriate access points over the flood defence wall.

Where possible any existing gabion baskets that have been placed in the watercourse to provide erosion protection will remain unless they restrict the construction of the defences or where they are thought to be unstable. Erosion protection will be introduced to some sections along the length of the toe of the sheet piled wall.

9.3.4 Confluence Road Bridge

(Drawing Ref; 716516_OPT_ 212, 213, 304 & 310)

In order to mitigate the risk of flooding in this area and to contain the flood water both within the East Pow Burn and the River Almond, it is proposed to remove the existing road bridge structure and replace it with a single span road bridge with an increased elevation to allow more water to pass beneath during a flood event. The raised elevation of the road and associated parapet structure will be tied in to adjacent flood defences to contain water within the watercourses, during the design event.

As a result of increasing the level of the road bridge crossing the confluence, the adjacent roads will also be subject to works to tie into the new elevations;

- The road to the north west of the confluence, past the Waste Water Treatment Works towards Main Street, will be re-graded to tie into existing road levels at a suitable gradient,

- The existing vehicle access to Puddledub, to the south of the confluence, will be re-routed as a result of the flood defences to the right (south east) bank of the East Pow Burn. The access will be located to the south east of its current location, giving access to both the rear of the property at Brockhill and also the property at Greenacres,

- The road to the north east of the confluence, providing access to Low's Weir Cottages, will be re-graded to tie back into existing road levels. Any increase in road elevation will be supported with structural retaining walls and the re-graded roads will be protected against the design event with the construction of a reinforced concrete flood wall extending to the first property in Almond Grove,

- The road to the south east of the confluence, providing access to Brockhill and the Huntingtowerfield Farm will also be re-graded to tie back into existing road levels. Increases to road elevation will be supported by structural retaining walls.

-

9.3.5 Brockhill

(Drawing Ref; 716516_OPT_212, 213, 304 & 310)

In order to mitigate the risk of flooding to the property at Brockhill a sheet pile flood wall (with cladding) will tie into the Confluence Road Bridge and will be constructed along the right (east) bank of the East Pow Burn, tying into an earth embankment to the south of the property. The access road to Brockhill and the road to the east will be realigned to tie into the bridge level. The new road levels will be supported by a structural retaining wall along the north east and north west boundaries of Brockhill. An alternative car parking area will be provided to the rear of the property with access from the re-aligned access track leading to the property at Greenacres.

The earth embankment will be constructed a small distance back from the existing riverbank in order to provide an additional area for the containment of any flood waters. The right (east) bank of the East Pow Burn will be widened at the south end of the earth embankment to increase the capacity of the river. Associated bank strengthening and erosion protection will be provided for this and the immediate upstream and downstream banks.

9.3.6 Puddledub (Formerly Green Acres)

(Drawing Ref; 716516_OPT_214 & 310)

In order to mitigate the risk of flooding to the property at Puddledub, a sheet pile flood wall with suitable cladding will be constructed adjacent to the property along the right bank of the East Pow Burn, in order to contain any flood water within the watercourse. This sheet pile flood wall will tie in to high ground to the south west of the property and will tie into the earth embankment to the north east. Erosion protection will be provided to the right bank of East Pow Burn in line with the sheet pile flood wall and earth embankment.

The earth embankment will continue north towards the property at Brockhill and will be constructed along the current access to the Puddledub property. It is therefore proposed to divert the access to Puddledub towards the rear of the property at Brockhill and join the access road to Huntingtowerfield Farm. These proposals will provide Puddledub with protection against flooding and will maintain access during the design event.

A maintenance access point will be incorporated on the right bank of the East Pow Burn, west of the Puddledub property to gain access upstream towards Lochty Park road bridge and downstream towards the confluence.

10 Scheme Economics

10.1 Introduction

The economic performance of a flood protection scheme is determined through its benefit/cost ratio. Benefits are measured in terms of the present value (PV) of damages avoided over the appraisal period, with the PV of capital, project and maintenance costs being estimated over that period.

The benefit/cost analysis has been carried out in accordance with 'Chapter 5 of Flood Prevention Schemes; Guidance for Local Authorities - Economic Appraisal'. This document (compiled by Scottish Government) provides guidance on the economic aspects of project appraisal for flood protection schemes and is largely based on DEFRA Guidance.

Currently, it is intended that funding for the Almondbank flood protection scheme will be sought from the Scottish Government (Scottish Executive) and Perth & Kinross Council. Scottish Government funding will be through an application following approval of the Flood Order under the recently implemented Flood Water Management (Scotland) Act 2009. In order to do this, the scheme under consideration must be proven to be economically viable.

The capital cost of the scheme is estimated to be **£13,180,126** and is the amount that is presented in the Flood Order documentation. This figure represents the costs associated with the design and construction of the scheme only (including uplift to account for the period of design followed by the period of construction with an optimum bias applied).

In order to evaluate the net benefits, the damage costs avoided with the proposed scheme in place were compared against those of the Do Nothing and/or Do Minimum options. The damages for flood events of a range of probabilities were calculated and an average annual damage value determined. Damage costs were calculated from 2010 flood loss tables, as detailed in the 'Multi-coloured Manual' prepared by the Flood Hazard Research Centre at Middlesex University. This assesses the damage to residential properties based on property type and age, social class of residents and depth and duration of inundation.

Damages to non-residential properties were assessed based on property type (i.e. retail, office, public building etc), property size and depth and duration of inundation and clean-up cost. Emergency services costs (i.e. police, fire, ambulance, Council, military, etc) were also estimated from recommendations in the Multi-coloured Manual. In order for a scheme to be eligible for funding, it must have a benefit/cost ratio greater than 1.

10.2 Benefits Methodology

The benefit of a scheme is measured in terms of the PV of the damages avoided over the life of that scheme. Using a range of flood events of different probabilities allows an annual average damage value to be determined for the scheme, which is then discounted to present day values. The damages are categorised into residential losses, non-residential losses, clean-up and emergency services costs.

To calculate the residential losses the type and age of each affected property and the social class of the occupants must be known. The depth of flood water in relation to ground floor level and the duration of the flooding must also be estimated.

The property type and doorstep elevation of each affected property were established from survey work and site visits. The social class of the residents were taken to be C1 - Lower Middle Class with the majority of people working in supervisory or clerical and junior managerial, administrative or professional fields. This is consistent with census data for the Almondbank area.

The extent and depth of flooding associated with floods for a range of return periods were established through the one and two dimensional hydraulic modelling. Modelled water level outputs were compared with surveyed threshold level data to estimate the flood depth at each property.

In order to derive depth damage relationships, a range of return periods had to be considered together with the calculation of damage associated with each event. Once the annual average damage value is derived it is possible to bring all future damage costs to a common timeframe. In this study, the return periods used to derive the depth / damage relationship were the 10, 25, 50, 75, 100 and 200 year return period flood events.

In accordance with guidance from SEPA, DEFRA and the United Kingdom Climates Impact Program (UKCIP) an allowance for climate change is accounted for, in the assessment of the damages for the scheme economics, through increasing the flows on the contributing watercourses to produce new climate change rating curves. No climate change allowance was included for the period up to 2025, a 10% allowance was used from 2025 to 2050 and a 20% allowance from 2050 onwards. Revised flood return periods were determined by comparing the new climate change rating curves with the existing rating curves, which were in turn used to derive the depth / damage relationship.

The damages incurred are also dependent on the duration of inundation (i.e. whether properties are flooded for less than or greater than twelve hours). It was conservatively assumed that all affected properties would be flooded for less than twelve hours.

The Multi-coloured manual provides flood damage data for non-residential properties in terms of area of premises inundated, depth and duration of inundation and type of business. The depth of the flood water was estimated in the same way as for the

residential properties. Information on business type was collected as part of the property survey and during site visits; the area of each of the premises was calculated from Ordnance Survey maps. The flood damages from the Vector Aerospace site have also been included in the assessment. The base date for all estimates is June 2013 and all flood damage costs are uplifted to present day rates using the Retail Price Index (RPI).

Research by the Flood Hazard Research Council (FHRC) into the Autumn 2000 and Summer 2007 floods published in the Multi-coloured Manual (MCM, 2010) recommends that the total property damage calculated in project appraisals of flood alleviation schemes should be multiplied by a factor ranging between 5.6% and 10.7% to allow for emergency services and recovery costs. The differing percentages are based on economies of scale with the lower value of 5.6% being more applicable to densely populated areas. Therefore, a figure of 10.7% has been used in this assessment as Almondbank is a less densely populated community. The data sources used by the FHRC for this estimation included the Environment Agency (who fulfil a similar role to SEPA but in England and Wales), District and County Councils, Highway Authorities, the fire, police and ambulance services, the military, water authorities and voluntary services.

Costs Methodology

The costs include, capital, maintenance, project appraisal (design and supervision) and damages incurred over the entire life of the scheme and are discounted to present day values (PV). The scheme cost estimate has been uplifted to present day values using the Tender Price Index (TPI). The appraisal period should reflect the physical life of the scheme. With the proposed scheme involving earthworks, concrete and masonry structures, a 50 year design life within a 100 year appraisal period is considered to be appropriate. The current test discount rates used (as specified by the Treasury Green Book) are 3.5% for years 0-30, 3% for years 31-75, and 2.5% thereafter.

There is a widely recognised tendency to be overly optimistic when estimating project costs, timescales and benefits compared with actual final outturn costs. This is known as ‘optimism bias’. This bias is applied as a percentage uplift of the estimated PV costs, this includes both capital and maintenance costs. For this scheme, an optimism bias of 38% has been applied to reflect the current stage of the scheme. The criteria and methodology used to determine the optimism bias for the Almondbank scheme is that set out in Chapter 5 of the Scottish Executives, Flood Prevention Schemes, Guidance for Local Authorities, 2005. A breakdown of the optimism bias calculation for the Almondbank Scheme is presented in Appendix H.

10.3 Benefit/Cost Methodology Summary

In summary, the following parameter assumptions have been made in the course of the benefit/cost analyses;

- Damages based on all latest ISIS-TUFLOW flood-mapping and modelling,

- Climate change allowance included in appraisal of damages - 10% uplift from 2025 to 2050 and 20% uplift from 2050 onwards,
- Prices and base year as of June 2013 – using RPI and TPI uplift rates,
- Optimism bias taken as 38%,
- Test discount rate of 3.5% for years 0-30, 3% for years 31-75, and 2.5% thereafter,
- Indirect/intangible and traffic related losses ignored,
- Flooding to land/gardens ignored,
- 100 year appraisal period and 50 year scheme design life,
- Maintenance costs applied for each year,
- 10.7 % of property damage value added to account for emergency services and recovery costs,
- Revised clean up costs based on flood depth (MCM, 2010) have been included in the individual property damages.

Once the damages and cost figures had been evaluated, a set of excel worksheets (developed by DEFRA) were used to carry out the benefit/cost analysis. The benefit/cost worksheets calculate the present value (PV) damages and costs for the options. An evaluation of scheme viability was then made based on the benefit/cost relationships of the various options.

10.4 Estimate of Benefits and Costs

In order to fully assess the economic benefits and costs of the scheme, three option scenarios were modelled.

10.4.1 Do Nothing

The Do Nothing Option represents a worst case scenario where routine maintenance is not carried out and inspections are not made to current flood defence assets. This is the base case option against which all other options are assessed. Therefore, no allowance is included in this option for any maintenance of watercourses or existing flood assets and there are no capital costs or project costs associated with this option. A summary of the benefits and costs associated with the Do Nothing option are presented in Table 12.

Item	Cost (£)
PV of damage	22,677,000
PV of damage avoided	0
PV Maintenance costs	0
PV Maintenance costs +38% optimism bias	0

Table 12 – Do Nothing option damages and costs

10.4.2 Do Minimum

The Do Minimum Option is the present case scenario. This option represents the present day conditions, where routine maintenance is carried out to clear water courses of any debris and blockages, banks are maintained, vegetation trimmed and the existing flood defence assets maintained to their current standard. Therefore, an annual allowance is included in this option to cover the cost of routine maintenance.

There are no capital costs or project costs associated with this option. A summary of the benefits and costs associated with the Do Minimum option are presented in Table 13.

Item	Cost (£)
PV of damage	15,780,000
PV of damage avoided	6,897,000
PV Maintenance costs[25]	96,000
PV Maintenance costs +38% optimism bias	132,000

Table 13 – Do Minimum option damages and costs

10.4.3 Do Something

The Do Something Option represents the situation when the proposed scheme is implemented. This option scenario includes all the capital design, build, and operation and maintenance costs of the scheme. Residual damages for flood events with greater magnitude than the 1 in 200 year return period event have also been included. The Do Something Option consists of reinforced concrete and sheet pile flood walls, earth embankments, a single online storage area and surface water drainage improvements, providing a 1 in 200 year standard of protection.

In total approximately 31 residential properties and 48 non-residential properties (the majority of which are located in Vector Aerospace and Lochty Industrial Estate) will benefit from the final scheme. Works undertaken by others outside of the scheme extents has identified some flood risk in the Ruthvenfield area. The Almondbank Flood Protection Scheme does not include the area of Ruthvenfield and therefore there may be additional benefits from the proposed scheme which have not currently been accounted for.

The Do Something Option scheme costs include; consultancy and contracting services, client costs, environmental mitigation (including contaminated land clean-up), construction costs, landscaping, reinstatement, operational and maintenance costs.

The capital design and build costs have been apportioned over the first two years of the scheme. Operational and maintenance costs have been apportioned on an annual basis according to estimated requirements. The appraisal period of the flood protection scheme is 100 years and the useful design life of the defences is 50 years, therefore the cost of capital replacement of the defences after 50 years has been included. A summary of the benefits and costs associated with the Do Something option are presented in Table 14.

[25] Maintenance costs for appraisal period of option (100 years) at present day prices

Item	Cost (£)
PV of damage (residual)	1,522,000
PV of damage avoided	21,154,000
PV Capital construction costs[26]	8,890,000
PV Capital construction costs +38% optimism bias	12,267,000
PV Project/design fees[27]	1,872,000
PV Project/design fees +38% optimism bias	2,584,000
PV Maintenance costs[28]	584,000
PV Maintenance costs +38% optimism bias	807,000

Table 14 – Do Something Preferred option (incl. surface water drainage) damages and costs

The key figures from the economic appraisal are summarised in Table 15.

Item	Do Nothing	Do Minimum	Do Something
PV costs (PVc)	£0	£96,000	£11,346,000
PV costs (PVc) with 38% Optimism bias	£0	£132,000	£15,658,000
PV damage (PVd)	£22,677,000	£15,780,000	£1,522,000
PV damage avoided	-	£6,897,000	£21,154,000
Intangible Benefits	-	-	-
Total PV benefits (PVb)	-	£6,897,000	£21,154,000
Net Present Value (NPV)	-	£6,765,000	£5,496,000
Average benefit/cost ratio	-	52.14	1.35

Table 15 – Economic appraisal summary

The estimated PV of flood damages for the Do Nothing option and the Do Minimum option are £22,677,000 and £15,780,000 respectively. The estimated present value of the damage avoided in the Do Minimum and Do Something preferred option is £6,897,000 and £21,154,000 respectively. Considering the present value cost of the preferred scheme is £15,658,000 (including 38% optimism bias, project/design fees, maintenance costs and capital replacement of the flood defences after 50 years), the benefit-cost ratio for the preferred flood protection scheme is 1.35, therefore the scheme is considered economically viable. A copy of the economic appraisal summary sheets has been included in Appendix H.

[26] Includes cost of capital replacement of flood defences after 50 years
[27] Includes project fees for capital replacement of flood defences after 50 years
[28] Maintenance costs for appraisal period of option (100 years) at present day prices

11 Further Consultation

11.1 Public Exhibition (2011)

On completion of the work to develop the scheme, it was appropriate to carry out another full consultation exercise to present the scheme to the local community. A public exhibition took place on 22nd and 23rd June 2011 at the Bowling Club in Almondbank, with approximately 70 members of the local community in attendance over the 2 days.

In addition to representatives from Perth & Kinross Council and Mouchel being available during the exhibition, representatives from (SEPA) and the Scottish Flood Forum were also in attendance to provide information about SEPA's new direct Floodline warning service and general advice on tackling flooding.

Following the exhibition, the display material remained available for viewing for a period of 28 days and was also available to view on the Perth & Kinross Council website, with the opportunity to submit any feedback.

As well as consulting with the local community, other key stakeholders were also notified of the developed scheme and given the opportunity to attend the Public Exhibition and / or provide feedback.

11.2 Local Community Feedback (2011)

Mouchel's Public Consultation Report[29] documents the 2011 consultation and presents all of the feedback received. In general the impression received was that the local community remained in favour of the scheme, with a greater appreciation and understanding of the developed scheme. There still remained a few concerns, although these were fewer than previously recorded and lesser in magnitude, focusing on the following issues in Figure 24 below.

[29] "Almondbank Flood Protection Scheme, 2013 Community Consultation Report," produced by Mouchel on behalf of Perth & Kinross Council in June 2013

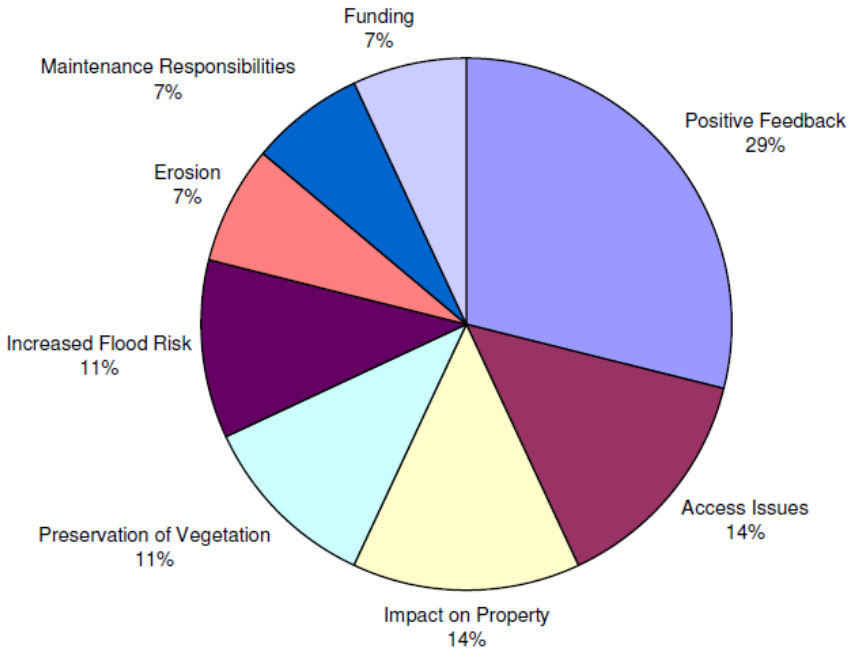

Figure 24 – Local community concerns (2011)

- There were some concerns that areas beyond the extents of the scheme may be at greater risk of flooding, due to 'backing up' of the flood waters,
- There were some concerns regarding the permanent loss of vegetation to accommodate the scheme and the direct impact of this on individual properties,
- There were some concerns that access routes may be compromised during construction and on completion of the scheme,
- There were some concerns with regard to control of the existing erosion and the possible future erosion of the watercourses,
- There were some concerns with regards to maintenance access and responsibilities on completion of the proposed scheme.

11.3 Post Consultation Actions (2011)

Responses to feedback are included in Mouchel's 2013 Community Consultation Report. The issues arising from the consultation exercise have been addressed and can be summarised as follows;

- With regard to the issue of flooding outside of the scheme extents, the detailed hydraulic modelling undertaken since the last consultation has confirmed this not to be a risk,

- With regard to the preservation of vegetation, outline designs have been progressed to minimise vegetation loss, with references to a replacement landscaping scheme to be developed during the detail design of the scheme. Where necessary Mouchel and Perth & Kinross Council have further liaised (in writing or in person) with individual consultees and where appropriate, revisions have been made to the final scheme proposals,

- With regard to any disruption to access to property and community areas, consultees are assured that this has and will continue to be considered as the scheme develops and as appropriate, further liaison will take place with those affected. Where necessary Mouchel and Perth & Kinross Council have further liaised (in writing or in person) with individual consultees and where appropriate, revisions have been made to the final scheme proposals,

- With regard to erosion issues, Perth & Kinross Council confirms that they are aware of and continue to monitor current erosion problems and make reference to the primary responsibility for the riverbank resting with the riparian landowner. Further to feedback received during the previous consultation, an extensive review of the scheme has been undertaken and where necessary, erosion protection has been incorporated into the scheme proposals,

- With regard to maintenance of the proposed scheme, Perth & Kinross Council confirm that responsibility for access to and maintenance of the proposed structures will remain with the Council and where appropriate, revisions have been made to the final scheme proposals.

In conclusion, the local community remain in favour of the developed scheme presented at the 2011 Public Exhibition and further to a few small changes to the proposals as a result of feedback received; the outline design for the scheme has been finalised.

11.4 Statutory &Third Party Consultations

In addition to the Public Consultations, there has also been consultation with a number of third parties and Statutory Consultees. Some of these consultations are previously documented in the report and this section seeks to record any additional consultations with these parties as the outline design has developed.

11.4.1 Perth & Kinross Council

Local Councillors have been invited to and attended the public consultation exercises and Perth & Kinross Council (Flooding) have undertaken liaison throughout the development of the scheme with individual Councillors.

The following departments within Perth & Kinross Council have been consulted with regards to the overall scheme and also with regards to specific elements of the outline design as it has developed;

- Rights of Way (footpaths including River Almond Footbridge),
- Highways / Roads Authority (road alignments and raising bridges),
- Parks and Gardens,
- Legal Department (land issues and Flood Management (Scotland) Act 2009),
- Community Greenspace (playing fields and pavilion structure),
- Maintenance (operational and maintenance issues, current erosion issues),
- Environmental Services (screening request, EIA, ES),
- Planning Department (screening request, Flood Management (Scotland) Act 2009),
- Street Lighting.

11.4.2 SEPA

Mouchel and Perth & Kinross Council have consulted with SEPA during 2007 and throughout the early part of 2008. SEPA provided a summary response on the overall scheme design developed by Royal Haskoning. After the 2008 public and statutory public consultation, Mouchel developed a 2-D hydrodynamic river model which altered the scheme design significantly. Mouchel contacted SEPA in July 2010 to confirm the scheme hydrology and the flow values for the proposed scheme. The hydrology was confirmed by February 2011. SEPA were invited to review and comment on the proposed outline design and returned their response during 2012.

11.4.3 Scottish Executive (Government)

During 2008, Mouchel consulted with the Scottish Executive with regards to the previously completed cost benefit analysis (for the Royal Haskoning Scheme). At this time no formal response was received.

During June 2012, Mouchel and Perth & Kinross Council met with the Scottish Government to present the scheme and confirm the requirements and processes in line with the Flood Management (Scotland) Act 2009.

11.4.4 Scottish National Heritage / Historic Scotland / RSPB / Tay Salmon Fisheries

These organisations were initially contacted in June 2005 by letter, informing them of the proposed scheme and requesting that they provide any specific baseline environmental information that they may hold or any comments that they may have concerning the proposals. The information requested was tailored specifically for each consultee and scheme layout drawings were provided. Additional consultations were also carried out during 2007 in order to update the information previously provided in 2005. Consultation with Scottish Natural Heritage and the Scottish

Environment Protection Agency has been ongoing throughout the development of the outline design.

11.4.5 Commercial Premises

11.4.5.1 College Mill Trout Farm

An initial site visit in December 2007 allowed Mouchel to become familiar with the complexity of the trout farm. Subsequent site visits in 2008, 2009 and 2010 have involved collating topographic data and geotechnical data. In early 2008 & 2009 Mouchel discussed flood defence options with the trout farm owner. In 2010 Mouchel discussed the construction methodology with the trout farm owner and incorporated his feedback into the design process. During the 2011 Public Consultation the owners of the trout farm were further consulted on the outline designs for the scheme during an arranged site visit and meeting to discuss the plans.

11.4.5.2 Vector Aerospace

Vector Aerospace have been consulted with throughout the development of the scheme including by those consultants involved prior to Mouchel.

Mouchel and Perth & Kinross Council have consulted with Vector Aerospace during the development of the proposed scheme. In 2008 Mouchel met with the site manager and visited the site, undertaking discussions with regards to the proposed flood defence options and possible construction methodologies. Perth & Kinross Council has continued to engage with the site owners to discuss flood defence options and the proposed outline designs. During 2009 and 2010, Mouchel and Perth & Kinross Councils drainage contractor have undertaken drainage investigations to develop the surface water drainage design proposals for the site. In 2011 Vector Aerospace were invited to the public consultation where the scheme proposals were discussed. Further to these discussions, Mouchel developed the preferred designs for the alleviation of surface water flooding on the site and consulted on these to the approval in principal from Vector Aerospace.

11.4.5.3 Lochty Industrial Estate

Perth & Kinross Council has held discussions with the tenants of the Industrial Estate, with some individual consultations taking place.

11.4.5.4 Waste Water Treatment Works

Scottish Water's Drainage Engineer has been consulted in relation to the proposed works affecting the Waste Water Treatment Works and other Scottish Water Assets within the scheme extents. These consultations have included a number of site visits and telephone conferences with Mouchel and Perth & Kinross Council during 2009 and 2010 to discuss the potential impact of the scheme. Scottish Water has been consulted on the final proposed design during 2012.

11.4.5.5 Landowners

Perth & Kinross Council has identified the landowners thought to be affected by the scheme. Current landowners were invited to the Public Consultation Events during 2008 and 2011. During the Preliminary Ground Investigation in 2010, affected landowners were contacted by Perth & Kinross Council to inform them of the proposed site investigations on their land. All landowners affected will be contacted during the process of publishing the scheme.

12 Project Risk

Associated with the promotion of any Flood Protection Scheme, there are various elements and stages of risk. Mouchel have sought to identify risks as they have become relevant. These risks have been mitigated where possible although some may remain and be mitigated or addressed as the scheme further develops or may remain through to the completion of the scheme. Where appropriate, these risks have been incorporated and factored into assessments and appraisals.

12.1 Preferred Solution

The preferred scheme offered the simplest solution in the construction of traditional flood defences to contain flood water within the river channels, mitigating risk associated with some of the other options investigated. Whilst risks remain in the construction and maintenance of the preferred scheme, the simplicity of the proposed works reduces the magnitude of these risks to site personnel, the public and the environment both during and on completion of the construction works.

Extensive survey, assessment, investigation, modelling and design works, along with community and stakeholder consultation were undertaken to ensure, where practical that the scheme presented for confirmation under the Flood Management (Scotland) Act 2009 addressed any major risks whilst managing residual risk.

12.2 Community Engagement

The flood protection proposals will benefit and therefore affect a significant number of domestic and commercial properties in the town of Almondbank. It could be expected that some of those affected may not be content with the personal impacts of these proposals. This may be as a result of the proximity and potential disruption due to the proposed structures and any perceived inconveniences during the construction, maintenance and operational phases of the scheme.

Managing public perception and expectation is key to the success of the project and continued consultation with the community is essential to minimise the risk of formal objections to the scheme. Maintaining community support for the scheme is crucial and extensive community and stakeholder consultation has been undertaken during the development of the scheme proposals.

Continued engagement with the local community must continue throughout the detailed design and construction phases of the scheme.

12.3 Limitations of Modelling Software

The key parameters in the design of a flood protection scheme are those that are used to define the hydraulic conditions, with risks arising from differing degrees of accuracy in the predicted values and also the sensitivities of the modelling packages predicting the scheme response.

In order to minimise these risks, attention was paid to ensuring the appropriate level of accuracy to the input parameters. Information was gathered during numerous site visits, to determine the nature and behaviour of the river channels and how they may perform in certain flood events. Twenty years of recorded gauge data was retrieved, from the SEPA gauge on the River Almond. Additional topographical survey data works were undertaken in order to more accurately model the overland flows using the two dimensional model.

Extensive liaison with SEPA throughout the development of the hydraulic model ensures that the proposed scheme is based on verified modelling outputs and meets with the approval of one of the key statutory consultees. Input flows are assessed to be conservative, with the resulting flood defence levels providing the required level of protection to the community of Almondbank.

During the detailed design phase of the scheme, the hydraulic model will need to incorporate any details or changes that are made as the scheme develops in order that the entire scheme can be assessed to ensure it is still able to provide the required level of protection.

During the construction phase of the scheme, increased risk of flooding to some areas may arise as a result of the temporary works or construction of the scheme being completed in phases. The hydraulic model will be used to assess any increased flood risks in these situations and it is recommended that the hydraulic model is used to help determine the most appropriate construction sequence, appropriate temporary works and to assist in the design of temporary flood defence structures.

12.4 Ground Conditions

Preliminary ground investigations have been completed. To date, the ground investigations have given the picture of relatively uniform ground conditions across the scheme area and as such the outline designs have been developed in accordance with typical parameters and behaviours for these ground conditions.

In order to minimise risk during detailed design and construction of the scheme it is recommended that a more comprehensive site investigation is completed and the appropriate geotechnical analysis of the results are carried out. These investigations must include an assessment of any contaminated land and early identification of the need for the disposal of any contaminated material.

Completion of a detailed site investigation should provide a level of information that would result in minimum risk of project delay and increased costs as a result of revisions to designs and construction methodologies due to unforeseen ground conditions and incorrect parameters.

12.5 Ecology, Heritage and Amenity

There are risks associated with natural habitats, archaeology, recreation and amenity and the actual impact on the environment of the scheme may differ from that which was predicted.

These risks have been minimised with the early involvement, data collection and ecological survey work of the Environment team that combines to develop the EIA, a live document that continues to be updated throughout the life of the scheme. Continued involvement and updating of the document and the conjoined working of engineers with environment professionals will enable any risks associated with this to be minimised. Continued environmental input during construction phases is crucial with base line survey data recorded before construction activities begin and monitored during and after completion of the works.

As part of the strategic planning of the detailed design and construction of the works it will be crucial to identify the most appropriate times for ecological survey and mitigation works and timescales for construction works on or adjacent to the water course.

Awareness of key historical archaeological areas close to site and watching briefs as excavations are commenced.

12.6 Statutory Authorities

Any potential disruption to the services located within the scheme extents have been assessed and identified to the relevant statutory undertakers and through further liaison with these bodies, a formal contact has been established for future liaison and development of the detailed designs in conjunction with any temporary or permanent protection and diversion works.

Continued liaison with the relevant statutory authorities is crucial to ensure the timely delivery of any required works by the statutory authorities which in some locations will need to be completed prior to commencement of any construction works. Early and continued liaison should mitigate the risk of project delays and unexpected costs due to the requirements of or any delays to protection or diversion works.

12.7 College Mill Trout Farm

Consultation with the trout farm owners has enabled Mouchel to understand the operational requirements of the trout farm and the importance of mitigating the risk of fluvial flooding to the site. Designs have progressed in line with these discussions.

Initial considerations included a number of demountable defences within the site to maintain operational access across the site. A demountable defence is reliant on human interaction to ensure they are located and functional in the event of high flows. A significant hazard to operatives and fish stocks results in these not being

located during flood event and, where possible, demountable defences have been removed from the designs.

It has been necessary for the inclusion of a single demountable defence at the lade intake to the north of the site. The defence has been designed to remain in place and will only be opened to allow access for operational and maintenance requirements.

Should the demountable defence not be in place during high flow events, the area of the trout farm (including the residential property) protected by the proposed defences would be at risk of fluvial flooding. The likelihood of this scenario is minimal subject to the correct operation of the structure by the trout farm owner and regular maintenance. There is no increased risk of flooding up or downstream of the trout farm as a result of the demountable defence not being in place.

It is envisaged that the responsibility for the day to day operation of the demountable structure will remain with the trout farm owner. It is proposed that as detailed design progresses, a form of agreement will be drafted between Perth & Kinross Council and the trout farm owners as to the appropriate responsibilities for the operation and maintenance of the structure.

A pumping station is proposed to the south of the site that will allow continuous operation of the site during normal and design event situations. Should the pumping station fail to operate as intended, the risk to the trout farm is that the ponds do not drain freely and maintain required water levels resulting in the release of fish stocks.

As with the demountable defence, it will be necessary for some form of agreement between the trout farm owner and Perth & Kinross Council as to the operation and maintenance of the pumping station.

12.8 Bowling Club

An area of open land to the northern perimeter of the bowling club is currently used for car parking; design proposals are that the finished ground levels in this area must be above the design event flood levels. Access to this car parking area is along the land adjacent to the River Almond and this access will be controlled during a flood event by the provision of a gated vehicle access located at the commencement of the vehicle access over the earth embankment forming the Playing Field flood storage area to the south.

The proposed measures have been put into place to mitigate the risk of flooding to the Bowling Green premises and the community members who use the facility. The provision of the flood protection structures and physical prevention of vehicle access to the areas at risk of flooding will reduce greatly the risk of damage to property and injury to facility users.

Residual risk remains to users who may try to access or egress the area during a flood event or other pedestrians in the locality as a flood event occurs. It is proposed that a memorandum of understanding or similar be drafted and agreed between the

community recreation groups as to the procedures for use and safe evacuation of the area during normal and design event conditions.

12.9 Bridge Structures

The River Almond Footbridge will be raised to give a freeboard of 300mm above top water levels for the design event. This will allow the safe passage of design flows beneath the structure and containment of flood water within the river channel, maintaining pedestrian access across the footbridge during the design event and mitigating the risks associated with collection of debris on the upstream face of the structure for the design event.

The Confluence Road Bridge will be replaced with a new single span structure to be raised to give a freeboard of approximately 210mm above modelled top water levels. The level of freeboard is below the typical value for the scheme of 300mm and it is assessed that the bridge structure will be subject to some surcharge during the design event. The bridge structure and adjacent flood defence structures will be designed to withstand and contain the relevant depths of flow.

Whilst the design allows for the containment of flow upstream of the structure, it is not intended that the vehicle access across the bridge will be maintained during a flood event due to the access road to the north being incorporated in the engineered flood plain for the right bank of the River Almond. Vehicle access will be controlled in this area with appropriate use of signage.

The Lochty Park Road Bridge culvert structures will be replaced with a single span structure. Due to the constraints of the adjacent highway elevations on Main Street, this is assessed to be the maximum permissible increase in finished road level. To mitigate the risk of flooding to the area, the new structure will be tied into the adjacent flood defence structures in order that flood waters are contained within the Burn channel and not allowed to pass over the bridge.

Raising the structure by 0.75m does not provide any freeboard to the underside of the structure above the modelled top water levels and the bridge will be subject to surcharge during the design event. The proposed single span bridge structure must be assessed and designed to withstand this depth of flood water.

12.10 Flood Storage Area

The Playing Field is currently used by local recreational groups and also provides access to the Bowling Club to the north. Consideration has been given to the use of this area both during normal and high flow conditions in development of the outline design.

The perimeter of the flood storage area will be delineated using a security fence with designated access points and regular signage warning of the operation of the flood storage area and the risk to users in the event of high flows. Life buoys will also be positioned to the perimeter of the flood storage area for use in an emergency.

The proposed measures have been put into place to mitigate against the risks to community members using the facility. The provision of the security fencing and signage along with the physical prevention of vehicle access to the areas at risk of flooding will reduce greatly the risk of damage to property and also the risk to the facility users.

Residual risk remains to users who may try to access or egress the area during a flood event or other pedestrians in the locality as a flood event occurs. It is proposed that a memorandum of understanding or similar be drafted and agreed between the community recreation groups as to the procedures for use and safe evacuation of the area during normal and design event conditions.

The proposals for the flood storage area will fall under the existing reservoir safety legislation (Reservoirs Act 1975) as well as the new Reservoirs (Scotland) 2011 Act and also be regulated under the Water Environment and Water Services (Scotland) Act 2003.

A SEPA CAR License will be required to undertake the impounding of the River Almond within the flood storage area.

12.11 Construction (Design and Management) Regulations 2007

The Construction (Design and Management) Regulations 2007 (CDM 2007) require Mouchel to comply with their duties as set out in the Regulations. For the outline design of the Scheme, Mouchel undertook Designers' responsibilities and CDM co-ordinator responsibilities. These responsibilities were undertaken in accordance with Mouchel's mandatory policies and procedures.

A Design Hazard Checklist and Hazard Elimination Management Schedule were developed as the outline design progressed in accordance with Mouchel's procedures. This document records significant (high risk) hazards and details of how these have been eliminated. If a hazard is not able to be completely designed out then this records how the hazard has been minimised and any residual risks.

12.12 Performance of Existing Works

Along sections of the River Almond and East Pow Burn there is evidence that measures have been put into place to prevent localised flooding and these have been reviewed on an individual basis. In order to mitigate the risk of any of these local structures failing to provide the required level of protection, these have either been proposed to be removed and replaced (i.e. earth embankments) or incorporated into the scheme proposals, with additional measures to provide the required level of flood defence (i.e. the gabion baskets in East Pow Burn have been incorporated as erosion protection whilst the introduction of the sheet pile wall is designed to provide the necessary level of flood protection).

Any future residential development proposals must be regulated from diverting surface or drainage waters directly to the defended watercourses.

12.13 Early Contractor Involvement

Where construction plant access and working space was assessed to be constrained, it was recommended that simple measures could be taken to reduce the impact of these proposals. Straightening lengths of flood defence structures, rather than following the exact line of the riverbank would make simpler, quicker and more cost efficient solutions and in some cases reduce the need for loss of vegetation. Changing the type of proposed defence structures to reduce the extent of the required working area or where very constricted working conditions were assessed to remain, propose working from the watercourse and / or careful sequencing of events to improve construction access was recommended.

The exercise highlighted potential risks associated with the inherent complexity of some of the scheme proposals that could lead to buildability issues, construction programme delays and increased scheme costs. Where possible, changes have been made to the outline designs to take account of this.

The detailed design of the scheme will benefit from the continued involvement of an experienced contractor who is able to contribute to the design review process to help mitigate against any contractual issues during the construction phase. Involvement and contribution with regards to any temporary works including any temporary flood defence requirements will be beneficial also.

12.14 Operation and Maintenance

It is important to make an allowance in the future maintenance and operations budget to ensure that monitoring is carried out, along the length of the proposed works and also to the sections of watercourse immediately up and downstream of the proposals. Any future development outside of the scheme must also be monitored. The Local Authority Planning Department will need to consider the impact of any proposals prior to planning approval, specifically the discharge of any additional surface water adjacent to the proposed defences.

12.15 Human Intervention

Whether authorised or not, there remains a risk to the performance of the scheme from human activity. Other capital schemes and developments that may affect the performance of the scheme would be assumed to be progressed through similar approval procedures and any mitigation could be planned and dealt with.

Risks remain with individual property and land owners being unaware or unconcerned of the impact of their activities on the performance of the protection scheme. This can be addressed through consultation with and if necessary, education of individuals and proposals for the monitoring of any such activities being incorporated into the post completion monitoring regimes

12.16 Flood Risk Management (Scotland) Act 2009

The Almondbank Flood Protection Scheme will be one of the first to be submitted under the Statutory Approval Process for the Flood Risk Management (Scotland) Act 2009. This may present risks due to unfamiliarity and variance of responsibilities from the Flood Prevention (Scotland) Act 1961 requirements.

The Flood Risk Management 2009 is designed to speed up the approval process and be managed at a local level with the move from Scottish Government approval to Local Authority approval. It is no longer a requirement to submit a formal Planning Application as planning permission is deemed to be included in the confirmed scheme (although the requirement for appropriate consultation still remains). Once the scheme is confirmed Perth & Kinross Council are responsible for referring the scheme to Scottish Ministers for deemed planning permission (Perth & Kinross Council Planning Department can identify any planning conditions they feel relevant), subject to any planning conditions from the Scottish Ministers.

Previous reference to community engagement is central in the mitigation of objections to the scheme during the Statutory Approval Process and, if the situation arises, efficient management of any valid objections to the scheme during the 28 day consultation. If Perth & Kinross Council are not able to conclude the satisfactory withdrawal of any valid objections received then the scheme will need to referred to the Scottish Ministers who will consider the scheme further and may be required to hold a public local enquiry

12.17 Funding

The availability of funding for the scheme presents a risk that could arise through changes in funding policy, particularly rules for grant aiding of schemes that can apply at a local or national level. The timing of the scheme submission may present some risk, in that the submission of the Flood Order falls as one of the first to be submitted in line with the Flood Risk Management (Scotland) Act 2009, with some ‘interim’ national funding available further to allocated funding for the latter schemes submitted in line with the Flood Prevention (Scotland) Act 1961.

The unknowns associated with Local Authority approval and management of the submission as a result of the 2009 Act are difficult to quantify at this stage with few completed applications to date. Government spending reviews may also determine the priority and availability of funding for the flood protection scheme.

The detailed design and construction phases of the flood protection scheme will need to be programmed to ensure continuity of funding as inefficiencies will arise as a result of intermittent funding.

13 Conclusions & Recommendations

Almondbank is at risk of flooding from both the River Almond and the East Pow Burn and has experienced major flooding events in 1909, 1993, and 1999 and more recently in 2011. SEPA's Indicative Flood Map shows the study area to be at risk of flooding from rivers within the study area.

13.1 Project Objectives

In order for the developed scheme to be viable it must provide an economically viable solution that is technically sound and sustainable that ultimately reduces the risk of flooding to the community of Almondbank.

13.2 Alternative Options Appraisal

Mouchel's Flood Management Options Report concluded that Royal Haskoning's recommendations presented an appropriate and economically viable scheme to mitigate the risk of flooding to the town of Almondbank although some changes were recommended to the existing scheme.

13.3 Public Consultation (2008)

Further to the conclusions of the alternative options appraisal the flood protection scheme was formally presented to the local community. The local community recognised the need for the flood scheme and were generally in favour of the proposals. A number of concerns were raised by those consulted and this resulted in a number of actions being identified in order to develop the flood protection scheme.

13.4 Fluvial Hydrological and Hydraulic Modelling

Consultation with SEPA has resulted in a conservative hydrology values. It has been agreed with SEPA that Mouchel would adopt and take forward SEPA's statistical flow estimates for the River Almond (311m^3/s) and Mouchel's FEH Statistical flows estimated for the East Pow Burn (41.51m^3/s).

SEPA have confirmed that the data used and the model verifications are suitable to develop the flood protection scheme, to test flood protection proposals and derive flood defence heights and volumes of storage and has been used to develop the flood protection scheme.

It was concluded that the incorporation of climate change for the 1 in 200 year design event was not practical and the level of protection for the scheme was confirmed at the 1 in 200 year design event plus freeboard allowance. This is consistent with the current SPP (Feb 2010).

During the detailed design phase of the scheme, the hydraulic model will need to incorporate any details or changes that are made as the scheme develops in order

that the entire scheme can be assessed to ensure it is still able to provide the required level of protection.

During the construction phase of the scheme, increased risk of flooding to some areas may arise as a result of the temporary works or construction of the scheme being completed in phases. The hydraulic model will be used to assess any increased flood risks in these situations.

13.5 Ground Investigations

Preliminary ground investigations have been completed. To date, the ground investigations have given the picture of relatively uniform ground conditions across the scheme area and as such the outline designs have been developed in accordance with typical parameters and behaviours for these ground conditions.

To minimise risk during detailed design and construction of the scheme it is recommended that a more comprehensive site investigation is completed and the appropriate geotechnical analysis of the results are carried out. These investigations must include an assessment of any contaminated land and early identification of the need for the disposal of any contaminated material.

13.6 Surface Water Drainage Investigations

In consideration of the delivery of an integrated solution to the fluvial flooding issues, it was Mouchel's recommendation that the scheme considered measures by which surface water flooding can be managed alongside fluvial flooding. Solutions are recommended at Bridgeton Brae, Main Street and for the Vector Aerospace Site.

13.7 Scheme Proposals

The outline design for the scheme proposes a combination of proven flood defences that have been assessed to be the most appropriate for their immediate environment. The preferred scheme offers the simplest solution in the construction of traditional flood defences to contain flood water within the river channels, mitigating risk associated with some of the other options investigated.

13.8 Environmental Impacts and Mitigation

The EIA has identified a number of measures to be included as mandatory commitments as part of the proposed scheme. As part of the strategic planning of the detailed design and construction of the works it will be crucial to identify the most appropriate times for ecological survey and mitigation works and timescales for construction works on or adjacent to the water course.

13.9 Cost Benefit

The estimated PV of flood damages for the Do Nothing option and the Do Minimum option are £22,677,000 and £15,780,000 respectively. The estimated present value

of the damage avoided in the Do Minimum and Do Something preferred option is £6,897,000 and £21,154,000 respectively. Considering the present value cost of the preferred scheme is £15,658,000 (including 38% optimism bias, project/design fees, maintenance costs and capital replacement of the flood defences after 50 years), the benefit-cost ratio for the preferred flood protection scheme is 1.35, therefore the scheme is considered economically viable. In total approximately 31 residential properties and 48 non-residential properties (the majority of which are located in Vector Aerospace and Lochty Industrial Estate) will benefit from the final scheme.

13.10 Early Contractor Involvement

The result of the consultation with a contractor concluded that the proposed scheme does not propose any obvious difficulties with construction. The detailed design of the scheme will benefit from the continued involvement of an experienced contractor who is able to contribute to the design review process to help mitigate against any contractual issues during the construction phase. Involvement and contribution with regards to any temporary works including any temporary flood defence requirements will be beneficial also.

13.11 Statutory Authorities

Continued liaison with the relevant statutory authorities is crucial to ensure the timely delivery of any required works by the statutory authorities which in some locations will need to be completed prior to commencement of any construction works. Early and continued liaison should mitigate the risk of project delays and unexpected costs due to the requirements of or any delays to protection or diversion works.

13.12 Forms of Agreement

It is proposed that as detailed design progresses, a form of agreement will be drafted between Perth & Kinross Council and the College Mill Trout Farm owners as to the appropriate responsibilities for the operation and maintenance of the proposed demountable defence structure and pumping station.

It is proposed that a memorandum of understanding or similar be drafted and agreed between the community recreation groups as to the procedures for use and safe evacuation of the flood storage area during normal and design event conditions.

13.13 Flood Storage Areas

The proposals for the flood storage area will fall under the existing reservoir safety legislation (Reservoirs Act 1975) as well as the new Reservoirs (Scotland) 2011 Act and also be regulated under the Water Environment and Water Services (Scotland) Act 2003. A Panel Engineer will need to be consulted with regards to the detailed designs, operational and maintenance requirement for this element of the scheme.

13.14 Controlled Activities (Scotland) Regulations

In line with the requirements of the Water Environment (Controlled Activities) (Scotland) Regulations 2006 (CAR), prior to construction activities, a SEPA CAR Authorisation will be required to undertake the impounding of the River Almond within the flood storage area, along with the other engineering elements of the scheme. The application should be developed alongside the development of the detailed design and in continued consultation with SEPA.

13.15 Public Exhibition (2011)

Further to development of the outline design the revised flood protection scheme was formally presented to the local community. The local community remain in favour of the scheme, with a greater appreciation and understanding of the developed scheme. There still remained a few concerns, although these were fewer than previously recorded and lesser in magnitude. Further to a few small changes to the proposals as a result of feedback received; the outline design for the scheme has been finalised.

Continued engagement with the local community must continue throughout the detailed design and construction phases of the scheme.

13.16 Flood Risk Management (Scotland) Act 2009

It is recommended that the outline design of the Almondbank Flood Protection Scheme is submitted via the statutory process as defined by the Flood Risk Management (Scotland) Act 2009.

The Almondbank Flood Protection Scheme will be one of the first to be submitted under the Statutory Approval Process for the Flood Risk Management (Scotland) Act 2009.

Community engagement is key to the mitigation of objections to the scheme during the Statutory Approval Process and, if the situation arises, efficient management of any valid objections to the scheme during the 28 day consultation. If Perth & Kinross Council are not able to conclude the satisfactory withdrawal of any valid objections received then the scheme will need to referred to the Scottish Ministers who will consider the scheme further and may be required to hold a public local enquiry

14 Appendices

Appendix A – List of Previous Documents Reviewed

Appendix B – SEPA Correspondence

Appendix C – Geotechnical Risk Register

Appendix D – Borehole Locations

Appendix E – Services Schedule

Appendix F – Responses from Statutory Undertakers

Appendix G – Flood Protection Order Drawings

Appendix H – Economic Sheets and Optimum Bias Calculation