Environmental Impact Assessment Report

Appendix C4 Introductory Chapters

Grangemouth Flood Protection Scheme 2024
Falkirk Council

GRANGEMOUTH
Flood Protection Scheme
Protecting the heart of our communities

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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:

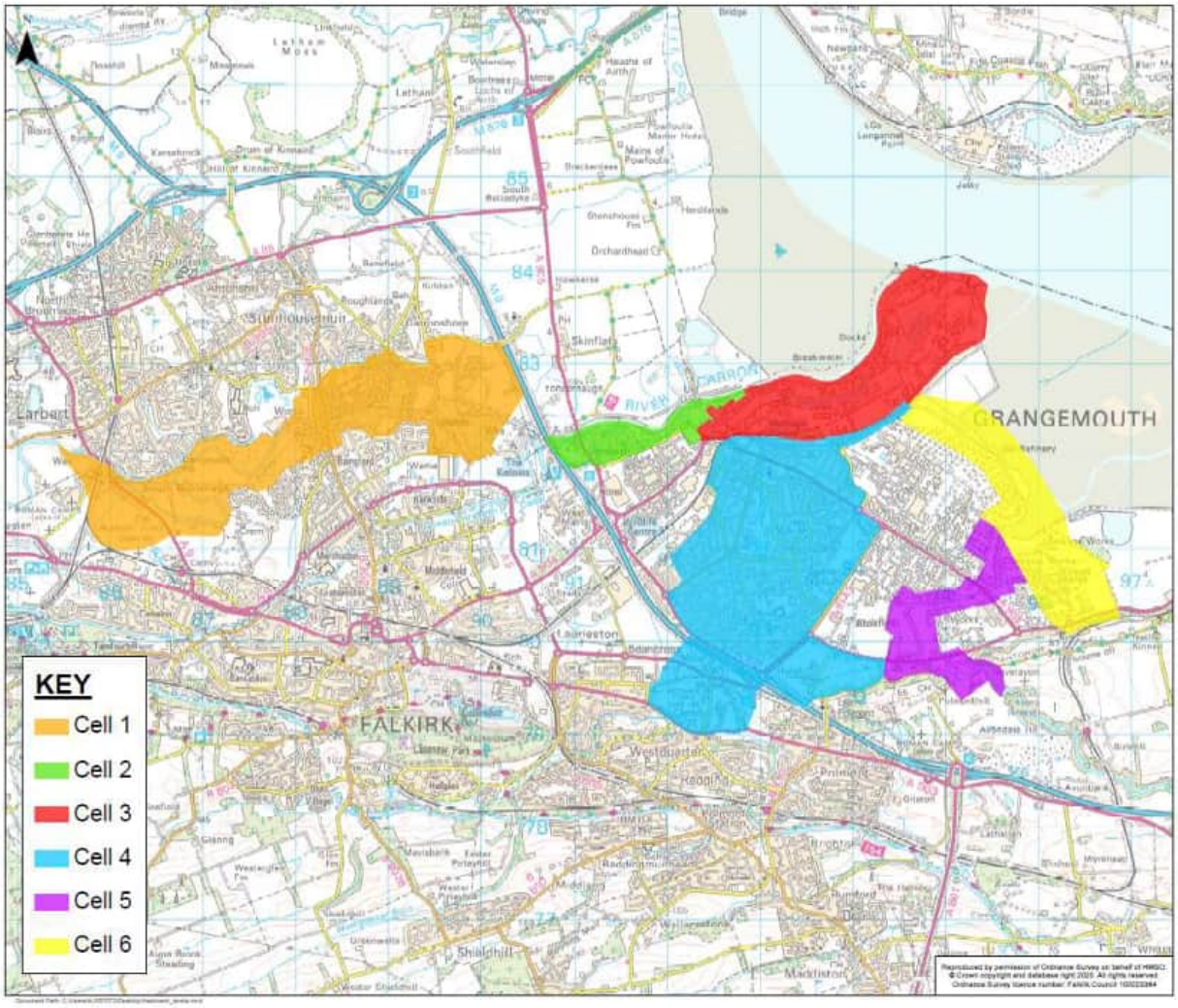

Figure 1 area covered in the option appraisal process

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 67th 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 95th 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.

Environmental Impact Assessment Report

Appendix C4.2 Construction Methodology Report

Grangemouth Flood Protection Scheme 2024
Falkirk Council

GRANGEMOUTH
Flood Protection Scheme
Protecting the heart of our communities

CONSTRUCTION METHODOLOGY REPORT

Document no: B2386100-JEC-S4-XXX-XXX-RE-C0007

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Acronyms and abbreviations

BCR	Benefit Cost Ratio
RC	Reinforced Concrete
SEPA	Scottish Environment Protection Agency
FC	Falkirk Council
FPS	Flood Protection Scheme

1. Introduction

1.1 Purpose

The purpose of this report is to discuss a possible outline construction methodology for Grangemouth Flood Protection Scheme (FPS). This has been done in the context of risk management with respect to the anticipated social and environmental impacts resulting from the construction process. It is considered necessary to discuss different possibilities at this stage such that the Project Team are comfortable that the outline design could be constructed safely and in a pragmatic and logistical manner.

Notwithstanding this, it is not possible for Falkirk Council or Jacobs to determine or prescribe exactly which methods of construction the contractor will select, or in which sequence they will construct the works. The contractor will be solely responsible for exercising their experience and professional judgement to construct the works in a manner which complies with the construction contract and all applicable laws and regulations. In doing so, the contractor may choose to use methods not considered or discussed in this report, subject to complying with any constraints imposed through contract specifications and requirements, including the committed mitigation measures identified in the EIA Report.

This outline construction methodology has been carried out with a view to informing the:

- Scheme application (including scheme cost estimate) under the Flood Risk Management (Scotland) Act 2009;
- Environmental Impact Assessment under the Flood Risk Management (Flood Protection Schemes, Potential Vulnerable Areas and Local Plan Districts) (Scotland) Regulations 2010;
- Habitat Regulations Assessment/ Appropriate Assessment under the Conservation (Natural Habitats & c.) Regulations 1994;
- CAR application under the Water Environment (Controlled Activities) (Scotland) Regulations 2011; and
- Marine Licence, under the Marine (Scotland) Act 2010.

1.2 Background to the Scheme

Grangemouth is a coastal town located on the Firth of Forth, approximately three miles east of Falkirk. The port of Grangemouth is the largest container terminal in Scotland, and intrinsically linked to the petrochemical plant, which is classified as nationally important infrastructure.

Large parts of Grangemouth are at risk from fluvial and tidal flooding; in late 2011 Falkirk Council instructed Jacobs to undertake a detailed flood risk mapping study. This investigation showed extensive inundation during a 1 in 200-year return period event, for both tidal and fluvial events. This included extensive flooding to the port and petrochemical plant, predominantly caused by elevated water levels in the Firth of Forth caused by high tides, surge events and wave overtopping.

Following the outcome of this study, in 2015 Jacobs were appointed by Falkirk Council to undertake the option appraisal and identify a preferred scheme option which was to be taken forward to the outline design stage for the Grangemouth Flood Protection Scheme.

2. Summary of Construction Areas

The proposed scheme has been divided into six Flood Cells, see Appendix A for plan outlining the six Cells. Each Flood Cell has been sub-divided in Working Areas. The Working Areas are based on form of construction, geographic divisions, source of flooding and sensible breaks within the Flood Cell. It is anticipated that the contractor will develop their programme and sequence of construction based on the Flood Cells or Working Areas. Details are as follows:

Cell no.	Working Areas	Location	Estimated overall length of flood defences in metres	Anticipated Form of Construction
1	1-1	Stirling Road	1611	Formed Concrete Wall, Brick Clad Wall, Seepage Only, Embankment
	1-2	Carron Bridges	1045	Brick Clad Wall, Stone Clad Wall, Stone Clad Wall with Glass Panels, Formed Concrete Wall, Embankment, Replacement Bridge (B902)
	1-3	Chapel Burn	685	Brick Clad Wall, Stone Clad Wall
	1-4	Dock Street	557	Formed Concrete Wall
2	2-1	Forth and Clyde Canal Lock	662	Embankment, Sheet Pile Wall
	2-2	Jarvie Plant/Rossco Properties	840	Sheet Pile Wall
3	3-1	Mouth of the River Carron	920	Sheet Pile Wall & revetment
	3-2	West Coast of the Port	965	Sheet Pile Wall & revetment
	3-3	West Gate to the Port	1167	Sheet Pile Wall & revetment
	3-4	East Gate to the Port	992	Sheet Pile Wall, Plain Concrete Wall, Formed Concrete Wall
	3-5	Mouth of the Grange Burn	683	Sheet Pile Wall
4	4-1	Upstream of M9	1078	Stone Clad Wall, Formed Concrete Wall

Cell no.	Working Areas	Location	Estimated overall length of flood defences in metres	Anticipated Form of Construction
	4-2	Rannoch Park	559	Formed Concrete Wall
	4-3	Inchyra Road	505	Formed Concrete Wall & Embankment
	4-4	Whole-flats Road	2359	Formed Concrete Wall, Stone clad Wall, Sheet Pile Wall, Raising footway, Embankment, Regrading Existing Embankment, New Bridges
	4-5	Zetland Park	767	Stone Clad Wall & Embankment, Replacement Bridge (Dalratho)
	4-6	Dalratho to Bo'Ness Road	804	Stone Clad Wall
	4-7	Grangeburn Road	1250	Sheet Pile Wall, Stone Clad Wall, Formed Concrete Wall
	4-8	Petroineos	1051	Sheet Pile Wall, Stone Clad Wall
	4-9	Mouth of Grange Burn	1142	Sheet Pile Wall, Seepage Only
5	5-1	Smiddy Brae & Avondale Road	1786	Sheet Pile Wall, Formed Concrete Wall
	5-2	Flare Road & Road 33	1102	Sheet Pile Wall, Seepage Only
	5-3	Grangemouth Road	1675	Sheet Pile Wall
	5-4	Mouth of the River Avon	438	Sheet Pile Wall, revetment

Cell no.	Working Areas	Location	Estimated overall length of flood defences in metres	Anticipated Form of Construction
6	6-1 & 6-2	West of River Avon (Beach Road & Mouth of River Avon)	2166	Sheet Pile Wall, Bored Pile Wall with revetment
	6-3 & 6 -4	East of River Avon (Chemical Works at River Avon & Chemical Works)	1422	Sheet Pile Wall & Embankment

Table 1 Summary of work areas (note that the above lengths have been rounded up or down and may vary slightly)

Summary of work areas (note that the above lengths have been rounded up or down and may vary slightly)

3. Advanced Works

The following section covers work which may be carried out in advance of the main works contract. This may be done also to reduce the risk of delay to the main works, provide greater certainty of cost, or reallocate activities which are more suited to specialist contractors.

It is considered unlikely that enabling works carried out in advance of the main works contract will require working within the watercourse. Where utility services cross bridges that are to be modified as part of the works, it is likely that the associated services will be diverted onto temporary support structures during the main works contract.

3.1 Tree Felling

The banks of the River Carron, River Avon, the Grange Burn, the Flood Relief Channel and parts of the Westquarter and Polmont Burns contain many trees. Most of these are self-seeded, and elsewhere, cultivated trees line sections of road and parkland. Both types of tree present an obstacle for construction of the flood defences, and several of them will have to be removed in their entirety (including stumps) to enable access and for the works to be constructed.

There are two possible approaches to tree felling which mitigate different risks to the project:

- The first approach would be to carry out tree felling in advance of the main works. This would enable trees to be felled outside the bird nesting season, therefore mitigating the risk of delay if trees identified for removal were found to contain nesting birds. However, this would likely have to be done prior to a main works contractor being appointed and might therefore result in more trees being felled than necessary, or trees being felled years in advance of works taking place.
- The second approach would be to make the main works contractor responsible for tree felling. This would reduce the number of trees felled to only those that the contractor needs to be removed. However, the contractor's construction programme may preclude all trees from being felled outside the bird nesting season, thereby increasing the risk of delay to the scheme's construction programme.

Further discussion is required to establish Falkirk Council's preferred approach to tree felling with a final decision unlikely to be made until they commence procurement of contractors which could be several years away. If trees are to be retained for as long as possible, and the number felled to be minimized, then tree felling should be included in the overall construction scope of works. It should be

noted that due to the spatial extent and size of the project, it is likely that construction works will be spread over multiple breeding bird seasons.

A large number of trees in Cell 4 along the north side of Rannoch Park and along Grangeburn Road have been identified as suffering from Ash dieback disease and may need to be felled in advance of the Scheme proceeding, depending on the condition of the trees and the safety concerns this may pose to the public and property.

3.2 Service Diversions

Grangemouth contains numerous buried services (electricity, gas, telecommunications, water, waste, oil, etc.), as well as overhead services (telecommunications, electricity and lighting). Many of these present an obstacle for construction of the flood defences, as they either clash with, or are close to the works. Each statutory undertaker has been consulted to determine which services can be diverted and which will have to be protected.

Experience indicates that the diversion of services is a complex and lengthy process. The process is normally regulated under the New Roads and Streetworks Act 1991, but there is no provision for enforcing diversions to be completed within a specific time. If diversion works were included within the scope for the main works contract, the contractor could be delayed from carrying out their work caused by the service providers, and this is considered a likely scenario which would result in a risk of unacceptably high additional costs and delay.

Planning and carrying out the service diversions in advance would mitigate the risk of delays to the construction programme. Engaging a single contractor to carry out the preparatory pipe and duct laying for all the service providers would also minimise the number of occasions the road was excavated and therefore minimise the impact to the public. This approach generally worked well for the Selkirk and Hawick flood protection schemes although there still remains a risk of identifying uncharted services during the main construction works.

It is preferable to carry out service diversions as advance works with a single contractor, where possible, carrying out all preparatory pipe and duct laying with the final connections undertaken by each statutory undertaker. Such works will develop into a sizeable project in its own right and will require adequate staff to manage, co-ordinate and supervise, along with a contractor who is suitably experienced in coordinating the separate service providers. It is likely that street lighting diversion works will be undertaken as part of the main works contract.

There are a considerable number of above ground and buried pipelines within the Grangemouth area generally associated with the petrochemical works/ refinery and are privately owned by companies such as Ineos, Shell, BOC etc. Discussions with pipeline owners are ongoing, however, it is unlikely that many of these pipelines will be diverted due to the products transported by the pipeline, therefore it is likely that work to protect pipelines during the construction phase will be required. This work is likely to form part of the main scheme work contracts.

3.3 Traffic Management Preparatory Works

It is likely that temporary road closures and partial closures will be required for some of the construction works. For the diversion route to work effectively it may be necessary to provide temporary signalised priority at some locations and/ or implement one way operation and suspension of parking. It may also be necessary to provide additional pedestrian crossings and/or traffic management measures. This will be investigated further as part of a more comprehensive traffic management plan which would be prepared at the detailed design stage.

The sections below outline, on a cell-by-cell basis, some of the required traffic management.

3.3.1 Cell 1

- Partial road closure of Stirling Road.

- Some footpath closures around the Carron Bridges, within the community woodland and by the Chapel Burn will be required.
- Temporary road closure of B902 for new bridge construction, traffic diverted via Stenhouse Road.

3.3.2 Cell 2

- Construction works are setback from the road on private land. A temporary closure of the Charlotte Dundas public footpath would be required.

3.3.3 Cell 3

- Partial road closure of South and North Shore Road would be required, any traffic management on Forth Ports land will need to be agreed with Forth Ports.

3.3.4 Cell 4

- Partial closure of Abbots Road, Grange Burn Road, Park Road and South Shore Road is required. This temporary closure will need to move with the construction works. Construction work will have to be sequenced to avoid Abbots Road, Grangeburn Road, South Shore Road and Park Road being closed at the same time. Pedestrian access will always be maintained in this cell.
- Partial closure of Wholeflats Road.
- Work to Dalratho bridge is required and would impact roads in the surrounding area.
- Work to multiple foot bridges on the Grange Burn and the flood relief channel, to incorporate new flood defences (reusing the existing footbridges but raising their height).
- Traffic Management on the A9 and Grandsable Road at Beancross.
- Traffic Management on Smiddy Brae and Reddoch Road.

3.3.5 Cell 5

- Most of the construction work for this cell is on private land. Access to the construction works area will be required from Wholeflats Road and Bo'ness Road. To ensure safe access to the site from both these roads, temporary road works may be required to construct construction site access points.
- Partial closure of Wholeflats Road.

3.3.6 Cell 6

- All construction works will take place on private / Falkirk Council owned land. Access for construction works will be taken from Wholeflats Road.

4. Site Compounds

Site compounds are necessary for the contractor to accommodate the facilities needed to construct the works. Ideally a main site compound would be located centrally and close to the construction works, and would comprise of offices, welfare facilities, parking, and space for storage of materials and equipment. Additional smaller satellite compounds would be advantageous, providing localised welfare facilities and storage for materials and equipment.

There are few unoccupied open areas in Grangemouth which lend themselves for use as site compounds. Possible sites include parks, car parks, brown field sites and disused buildings. Appendix C outlines locations the project team have identified as possible site compounds and main access routes. Subject to a contractor being appointed the exact location of site compounds is to be confirmed.

5. Construction Access

5.1 General

As described in the introduction, many of the proposed work areas are difficult to access. This is due to the proximity of buildings, roads and other infrastructure to the riverbanks. Working from within the watercourse is a possible solution but it presents its own challenges.

Due to environmental and health and safety issues, construction plant cannot operate directly in the watercourse. Dry working areas are required to enable the works to be constructed safely, protect the equipment from water damage and to protect the watercourse from pollution. This can be achieved by forming temporary cofferdams to exclude water or raised platforms (typically formed from rock) which are above the 'normal' water level.

The use of such temporary working areas must be carefully planned and executed since they can affect the conveyance of the watercourse and increase flood risk. Narrowing the channel will result in river water levels which are higher and more sensitive to low return period rainfall events and the narrowing could lead to increased erosion and scour damage. Platforms which are set too low will be frequently inundated resulting in construction work stopping, and those set too high will have an unacceptable impact on river levels and flood risk. When the exact construction sequence is confirmed, further hydraulic modelling will be undertaken to determine the impact of the temporary works on water levels/ velocities, with further mitigation developed, if required, to ensure no greater residual impact than that reported in the EIA Report.

The position and extent of such working areas can also have an ecological impact. Disturbing the riverbed material during salmon spawning season is prohibited under legislation. Even when lawfully constructed outside this season, the position of working areas may affect the viability of habitats when spawning begins due to change in the normal river flow regime.

The design and implementation of temporary works, which includes construction access, will be the sole responsibility of the contractor. It will be for the contractor to propose temporary works as part of their method statements, taking into account the committed mitigation measures specified in the EIA Report, which will then be submitted to the employer's representative for review and acceptance. These proposals would include measures to be taken (e.g. temporary flood defences) to mitigate any adverse impacts with the aim of ensuring there is no increase in flood risk. The purpose of the following sections is to discuss the advantages and disadvantages of different forms of temporary works and how these might affect the design of the flood defences and preparation of scheme documentation, noting that the contractor will be required to take into account the relevant mitigation measures set out in the EIA Report's Schedule of Environmental Commitments.

Appendix C outlines the possible site compounds.

5.2 Cofferdams

A cofferdam is a temporary structure, constructed around a working area to exclude water, and is normally formed with sheet piles. The effectiveness of this form of construction depends on the ability to make the cofferdam watertight. Water may enter the cofferdam either through the clutches between the piles, by seeping up through the underlying soils, or by overtopping the sheet piles.

The clutches of the sheet piles can be made mostly watertight by sealing them with wadding or welding them together. This is less common for temporary structures however, and it may be practical to pump out water which does seep through. This can be achieved with a trench which drains to a sump containing a submersible pump.

Where the underlying soil is permeable, the differential water pressure across the cofferdam may cause ground water to seep up through the bottom of the working area. This can be managed to some extent with over-pumping, described above. If the soil is very permeable however, the pumps may be unable to cope with the flow of water entering the working area. In addition, the pumped water will not be permitted to be discharged straight into the river, it will need to be filtered or settled out prior to discharge to reduce the pollution risk.

Figure 1: Example of a cofferdam, White Cart Water FPS, Glasgow, 2009

5.3 Raised Platforms

As an alternative to a cofferdam, a working area could also be formed in the watercourse by constructing a raised platform. This would occupy the same space as a cofferdam but would be raised

above the water level and formed with crushed granular aggregate. The effectiveness of this form of construction depends on limiting the frequency of inundation and resisting erosion damage from the watercourse.

The level of the platform must be selected such that work can progress without regular interruption from rising river levels. However, narrowing the watercourse will make the river level more sensitive to changes in flow, and therefore rise more quickly. Raising the platform further to compensate may have the effect of increasing flood risk because of reducing channel capacity. The platform must therefore be high enough to provide the contractor with a reasonable ability to work during typical conditions and wide enough to provide safe passage of construction vehicles and their operators.

Operating criteria are needed to establish optimal extents for such platforms. It must be wide enough to accommodate the largest plant (with space for manoeuvring), and high enough to limit inundation to an acceptable frequency. A piling rig could require 5-9 metres width in which to manoeuvre, and a platform level of c.1-1.5 metres above riverbed level could limit inundation to a tolerable frequency of once or twice per month during wet periods.

It is considered reasonable to assume that platforms would be constructed of clean crushed rock approximately 75-150mm in size placed on a separation geotextile and surrounded with sand-filled bulk bags. This was demonstrated to be effective at resisting erosion on previous projects such as White Cart Water FPS, pictured below.

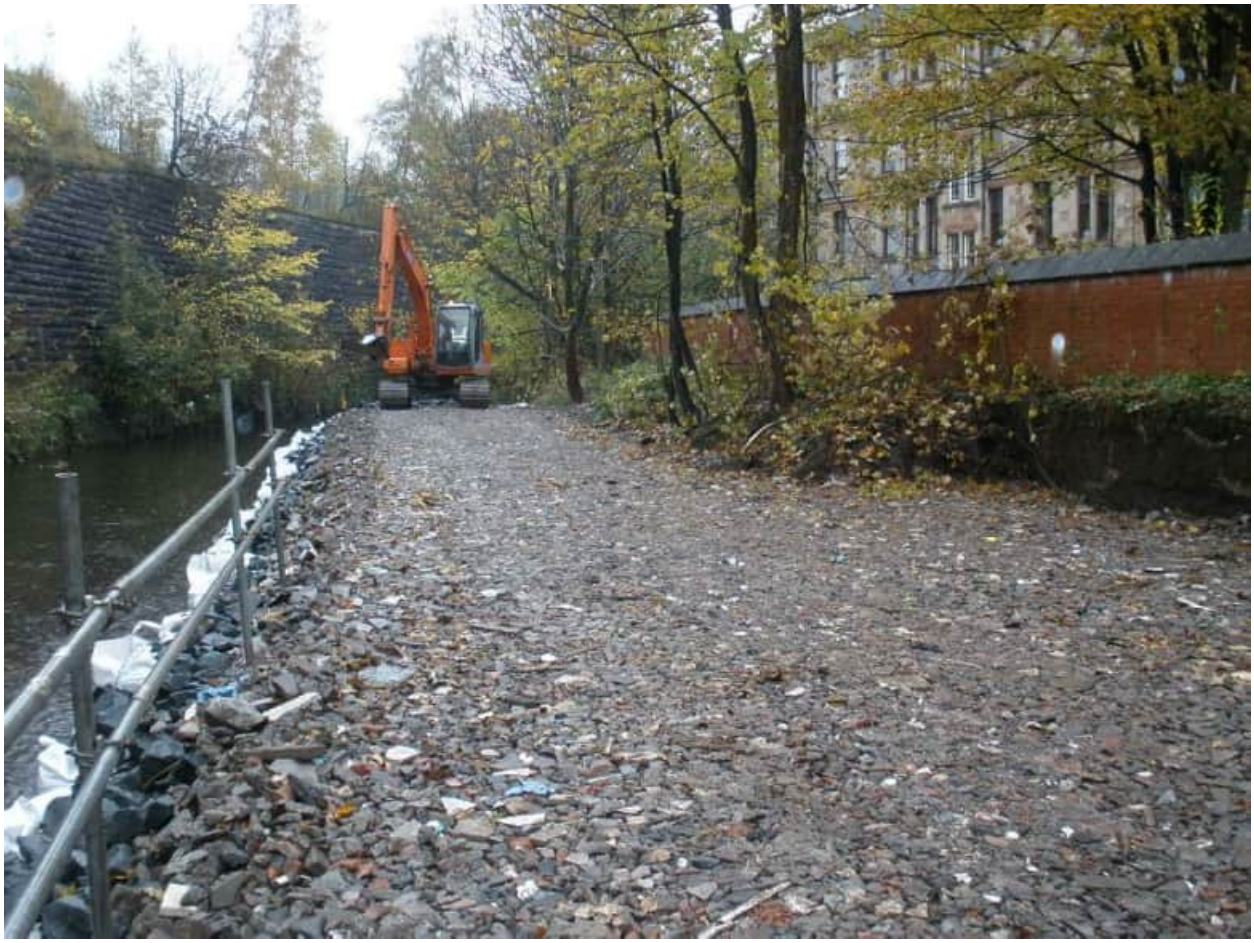


Figure 2: Example of a raised platform

Fish rescue may be required during installation of the temporary raised platforms in the watercourse, and after inundation events. The contractor will be required to develop an appropriate procedure for this as part of their method statements.

5.4 Crossing Points

Working areas in the watercourse would likely be parallel to the alignment of the flood defences. Access would be from the adjacent riverbank, except where this was not possible due to the presence of buildings or other barriers. In this event, crossing points would be required to access the working area from the opposite riverbank, and would most likely be formed from either:

- A pipe / flume bridge;
- A Bailey bridge; or
- Tracking directly across

Temporary works carried out in the River Teviot (Hawick) during September 2016 provided evidence of how a pipe crossing might perform under moderate flow conditions. A pipe bridge was constructed during low flow conditions, and comprised multiple concrete pipes of varying sizes, surrounded in 25-40 millimetre diameter aggregate. The river level rose in response to a rainfall event, exceeding the capacity of the pipes and engulfing the working area. Prolonged high river levels washed out the aggregate and washed the pipes downstream.

This suggests that the effectiveness of pipes bridges is largely dependent on the materials used and construction. They may be unsuitable during prolonged wet periods and depending on the nature of their construction, could result in increased flood risk.

Figure 3: Pipe bridge under construction

A Bailey bridge can take several forms, but generally comprises a portable, modular deck supported on temporary abutments. This may be a more expensive solution than a pipe bridge, but it has advantages. The Bailey bridge presents less restriction to the flow of the watercourse and the deck can be more easily removed in the event of a flood alert.

Figure 4: Example of a Bailey bridge in use

The final option of tracking directly over the river bed presents the least impact to the flow of the watercourse. It is however most susceptible to rising water levels and would quickly become impassible. It would also impact ecological habitats on the riverbed, with work restricted during certain times of the year. For these reasons, this option was deemed unsuitable and not considered further.

5.5 Dewatering of Excavations

Where working within the watercourse is required, it is considered unlikely that dewatering techniques would be used, and that they would be largely ineffective if attempted.

Notwithstanding this, the contractor will be entitled to design their temporary works as they consider appropriate, subject to any constraints imposed through the construction contract, taking into account the committed mitigation measures identified in the EIA Report, and / or by licencing authorities. If the contractor chooses to use dewatering as part of their temporary works, they will be responsible for complying with SEPA's relevant General Binding Rules (GBRs), and for securing a license where necessary.

5.6 Temporary Culverting a Channel

As some of the watercourses and tributaries within in the scheme works are relatively narrow, it may be feasible to temporary culvert short lengths of the channel. This would allow a temporary working area to be created directly over the channel and facilitate access to construct flood defences, which would otherwise require significant working areas within the gardens of residential properties or require significant temporary works on the existing banks to divert the channel or over pump water. Once each section of flood defence is complete, the culverted section of the channel would be reverted to an open channel (current condition). If temporary culverting the waters courses is undertaken, the culvert capacity should be sufficient to pass at least a nominal flow determined by the project team and agreed with SEPA, and appropriate method statements should outline the procedure which is to be followed in the event of high flows, which may require the culvert to be removed or over pumping to take place.

6. Outline Construction Methods

The following section outlines possible construction methods for the main forms of construction that are likely to form part of the Grangemouth FPS. These methods are based on experience of similar construction activities which formed part of White Cart Water FPS, Broxburn FPS, Jedburgh (Skiprunning Burn) FPS, Selkirk and Hawick FPS from 2008 to 2023.

The form of construction for each work section was based on several factors, including cost, speed of construction, appearance, ground conditions, site access, and adjacent buildings.

It should be noted that while outline construction methods are provided, the actual construction method may vary. This is because the contractor will be responsible for selecting the most appropriate construction method in accordance with their contractual and regulatory obligations. As part of these obligations, they will also be required to submit detailed method statements for each construction activity to SEPA, Marine Scotland, Falkirk Council and Jacobs for acceptance prior to the activity being carried out.

The contractor will be required to prepare several management plans and method statements for carrying out the works. For example, the contractor will be required to prepare a Site Waste Management Plan, which will contain details of how different waste will be handled in accordance with the waste hierarchy and regulatory requirements. Also, as part of their method statements, the contractor will be required to propose appropriate methods for managing sedimentation risk during their construction works.

It is worth noting that in the maps provided for the EIA Report, the term "Flood Gates: Ground Raising" is used in the map key. Ground raising refers to raising the existing ground level by <0.5m. The raised ground may be surfaced with a material to allow a footpath or vehicular access. Where required some surrounding ground may need to be re-landscaped to suit the new ground level.

6.1 General

6.1.1 Site Preparation

- Clear site of vegetation and fell trees, as necessary, which were not already removed during advance tree felling works.
- Locate/protect/divert, as necessary, any services which were not already dealt with during advance service diversion works. This includes individual connections to business and residential properties, and outfalls to the watercourse.
- Remove street furniture, fencing and walls as necessary. Steel items may be removed by burning or cutting through foundations. Concrete and timber items may be removed manually or with mechanical excavator. Precautions will be taken to prevent debris entering the watercourse and waste arising will be disposed of off-site.
- Excavate bound surfaces, as necessary, to carry out the works.
- Apply measures as necessary to avoid suspended solids, sediment, and contamination being released into the watercourse. This forms part of the contractor's temporary works and may include attenuation lagoons and settlement tanks to manage runoff.
- Strip topsoil using a mechanical excavator and store on site for later re-use on site where possible. Where topsoil is unacceptable for re-use on site, it will be disposed of off-site.
- Excavate to formation level using mechanical excavator and store arisings on site for later re-use on site where possible. Where arisings are unacceptable for re-use on site, they will be disposed of off-site.
- Formation to be inspected and soft spots excavated and replaced with structural upfill. Arisings will be disposed of off-site if they cannot be re-used.

6.1.2 Equipment and Materials

The following list provides an indication of the likely equipment which may be used to construct the flood protection scheme:

- 360 degree tracked excavators
- Wheeled excavators
- Dumpers
- Mobile cranes
- Tracked / Non-Tracked piling equipment
- Vibrating roller compactors
- Vibrating plate compactors
- Concrete cutting equipment
- Concrete pumps and skips and vibrating pokers
- Burning and steel cutting and welding equipment
- Drilling and coring equipment
- Mobile pumps
- Mobile settlement tanks

- Mobile generators
- Mobile compressors
- Mobile heaters
- Tarmac planers and pavers

The following list provides an indication of the likely materials which may be used to construct the flood protection scheme:

- Cohesive, low permeability fill
- Granular fill (Sands, gravels, and rock~)
- Rock armour stone
- Topsoil
- Steel sheet piles
- Precast concrete piles
- Mass and reinforced concrete
- Geotextiles
- Timber fencing
- Metal fencing
- Bitumen macadam
- Plastic pipework and ductwork
- Metal pipework
- Concrete pipework
- Mechanical/ electrical pumps
- Stonework, brickwork, and reconstituted stone products
- Precast concrete products
- Glass products
- Metal and plastic fixings and fixtures
- Hydrocarbon-based cellular products
- Organic-based coatings and sealants
- Paints, coatings, and sealants
- Lighting, wiring and fixtures
- Fuel oils
- Seeds, trees and plants
- Steel gates (flood gates and lock gates)
- Soil mixing additive (for example this could be cement, lime or pulverised fly ash)

6.2 Embankments

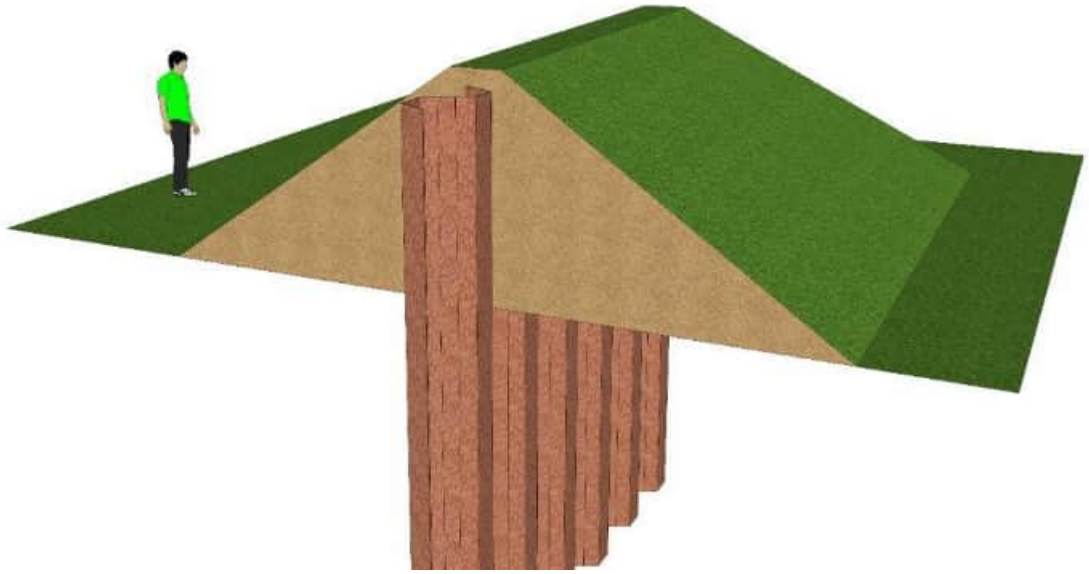


Figure 5: Schematic of Embankment with steel sheet pile core

- Where a sheet pile core is specified, excavate a leader trench to a depth of approximately 1 metre below existing ground level along the centre line of the proposed structure (if required). Pre-auger where necessary, and drive sheet piling to the required toe depth. Driving may be achieved by either vibro-driving, impact-driving or hydraulic pressing.
- Lay flood defence drainage where required, which may comprise filter pipes in a granular trench, gully pots, gratings, precast concrete or plastic manholes, carrier pipes, headwall structures and flap valves. Cut openings in sheet piling as required to accommodate pipework or stop piles either side of existing pipes/ cables that cross the defence. Cap pipework until such time as it is fully connected.
- Place material separation geotextile across the extent of the excavation profile and fix to the underlying soil.
- Where required, place anti-burrowing geotextile across the extent of the excavation profile and provide sufficient material to wrap the entire surface of the embankment once placed.
- Place, compact and trim embankment fill material in layers and to the profiles shown on the drawings.
- Where a crest path is proposed, lay precast concrete edging on the crest to the widths shown on the drawings and secure with concrete haunching. Place and compact granular sub-base. Place bitumen-based binder course. Place asphalt surface course, add stone chips and roll to achieve an appropriate surface finish.
- Place and trim topsoil to the faces of the embankment, and seed with an appropriate grass and/ or wildflower mix.
- Place erosion protection geotextile on the faces of the embankment, overlapping the sheets, fix to the underlying embankment, and secure ends within anchor trenches at the toe and crest.
- Reinstate surrounding disturbed areas with topsoil and seed with an appropriate grass and wildflower mix.

6.3 Sheet Pile Walls (top of riverbank)

Figure 6: Schematic of Sheet Pile Wall with reinforced concrete stem (at top of riverbank)

- Excavate a leader trench to a depth of approximately 1 metre below existing ground level along the centreline of the proposed structure (if required). Pre-auger where necessary, and drive sheet piling to the required toe depth. Driving may be achieved by either vibro-driving, impact-driving or hydraulic pressing.
- Cut openings in sheet piling as required to accommodate existing and proposed outfall pipework. Form box-outs prior to concreting works.
- Pour blinding concrete within trench.
- Fix steel reinforcement and formwork for in situ concrete pile cap. Pour concrete pile cap and cure. Strike formwork, setting aside materials for re-use, and dispose of waste arisings off-site.
- Fix steel reinforcement and formwork for in situ concrete wall stem. Pour concrete wall stem and cure. Strike formwork, setting aside materials for re-use, and dispose of waste arisings off-site.
- Excavate further as required and lay flood defence drainage, which may comprise filter pipes in a granular trench, gully pots, gratings, precast concrete or plastic manholes, carrier pipes, headwall structures and flap valves. Cap pipework until such time as it is fully connected.
- Backfill flood defence wall and drainage with structural backfill.
- Where glazing is specified, post-drill holes for mechanical fixing. Insert glazing panels in the openings in the wall and secure to the concrete with mechanical fixings. Apply sealant around the edges of the glazing panel to provide a watertight seal with the surrounding wall.
- Where stone cladding is specified, fix individual masonry or prefabricated panels to face of wall with appropriate adhesive and point mortar beds. Lay mortar bed along top of wall and affix stone copes.

- Where there is a riverbank in front of the flood fence wall, reinstate riverbank using appropriate remediated recycled excavated material were available, or appropriate imported material where not available. Place and trim topsoil to the face of the riverbank, and seed with an appropriate grass and wildflower mix.
- Place erosion protection geotextile on the face of the riverbank, overlapping the sheets, fix to the underlying soil, and secure ends within anchor trenches at the toe and crest.
- Where rip rap is specified, place rock at the toe of the flood defence, ensuring sufficient interlocking occurs.
- Where a footpath is specified, lay precast concrete edging to the widths shown on the drawings and secure with concrete haunching. Place and compact granular sub base. Place bitumen-based binder course. Place asphalt surface course, add stone chips and roll to achieve an appropriate surface finish.
- Where a road is specified, lay precast concrete kerbs to the widths shown on the drawings and secure with concrete haunching. Place and compact granular sub base. Place bitumen-based binder course. Place asphalt surface course, add stone chips and roll to achieve an appropriate surface finish.

6.4 Reinforced Concrete Cantilevers Walls

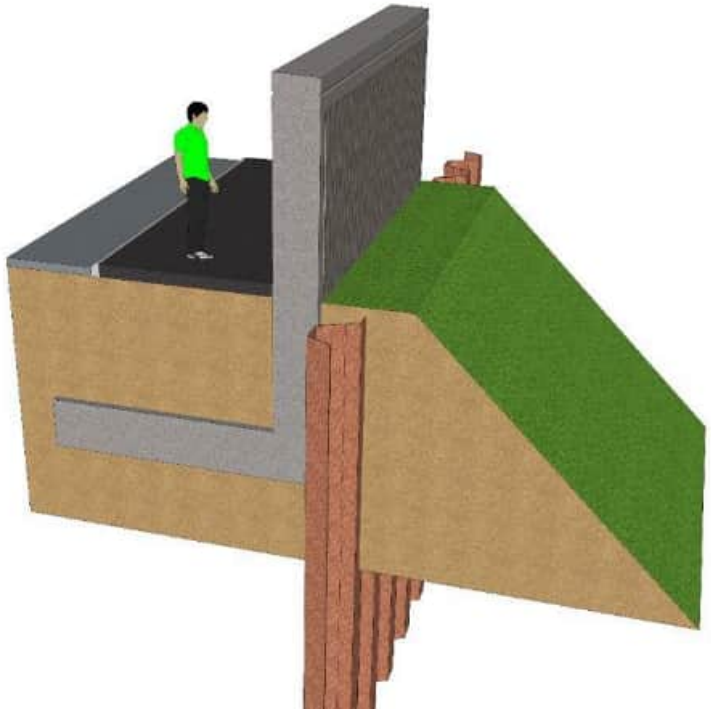


Figure 7: Schematic of Reinforced Concrete Cantilever Wall with steel sheet pile seepage cut-off

- Where a seepage cut-off is specified excavate a leader trench to a depth of approximately 1 metre below existing ground level along the centerline of the proposed seepage protection (if required). Pre-auger where necessary, and drive sheet piling to the required toe depth. Driving may be achieved by either vibro-driving, impact-driving or hydraulic pressing.
- Cut top of piles to the level shown on the drawings, ensuring that when the leader trench is backfilled, the top of the sheet piling will be buried.
- Cut openings in sheet piling as required to accommodate existing and proposed outfall pipework. Form box-outs prior to concreting works.
- Excavate down the dry side of the sheet piling, to formation level of the in situ concrete works, ensuring a safe excavate profile based on the ground conditions encountered.
- Pour blinding concrete within excavation.
- Fix steel reinforcement and formwork for in situ concrete wall base. Sheet pile seepage cutoff will form the rear formwork for the concrete. Pour concrete wall base and cure. Strike formwork, setting aside materials for re-use, and dispose of waste arisings off-site.
- Fix steel reinforcement and formwork for in situ concrete wall stem. Pour concrete wall stem and cure. Strike formwork, setting aside materials for re-use, and dispose of waste arisings off-site.
- Lay flood defence drainage, which may comprise filter pipes in a granular trench, gully pots, gratings, precast concrete or plastic manholes, carrier pipes, headwall structures and flap valves. Cap pipework until such time as it is fully connected.
- Backfill flood defence wall and drainage with structural backfill. Backfill seepage cutoff leader trench.

- Where glazing is specified, post-drill holes for mechanical fixing. Insert glazing panels in the openings in the wall and secure to the concrete with mechanical fixings. Apply sealant around the edges of the glazing panel to provide a watertight seal with the surrounding wall.
- Where stone cladding is specified, fix individual masonry or prefabricated panels to face of wall with appropriate adhesive and point mortar beds. Lay mortar bed along top of wall and affix stone copes.
- Where there is a riverbank in front of the flood fence wall, reinstate riverbank using appropriate remediated recycled excavated material were available, or appropriate imported material where not available. Place and trim topsoil to the face of the riverbank, and seed with an appropriate grass and wildflower mix.
- Place erosion protection geotextile on the face of the riverbank, overlapping the sheets, fix to the underlying soil, and secure ends within anchor trenches at the toe and crest.
- Where rip rap is specified, place rock at the toe of the flood defence, ensuring sufficient interlocking occurs.
- Where a footpath is specified, lay precast concrete edging to the widths shown on the drawings and secure with concrete haunching. Place and compact granular sub base. Place bitumen-based binder course. Place asphalt surface course, add stone chips and roll to achieve an appropriate surface finish.
- Where a road is specified, lay precast concrete kerbs to the widths shown on the drawings and secure with concrete haunching. Place and compact granular sub base. Place bitumen-based binder course. Place asphalt surface course, add stone chips and roll to achieve an appropriate surface finish.

6.5 Bare Sheet Pile

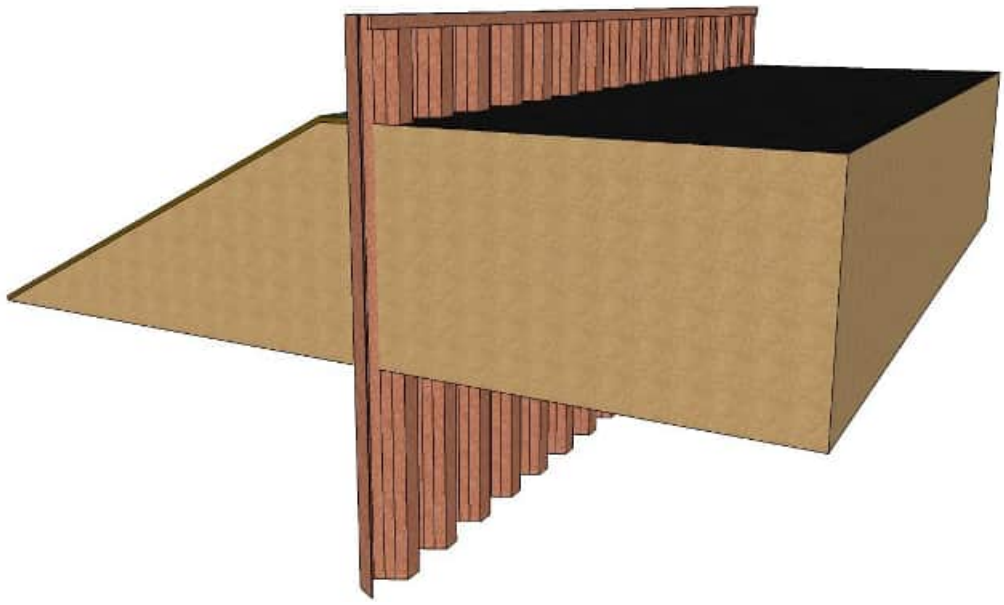


Figure 8: Bare sheet pile wall

- Pre-auger where necessary, and drive sheet piles to the required depth. Driving may be achieved by either vibro-driving, impact-driving or hydraulic pressing.

- Weld pile clutches above ground/ clutch sealant installed prior to driving.
- Weld a flat steel plate to the top of the piles.

6.6 Bare Sheet Pile with granular shoulders

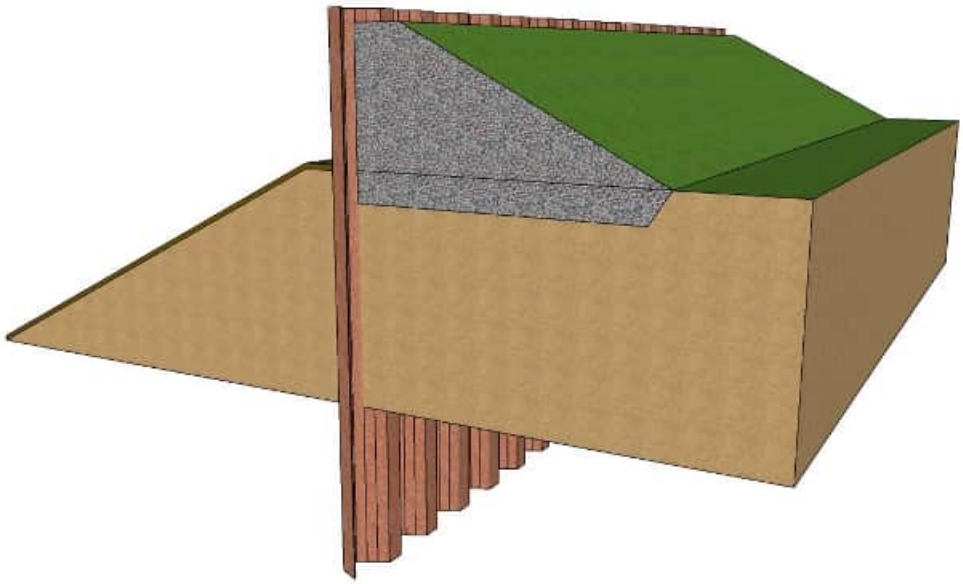


Figure 9: Bare sheet pile wall with granular shoulder fill

- Pre-auger where necessary, and drive sheet piling to the required toe depth. Driving may be achieved by either vibro-driving, impact-driving or hydraulic pressing.
- Weld pile clutches.
- Place material separation geotextile across the extent of the excavation profile and fix to the underlying soil.
- Place, compact and trim embankment fill material in layers and to the required profile.

6.7 Augured (continuous flight augured) piles

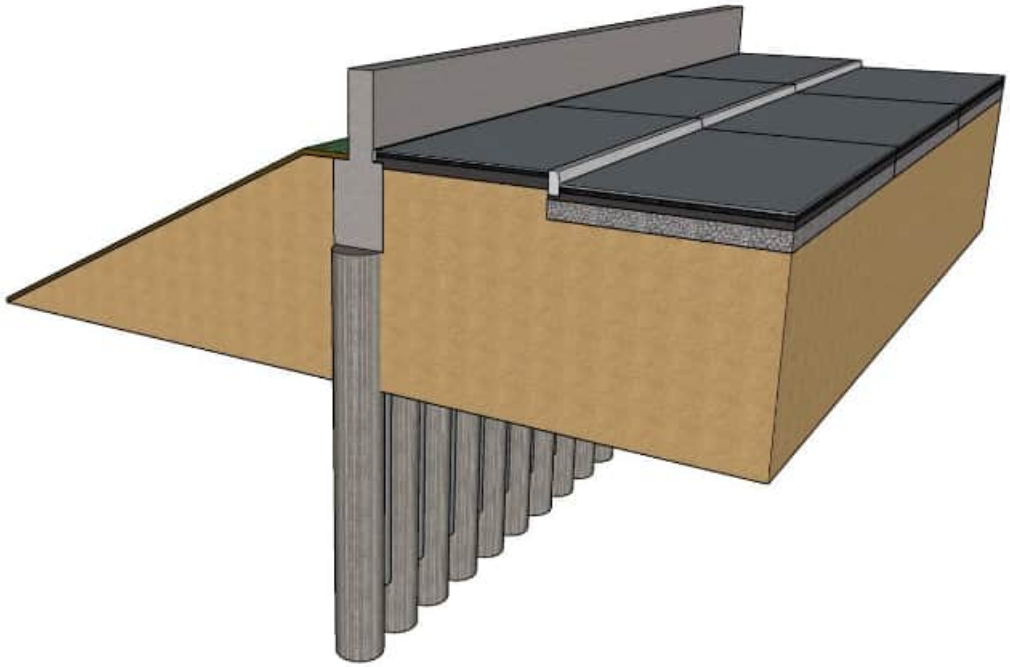


Figure 10: Schematic of Bored pile with reinforced concrete stem

- Install any formwork, or pre-made mould/pile guide, this may require formwork to be erected and concrete poured.
- Auger (drill) into the ground to the required depth.
- Pump concrete into the hole through auger and withdraw auger as hole is being filled.
- Install reinforcement, with started bars exposed to connect to wall stem.
- Place steel reinforcement for wall stem.
- Erect wall stem formwork and pour concrete.
- Remove wall stem formwork.

6.8 Coastal Structures

Three types of coastal defence structures have been designed, to protect against coastal erosion/scour and wave action. Figure 11 outlines the location of the three defence structures.

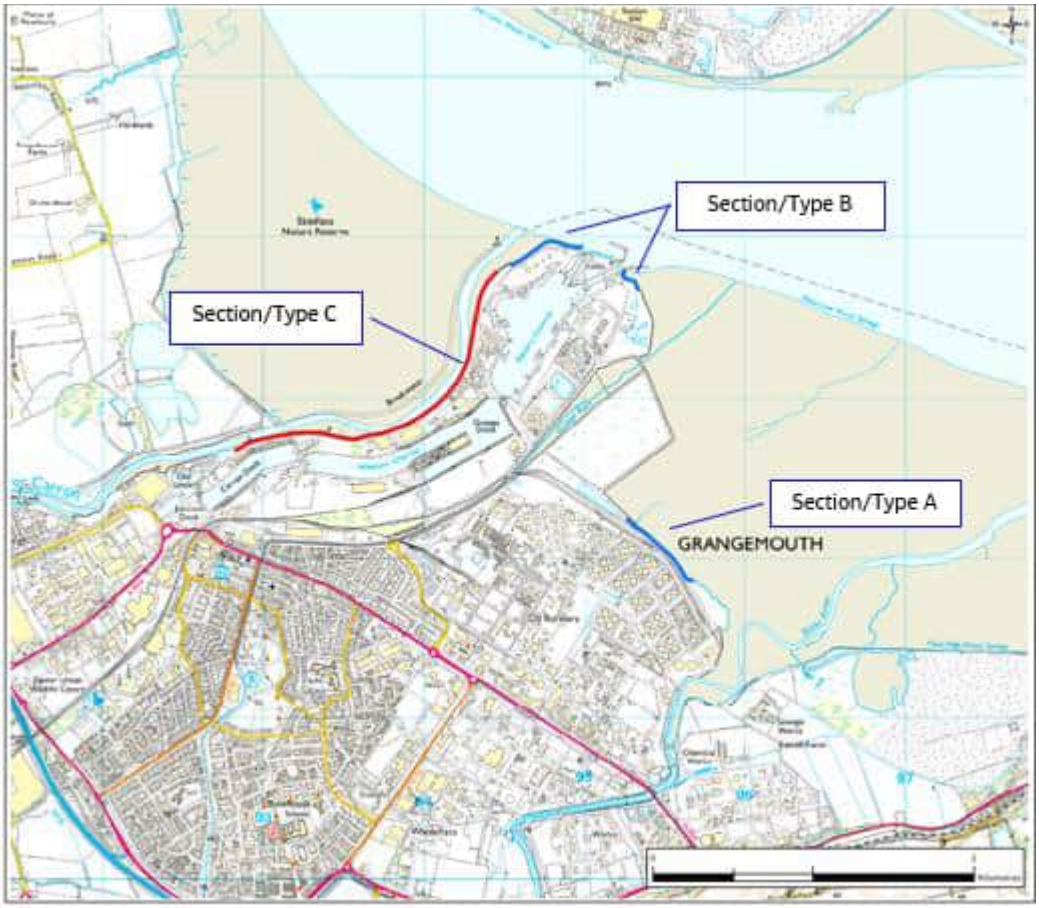


Figure 11: Location of coastal structures

6.8.1 Rock Revetment with a flood wall along the estuary frontage (Section /Type A)

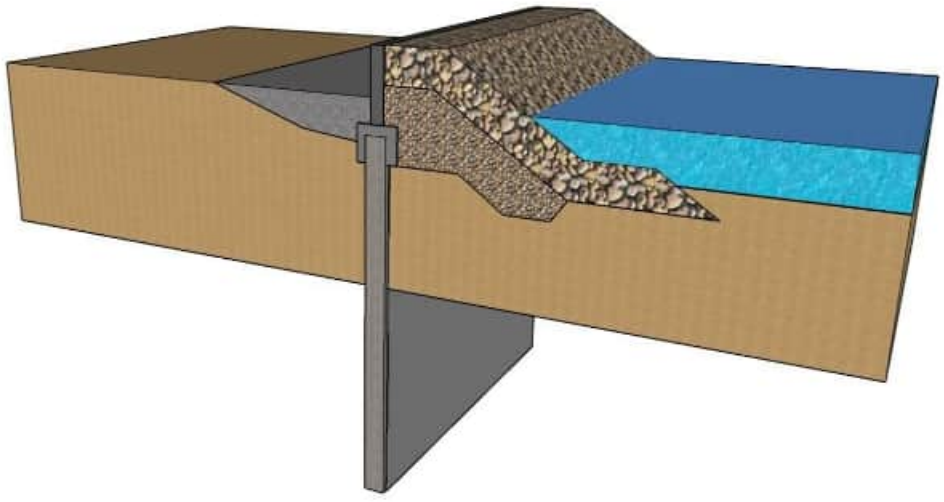


Figure 12 Schematic of rock revetment along the estuary frontage.

The text below only relates to the construction of the rock revetment. Section 6.6 will describe the ground improvements and wall construction.

- Install temporary access road/platform through ground improvement work see section 6.6.
- Break out and remove any improved ground, where necessary.
- Install a geotextile on top of the improved ground, and ensure the ends sufficiently bedded in.
- Install riprap underlay stone.
- Install rock armour stone on top of the riprap, in two layers with stones interlocked.
- All work would be constructed from the dry side of the wall, with the bored pile installed prior to installation of the revetment.

6.8.2 Rock Revetment with flood wall adjacent to the harbour entrance (Section/Type B)

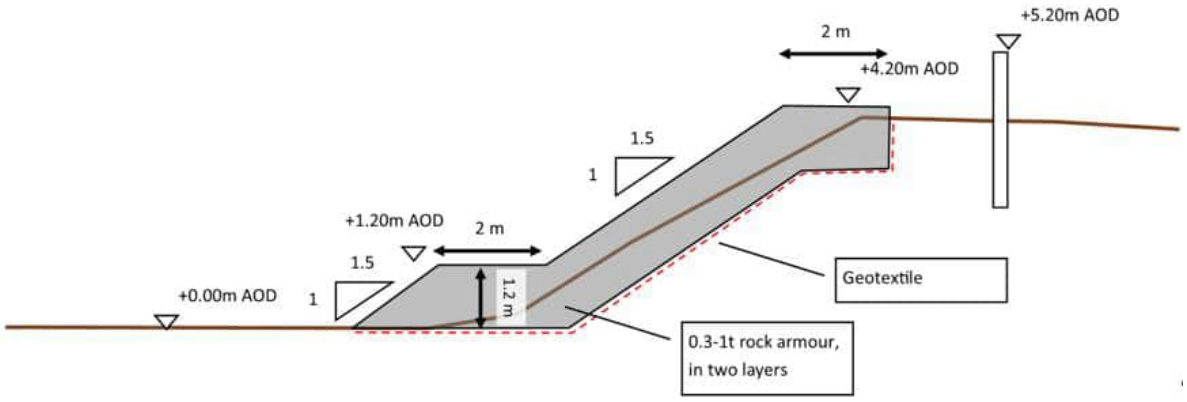


Figure 13: Typical cross-section steel sheet piled wall with capping beam/plate and rock armour revetment the revetment may be directly adjacent to the wall or separated with a gap depending on the local constraints

- Excavate a leader trench to a depth of approximately 1 metre below existing ground level along the centreline of the proposed structure (if required). Pre-auger where necessary, and drive sheet piling to the required toe depth. Driving may be achieved by either vibro-driving, impact-driving or hydraulic pressing.
- Cut openings in sheet piling as required to accommodate existing and proposed outfall pipework. Form box-outs prior to concreting works.
- Pour blinding concrete within trench.
- If concrete capping beam is required, fix steel reinforcement and formwork for in situ concrete pile cap. Pour concrete pile cap and cure. Strike formwork, setting aside materials for re-use, and dispose of waste arisings off-site.
- Excavate further as required and lay flood defence drainage, which may comprise filter pipes in a granular trench, gully pots, gratings, precast concrete or plastic manholes, carrier pipes, headwall structures and flap valves. Cap pipework until such time as it is fully connected.
- Backfill flood defence wall and drainage with structural backfill.
- The ground on the wet-side of the wall will be excavated to formation, a geotextile will be laid with sheets overlapping. Two layers of armour stone will be placed on top. The revetment toe

will need to be anchored into the existing ground with geotextile wrapped around the anchor stone and buried at least 1m below existing ground level.

- Armour stone will be placed from toe to top when above water, armour stones are placed starting at the base of the slope towards the top; when below water, the boulders are placed using clamshells onto the mud.
- Where armour stone is specified, the stone will be placed to ensure enough interlocking / points of contact occur as outlined in the specification. A minimum two layers of stone will be required.

6.8.3 Scour Protection Revetment (Section/Type C)

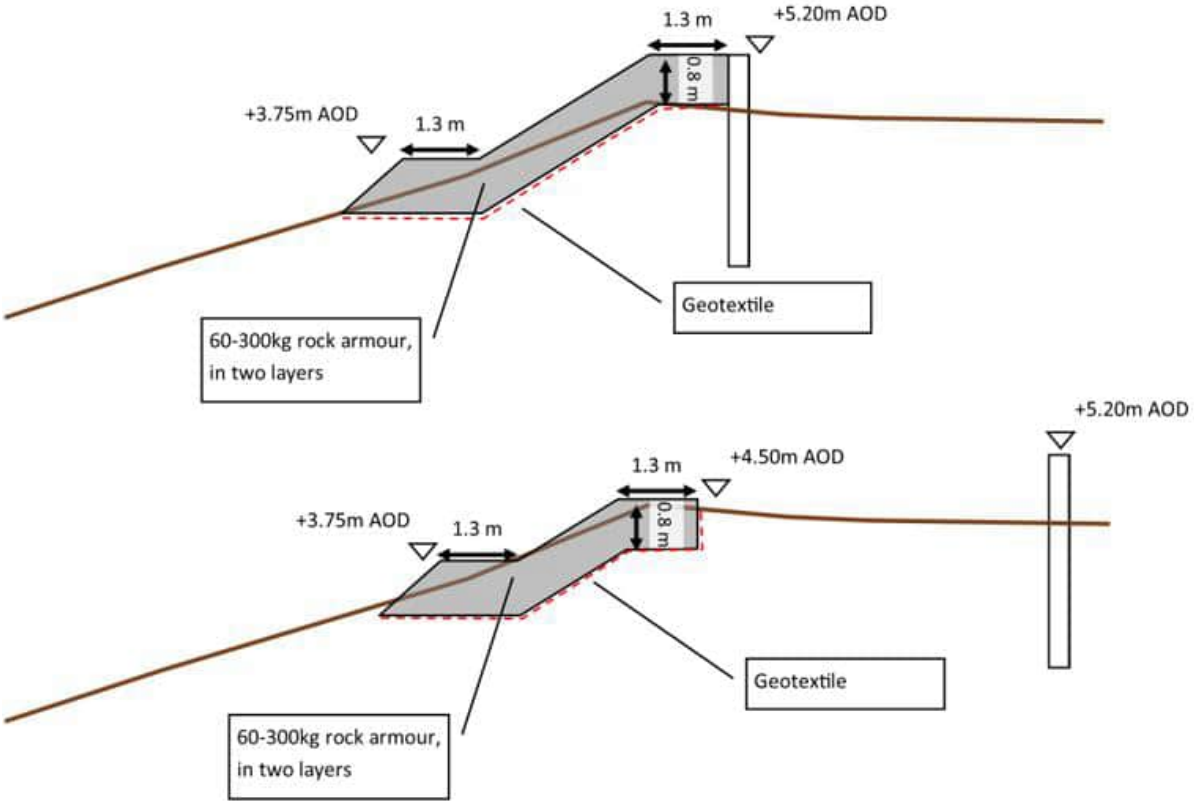


Figure 14: Typical cross-section bare steel sheet piled wall with scour protection – depending on local constraints the scour protection revetment may be directly adjacent to the piled wall or set back.

- Excavate a leader trench to a depth of approximately 1 metre below existing ground level along the centreline of the proposed structure (if required). Pre-auger where necessary, and drive sheet piling to the required toe depth. Driving may be achieved by either vibro-driving, impact-driving or hydraulic pressing.
- Cut openings in sheet piling as required to accommodate existing and proposed outfall pipework. Form box-outs prior to concreting works.
- Excavate further as required and lay flood defence drainage, which may comprise filter pipes in a granular trench, gully pots, gratings, precast concrete or plastic manholes, carrier pipes, headwall structures and flap valves. Cap pipework until such time as it is fully connected.
- Backfill flood defence wall and drainage with structural backfill.
- The ground on the wet side of the wall will be excavated to formation, a geotextile will be laid with sheets overlapping. Two layers of armour stone will be placed on top. The revetment toe

will need to be anchored into the existing ground with geotextile wrapped around the anchor stone and buried at least 1m below existing ground level.

- Armour stone will be placed from toe to top (when above water, rock armour boulders are placed starting at the base of the slope towards the top; when below water, the boulders are placed using clamshells onto the mud).
- Where armour stone is specified, the stone will be placed to ensure enough interlocking / points of contact occur as outlined in the specification. A minimum two layers of stone will be required.

6.9 Ground Improvements

Due to the extremely soft ground along the estuary frontage, improvement works to the existing ground are required to increase the strength (bearing capacity) of the ground. The flood wall will consist of a bored pile into the improved ground. The bored pile is likely to be concrete and extend no more than 4m below the existing ground level. The bored pile will have a concrete capping beam and a reinforce concrete wall stem or pre-cast concrete wall stem.

The following outlines the activities associated with carrying out the ground improvements:

- An additive (lime, cement, pulverised fly ash – PFA) will be added to the ground.
- The additive will be mixed into the ground to a depth of up to 4m below existing ground level.
- The additive will be pumped to a rotavator head and mixed into the existing ground using an excavator.
- The additive is not a free draining liquid and needs to be mixed into the ground.
- All work will take place at low tide and be submerged by the high tide.
- The improved ground will all be below the existing ground level.
- Ground improvement works will be undertaken before the piles are installed and the rock revetment is installed. The improved ground will form part of the temporary haul road along the estuary frontage.

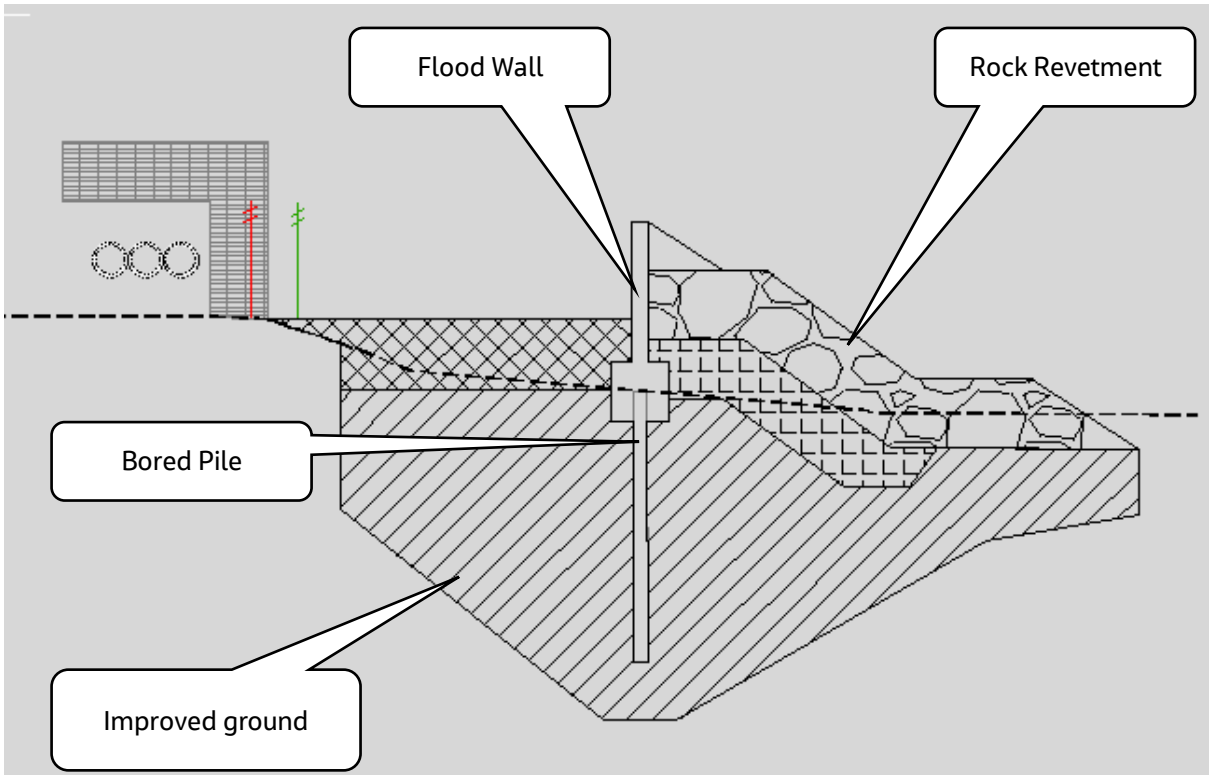


Figure 15: Typical x-section of the ground improvement work with flood wall and rock revetment

Appendix D has more detail on the method of construction for works along the estuary frontage.

6.10 New Culverts

- Set up mobile pump(s) and form temporary sump at upstream end of the proposed culverting works. Over-pump the working area, returning the flow of water to beyond the downstream extent of the works.
- Excavate existing channel to the required formation level, setting aside river cobbles for re-use if appropriate. Demolish or partly demolish existing riverbank structures as necessary to concrete the proposed culvert.
- Lay new culvert sections within the excavation, ensuring securing a good seal between lengths.
- Backfill around culvert with mass concrete or structural backfill, as specified.
- Pour blinding concrete for connections at upstream and downstream ends of culvert.
- Fix steel reinforcement and formwork for in situ concrete connection chambers. Pour concrete connection chambers and cure. Strike formwork, setting aside materials for re-use, and dispose of waste arisings off-site.
- Stop over-pumping and return flow of water to new connection chamber and culvert.
- Backfill crown of culvert with structural backfill, dress with topsoil and seed with an appropriate grass and wildflower mix.
- Where specified, fit manhole covers to connection chambers.
- Reinstate surrounding disturbed areas with topsoil and seed with an appropriate grass and wildflower mix.

6.11 Riverbank (fluvial) Erosion Protection

The maximum velocities for a 1 in 200-year event are estimated to be 4.2m^3/s for the fluvial dominated areas and 1.5m/s for the tidal dominated areas. Due to difficult access to areas where proposed flood defences are required to be constructed, some construction work equipment is likely to be required to be positioned within the river channel on temporary work platforms / areas. To access the construction zone for the flood defences, the existing bank vegetation and some trees will need to be removed to facilitate access for the construction works. Once the flood defences are constructed, riverbank erosion protection, or bank protection, will need to be installed on the riverbank. Various methods and materials could be used to provide bank protection and at this stage it is not known the exact method of bank protection. The proposed bank protection can be split into soft-engineered techniques; bio-engineered products such as a pre-seeded hessian mat that are anchored to the bank with wooden or metallic anchors, overtime the hessian mat breaks down and bio-degrades into the bank leaving a vegetated bank. The other option will be for a hard-engineered technique; rock gabions or reno mattresses could be installed with some planting in the gaps between rocks.

For the EIA Report, a soft engineered technique is assumed to be used for all the areas identified as requiring bank protection, unless stated otherwise on the plans.

- Prepare slope for geotextile separation layer and excavate anchor trench at top of slope.
- Starting at the downstream extent of the area requiring protection, unroll geotextile from top to bottom of slope, securing sufficient length inside the anchor trench with wooden / metallic stakes. Secure down the slope with further stakes in a pattern in accordance with the manufacturer's recommendations.
- Repeat the process, continuing in an upstream direction until the full stretch of riverbank is protected. Place adjacent lengths of geotextile, ensuring a minimum 500mm overlap, with each upstream length on top of the previous length.
- Anchor matting as required.

6.12 Bridge Modification

- Breakout / take down existing parapet walls and prepare surface for additional reinforcement to be attached. If required drill holes for metal dowels to be installed.
- Fix reinforcement / dowel bars with resin and prepare for concrete pour, erect formwork.
- Pour concrete and strike formwork.
- Where required, clad wall with stone; reinstate surrounding ground as required.

6.13 Bridge Replacement

- Divert existing services contained within or suspended from the bridge deck.
- Provide containment/protection below deck to prevent debris falling into watercourse.
- Remove existing bridge deck – breakout concrete deck and crane out girders.
- Breakout and remove existing concrete abutments.
- Construct new bridge abutments.
- Construct new bridge deck and incorporate services if required.
- Reinstate riverbank.

6.14 Flow Control Structures

A flow control structure is proposed on the upper section of the Grange Burn, to limit / control the downstream flow. The flow control structure will be an orifice with an overflow weir, discussions with SEPA are ongoing to assess what types of structure what be acceptable. Whatever structure is proposed, some construction work would be carried out within the channel, existing flows will be temporarily diverted / over pumped or the channel narrowed to allow a working area to be constructed. Once the water in the channel has been controlled, a dry working area will be created, the bed of the channel will be excavated, and blinding concrete will be poured. Steel reinforcement and formwork for the insitu bed and weir / control structure will be installed. Strike formwork and set aside material for re-use if the structure is cast in multiple stages. The bank and channel bed upstream and downstream will need to be reinstated, possibly reprofiled.

6.15 Flood Relief Channel Relining

The Flood Relief Channel is a concrete / bitumen lined channel that was constructed in the 1960's to divert flow from the Grange Burn during storm events. Minimal maintenance and remedial work have taken place since its construction. The Flood Protection Scheme proposes to utilise the channel and requires the channel to be relined. This could involve demolishing and rebuilding the channel or relining the channel with engineered pre-cast concrete sections or shotcrete.

For the EIA Report, shotcrete should be assumed to be used, with some degree of work required to fill-in voids.

- Break out existing channel when required.
- Fill voids and broken out areas with concrete.
- Install shotcrete as per manufacturer's instructions.

6.16 Demolished Structures

Where required some existing structures/building will need to be demolished. All services to be disconnected and made safe. A mechanical excavator will be used to remove the roof and walls. Where required dust suppression measures will be used.

6.17 Other Works to be Undertaken

6.17.1 Forth Ports - Lock/Flood Gates

The middle set of gates within the port entrance channel will be replaced with new bespoke flood gates. This will require the existing lock gates to be removed, civil works will need to be undertaken on the quayside and within the lock (possibly requiring a limpet dam, and underwater working). The level of detail at this stage of the project is limited, as a specialist contractor will undertake these works. For the purposes of this report, it is assumed all construction work will take place on Forth Ports land and not encroach into the SPA.

6.17.2 A9 (Beancross) Underpass

Closing off the A9 underpass during a flood event would require the underpass to be infilled with concrete. A new at-grade, traffic signal controlled crossing is to be provided on the A9 west of the underpass. Falkirk Council plan to install the basic infrastructure for the crossing (ducts, sockets for signals etc) as part of a planned upgrade of the A9/ Grandsable Road junction which will be carried out in advance of the FPS.

6.17.3 Flood Wall across the Western Lock

At present, no specific design or construction method has been identified for constructing a flood wall across the lock. Further analysis and exploratory works are required. For the EIA Report and HRA, an

assumed method of installing a coffer dam should be used, whereby a dry working area is created by installing piles at the end (estuary edge) of the lock. A piled wall would be installed within the dry working area with the top section of the wall protruding above the existing quayside.

6.18 Access for Construction/Working in the Channel

The project team have identified locations where temporary construction work is likely to take place within the channel on a cell-by-cell basis:

6.18.1 Cell 1 – Upper Carron

Cell 1 has been sub divided into the following Working Areas:

- Stirling Road,
- Carron Bridges/Beaumont Drive,
- Chapel Burn
- Dock Street

Stirling Road

Some working in the water course will be required, however this will be limited to a short section where a new head wall and flood wall is required. Construction access for the majority of flood defences will be from Stirling Road, which will require traffic management.

Carron Bridges/Beaumont Drive

Working in the river channel will be required to access river bank between Stenhouse Road and New Carron Road bridges, extending downstream to access sections adjacent to Beaumont Drive. In most cases a temporary access track/working platform will be required from the existing banks down to the channel. For the section between the Carron bridges it may be possible to create a temporary working platform on the north bank and not within the channel, this would be determined on site. Where possible construction work should take place from the bank.

A temporary road closure of the Stenhouse Road Bridge will be required along with some footpaths in the area. Access to the flood defences on the south bank, upstream of Stenhouse Bridge, would be taken from the existing footpath off Stenhouse Road. Access to the flood embankment at the rear of the properties on Park Road, will be taken from the roundabout on Cotland way, with a haul road created in the landscaped area to the rear of the properties.

A temporary working platform will be constructed within the river channel downstream of the New Carron Road bridge, retained using bulk sandbags and/ or sheet piles. This will provide construction access along the riverbank, directly to the rear of the properties along Beaumont Drive. The working platform would be accessed from the opposite riverbank via Bailey bridges (or similar).

Chapel Burn

Construction of a temporary working platform along the south bank of the Chapel burn would be the preferred option here to allow construction of a flood wall along the rear of the properties backing onto the Chapel Burn. Bulk sandbags would be installed to retain the working platform along the bank edge. Access from the opposite bank (car park area) would be provided by installing Bailey bridges or culvert crossing points along the length of the burn. Alternatively, temporarily culverting the burn from Carronshore Road, in 50-100m sections could be carried out to create a temporary working platform on top of the culvert. Near the mouth of the Chapel Burn the installation of a river working platform would be required to allow access for a temporary working platform to be created in the River Carron, directly upstream of the Chapel Burn. This would allow access to construct a flood wall along the alignment of the existing fence line and provide bank protection works. Flood defences on the

north bank of the Chapel Burn and River Carron would be constructed from the footpath between Carronshore Road and Rae Court, the footpath would need to be closed for the duration of the works.

Dock Street

Access from Dock Street to the working area, temporary ramped access to the channel at the end of Dock Street would be constructed.

6.18.2 Cell 2 – Lower Carron

Dry side working is mainly proposed for the construction of the new flood defences between the Helix Sea Lock on the Forth and Clyde canal to the Leisure Harbour/boat yard. Access can be gained to the upstream end of defences via Clyde Street, through the Scottish Water pumping station site. Downstream access can be gained via Jarvie Plant's premises, the scaffold storage yard, Roscco Properties premises and the Leisure Harbour/Forth Clyde boat repair yard off Grange Lane. A short section of in-water working is proposed at the rear of Rossco Properties and would require bulk bags to be used to create a platform for construction plant to sit on.

6.18.3 Cell 3 – Port of Grangemouth

Access to the channel would be taken from North Shore Road. Temporary access ramps would be constructed at appropriate locations to allow access to the channel if required. Most construction works would take place from the carriageway of North and South Shore Roads, with the toe of the revetment requiring some construction work in the channel. Some In-channel working will be required around the rear of the RLPG facility with construction of a temporary working platform into the Forth Estuary. Some construction work will be required in and around the Port Lock-Gates, with some temporary working areas created at the edge of the Forth Estuary. It is highly likely that construction plant will be able to be positioned on the bank and reach the toe of the revetment without needing to be positioned in the water or creating a temporary working platform with the water environment. The exception for this, is the work on the western lock, which is likely to require a floating barge to install piles at the edge of the lock to create a dry working area within the lock.

6.18.4 Cell 4 – Grange Burn

Cell 4 has been sub divided into the following Work Areas:

- Upstream of M9
- Flood Relief Channel (FRC) – Rannoch Park
- FRC – Inchyra / Whole-flats Road
- Millhall Burn
- Grange Burn (GB) – Zetland Park
- GB – Dalratho Road to Bo'ness Road
- GB – Grangeburn Road
- GB – Petroineos
- GB – Mouth of Grange Burn

Upstream of M9

Some temporary work within the channel will be required, temporary ramped access to the channel will need to be created. Where possible access for construction works will be taken from Grandsable

Road / A9, fields and public footpaths. Some traffic management will be required on Grandsable Road /A9. It should be noted that Falkirk Council plan upgrade works at Grandsable Road / A9 junction – details of the upgrade are still to be confirmed.

FRC – Rannoch Park

Ramped access to the Grange Burn (GB) and the Flood Relief Channel (FRC) will be required. Some construction work will be required in the channel for the construction of the flow control structure in the Grange Burn and lining the FRC. Managing flows within the Grange Burn and FRC will need to be considered during the construction works, this may involve over pumping or temporary diversion of flows.

FRC – Inchyra / Whole-flats Road

Ramped access to the FRC will be required to and from the surrounding banks. Most access for construction works will be from fields and roadside verges. Managing flows within the FRC, will be required when the channel is relined. Some access from Reddoch Road and Grange Road will be required.

Millhall Burn

Most construction work will require access from Smiddy Brae, Reddoch Road, Millhall Gardens and land parallel to the channel. Any in channel work will need to manage flows within the Millhall Burn.

GB – Zetland Park

Access to the right bank (looking downstream) will be from Zetland Park, this will require the temporary closure of some footpaths within Zetland Park. If access to the channel is required, ramped access from the bank will be taken. Access to the left bank will be from the B9132 (Abbots Road), this will require a partial road closure. The length of the partial road close of Abbots Road will be restricted to 250m and pedestrian access will always be maintained.

GB – Dalratho Road to Bo'ness Road

Access to the right bank (looking downstream), will be from Park Road, this will require a full closure of Park Road, to limit the disruption to the communities in Grangemouth, the maximum length of the road closure (Abbots Road and Park Road) will be 250m. If access to the channel is required, temporary ramped access from Park Road will be created. Access to the left bank, will be from the B9132 (Abbots Road), a partial road closure of the B9132 will be required. Temporary bridges / access points from the right bank will be required across the channel. If this is not possible, a full closure of the B9132 will be required, this may require enabling works on the surrounding roads to maintain access to the town center of Grangemouth. If access to the channel is required, temporary ramped access from the B9132 will be required.

GB – Grangeburn Road

Access to the right bank (looking downstream) will be from Grangeburn Road, which will require a full road closure. To minimize the impact on communities in Grangemouth, the road closure will be limited in length to a maximum of 250m of Grangeburn Road. If access to the channel is required, temporary ramped access from Grangeburn Road will be required. Access to the left bank will be from South Shore Road, which will require a full road closure from Bo'ness Road to the roundabout. To minimize the impact on communities in Grangemouth, the road closure will be limited in length to a maximum of 250m. If access to the channel is required, temporary ramped access from South Shore Road will be required.

GB – Petroineos / Mouth of GB

Access to the right bank (looking downstream) will be taken from within Petroineos's site, due to the limited space and steep bank, access from the bank to the channel may be difficult, if work is required in the channel, a temporary working platform will be created with machinery / materials craned down

to the platform. Access to the mouth of the Grange Burn, will require construction plant and materials to take access through Petroineos's site, via the site entrance off Powdrake Road, the exact route through Petroineos's site is to be confirmed with Petroineos . If access to the channel is required, downstream of the railway line, a temporary ramp and working platform in the channel will be constructed.

6.18.5 Cell 5 – River Avon

Access for construction works will be taken from either the A905 or A904. Where flood defences are constructed in this cell, a permanent access track is proposed, which will be contained within the temporary construction zone.

Access from the A905, will provide access to construct flood defences on both banks from the A905 Road Bridge. Access from within INEOS's site will be needed, exact access routes will be confirmed. Where bank protection works are required, construction work will take place from the existing bank, some temporary construction platforms may be required along sections of the River Avon, ramped access from the bank will be taken. Flood defences upstream of the A905 Road Bridge will be access from the A905 and Avondale Road, no working in the channel is required here.

For flood defences on the banks near the A904 Road Bridge, access will be taken from the A904 and within INOES's, INEOS FPS's and Versalis sites, temporary construction access points will be required off the A904. Access from the A904, will also be used as an access route for construction of flood defences in parts of Cell 6, significant amounts of construction materials would need to be brought into Cell 6 via this access point.

6.18.6 Cell 6 – Estuary Frontage

Access for construction work would be taken from the east and west extents of the cell. Where flood defences are constructed in this cell, a permanent access track is proposed, which will form part of the temporary construction zone. The western and eastern extents refer to extents from the mouth of the River Avon.

West Extents

Temporary construction access from within Petroineos's site to cross the railway line and construct an access track outside Petroineos's fence line, along the estuary frontage.

A permanent access track will be constructed at the rear of the proposed flood defences on the west bank of the River Avon from the A904. The temporary construction zone will include the footprint of the permanent access track and flood defence. Land reclamation will be required for some of the permanent access track along the estuary frontage. Where land reclamation takes place, temporary working platforms / areas may be required, the height of these temporary working platforms will need to be determined at the detailed design stage to ensure the height of platform is above the mean high tide level to allow construction work to take place during the daily tidal cycles. See Appendix D which details the construction methodology along the estuary frontage.

East Extents

Access from the A904, along the track to Scottish Water's Kinneil Waste Water Treatment Plant will be taken. Temporary access across twin above ground pipelines is required, this may require a temporary bridge to be constructed, ramped access over the pipelines. A temporary ramp into the channel for constructing flood defences on the east bank of the River Avon, downstream from the A904 Road Bridge will be required.

7. Project Mapper

Table 2 outlines the layers and a brief description that have been created in ProjectMapper (a web-based interactive mapping tool). The layers have been developed to assist the EIA Team in producing the EIA Report.

ProjectMapper Layer	Description
Access Tracks	Identifies where new permanent access tracks are proposed
Alignment Operation schedule - point	Identifies the scheme operations - points only
Alignment Operation schedule	Identifies the scheme operations
Blocked Underpass	Identifies the location of the underpass that will be permanently blocked off
Cell Boundary	Identifies the Flood Cell Boundaries
Coastal Revetment (line)	Identifies the location of the proposed coastal revetment structures – there are three types of the coastal revetment, the types are identified as an attribute in PM with the types explained in the Construction Methodology Report
Trees to be retained	Identifies trees to be retained
Trees to be removed	Identifies trees to be removed
Coastal Revetment_PG	Identifies the location and area of the coastal revetment structure
Demountable Flood Defences	Shows the location of demountable flood defences
Direct Defences Sections Only	Measure each defence section for the finishes
Demolished Buildings	Identifies buildings which are to be demolished as part of the scheme
Direct Defences Finishes	Identifies the proposed finish to the flood defences
Flow Control	Identifies the location of the proposed flow control structure on the Grange Burn
Flood Defence Oct 23	Identifies the flood defences for October 2023
Flood Defence ALL Nov 23	Identifies the proposed flood defences for November 2023
Flood Defence Levels 2023	Identifies the flood defence levels for Oct 23 and Nov 23
Flood Gates	Identifies where new flood gates are located
Flood Gate_PL	Flood gates as Polyline
Ground Improvement Cell 6	Identifies the area where soil/ground improvement works are required
Haul Road Compensatory Site	Haul road to the compensatory site only
Haul Roads	Identifies the location of the proposed temporary Haul Roads
HRA Compensatory Sites	Identifies the location of the two proposed Compensatory sites, which have been developed through the HRA
In-water Working	Identifies the locations where construction work is proposed within the channel
New Bridges	Identifies where new bridges are proposed
New Proposed Buildings	Identifies areas where new buildings will be built to replace demolished buildings
New Culvert	Identifies the location of any new culverts/extension to existing culverts
New Footway	Identifies the location of any new footways, includes raising of existing footways

ProjectMapper Layer	Description
New Lock Gates	Identifies the location of the port lock gate to be replaced with new hybrid lock/flood gate
Notification Boundary	Identifies the scheme notification area, which is part of the statutory process for notifying the scheme under the FRMA
Permanent Works Footprint	Identifies the permanent footprint of the proposed flood defences
Permanent Works Footprint Cell 3 & 6 only	Identifies the permanent footprint of the proposed flood defences in Cells 3 & 6 only
Pile Depths Below Ground	Identifies the depth of piles below existing ground, in increments of 5m.
Raised Bridges	Identifies existing bridge structures which need to be raised in elevation
Ramps	Identifies the location of new ramp structures which have been proposed over the flood defences
Ramp_PL	Identifies the location of new ramp structure - provides the spatial extents of the ramps
Re-Lining Flood Relief Channel	Identifies the proposed re-lining work on the flood relief channel
Seepage Only Flood Defences	Identifies the location of seepage only flood defences – this will involve installing piles in the existing ground without changing the ground levels
Site Boundary	Identifies the area needed to construct the flood defences, this is the area where the contractor will be working
Site Boundary Compensatory Site	Identifies the site boundary for the compensatory sites only
Site Compounds	Identifies the proposed site compounds and haul road locations outwith the Site Boundary
Soil Improved Ground	Identifies the proposed area where soil/ground improvement works are proposed along the estuary frontage. The layer shows the approx. location and not the exact area.
Site Notices	Identifies where the scheme notice will be advertised
Trees	Identifies where trees/vegetation are to be removed or retained
Zetland Park Kiosk	Identifies the proposed location of the new Kiosk in Zetland Park
Vegetation	Identifies where trees/vegetation are to be removed or retained
EIA Working Areas	Working areas defined in the EIA Report

Table 2: ProjectMapper Layers

8. Impact of Construction Sequence and Timing

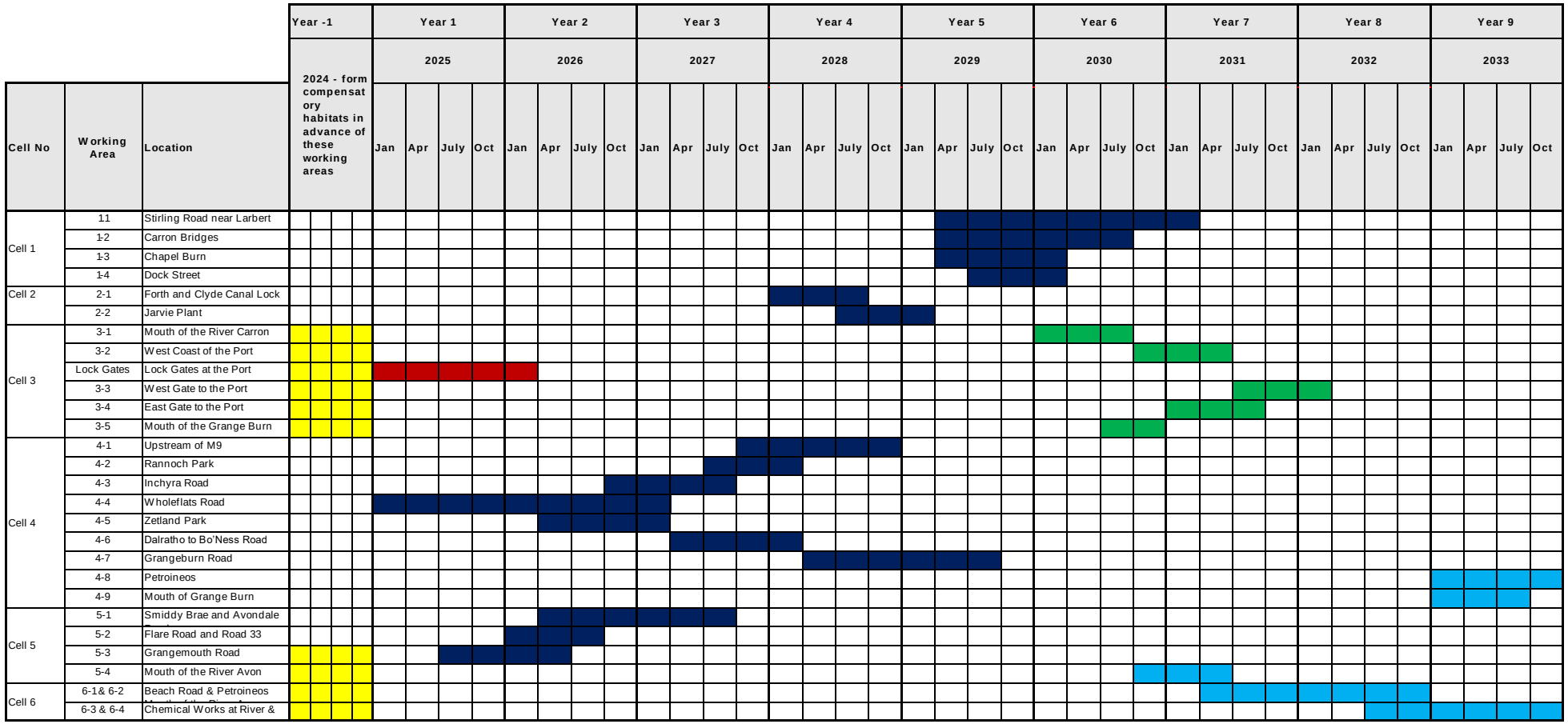
The project is complex in its nature, incorporating aspects of construction, logistics, river management, traffic management, and public interface. The work is spread over a large spatial area, across Grangemouth and the surrounding area. The contractor will be responsible for determining the programme and construction sequence of the works in accordance with their contractual and regulatory obligations. There are innumerable possible combinations for this, therefore it is not possible to determine with any certainty the construction sequence prior to a contractor being appointed.

8.1 Sequence/Phasing

Due to the scope / extent of the proposed flood defences (~28km in total), it is very unlikely that a single construction contract will be let for all the scheme works. It is more realistic to assume the construction works will be divided into 4 phases, with each phase potentially involving more than one construction contract. At this stage, the exact construction phasing plan cannot be confirmed, but it is likely that construction work will take place in a range of flood cells within each construction phase as noted in the table below.

Phase no.	Cell no.
1 (Mainly Residential Properties)	1 & 2, 4 (part) & 5 (part)
2 (Port Lock Gates)	3
3 (Port Flood Defences)	3
4 (Industrial areas)	Cell 4 (part), 5 (Part) & 6

Although the sequencing and timing of construction works is not confirmed at this stage, it is envisaged that the construction phase of the scheme works will last for 10 years, depending on how the construction contracts overlap. The sequencing of construction works is likely to mean that only two phases can be undertaken at the same time. The gantt chart below indicates the current anticipated construction phasing plan which has been used for the EIA. The compensatory habitats referred to in Figure 16 are those identified in the Habitats Regulations Appraisal report.



Colour coded by proposed phasing: Phase 1 (dark blue), Phase 2 (Red), Phase 3 (Green), Phase 4 (light blue)

Figure 16: Estimated phasing of construction work

8.2 Timing

Table 3 gives an indication of the overall construction durations in each working area. Assets such as flood gates and demountable barriers are included in the estimated overall length but not in the anticipated finish column:

Cell no.	Working Areas	Location	Estimated overall length of flood defences in m	Anticipated Form of Construction	Duration of Construction	Anticipated Finish – in m
1	1-1	Stirling Road	1611	Formed Concrete Wall, Brick Clad Wall, Seepage Only, Embankment	24 months	Formed Concrete – 303 Brick Clad – 1177 Embankment - 44
	1-2	Carron Bridges	1045	Brick Clad Wall, Stone Clad Wall, Stone Clad Wall with Glass Panels, Formed Concrete Wall, Embankment, Replacement Bridge (B902)	18 months	Stone Clad – 211 Stone Clad with glass panels - 110 Earth Embankment - 400 Brick Clad- 217 Formed Concrete Wall – 16 New bridge - parapet 36
	1-3	Chapel Burn	685	Brick Clad Wall, Stone Clad Wall	12 months	Brick Clad – 662 Stone Clad - 24
	1-4	Dock Street	557	Formed Concrete Wall	9 months	Formed Concrete – 529 Local ground raising – 9
2	2-1	Forth and Clyde Canal Lock	662	Embankment & Sheet Pile Wall	9 months	Bare Sheet Pile – 348 Earth Embankment - 305
	2-2	Jarvie Plant/Rossco Properties	840	Sheet Pile Wall	9 months	Bare Sheet Pile – 840
3	3-1	Mouth of the River Carron	920	Sheet Pile Wall & revetment	9 months	Bare Sheet Pile - 920
	3-2	West Coast of the Port	965	Sheet Pile Wall & revetment	9 months	Bare Sheet Pile - 965
	3-3	West Gate to the Port	1167	Sheet Pile Wall & revetment	9 months	Bare Sheet Pile - 1167
	3-4	East Gate to the Port	992	Sheet Pile Wall, Plain Concrete	9 months	Bare Sheet Pile – 751

Cell no.	Working Areas	Location	Estimated overall length of flood defences in m	Anticipated Form of Construction	Duration of Construction	Anticipated Finish – in m
				Wall, Formed Concrete Wall		Plain Concrete – 135 Formed Concrete – 2
	3-5	Mouth of the Grange Burn	683	Sheet Pile Wall	6 months	Bare Sheet Pile – 683
4	4-1	Upstream of M9	1078	Stone Clad Wall, Formed Concrete Wall	15 months	Formed Concrete – 972 Stone Clad - 83
	4-2	FRC – Rannoch Park	559	Formed Concrete Wall	9 months	Formed Concrete - 559
	4-3	FRC – Inchyra Road	505	Formed Concrete Wall & Embankment	12 months	Formed Concrete – 387 Earth Embankment 118
	4-4	FRC – Whole-flats Road	2359	Formed Concrete Wall, Stone clad Wall, Sheet Pile Wall, Raising footway, Embankment, Regrading Existing Embankment, New Bridges	27 months	Local ground Raising – 105 Stone Clad – 689 Bare Sheet Pile - 899 Formed Concrete – 622 Earth Embankment – 25 New bridge Parapet - 11
	4-5	GB – Zetland Park	767	Stone Clad Wall & Embankment, Replacement Bridge (Dalratho)	12 months	Stone Clad – 667 Embankment – 177
	4-6	GB – Dalgrain to Bo'Ness Road	804	Sheet Pile Wall	12 months	Stone Clad – 763 New bridge parapet - 37
	4-7	GB – Grangeburn Road	1250	Sheet Pile Wall, Stone Clad Wall, Formed Concrete Wall	18 months	Bare Sheet Pile - 595 Stone Clad – 644 Formed Concrete Wall – 11
	4-8	GB – Petroineos	1051	Sheet Pile Wall, Stone Clad Wall	12 months	Bare Sheet Pile – 842 Stone Clad - 131
	4-9	GB – Mouth of Grange Burn	1142	Sheet Pile Wall, Seepage Only	9 months	Bare Sheet Pile – 1142

Cell no.	Working Areas	Location	Estimated overall length of flood defences in m	Anticipated Form of Construction	Duration of Construction	Anticipated Finish – in m
5	5-1	Smiddy Brae & Avondale Road	1786	Sheet Pile Wall, Formed Concrete Wall	18 months	Bare Sheet Pile – 923 Formed Concrete - 841
	5-2	Flare Road & Road 33	1102	Sheet Pile Wall, Seepage Only	9 months	Bare Sheet Pile – 1102
	5-3	Grangemouth Road	1675	Sheet Pile Wall	12 months	Bare Sheet Pile – 1675
	5-4	Mouth of the River Avon	438	Sheet Pile Wall, revetment	9 months	Bare Sheet Pile – 438
6	6-1 & 6-2	West of River Avon (Beach Road & Mouth of River Avon)	2166	Sheet Pile Wall, Bored Pile Wall with revetment	21 months	Bare Sheet Pile - 1215 Bored Pile– 941
	6-3 & 6 -4	East of River Avon (Chemical Works at River Avon & Chemical Works)	1422	Sheet Pile Wall &Embankment	18 months	Bare Sheet Pile Combined with Earth embankment – 692 Bare Sheet Pile - 730

Table 3 Construction duration estimates for work areas

The durations for the work areas outline above in Table 3 are estimates of duration and may change subject to further design development.

It is important to note the engineering team do not envisage construction works taking more than 12 months in duration at a single location within a Cell or Working Area. For the purpose of the EIAR and HRA the assessment is to be based on:

Flood Defences	Weeks taken to construct approx. 100m
Wall – sheet piled foundation with reinforced concrete stem and clad	8
Wall – sheet piled foundation with reinforced concrete stem and formed finish	7
Embankment – Granular fill and seepage barrier	8
Bare sheet pile wall	5
Soil Mixed ground with bored pile, concrete wall and rock armour revetment	16

It is likely that flood walls will be constructed in sections of 10-15m lengths, it is highly unusual to finish a 10-15m section of wall before moving onto the next section. Work is usually carried out over a number of wall sections simultaneously, particularly for the clad walls.

8.3 Transport Planning

8.3.1 HGV Movements

The number of HGV movements has been assessed considering the main construction activities at each working area (e.g. mobilisation/ demobilisation, piling, concrete, reinforcement, formwork, earthworks, temporary surfaces, rock armour, cladding and drainage). The average number of vehicles per day was calculated by taking the total number of vehicles and dividing by the duration. In order to reflect that for different forms of flood defence construction there may be multiple activities being carried out in parallel (e.g. a clad flood defence may have piling, concrete and cladding all progressing at the same time), a multiplier was applied depending on the principal type of defence construction in each working area. There were 1.5 for bare sheet piles, 2 for formed concrete and 3 for clad flood defences.

The estimated HGV numbers are noted in the table below. These represent one-way movements i.e. HGV's travelling to site. The total two-way movements of vehicles travelling to site and then leaving will be double these numbers.

Cell No	Working Area	Duration (weeks)	Average Vehicles per day	Peak vehicles per day
Cell 1	1.1	108	4	8
Cell 1	1-2	81	5	15
Cell 1	1-3	54	4	12
Cell 1	1-4	41	4	8
Cell 2	2-1	41	5	10
Cell 2	2-2	41	5	8
Cell 3	3-1	41	5	8
Cell 3	3-2	41	5	8
Cell 3	Lock Gates	68	5	10
Cell 3	3-3	41	6	9
Cell 3	3-4	41	5	8
Cell 3	3-5	27	6	9
Cell 4	4-1	68	4	8
Cell 4	4-2	41	4	8
Cell 4	4-3	54	5	10
Cell 4	4-4	122	5	15
Cell 4	4-5	54	4	12
Cell 4	4-6	54	4	12
Cell 4	4-7	81	4	12
Cell 4	4-8	54	5	8
Cell 4	4-9	41	6	9
Cell 5	5-1	81	5	15
Cell 5	5-2	41	6	9
Cell 5	5-3	54	7	11

Cell No	Working Area	Duration (weeks)	Average Vehicles per day	Peak vehicles per day
Cell 5	5-4	41	6	9
Cell 6	6-1 & 6-2	95	9	14
Cell 6	6-3 & 6-4	81	8	12

8.3.2 Car Movements

The number of private car movements has been assessed on the basis of an estimate of the workforce and assuming 1.5 persons per car to reflect there will be some car sharing and/ or crew buses used to transport people to and from the site.

Cell No	Working Area	Duration (weeks)	Average Cars per day (summer)	Average Cars per day (winter)
Cell 1	1.1	108	22	13
Cell 1	1-2	81	17	9
Cell 1	1-3	54	13	7
Cell 1	1-4	41	8	4
Cell 2	2-1	41	5	3
Cell 2	2-2	41	6	4
Cell 3	3-1	41	7	5
Cell 3	3-2	41	7	5
Cell 3	Lock Gates	68	10	8
Cell 3	3-3	41	8	6
Cell 3	3-4	41	7	5
Cell 3	3-5	27	5	4
Cell 4	4-1	68	16	7
Cell 4	4-2	41	8	4
Cell 4	4-3	54	12	6
Cell 4	4-4	122	35	20
Cell 4	4-5	54	14	7
Cell 4	4-6	54	15	8
Cell 4	4-7	81	17	9
Cell 4	4-8	54	14	7
Cell 4	4-9	41	8	6
Cell 5	5-1	81	19	11
Cell 5	5-2	41	8	5
Cell 5	5-3	54	12	8
Cell 5	5-4	41	3	2
Cell 6	6-1 & 6-2	95	15	10
Cell 6	6-3 & 6-4	81	10	7

8.4 Contract Constraints

Notwithstanding this, contract conditions can be imposed on the contractor to constrain how they are permitted to sequence the work. These constraints should be used with caution however, as overuse of contractual constraints can increase the duration, cost, and complexity of the works and even cause certain operations to become impossible to construct. Taking this into consideration, the following combinations and sequences of work may be discounted due to contractual constraints which are likely be placed on the contractor:

- Where work areas on directly opposite riverbanks are both to be constructed from working areas in the watercourse, these may be prohibited from occurring at the same time due to the excessive constriction which would be imposed on the watercourse.
- Where a work area will require traffic management (such as diversions, and one-way traffic under traffic light control), and where another work section affects a likely alternative route, these two work sections may be prohibited from occurring at the same time.
- Where a work area will require traffic management to a long length of road, the contractor may be restricted to the length of working area which can be closed to the public at any one time, thereby limiting the extent of the traffic management.
- Haul roads in the watercourse can have an impact on the flow of water, a limit may be imposed on the total length of such haul roads that is permitted to be in place at any one time.
- Specific construction activities which produce considerable noise, and which are in proximity to schools, are likely to be restricted during major examination periods.
- Work which disturbs the riverbed, such as construction or removal of cofferdams or raised platforms, is likely to be restricted during salmon spawning season.
- Prior to felling trees during bird nesting season, supplementary surveys for breeding birds may be required to comply with relevant legislation.
- Where bridges are closed because of the works, adjacent bridges must remain open to pedestrians at all times.
- Depending on the outcome of discussions with SEPA, Marine Scotland and NatureScot, some constraints may be placed on certain activities, and this will be discussed further in the EIA Report.
- Some construction work will take place on private land, and the contractor will be required to comply with site rules.
- Depending on the outcome of the HRA, a restriction of working out-with the over wintering bird season may be applicable for Cells 3, 5 and 6.

8.5 Temporary Flood Protection

The sequence of construction may have the effect of temporarily lowering the standard of protection at locations where flood defences have yet to be constructed. Where a flood defence is constructed on one riverbank, it may direct more flow to the opposite riverbank where defences have yet to be constructed, lowering the standard of protection there until both sides are complete. Likewise, defences completed on both sides may channel flow further downstream, lowering the standard of protection there until their defences are completed.

Temporary changes to the standard of protection are an inevitable consequence of constructing large flood protection schemes, since all defences cannot all be constructed simultaneously. The risk may be mitigated by providing temporary flood defences at locations where the permanent works have not yet been completed or leaving out small sections of otherwise complete sections of flood defences. The

level of such protection could be selected such that the same standard of protection is maintained as existed before the project began. Establishing this level would require hydraulic modelling to be carried out by the Employer, based on a construction sequence provided by the contractor.

Provision of temporary defences could be incorporated in the main works contract. This could require the contractor to deploy temporary defences over specified stretches based on the contractor's construction sequence, or simply to maintain ready supplies of materials which could be easily and effectively deployed in the event of a flood alert.

9. Reinstatement

9.1 Residential Gardens

The required standard of reinstatement for residential gardens is a subjective matter to each landowner and will be discussed at a later date with each affected landowner.

9.2 Amenity Areas

Public amenity areas such as parks, playgrounds and grass verges will be reinstated by the contractor. A similar form of landscaping could be provided, or alternatives developed in consultation with the relevant authorities within Falkirk Council. This will form part of the detailed design phase of the project.

9.3 Roads and Footpaths

Where roads are open to both the public and the contractor, experience indicates that it is difficult to attribute deterioration to construction traffic and thereby require the contractor to carry out repairs at their expense. This is particularly the case where roads are used by buses and HGVs.

One option is to prescribe within the contract which roads are expected to require reinstatement and to what standard. Where reinstatement is not necessary, this activity could later be removed from the contract, although experience indicates that the true cost may not be fully recovered by doing this.

A second option is to remove road reinstatement from the main works contract and make provision for it to be carried out separately by Falkirk Council. This would ensure that cost is only incurred where reinstatement is necessary and is likely to be a more cost-effective option as the extra fees associated with NEC compensation events would not be incurred.

Where roads are within the site boundary and excavation by the contractor is required, it is more straightforward to include reinstatement of these surfaces under the contract. Likewise, where damage or deterioration is clearly due to the contractor (such as track marks or concrete spills) reinstatement of these areas can more easily be included in the contract. A comprehensive dilapidation survey in advance of the contractor taking possession of the relevant Working Area is essential.

9.4 Existing Structures

As described in Section 6.1 , many of the work sections are near existing structures, and the risk of damage should be considered carefully. The NEC Engineering and Construction Contract Clause 80.1 states that the following is an Employer's risk:

> "Claims, proceedings, compensation and costs payable which are due to use or occupation of the Site by the *works* or for the purpose of the *works* which is the unavoidable result of the *works*."

Damage caused by the Contractor providing the works is therefore only a Contractor's risk if it is deemed to be avoidable. Experience indicates that, particularly in the case of old structures, this can be difficult to resolve after the fact.

It is therefore recommended that provision be made within the contract such that the Contractor is required to declare that their method of working has been selected such that no damage or deterioration shall occur to any building, structure, property, or the natural environment as an unavoidable result of the works. Failure to make this declaration would give the Employer cause to reject the Contractor's method statement.

Notwithstanding the above provision, it is also recommended that allowance be made within the monetised risk register for claims, proceedings, compensation, and costs payable due to damage of this nature.

10. Recommendations

This report is reviewed by members of the project team at key stages of the outline design, to ensure any changes to the design are reflected in this report.

Regular dialogue with the EIA coordinators is undertaken during development of the EIA and HRA.

Appendix A. Cell Layout Plan

APPENDIX A

Legend

Flood Cells

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P01.1	MAR 24	Initial Issue	TM	RM	DM	AMc

Jacobs

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Tel: +44(0)141 243 8000
www.jacobs.com

Client

FALKIRK COUNCIL
The Foundry, 4 Central Park,
Central Boulevard, Larbert, FK5 4RU

grangemouthfps@falkirk.gov.uk

Project

Grangemouth
Flood Protection Scheme

Drawing Title

FLOOD CELLS

SHEET: 1 OF 1

Drawing Status	S8-SUITABLE FOR STATUTORY CONSENT	
Scale @ A3	1:40,000	DO NOT SCALE
Jacobs No.	B2386100	
Client No.		
Drawing No.	Appendix A	

0 0.5 1 1.5 2 2.5 km

Appendix B: Layout Plans of Work Areas

APPENDIX B - CELL 1

Legend

Cell 1 Working Areas

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P01.1	MAR 24	Initial Issue	TM	RM	DM	AMc

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Project

Grangemouth
Flood Protection Scheme

Drawing Title

WORKING AREAS
CELL 1

SHEET: 1 OF 6

Drawing Status	S8-SUITABLE FOR STATUTORY CONSENT	
Scale @ A3	1:18,000	DO NOT SCALE
Jacobs No.	B2386100	
Client No.		
Drawing No.	Appendix B	Cell 1

APPENDIX B - CELL 2

Legend

Cell 2 Working Areas

P01.1	MAR 24	Initial Issue	TM	RM	DM	AMc
Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd

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Project

Grangemouth
Flood Protection Scheme

Drawing Title

WORKING AREAS
CELL 2

SHEET: 2 OF 6

Drawing Status	S8-SUITABLE FOR STATUTORY CONSENT	
Scale @ A3	1:8,000	DO NOT SCALE
Jacobs No.	B2386100	
Client No.		
Drawing No.	Appendix B	Cell 2

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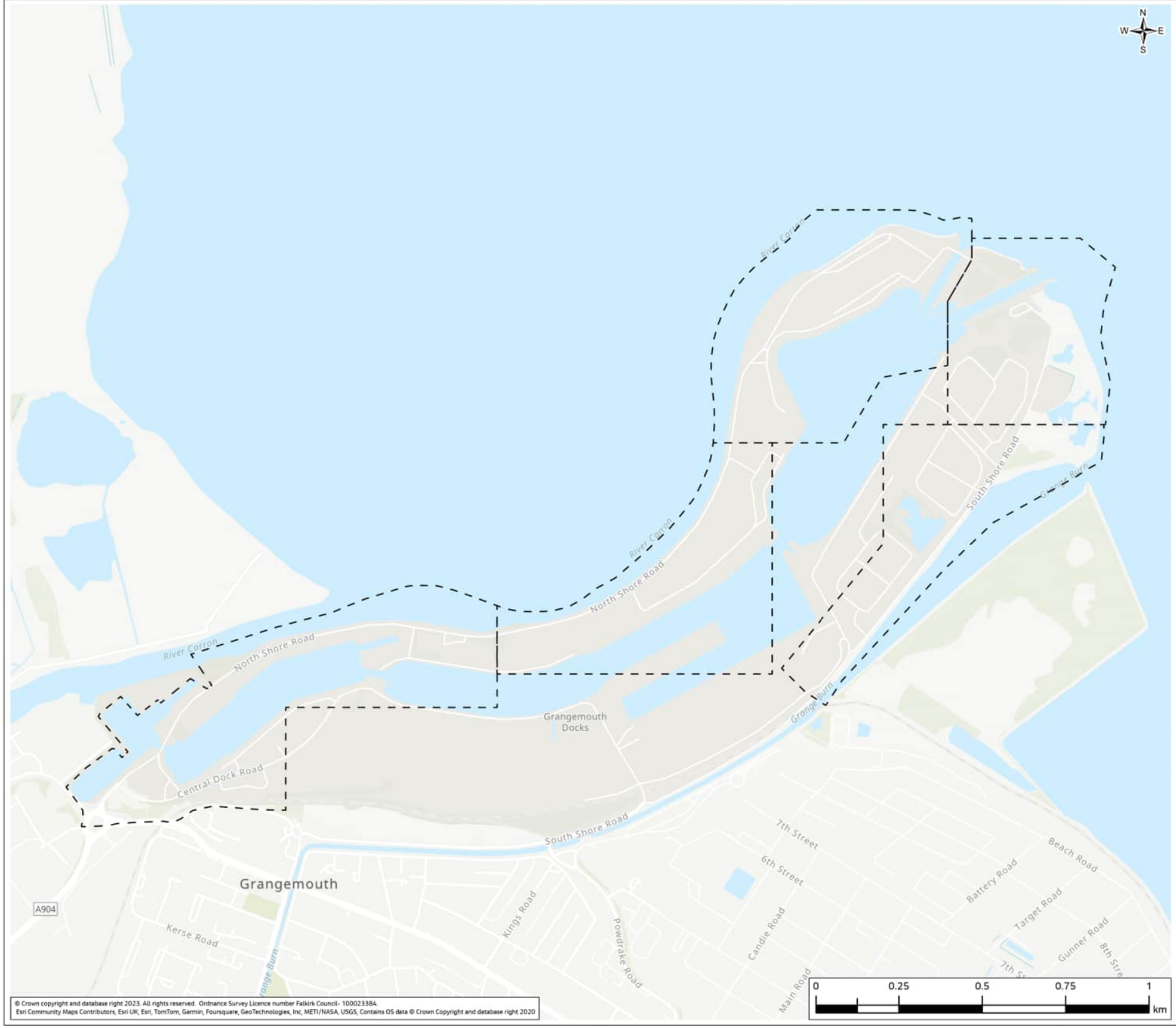

APPENDIX B - CELL 3

Legend

Cell 3 Working Areas

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P01.1	MAR 24	Initial Issue	TM	RM	DM	AMc

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Project

Grangemouth
Flood Protection Scheme

Drawing Title

WORKING AREAS
CELL 3

SHEET: 3 OF 6

Drawing Status	S8-SUITABLE FOR STATUTORY CONSENT	
Scale @ A3	1:11,000	DO NOT SCALE
Jacobs No.	B2386100	
Client No.		
Drawing No.	Appendix B Cell 3	

APPENDIX B - CELL 4

Legend

- Cell 4 Working Areas

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P01.1	MAR 24	Initial Issue	TM	RM	DM	AMc

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grangemouthfps@falkirk.gov.uk

Project

Grangemouth
Flood Protection Scheme

Drawing Title

WORKING AREAS
CELL 4

SHEET: 4 OF 6

Drawing Status	S8-SUITABLE FOR STATUTORY CONSENT	
Scale @ A3	1:15,000	DO NOT SCALE
Jacobs No.	B2386100	
Client No.		
Drawing No.	Appendix B	Cell 4

APPENDIX B - CELL 5

Legend

Cell 5 Working Areas

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P01.1	MAR 24	Initial Issue	TM	RM	DM	AMc

Jacobs

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Tel: +44(0)141 243 8000
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Project

Grangemouth
Flood Protection Scheme

Drawing Title

WORKING AREAS
CELL 5

SHEET: 5 OF 6

Drawing Status	S8-SUITABLE FOR STATUTORY CONSENT	
Scale @ A3	1:8,000	DO NOT SCALE
Jacobs No.	B2386100	
Client No.		
Drawing No.	Appendix B	Cell 5

0 0.25 0.5 0.75 1 km

APPENDIX B - CELL 6

Legend

Cell 6 Working Areas

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P01.1	MAR 24	Initial Issue	TM	RM	DM	AMc

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Grangemouth
Flood Protection Scheme

Drawing Title

WORKING AREAS
CELL 6

SHEET: 6 OF 6

Drawing Status	S8-SUITABLE FOR STATUTORY CONSENT	
Scale @ A3	1:11,000	DO NOT SCALE
Jacobs No.	B2386100	
Client No.		
Drawing No.	Appendix B	Cell 6

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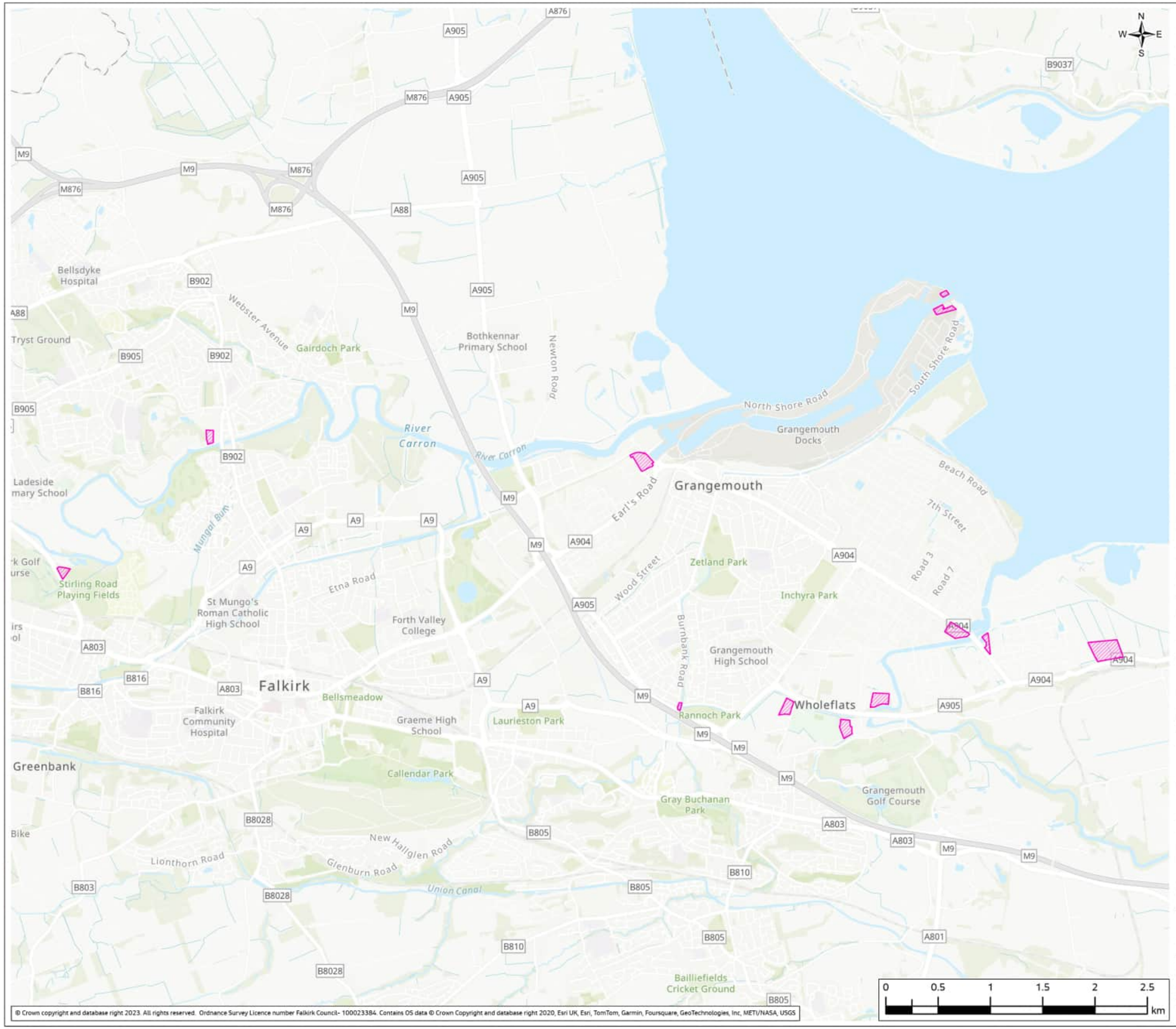
Appendix C: Site Compounds



APPENDIX C

Legend

- Site Compounds

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
P01.1	MAR 24	Initial Issue	TM	RM	DM	AMc

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Project

Grangemouth
Flood Protection Scheme

Drawing Title

SITE COMPOUNDS

SHEET: 1 OF 1

Drawing Status	S8-SUITABLE FOR STATUTORY CONSENT	
Scale @ A3	1:35,000	DO NOT SCALE
Jacobs No.	B2386100	
Client No.		
Drawing No.	Appendix C	

Appendix D: Construction Method along the estuary frontage

Appendix D: Construction Method along the Estuary Frontage

1 Introduction

This appendix is an interim document that has preliminarily been prepared for the Construction Methodology Report and to inform the EIA and Habitats Regulations Appraisal (HRA) Report to outline how the design team envisage the proposed flood defences will be constructed. At the detailed design phase and when applications are made for the relevant consents, more detailed information will be provided, such as contractors method statements and programmes.

2 Background

Due to the very poor ground conditions (low strength) along the estuary frontage a solution was required, to allow the flood defences (wall) to be constructed along the estuary frontage. Due to multiple oil/gas pipelines and the petro-chemical plant, the position of the flood defences is at the edge of the Firth of Forth estuary, within the estuary mud. Significant improvements are required allow both construction equipment to access the area (without sinking) and to support the proposed flood defences

The project team assessed a variety of options with the two options most likely to provide a viable solution being:

- Geogrid/textiles with granular stone (fill) installing layers on top of geogrids/textiles.
- Soil mixing – mixing a binder material (e.g. cement or PFA/ GGBFS) into the mud.

Geogrid/textile – this option was assessed, discussed with several geogrid manufacturers and deemed to be unsuitable primarily due to the significant volume of stone that would be required and the very large settlement that was predicted requiring frequent monitoring and topping up (importing new stone) of material to maintain a suitable working platform. Additionally, if the revetment was positioned on the geogrid and stone, additional settlement would occur, requiring additional armour stone to be brought to site to top up the revetment. This process could be infinite due to the constant settlement of the revetment structure.

Soil Mixing – this option was assessed and deemed to be feasible by the project team, following in-situ soil samples and initial laboratory testing and further discussions with specialist contractors and is discussed further below.

3 Soil Samples

In 2021, 10 soil samples were collected from along the estuary frontage at various locations where construction works are proposed to take place by a specialist ground investigation contractor. The soil samples taken were analysed in a laboratory by a specialist soil mixing contractor. The outcome of the testing was considered by both the project team and the specialist contractor and both deemed the results positive, indicating soil mixing could increase the strength of the ground (mud) sufficiently to allow construction vehicles and the flood defences and rock armour revetment to be positioned on it.

4 Example Projects

Soil improvement techniques have been around for many years, and have been used on a range of projects, from coastal / marine environments (e.g. Mersey Gateway Bridge) to inland areas. Soil mixing has been used to; stabilise ground, protect utilities, avoid disturbing contaminated ground and to support the foundation of buildings, retaining walls and dams. The technique has been developed to

allow construction works to take place on poor (low ground bearing capacity) or contaminated ground that would otherwise not be possible or require significant work to excavate and remove unsuitable material from site and import new material, which would have time, financial and environmental implications.

The following two projects provide examples of where soil mixing has been successfully used in coastal/marine environments in the UK.

1. St. Mary's Bay, Kent – soil improved ground for a housing development, adjacent to the English Channel.
2. Poole Quay – soil improved ground to create a new structure on the quayside, requiring some marine land to be reclaimed.

Figure 1 Soil improved ground at Saint Mary's Bay, Kent. Photo courtesy of Deep Soil Mixing

Figure 2 Soil improved ground at Poole. Photo courtesy of Deep Soil Mixing

5 Work sequencing

Construction works are assumed to commence at the mouth of the River Avon, and progress towards the Grange Burn in a linear manner.

The following work sequence will need to be undertaken to construct the flood defences:

- Undertake soil mixing to improve the bearing capacity of the ground, to allow access for construction vehicles to track over the soil improved ground.
- Install piles, within the soil improved ground.
- Construct the flood defence wall.
- Install the rock armour stone revetment on top of the soil improved ground.
- Install the access track and surface water drainage system.
- Undertake reinstatement works.

6 Method Statement

This section outlines the general the method for undertaking the soil mixing and construction of the flood defence wall and revetment.

Soil Mixing

- Site clearance including the removal of existing fence and stone blocks/revetment where required. Erection of temporary fences and forming temporary access track. Bankside vegetation to be protected to minimise disturbance.

- Create access down the bank for construction equipment to access the area where soil mixing will commence – this may require excavation of the bank to create a ramp and placement of rock fill and geotextiles/ geogrids.
- Locate/ protect/ divert as necessary any existing services, including outfalls to the estuary.
- Implement measures to protect estuary from solids/ sediments/ contamination from the works. This may include a temporary bund between the working area and the estuary.
- Set up soil mixing equipment including material storage silos etc
- Soil mix the ground at the bank toe, this will involve an excavator with a mixing head depositing the binder material into the ground (mud) to a depth of 4m. The binder material is mixed into the ground. The binder material may be a dry mixture, which is air pumped but it is more likely to be a wet mixture that is pumped (under low pressure) to the mixer head.

Figure 3 An example of soil mixing taking place. Photo courtesy of Deep Soil Mixing

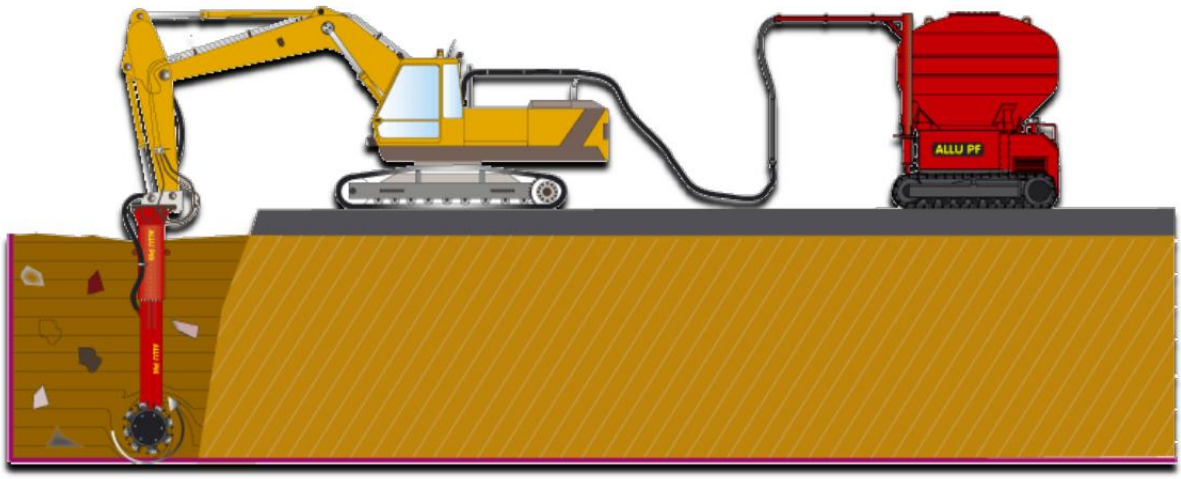

Figure 4 An illustration of soil mixing, with an excavator with a mixing head mixing the ground and blinder being pumped.

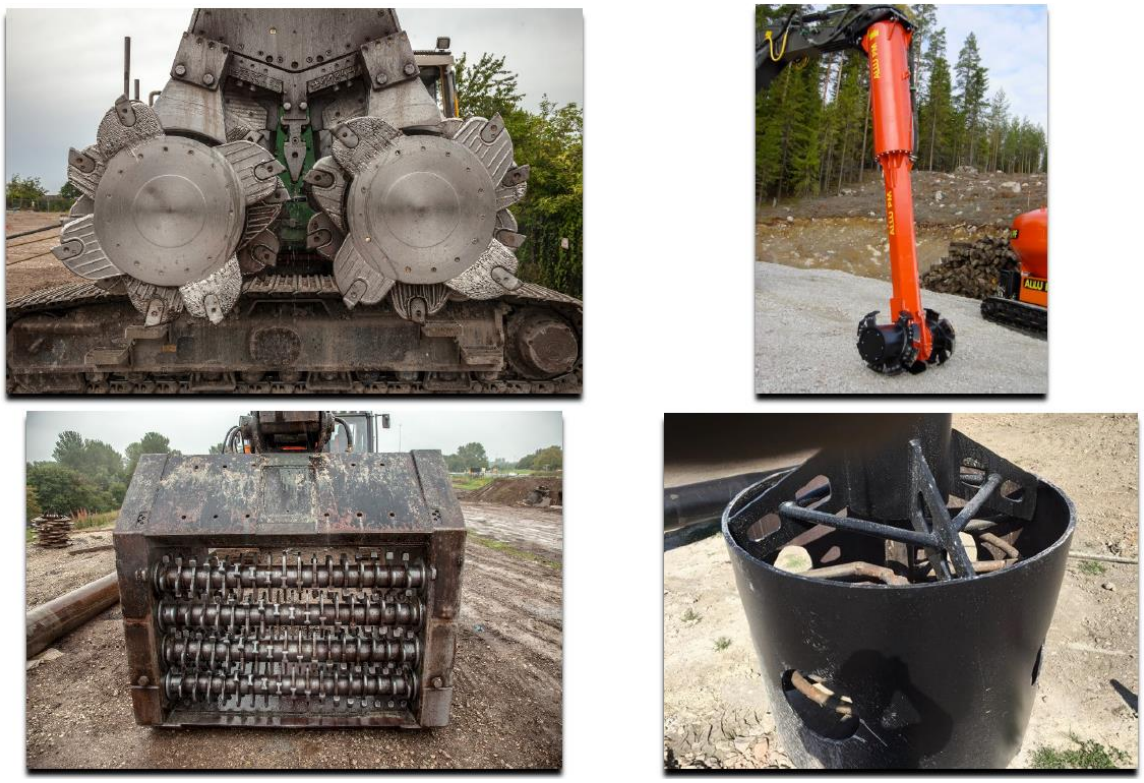

Figure 5 Range of different mixing heads for soil mixing. Photo courtesy of Deep Soil Mixing

- The area to be mixed will be dictated by the reach of the excavator and the tide times. Soil mixing will only commence once the tide has receded past the working area (i.e. a falling tide) and will halt in sufficient time before the area is submerged by the rising tide each day.
- The soil mixed ground will be allowed to cure, with curing times affected by moisture and temperature.
- Geotechnical sampling and testing will be carried out to ensure the improved ground achieves the specified design parameters.
- Once the soil mixed ground has cured sufficiently, the excavator with the mixing head and pump will track over the soil improved ground and begin mixing the next area of ground. This process will continue along the estuary frontage until all the necessary ground is mixed/ improved.

Figure 6 Shows a soil mixed column through sandy ground, note how the binder is defined to a specific area and does not spread to the surrounding ground. Photo courtesy of Deep Soil Mixing

Figure 7 Soil mixed columns coloured in cream, with little to no mitigation of the added binder to the surrounding ground. Photo courtesy of xxxx

Wall construction

- Once an area of soil mixed ground has been completed, granular fill be placed on top of the soil improve ground to create a working platform and limit any risk of the surface material being eroded. If required a geotextile will be installed. Bulk bags (filled with clean granular stone) may be placed at the edge of the soil mixed area to limit surface water runoff into the estuary.
- A bored pile wall will be installed in the soil mixed ground (up to 4m deep), the piling rig (20t rig/excavator) will be positioned on the soil mixed ground,

- Initially a trench will be excavated and a guide wall/ frame constructed to ensure the bored piles are installed in the correct location
- The piling rig will drill / auger a hole to a depth of 4m, within the soil mixed ground,
- As the auger is removed, concrete will be pumped into the hole. It is unlikely that any temporary casing will be required due to the anticipated stiffness of the soil mixed ground.
- When the hole is filled with concrete, the reinforcement cage is plunged / pushed into the concrete with steel reinforcing bars protruding above the ground,
- Reinforcement and form work will be erected for the wall stem / capping beam,
- Concrete will be poured within the formwork to create the wall stem,
- It is likely 10-15m sections of wall will be poured in a single operation, depending on wall height.
- Once the concrete has cured (a few days), the formwork will be removed.
- On the landward side of the flood defence, granular fill will be transported to the area and deposited, forming an access track. Surface water drainage will also be installed.

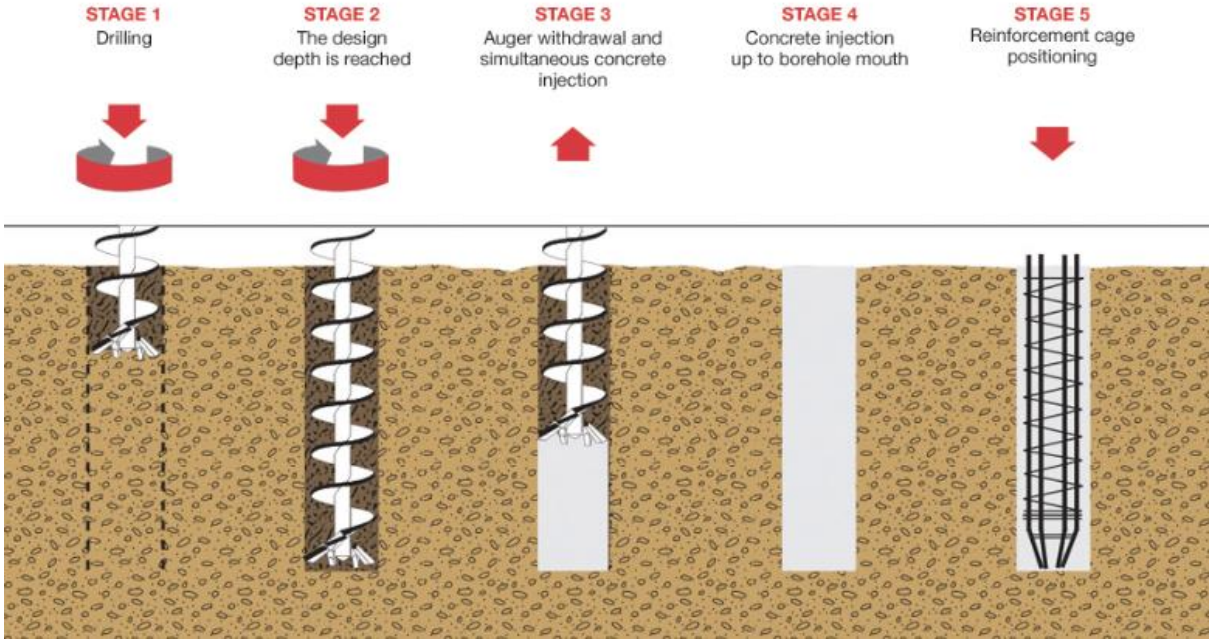

Figure 8 Schematic description of pile being installed.

Figure 9 10t excavator with piling rig attachment for installing continuous flight augured piles.

Rock Revetment

- Following construction of the flood defence wall, rock armour stone will be imported and transported to the working area and stockpiled at various locations along the defence.
- Excavator(s) will be positioned on the soil improved ground and used to move the armour stone.
- Smaller stone (bedding material) and a geoxtextile may be required prior to installing the armour stone and be deposited on the sea ward side of the flood defence using excavators/ dumpers.
- Following installation of the bedding material the armour stone will be placed by excavators to create the revetment.
- The revetment is likely be constructed from the Grange Burn working towards the River Avon,

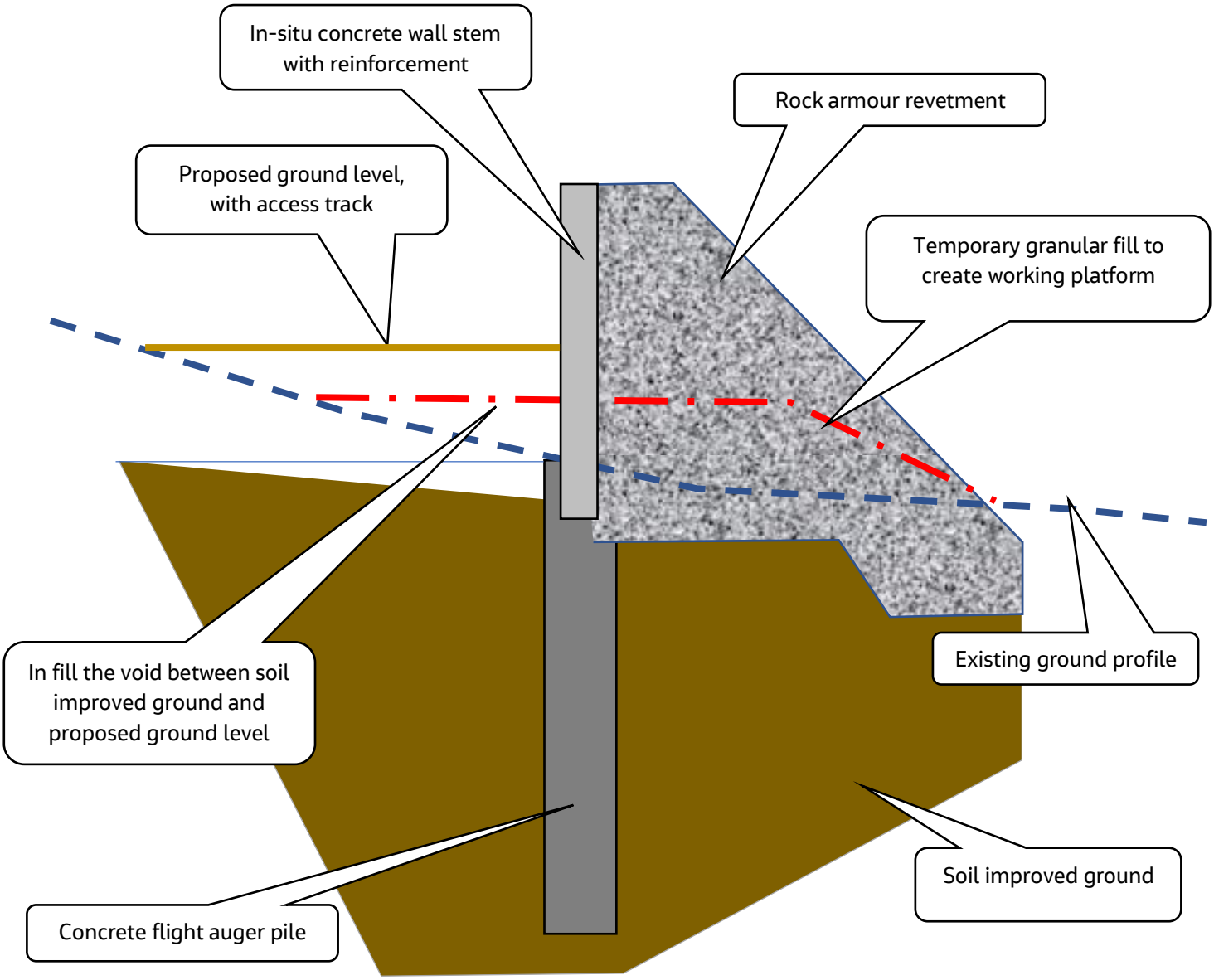

Figure 10 Schematic outline of the proposed flood defences along the estuary frontage

Environmental Impact Assessment Report

Appendix C4.3 Flood Protection Measures

Grangemouth Flood Protection Scheme 2024
Falkirk Council

GRANGEMOUTH
Flood Protection Scheme
Protecting the heart of our communities

Table A1: Flood protection measures (should be read in conjunction with Figures A4.1 – A4.28 and A4.29 – A4.56; NB maximum heights given here refer to highest point of defence above existing ground-level. The defence heights relative to the proposed landform and position of viewers are discussed in Chapter 9: Landscape and Visual Impact Assessment)

Flood Cell No	Working Area	Location	Description of Works	Figure Ref No
1	1-1	Stirling Road	Flood defences in this working area are located along Stirling Road (extending around the business area) and comprise the following: • a flood defence wall (brick clad), seepage defence (underground sheet pile) and earth embankment (with pedestrian and vehicular ramps) extending west to east along the northern side of Stirling Road totalling approximately 860m in length. The wall will have a height above existing ground level of up to ~2.0m, while the embankment will be ~2.2m. • flood defence wall (formed concrete) around the small burn to the south of Stirling Road and west of the bus depot totalling approximately 306m in length, with height ranges up to ~1.8m. • a flood defence wall (brick clad) along the southern side of Stirling Road totalling approximately 445m in length, with height ranging up to 0.81m. A flood gate will be positioned at the carpark across from the bus depot, with another two located at the business area facilitating access thereto and into adjacent properties.	A4.1
	1-2	Carron Bridges	Defences in this working area comprise the following: • A 356m long earth embankment up to ~4.2m in height located to the west of Park Road, Sainford Crescent and Sword's Way with three pedestrian ramps. • A 42m earth embankment up to ~1.2m in height located to the west of Carron Road with a pedestrian access ramp. The Mungal Burn will be culverted beneath the structure. The culvert will be 30m in length. • A 24m stone clad wall to the west of Carron Road leading to the existing Carron Road Bridge (western parapet). • Infrastructure to facilitate the erection of demountable defences prior to any major flood event across Carron Road on either side of Carron Road Bridge. • A 110m stone-clad wall up to 2.8m in height with pedestrian ramp and glass panels along the footpath to the south of the river Carron between the Carron Road Bridge and the New Carron Road Bridge (bordering Dawson Community Church grounds).	A4.2

Flood Cell No	Working Area	Location	Description of Works	Figure Ref No
			• A 16m formed concrete wall to the west of New Carron road and tying into the new (raised) bridge parapet (a new 36m long bridge and parapet will replace the existing New Carron Road Bridge). • A 108m long brick-clad wall to the north of the River Carron set between the two bridges. • A 188m replacement stone-clad wall with two flood gates to the north of the River Carron and west of Carron Road (up to ~1.2m in height; the adjacent building will be demolished; includes a new footpath). • A 109m and a 69m brick-clad wall to the north of the River Carron, either side of New Carron Road. • A 39m brick-clad wall and flood gate and ramp at the northern extent of Carronside Street.	
	1-3	Chapel Burn	A flood defence wall (brick clad wall) will be located along the left bank of the River Carron, in close proximity to a residential area (including Bryce Avenue, The Meadows and Waters End), as well as Carrondale Care Home. The flood defence extends to both banks of Chapel Burn to Carronshore Road. The flood defence wall will also be located to the north of Chapel Burn and the River Carron and is in close proximity to a residential area (including Duncan Avenue and Rae Court). The total length of these sections of flood defence wall will be 662m with a height range up to ~2.6m. Another section of flood defence wall (stone clad wall) will be located at the intersection of Carronshore Road bridge and Chapel Burn. The total length of this section of flood defence wall will be 24m, with a height range of up to ~1.4m.	A4.3
	1-4	Dock Street	Flood defence walls (formed concrete walls) in this area will mostly be located in alignment and between the River Carron and surrounding residential areas (Gilfillan Place, Wardlaw Place and Dock Street). A flood gate is incorporated into the flood defence wall south of Dock Street. The total length of this section of flood defence wall will be 536m, with a height range of up to ~2.4m. Two buildings adjacent to the defence alignment may have to be demolished. At the northern extent of the defence wall, a 17m stretch of land crossing "The Avenue" will be raised by ~0.03m.	A4.4
Cell 2	2-1	Forth and Clyde Canal Lock	An earth embankment will be located between the River Carron and an industrial / commercial area and multiple residential properties located on Clyde Street / West Church Drive. The total length of this section of earth embankment will be 320m, with a height range up to ~1.8m. A new footpath will be incorporated here with a ramp facilitating access over the embankment, and there will be a flood gate toward the western extent.	A4.5

Flood Cell No	Working Area	Location	Description of Works	Figure Ref No
			A flood defence wall (bare sheet pile wall) will continue from the embankment along the riverside within the industrial / commercial area for approximately 348m to the boundary with working area 2-2 (includes Custom Operators and Jarvie Plant Group). A flood gate will be positioned in this section of flood defence wall. The total length of this section of flood defence wall will be 347m, with a height range of up to ~1.6m. A building within the industrial plant area will be demolished to make way for the new defence.	
	2-2	Jarvie Plant/ Rossco Properties	A flood defence wall (bare sheet pile wall) will continue some 820m through the industrial site into Grangemouth Marina to the boundary of working area 3. Two flood gates will be incorporated into the flood defence wall – one is located on North Bridge Street and the other next to Forth Ports. The height of the defence ranges up to ~2.0m. A ramp will be located at the eastern extent of the defence to facilitate vehicular access to the riverside. Further west, a 30m section of infrastructure will be constructed to allow for a demountable defence to be erected prior to more extreme flood events.	A4.6
Cell 3	3-1	Mouth of the River Carron	Flood defence wall (bare sheet pile wall) will be located along the northern extents of North Shore Road along the boundary of Forth Ports (Port of Grangemouth). The total length of this section of flood defence wall will be 920m, with the height ranging up to ~1.7m. Some sections of coastal revetment (rock armour) will be included on the wet-side of the defence to address erosion risk. The combined length of coastal revetment will be ~335m.	A4.7
	3-2	West Coast of the Port	The flood defence wall (bare sheet pile wall) will continue along the northern extents of North Shore Road and beyond to working area 3-3 for 965m, with a ~31m of coastal revetment required to address erosion risk. The height of the flood defence wall will range up to ~1.5m.	A4.8
	3-3	West Gate to the Port	The flood defence wall (bare sheet pile wall) will continue along the northern extents of North Shore Road for approximately 1171m crossing the west gate of the port (former lock gate). The height of defence ranging from up to ~2.2m. Coastal revetment will follow the same alignment as the flood defence wall, ending in close proximity to E2 Jetty Petroineos. In total, the length of coastal revetment in this area will be 765m.	A4.9
	3-4	East Gate to the Port	A 135m flood defence wall (bare sheet pile) with a vehicular ramp shall be constructed between the west and east gates with a height up to ~1.6m. The East Gate is the only working navigable access for ships into the port,	A4.10

Flood Cell No	Working Area	Location	Description of Works	Figure Ref No
			which will be fitted with a new lock gate, and demountable defence will be located at either side of the gate. The new lock gate will be 37m in length, and there will be a total of 38m of demountable defence in this section. A section of formed concrete wall flood defence with three access gates and a small section of demountable defence (total ~180m) shall be constructed along the southern alignment of the lock to the coast (up to ~0.6m in height). An approximate 40m area of coastal revetment will protect the exposed section of concrete wall defence, which will tie into a 605m section of sheet pile defence (with access gate), which follows the perimeter of the port complex to working area 3-5. The defence height in this working area will range from 4.7m in height at the tie-in and up to ~2.1m along the wall.	
	3-5	Mouth of the Grange Burn	Flood defence wall (bare sheet pile wall) will follow the alignment of the eastern extents of South Shore Road for approximately 678m, with one flood gate linking a shoreside access track. The height of the defence will range up to ~2.0m.	A4.11
Cell 4	4-1	Upstream of M9	A flood defence wall (formed concrete wall up to ~2.3m high) will be constructed along the right bank of Westquarter Burn within Grandsable Cemetery (78m), which will tie into a 75m stone clad section (up to ~2.5m) that follows the rear garden boundary of the house within the Cemetery and then north across the bridge. Across the bridge, an adjoining formed concrete wall will continue some 135m along the verge of Grandsable Road, the A9 and Mumrills Road. This section incorporates a flood gate (to facilitate access to small structure) and a new footpath along its length. The existing underpass at the A9 shall be blocked off and infilled with concrete. A 125m concrete clad floodwall up to ~0.9m will be constructed to the east of Grandsable Road, with a 7m section being stone clad at the bridge to match that specified on the opposite parapet. To the east, a 280m concrete clad floodwall up to ~2m will follow the western boundary of the commercial area. North of the A9, a 227m formed concrete wall will follow the eastern boundary of the developed area including the Cherry Tree Nursey along the western bank of Westquarter Burn between the A9 and M9 with a height ranging up to ~2.3m.	A4.12

Flood Cell No	Working Area	Location	Description of Works	Figure Ref No
	4-2	FRC - Rannoch Park	A 738m flood defence wall (formed concrete wall) will be constructed along the left bank of the Flood Relief Channel to the north of Rannoch Park, with heights ranging up to ~0.9m. Three ramps and a floodgate will facilitate access over the wall from Rannoch Road. A flow control structure will be located on the upper section of the Grange Burn, near the confluence of the flood relief channel and Grange Burn. A small structure in the park will be demolished and replaced.	A4.13
	4-3	FRC - Inchyra Road	An earth embankment will be constructed to the northeast of the Macdonald Inchyra Hotel & Spa and will be 118m in length and up to 1.1m in height. A 387m flood defence wall (formed concrete) will be constructed along the left banks of the Flood Relief Channel with heights up to ~1.2m. It will cross the Flood Relief Channel at Grange Road.	A4.14
	4-4	FRC - Whole-flats Road	The Flood Relief Channel will be contained in this works area with 79m of formed concrete wall crossing the burn at Grange Road tying into a 105m section of raised ground (with access ramp) connected to a 418m stretch of bare sheet pile wall along the left bank (north) of the channel (height ranges of <0.25m – ~2.4m). Another ramp provides access over 168m stretch of stone clad wall. Along the right bank of the channel (south) a 481m long stretch of bare sheet pile wall will connect the concrete wall top the west with a 173m stretch of stone clad wall, with a flood gate at the eastern extent facilitating access into the commercial area east of Reddoch Road. The stone clad wall will continue a further 173m to the south along the eastern verge of Reddoch Road to the point where is crosses Millhall Burn, where a new bridge will be constructed. A 25m embankment will be formed from the bridge to the south, while a 230m formed concrete wall (<0.25m – ~2m in height) will follow the right bank (east) of Millhall Burn and before diverting clockwise round the equestrian centre (stables). A 298m long formed concrete wall will continue southwest from the bridge along the left bank (north) of Millhall burn which crosses the burn and turns back east along the verge of Smiddy Brae. A 174m stone clad wall will also be constructed along the southern verge of Smiddy Brae and Millhall Gardens up to ~3.3m in height) with a flood gate facilitating access to the burn.	A4.15
	4-5	Zetland Park	A 290m flood defence wall (stone clad wall) will follow the left (west) bank of Grange Burn, extending north from the Grangemouth Community Education Unit and Grangemouth Sports Complex (up to ~1.5m in height) to a raised bridge (with access ramps) at Wallace Street and on past a flood gate toward Dalratho Road. At the southern extent, the existing bridge next to the car park at the Sports Complex, the footbridge leading over the burn to the playpark will be raised and pedestrian ramps will facilitate access to it. A 177m	A4.16

Flood Cell No	Working Area	Location	Description of Works	Figure Ref No
			embankment up to 1.2m in height will be constructed from the playpark area along the right (east) bank of Grange Burn terminating at the ramps to the raised bridge at Wallace Street, where a small building to the west of the tennis courts will be demolished and rebuilt to the east. From here, a 196m long stone clad wall with a flood gate will continue north to Dalratho Road with a height up to ~1.4m in height.	
	4-6	Dalratho to Bo'Ness Road	Flood defence walls (stone clad) will continue from work area 4-5 to the bridge at Dalratho Road (48m and 32m along left and right bank respectively), tying into the parapet of the new bridge to be constructed with a height of up to ~1.2m. North of the bridge, stone clad walls will follow the banks of the Grange Burn from Dalratho Road to Bo'Ness Road measuring 487m in total with heights up to ~1.4m. Two flood gates will be located either side of the burn at Ronaldshay Crescent. North of Bo'Ness Road 205m of stone clad flood wall will follow either side of the burn with heights up to ~1.4m.	A4.17
	4-7	Grangeburn Road	On the left bank of Grange Burn, the stone clad wall will continue for 41m with a height up to ~1.73m and will tie into a 595m long bare sheet pile wall up to ~0.7m in height running along the southern verge of South Shore Road. On the right (south) bank of Grange Burn, a short (10m) section of formed concrete wall will tie into a 602m section of stone clad wall up to ~2.2m in height along the existing embankment to the north of Grangeburn Road.	A4.18
	4-8	Petroineos	An up to ~0.5m high bare sheet pile wall will continue for 481m along the left (north) bank of Grange Burn, with a flood gate at the Powdrake Road Bridge and 25m of demountable defences near the former rail crossing bridge at the entrance to the refinery. On the right (south) bank of the burn, the stone clad wall will continue for 131m to the road bridge at Powdrake Road Bridge with a height of up to 0.7m. Beyond the flood gate at the bridge a bare sheet pile wall will continue for 342m (up to ~1.5m in height) with 25m of demountable defences near the former rail crossing bridge at the entrance to the refinery.	A4.19
	4-9	Mouth of Grange Burn	The up to ~0.3m high bare sheet pile flood wall will continue for 419m along the left (north) bank of Grange Burn to the pipe bridge, where it will tie into a vehicular ramp crossing South Shore Road, with a flood gate at the northern side of the road and a further 43m section of base sheet pile wall.	A4.20

Flood Cell No	Working Area	Location	Description of Works	Figure Ref No
			On the right (south) bank of the burn, the bare sheet pile flood wall will continue for 553m with a height up to ~2.3m, and part of a small building near the pipe bridge will be demolished. At its northeastern extent, a vehicular ramp will be constructed facilitating access along the maintenance track to the pipe bridge. At the rail bridge further along the burn, a flood gate will be built into a 30m section of bare sheet pile flood wall	
Cell 5	5-1	Smiddy Brae and Avondale Road	A 598m long formed concrete flood wall up to ~2.5m high will be constructed along the southern verge of Wholeflats Road and will incorporate three flood gates. On the norther verge, a 241m long formed concrete wall up to 1.5m in height with one flood gate will extend along the road and then north toward the boundary of the refinery complex. From here, a bare sheet pile wall follows the refinery complex boundary for 418m with heights up to ~2.5m. Toward the west, starting from the left bank of the River Avon, a 507m long stretch of bare sheet pile flood wall up to ~3.4m in height will extend northward interrupted by a vehicular ramp facilitating access into the land to the east.	A4.21
	5-2	Flare Road and Road 33	Along the left (north) bank of the River Avon, a 622m bare sheet pile wall will be constructed (up to 3.4m in height), with two gates either side of the pipe bridge. Along the right (south) bank of the river, a 374m long bare sheet pile wall up to ~2.7m in height will be constructed, with a vehicular ramp facilitating access to the river's edge. A section of seepage only flood defence measure will be located between this section of flood defence wall and will be in total 98m in length and <0.25m in height.	A4.22
	5-3	Grangemouth Road	Flood defence walls (bare sheet pile wall) will be located either side of the River Avon and will border the extents of the refinery complex. On the right (south) bank of the river, the defences will be up to ~2.5m in height and stretch some 913m, incorporating seven flood gates. On the left (north) bank of the river, the bare sheet pile wall defences will be up to ~3.0m in height and extend 723m incorporating five flood gates.	A4.23
	5-4	Mouth of the River Avon	A bare sheet pile flood defence wall up to ~3.2m in height will continue along the left (west) bank of the River Avon for 440m, incorporating two flood gates. A 170m section of coastal revetment will be placed along the norther extent of this section to protect against erosion.	A4.24

Flood Cell No	Working Area	Location	Description of Works	Figure Ref No
Cell 6	6-1	Beach Road	The flood defence in this area will follow the northern extent of the refinery complex and will comprise 948m of bare sheet pile wall with a height range of up to ~3.3m in height, interrupted by a ~567m of bored pile and coastal revetment up to 3.7m in height. A new 10m long culvert will facilitate drainage through the revetment.	A425
	6-2	Petroineos Mouth of the River Avon	The bare sheet pile wall, with a height range of up to ~1.8m in height will continue along the refinery complex perimeter here for 267m and tie into a 442m section of bored pile and coastal revetment with a height range of up to ~3.7m in height. A gate will be located at the intersection facilitating access onto the shoreline.	A4.26
	6-3	Chemical Works at River Avon	A bare sheet pile wall with earth embankment against it will extend some 694m, with a height range of up to– ~3.0m. A ~2.34m high vehicular ramp will facilitate access over the defence at its northern extent.	A4.27
	6-4	Water Treatment Works	A 728m long bare sheet pile wall up to ~1.6m in height will be constructed along the northern extents of the access road to the water treatment works.	A4.28