# Grangemouth Flood Protection Scheme

## Option Appraisal Summary Report

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May 2021

**Falkirk Council**

B2386100

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# Grangemouth Flood Protection Scheme

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# Executive Summary

The Flood Risk Management (Scotland) Act 2009 (FRM Act) introduced a co-ordinated partnership approach to how we tackle flood risk in Scotland sustainably. SEPA, Responsible Authorities and Scottish Government have been working closely, building on current evidence and understanding, to improve knowledge and explore sustainable ways to protect communities. It has involved assessing whole catchments and coastlines and examining all sources of flooding. This approach ensures targeted and effective flood risk management decisions across Scotland

In 2011, the Scottish Environment Protection Agency (SEPA) undertook a National Flood Risk Assessment throughout Scotland and identified Potentially Vulnerable Area (PVAs) where there was a significant risk of flooding. Grangemouth and the surrounding area are located within PVA 10-11 and PVA 10-12 and are at risk of flooding from the Rivers Carron, Avon and Grange Burn as well as the Firth of Forth for a range of events, up to and beyond the 1 in 200-year event. Following the publication of the Local Flood Risk Management Strategies (LFRMSs) in 2015, the Grangemouth Flood Protection Scheme (the Scheme) was identified as the number one priority scheme in Scotland.

An initial assessment of flood risk was completed to assess the depth and extent of predicted flooding with an options appraisal undertaken to assess the practicality of potential flood risk management (FRM) options and identify a preferred option which could be progressed by Falkirk Council through the statutory processes under the Flood Risk Management (Scotland)Act 2009. This document summarises the options appraisal study and outcomes.

A 1d/2d hydraulic model was developed which represents the three main watercourses and estuary and was used to determine the flood extents and depths for a range of probabilities /likelihood of a given flooding event occurring. Various FRM options were represented in the model, with options appraised using a multi criteria analysis, which included economic, environmental, social, and technical aspects which were assessed against defined criteria that was linked back to the Scheme objectives as agreed in 2017.

During the initial stage of the option appraisal, a long list of options was initially considered with non-feasible options removed, primarily due to technical and environmental issues, to produce a short-list of potential options. Through consultation with stakeholders, technical analysis, and further hydraulic and economic modelling a preferred option was identified, which would be progressed to the outline design stage.

Due to similarities in land use (major industry), land ownership, the intrinsically linked nature of sites and for technical reasons the options for Flood Cells 3, 5 & 6 have been merged while Flood Cells 1, 2 and 4 have been assessed individually in the option appraisal. The identified preferred option was a mix of wall and embankment structures totalling approximately 25km. Flood defences that face directly onto the Forth Estuary (Flood Cells 3, 5 & 6) require a rock armour revetment on the wet side (estuary side) of the flood defence structure to reduce wave heights and limit wave overtopping. The lock gates at the entrance to the Port of Grangemouth need to be raised and capable of sealing in a flood condition where the water level in the estuary is higher than that of the water in the dock. A flow control structure is required on the Grange Burn to limit the flow through Grangemouth, and for certain events this will direct a greater volume of water from the Westquarter Burn into the flood relief channel.

The outline design phase will give a greater depth of detail on scheme, with further analysis required to assess the potential flood risk from both seepage and surface water (pluvial) impacts. Discussions with stakeholders will continue throughout the development of the scheme.

# 1. Introduction

## 1.1 Study background

Grangemouth has a history of flooding, with records going back to 1926, with extensive flooding occurring in the 1950's. Significant fluvial flood events have occurred in 2002 and 2006 with a flooded number of properties; several tidal near misses have been recorded over the last 5-10 years, primarily due to heightened tide levels. Additionally, several fluvial events have occurred in the past 5 years which locally over topped the banks in isolated areas or came very close to over topped banks of the main waters in the area. The anecdotal and recorded evidence of flooding does not fully reflect the significance of the current identified flood risk to Grangemouth and the surrounding areas.

Grangemouth has a history of flooding, with the 2006 SEPA floodmaps showing the potential flood risk. The Scottish Government/ SEPA confirmed the risk when it was listed as a Potentially Vulnerable Area (PVA) in SEPA's 2011 National Flood Risk Assessment. In 2015, SEPA published the Local Flood Risk Management Strategies (LFRMS) which identified the Grangemouth Flood Protection Scheme as the highest priority scheme in Scotland out of the forty-two identified flood protection schemes. The LFRMS identified 330 properties as being at flood risk from the 1 in10-year event, with 3,000 properties at risk from the 1 in 200-year event. The Grangemouth area is at risk from fluvial flooding; (Rivers Carron, Avon and the Grange, Westquarter and Polmont Burns), as well as coastal flooding from the Firth of Forth and the lower reaches of the Rivers Carron and Avon and Grange Burn.

The Grangemouth flood protection scheme will protect residential and non residential areas including the petrochemical works and the port. The Port of Grangemouth is Scotland's largest sea container port and the only port in Scotland that is currently able to import Shale gas in the form of Ethane. Grangemouth is also home to a major petrochemical plant / refinery. The refinery petrochemical site is important national infrastructure to Scotland and the wider UK. The risk of flooding to the port and petrochemical plant and the subsequent disruption to the economy contributes considerably to the value of potential flood damages.

Jacobs were commissioned by Falkirk Council to undertake the option appraisal and develop the outline design of the scheme. The option appraisal assesses options through an multi criteria matrix, which concluded with the identification of the preferred combination of flood risk management measures to reduce the risk of flooding to Grangemouth and surrounding communities.

# 2. Appraisal overview

## 2.1 Appraisal approach

The appraisal approach was based on documentation published by the Scottish Government in February 2012: "*The Flood Risk Management (Scotland) Act 2009, Chapter 5: Project Appraisal: Assessment of economic, environmental and social impacts"* and May 2016: "*Option appraisal for flood risk management: Guidance to support SEPA and the responsible authorities"*.

The appraisal approach is in three stages;

- DEFINE - the problem should be defined, and a case should be made for the need for a flood scheme,
- DESCRIBE - the problem should be described, this entails developing feasible actions, describing the flood risk benefits (and wider benefits) and quantifying the damages caused by flooding against costs of the options, and
- COMPARE - the options should be compared, and the most suitable option should be selected.

For Grangemouth, the approach was to:

- Identify and describe the fluvial and coastal risk alongside the geomorphological, geological, topographical, environmental and infrastructure constraints which exist.
- Spatially divide the scheme area into discrete flood cells.
- Identify basic design parameters which could be applied to the different options to maintain a consistent approach to cost estimation.
- A do-nothing scenario was not considered as it was thought to be an unrealistic scenario due to the land use
- Filter the initial long list options, with a high-level appraisal to remove those options which are not technically feasible – these will be classed as *Early Discounted Options.*
- Appraise the remaining short list of options using a multi-criteria analysis (MCA). The MCA will combine a mixture of monetary and non-monetary aspects. The criteria will be linked to the 2017 Scheme Objectives.
- The MCA considered the following categories, each of which was scored against criteria linked to the scheme objectives and ranked against other options:
    - **Benefit Cost Ratio (BCR)**: includes capital costs, maintenance, and whole life costings. This ratio is calculated by dividing scheme benefits by the total scheme cost.
    - **Utilities**: Impacts on existing utility infrastructure e.g. pipes, cables etc
    - **Environmental:** Potential impacts on designated sites and habitats
    - **Social:** Issues which may affect people and communities.
    - **Carbon Emission Footprint ($CO^2e$, Carbon Dioxide Equivalent):** The Environment Agency's Carbon Accountancy tool was used to estimate the tonnage of Carbon Emissions based on dimensions of the proposed flood defence structures.
- Consult with key stakeholders; Falkirk Council - FC, SEPA, Scottish Natural Heritage - SNH, Marine Scotland - MS, Historic Environment Scotland - HES, industrial landowners, utility companies and local communities on the short list options.
- Identify a preferred option for progression to design.

## 2.2 Appraisal area

The area considered for the option appraisal is shown in figure 1 below:

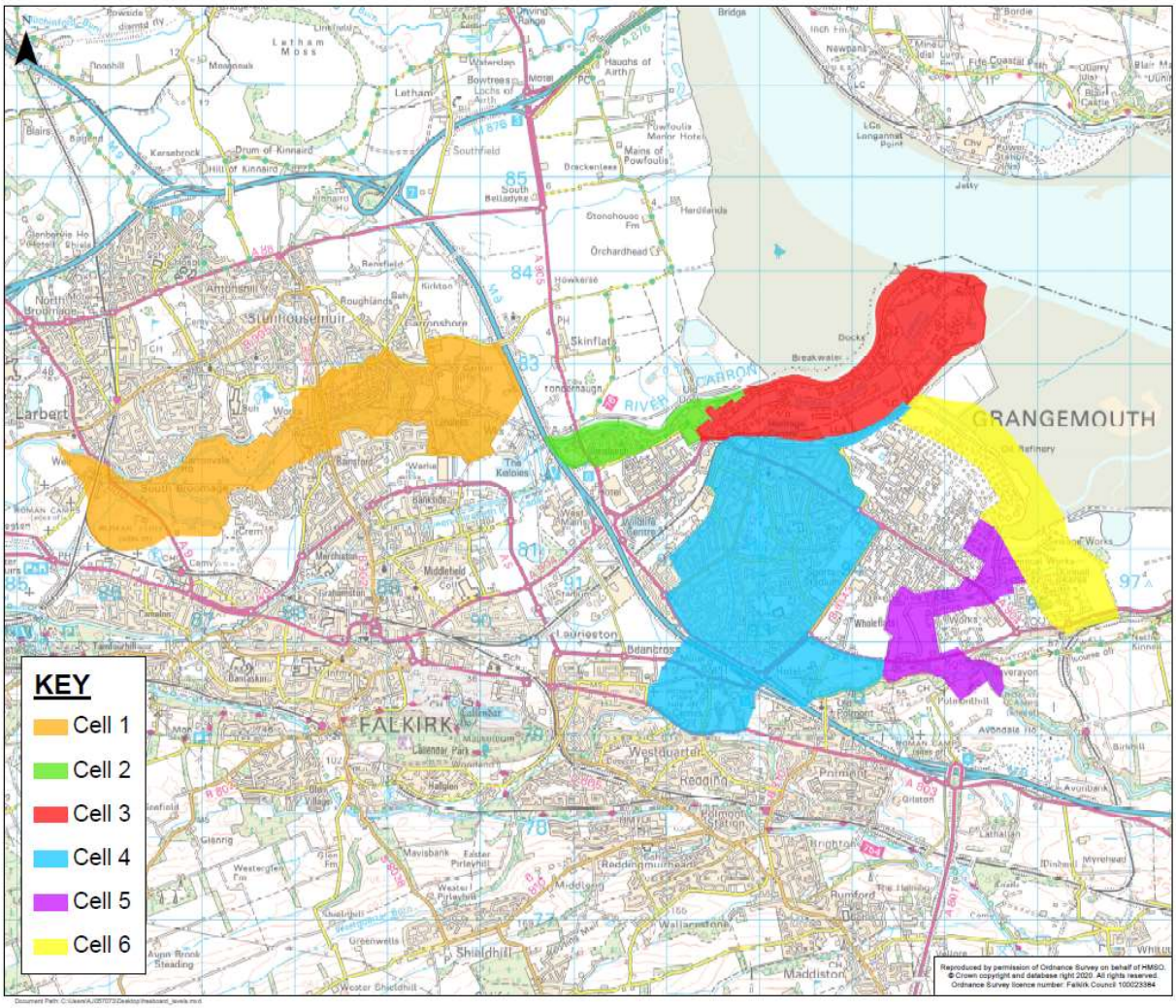


*Figure 1 area covered in the option appraisal process*

## 2.3 Scheme Objectives

The scheme objectives at the time of option appraisal have been split into six categories:

- **General**: The Scheme should reduce flood risk at Grangemouth. The Scheme should be promoted under the Flood Risk Management (Scotland) Act 2009 and should consider all practical options for reducing flood risk and provide multiple benefits to the local community.
- **Social:** The Scheme should meet the goals and values of Falkirk Council, and be aligned with their priorities in their *Strategic Outcomes* and *Local Delivery Plan*.
- **Economic**: An economic assessment should be undertaken to evidence the benefits and costs of the Scheme; the benefit cost ratio should be greater than 1. The Scheme should represent value for money for Falkirk Council and should be delivered in line with the National Planning Framework and the Grangemouth Investment Zone which promotes increase commercial activity in the Grangemouth area through providing a platform for the regeneration of Grangemouth.
- **Environment:** The Scheme should aim to achieve a neutral impact on the environment, incorporate natural flood management measures where appropriate and maximise environmental benefits.
- **Hydraulics:** The Scheme should reduce overall flood risk, deliver the required level of protection and not increase flood risk to property.

- **Technical:** The Scheme should be technically viable and residual flood risk should be documented and identified.

# 3. Flood risk to Grangemouth area

## 3.1 Flood risk overview

Grangemouth is at risk from fluvial and coastal flooding. Three principal water courses are located within the scheme area; the River Carron, River Avon and Grange Burn with a large proportion of the scheme being on the shore of the Firth of Forth. All three watercourses and the Forth estuary contribute to flood risk across the scheme area which includes Wholeflats, Glensburgh, Langlees, Carron, Carronshore, Grangemouth and parts of Stirling Road, Camelon.

The pluvial (surface water) and ground water flood risk will be assessed during the subsequent outline design stage.

## 3.2 Fluvial Hydrology and consideration of climate change

Hydrological analysis was undertaken on five catchments, two locations on the River Carron (including the Bonny Water catchment), and one on each of the River Avon, Westquarter Burn and Polmont Burn. The analysis was discussed and presented for review to SEPA, who were in broad agreement with the results.

A climate change scenario was investigated for the 200-year return period event, in accordance with the *National Flood Hazard Mapping and Flood Modelling Guidance for Responsible Authorities Version1.1*. The 2080 high emissions scenario 67$^{th}$ percentile was adopted for all fluvial events. This represents a 40% uplift on river flows and was applied to all rivers and tributaries in the scheme area.

## 3.3 Coastal Hydrology and consideration of climate change

The coastal influence was represented on the lower section of the model for all applicable water courses. Coastal still water flood levels were estimated using the extreme water levels provided in the *Coastal Flood Boundary Dataset 2018*. Wave heights were also estimated, and a joint probability analysis carried out to determine the design combination of still water and wave heights.

When considering climate change for the coastal areas, the 2080 high emissions scenario 95$^{th}$ percentile relative sea level rise was adopted, which requires an uplift sea level by 0.437m compared to 2016 200-year sea level.

## 3.4 Surface Water Hydrology and consideration of climate change

Although surface water is not thought to be a significant flood risk based on the SEPA flood maps, further analysis will be undertaken at the outline design stage to assess the risk of surface water flooding. A study was undertaken to assess the pluvial flood risk.

## 3.5 Hydraulic modelling

Outputs from the model for fluvial and coastal events were provided for the following Return Periods: 2, 5, 10, 20, 50, 100, 200, and 1000 year. Joint probability was assessed for a combined 200-year return period, using a 50-year tidal and 20-year fluvial for the tidal dominated event, and a 10-year tidal, 75-year fluvial for the fluvially dominant event. The flood extents from the joint probability runs were assessed against the 200-year individual fluvial and tidal results and the worst case (most extreme flood extents / levels) were taken to determine the 200-year flood extents and depths.

Due to a lack of data relating to past flood events,  model calibrationcould not be undertaken. Sensitivity testing of the model was undertaken to improve confidence. The following measures were assessed:

- Manning's n was varied by ±20% both in-bank and out-bank
- Results were analysed to assess the model's sensitivity to variation in flow

- Blockages were applied at key structures for each watercourse

# 4. Appraisal of options

## 4.1 Long list screening

A 'long list' of options was considered based on those adopted in SEPA's National Flood Risk Management Strategies (2015). These were considered and those that were unfeasible were discounted, while potential options were flagged for further consideration.

The following options from the long list were deemed to be unfeasible by the project team and not included in the short list:

- Natural Flood Management – not appropriate as a standalone measure due to very large river catchments, tidal flooding and very low numbers of receptors at risk for the higher probability (more frequent) flood events.
- Surge / storage attenuation – limited space and size of attenuation would be Insufficient to provide benefit.
- Realigning channel - limited space, no impact on tidal flooding.
- Diversion channel - limited space, no impact on tidal flooding.
- Storage at Carron Valley reservoir – limited impact due to location in the catchment, no impact on tidal flooding.
- Modification of conveyance – limited opportunity and impact due to very high flows, no impact on tidal flooding.
- Coastal control structure – no impact on fluvial flooding, challenging operational aspects and in the case of a tidal barrier/ barrage across the Forth it would be prohibitively expensive.
- SUDs – not suitable where dominant risk is from large rivers and tidal flooding
- Property flood resilience – not practical on its own due to large flood depths and significant numbers of receptors at risk. May be considered for individual or small groups of properties.

## 4.2 Short list screening

The short list of options was split into Flood Cells as noted in Table 1. It should be noted that Flood Cells 3, 5 and 6 were merged for the option appraisal since the operation of the petrochemical plant and parts of the port area are intrinsically linked (operationally) despite being located in different Flood Cells.

| Flood Cell No. | Flood Cell Name | Option No. | Standard of Protection (1 in ***-years) | Description |
|---|---|---|---|---|
| 1 | Upper Carron | 1a | 200 | Flood defences on both existing banks |
| | | 1b | 100 | Flood defences on both existing banks |
| | | 1c | 200 | Realign part of the River Carron (right bank), flood defences next to realigned channel |
| | | 1d | 100 | Realign part of the River Carron (right bank), flood defences next to realigned channel |

| Flood Cell No. | Flood Cell Name | Option No. | Standard of Protection (1 in ***-years) | Description |
|---|---|---|---|---|
| 2 | Lower Carron | 2a | 200 | Flood defences on existing right bank only |
| 3, 5 and 6 | Port, Avon and Estuary Frontage | 3a, 5a and 6a | 200 | Flood defences on existing banks |
| 4 | Grange Burn (and FRC) | 4a | 200 | Flood defences on both existing banks of the Grange Burn and flood defences along parts of the Flood Relief Channel (FRC) |
| | | 4b | 100 | Flood defences on both existing banks of the Grange Burn and flood defences along parts of the FRC and Property flood resilience (PFR) for some properties in Grangemouth |
| | | 4c | 200 | Create Flood Storage Area (FSA) on Westquarter Burn, flood defences along parts of the FRC and Grange Burn, tidal barrier and control gate on Grange Burn / FRC |
| | | 4d | 100 | Create FSA on Westquarter Burn, flood defences along parts of the FRC and Grange Burn, tidal barrier and control gate on Grange Burn / FRC |
| | | 4e | 200 | Flood defences on existing banks of the Grange Burn and around Zetland Park and some of the FRC and PPFR for some properties in Grangemouth |
| | | 4f | 100 | Flood defences on existing banks of the Grange Burn and around Zetland Park and some of the FRC and PFR for some properties in Grangemouth |
| | | 4g | 200 | Some flood defences on the banks of the Grange Burn, with a flow control structure at the FRC limiting flows down the Grange Burn. Defences are required along the majority of the FRC. |
| | | 4h | 200 | Flow control structure at the FRC, limits flows on the Grange Burn, additionally, a tidal barrier at the mouth of the Grange Burn limits tidal flows up the Grange Burn. Some flood defences are required on the Grange Burn, as well as the banks of the FRC. This option utilises Zetland Park for flood storage. |
| | | 4i | 200 | Flow control structure at the FRC, limits flows on the Grange Burn, additionally, a tidal barrier at the mouth of the Grange Burn limits tidal flows up the Grange Burn. Additionally, a flow control structure at Zetland Park would limit flow on the lower section of the Grange Burn and reduce the extent of flood defences. Some flood defences are required on the FRC and on a short section of the Grange Burn. |

*Table 1 short-list of options considered for the Grangemouth FPS*

During the option appraisal process, Falkirk Council defined the minimum standard of protection to be provided by the scheme to be 1 in 200-years. Therefore, all options with less than 1 in 200-year standard of protection will not be considered. Adopting a minimum standard of protection of 1 in 200 years also aligned with the specific action in the Forth Estuary Flood Risk Management Strategy which states **"A flood protection scheme**

**has been proposed for the Grangemouth area. It would include the River Carron, Grange Burn, River Avon and the Forth Estuary shoreline. The scheme would consist of flood defences, sediment management, tidal barriers/ gates and natural flood management and would provide a 1 in 200 year standard of protection."**

## 4.3 Short-list assessment methodology

A multi-criteria analysis (MCA) was used to evaluate the options, which included the following criteria:

- **Benefit Cost Ratio:** potential flood damages compared with the estimated cost of constructing and maintaining flood defences.
- **Environmental:** options assessed against environmental criteria linked to the scheme objectives.
- **Social:** options assessed against social criteria linked to the scheme objectives.
- **Utility:** options assessed against criteria relating to impact on the existing utility network.
- **Operational Risk:** operational risks associated with options were assessed against criteria determined by the project team and Falkirk Council. This was not included in the overall option scoring.

## 4.4 Consideration of non-economic factors

While it generally is a requirement that the BCR is greater than 1, non-economic factors are vital components of the project and must be given due consideration. Stakeholders were consulted throughout the option appraisal process. Some options were dismissed if they were deemed unfeasible or had significant adverse public feedback.

### 4.4.1 Health and Safety

Health and safety aspects were not a separate category in the MCA, since it is considered that all options will include best practice, and health and safety risks will be within acceptable limits. The assessment of health and safety risks will be undertaken alongside any further design work to ensure that health and safety is carefully considered as part of the design and any risks eliminated where possible.

### 4.4.2 Public consultation

Two public consultation events took place in 2018 which outlined the scheme and provided an opportunity for the public to comment on the scheme design. Based on completed feedback forms, 83% of the public were in support of the scheme with the remaining 17% undecided.

Most people who had concerns noted the visual impact of flood defences and the potential removal of trees as being their main worries. These concerns whilst applicable across all flood cells were more likely to be focused on Cell 4. A range of options for Cell 4 were put forward with those who took part in the consultation event asked to select their preference. Most people indicated a preference to the option of flood storage on the Westquarter Burn which resulted in less flood defences along the Grange Burn through the town of Grangemouth.

### 4.4.3 Utilities and existing infrastructure

There is a considerable number of utilities within the scheme area, some of these will need to be diverted where it is feasible. Where it is not feasible to divert utilities these may require to be protected. Some of the utilities are classified as major accident hazards and the flood defence structures will need to be designed to account for this. Cells 4, 5 and 6 are particularly impacted by utilities associated with the petrochemical plant and port.

### 4.4.4 Environmental considerations

The scheme is considered likely to have some impact on the environment, but there will be significant opportunities for mitigation of any impact and also to deliver environmental enhancements. All proposed

options will require some of the existing vegetation to be cleared from riverbanks and other areas to allow construction work to take place, resulting in short term adverse impacts. Some short term disturbance is likely along the Firth of Forth SPA, however, most works will only have a short-term impact on the environment during the construction phase. Work that directly impacts the Firth of Forth SPA will be assessed through a Habitats Regulations Appraisal (HRA). Where feasible the slopes of the proposed flood embankments will be landscaped which will provide habitat for native flora and fauna. Some construction work is proposed within the UNESCO World Heritage site, and its associated buffer zone, this will require consultation with Historic Environment Scotland.

#### 4.4.5 Social considerations

The flood defences will improve the safety and wellbeing to people and communities in the Grangemouth area. Additionally, there may be an increased level of commercial confidence, which could raise investment in the area and potentially led to more employment opportunities in the local area. Some short-term disruption is likely during the construction phase as a result of traffic management and road closures. The proposed flood defences in Cell 4 need to consider how best to maintain access across the Grange Burn to avoid physical barriers dividing the communities in the scheme area.

#### 4.4.6 Engineering and buildability

All the proposed options pose technical challenges, such as limited space to construct flood defences, restrictions imposed by stakeholders, including those with statutory responsibilities or significant enabling works required to allow temporary work platforms to the be built to facilitate defence construction. The lock gates at the entrance to the Port of Grangemouth (Cell 3) need to the increased in height which will be technically challenging due to the need to limit possessions of possessions of the lock to undertake any construction works. The option 4h, the tidal barrier and the flow control structure on the Grange Burn would need to be synchronised to avoid increasing the flood risk.

#### 4.4.7 General

Feedback received at the public consultation events, technical concerns and residual flood risk, led the model for Cell 4 to be extended up the Westquarter and Polmont Burns. This extension was to allow better understanding of the principal flow paths in this area and how they may impact the downstream area. Options 4g was divided into 4gi with a flood storage area and option 4gii with no flood storage area.

### 4.5 Economic appraisal

An economic appraisal was undertaken to determine the viability of the scheme and help the project team assess the appropriate level of protection. Capital and operation and maintenance costs were included in line with the Scottish Government's "The Flood Risk Management (Scotland) Act 2009, Chapter 5: Project Appraisal: Assessment of economic, environmental and social impacts", published in February 2012, decommissioning costs were not considered significant so were not included.

#### 4.5.1 Estimation of costs

Costs were estimated using a combination of the:

- Civil Engineering and Highway Works Price Book (SPON'S 2012) and the Environment Agency's Long Term Costing Project, with rates interpolated for the height of flood defence,
- Experience drawn from similar works on other flood protection schemes in Scotland and,
- the Environment Agency's Long Term Costing Project. For Flood Mitigation Tool,

The appraisal period used for the economic assessment was 100 years.

Since the options considered have not been developed to an outline design standard, the exact form of the flood defences was unknown. It was therefore assumed that all flood defences will be concrete walls with sheet piled foundations to allow a cost estimate to be produced. Following discussions with Falkirk Council, it was agreed that climate change should be included for Flood Cells 3, 5 and 6 but not for Flood Cells 1, 2 and 4. An optimism bias of 60% was used. A 2.5% allowance was included for operation and maintenance when determining whole life cost.

In addition to capital costs of materials and labour and the optimism bias, other factors have been included to account for the cost of; supervision; providing construction access; utility diversions; secondary drainage; and the contractor's profit and overheads. The cost estimates also accounted for climate change, based on 2080 levels and a proportional uplift applied to the Consumer Price Index. No additional costs were factored in for land purchase / compensation as these costs were unknown.

### 4.5.2 Estimation of damages

With the aim of determining the cost benefit ratio of the different options, the value of benefits gained from the scheme must be calculated for the different return periods. The benefits were taken as the sum of both the direct and indirect damages that would subsequently by avoided by construction of the scheme.

Using the Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal', flood damages were calculated for residential and non-residential properties. Damages were capped to the market value of the properties to ensure that damages are not accrued beyond the economic value of any given property. Alternative methods were adopted for assessing damages within the petrochemical plant and port area. Indirect damage estimates are included for the petrochemical plant.

### 4.5.3 Calculation of benefit cost ratio

The benefit cost ratio (BCR) is the value of benefits divided by the costs to implement and maintain the scheme. It is generally accepted that the BCR should be greater than 1 to represent value for money. Table 2 provides a summary of the costs, benefits and BCR for each of the options considered.

| Cell | Option | Present Day Value Costs (whole-life cost) | | Present Day Value Benefits (damages avoided) | | BCR | |
|---|---|---|---|---|---|---|---|
| | | 100-year Return Period | 200-year Return Period | 100-year Return Period (£) | 200-year Return Period (£) | 100-year Return Period | 200-year Return Period |
| 1 | 1a | | 20,911,301 | | 30,128,159 | | 1.4 |
| | 1b | 12,883,655 | | 23,375,688 | | 1.8 | |
| | 1c | | 21,869,709 | | 30,128,159 | | 1.4 |
| | 1d | 13,834,253 | | 23,375,688 | | 1.7 | |
| 2 | 2a | | 6,494,124 | | 20,420,241 | | 3.1 |
| 3, 5 & 6 | 3,5 & 6a | | 102,081,797 | | 3,819,555,585 | | 37.4 |
| 4 | 4a | | 48,832,473 | | 84,006,744 | | 1.7 |
| | 4b | 42,280,674 | | 68,740,686 | | 1.6 | |
| | 4c | | 35,917,413 | | 84,006,744 | | 2.3 |
| | 4d | 31,089,664 | | 68,740,686 | | 2.2 | |
| | 4e | | 45,040,025 | | 84,006,744 | | 1.9 |
| | 4f | 37,335,914 | | 68,740,686 | | 1.8 | |

| Cell | Option | Present Day Value Costs (whole-life cost) | | Present Day Value Benefits (damages avoided) | | BCR | |
|---|---|---|---|---|---|---|---|
| | | 100-year Return Period | 200-year Return Period | 100-year Return Period (£) | 200-year Return Period (£) | 100-year Return Period | 200-year Return Period |
| | 4g | | 37,472,563 | | 84,006,744 | | 2.2 |
| | 4h | | 45,251,875 | | 84,006,744 | | 1.9 |
| | 4i | | 30,652,729 | | 84,006,744 | | 2.7 |
| | 4gi | | 49,657,086 | | 62,239,542 | | 1.3 |
| | 4gii | | 49,307,188 | | 62,239,542 | | 1.3 |

*Table 2: summary of BCRs for all options*

It should be noted that cells 3, 5 & 6 cover the Petrochemical plant and port area. The BCR for this area is significantly higher than other Flood Cells.

## 4.6 Identification of a preferred option

Each option was evaluated using the option scoring matrix. This considered economic, environmental, social and technical considerations, including the potential diversion of utilities. For all criteria there was a positive correlation with the overall top ranked option for each cell. The only criteria which did not give the same top ranked option as the other options was the estimated Carbon emissions for Flood Cell 4.

Due to operational risks (e.g. requirement to open and close gates/ barriers etc) associated with some of the proposed options, an operational risk score was included in the multi-criteria analysis of each option. Falkirk Council were keen to identify options that potentially posed higher operational risks, as these would be less favourable. Options that were given an operational risk score, of 3 were discounted from the option appraisal as Falkirk Council deemed the risk too great to continue with.

The combination of options 1a, 2a, 3a, 4gii, 5a and 6a were identified as the preferred scheme. The scheme will provide a minimum 1 in 200-year standard of protection, and climate change will likely be accounted for in Flood Cells 3, 5 & 6 subject to further review. The flood defence heights are generally less than 2.0m above existing ground level which is deemed the maximum height likely to be acceptable to the general public.

To obtain an overall BCR value for the scheme, the benefits and costs for a 200-year standard of protection were totalled for the preferred options. Since the petrochemical plant will affect the results significantly, this analysis was done both including and excluding Flood Cells 3, 5 & 6;

- excluding the petrochemical plant and port - BCR for options 1a, 2a and 4gii = **1.5**
- including the petrochemical plant and port - BCR for options 1a, 2a ,3a, 5a, 6a and 4gii = **22**

Whilst a Scheme that only offers protection to property in Cells 1, 2 and 4 would still be justifiable on economic grounds, it would not address the Scheme's objectives nor those set in the national flood risk management strategy and for that reason the preferred Scheme to be taken forward includes defences in all six flood cells. If the flood defences in Cells 3, 5 and 6 were not constructed, commercial and residential properties in Cell 2 would remain at flood risk. The flood defences constructed on in the industrial areas, provide flood protection to a wider area which contains residential and other commercial properties.

| Flood Cell | Flood Defence Description | Approx. length of Flood Defences (km) |
|---|---|---|
| 1 | Flood walls and embankments on the banks of the River Carron intermittently from Stirling Road to Carron House. | 2.7 |
| 2 | Flood walls and embankments on the bank of the River Carron from the Canal entrance to the Forth Clyde boat yard. | 1.3 |
| 4 | Intermittent flood defences on the Westquarter and Polmont Burns (between the Polmont Road and M9). Flow control structure at Grange Burn / Flood Relief Channel confluence, to restrict flood flows through Grangemouth. Continuous flood defences on the banks of the Grange Burn, downstream of Zetland Park and the banks of the Flood Relief Channel. | 7.7 |
| 3, 5 & 6 | Flood defences on top of the bank. Numerous gates structures including lock and railway flood gates | 10.7 |

# 5. Recommendations

Whilst a preferred option for the scheme has been selected, further development needs to be done in several areas before the Scheme can be published. Residual risks need to be identified and addressed, and opportunities for further enhancements considered.

Following completion of the outline design stage, the economic appraisal should be updated to reflect a more accurate cost estimate of the scheme and a re-appraisal of the benefits.

## 5.1 Residual risks requiring further consideration

A surface water (pluvial) assessment needs to be undertaken to determine if secondary drainage is required. Additionally, an assessment of ground water and seepage needs to be undertaken to determine risk flood risk from these sources and what engineered structures would be required to manage the risk.

The flood defence alignment is very much dependent on the location of utilities, especially those in the petrochemical plant and port area. The location of utilities and access requirements for the industrial area will need to be discussed further with the industrial site operators before the alignment of flood defences can be developed further.

Structural surveys of the existing embankments / walls should be undertaken to assess whether they would be suitable to satisfy the requirements of the proposed scheme. Additionally, condition surveys of all culverts / bridges which require flood defences on them or to connect into them need to be assessed. Raising the height of the existing port lock-gates needs to be investigated and further modelling should be undertaken to assess the flows in the flood relief channel and determine whether remedial works would be required.

Early engagement with industrial stakeholders will be key to managing the disruption to the petrochemical plant effectively.

Liaison with regulatory bodies will also be necessary to obtain consents such as the Controlled Activity Regulations License (CAR Licence), Marine Licence and Scheduled Monument Consent.

## 5.2 Further recommendations

As the Scheme will involve significant construction works, this presents an opportunity to carry out other works to provide additional benefits in additional to flood protection. This may include re-landscaping, incorporating new play facilities, creating new habitats, new footways and cycle paths, improving the hydro-geomorphic classification of the Grange Burn and improving the flood relief channel amongst other opportunities which may be possible with the identification of suitable funding.

Further consultation with individual stakeholders and wider community groups will need to take place throughout the development of the scheme.

Going forward, further surveys and investigations will need to be progressed alongside the design development. Some areas will require further topographic survey, including the Westquarter Burn. Non-intrusive structural surveys should be done to assess the condition of existing structures. Environmental and ecological surveys will be required to inform the EIA and ground investigations will continue. Land searches should be carried out to identify parties considered affected as described by the Flood Risk Management (Scotland) Act 2009.