Helensburgh Coastal Flood Protection Study

Final Report

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Contract

This report describes work commissioned by Grant Whyte on behalf of Argyll & Bute Council, by Purchase Order number AB315359. Argyll & Bute's representative for the contract was Grant Whyte. Hannah Otton, Rachel Perks, Alice Gent, Douglas Pender and Nicci Buckley of JBA Consulting carried out this work.

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Purpose

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Executive summary

Overview

JBA were commissioned in April 2018 to undertake a coastal flood study for Helensburgh, Craigendoran and Rhu. This report is the culmination of this work and explains the steps carried out to identify a preferred set of interventions that offer sustainable flood risk management whilst also seeking to benefit the environment and local communities.

Helensburgh has a history of coastal flooding, and a review of historical events formed a first step in the modelling of coastal flood risk and the development of options. The modelling undertaken included the assessment of still water levels, local wave characteristics, joint probability analysis, wave overtopping, and flood inundation modelling, both for present day conditions and with an assessment of climate change. Models were calibrated against a series of historical events for which anecdotal evidence was available.

Following on from the modelling, a long list of potential flood protection options was developed, and subsequently screened using a multi-criteria approach in order to form a short list of options for each section of the frontage. The short-listed options have been developed to a concept design level, with a full economic assessment of the options undertaken.

Preferred option

The preferred option being presented for prioritisation is for an initial cycle of Property Flood Resistance and Resilience (PFR) measures, followed by the construction of direct defences to respond to climate change; the form of these defences varies along the frontage. This fits in with the Scottish Government's 'managed adaptive approach', giving due consideration in the differences between present day and future risk as the effects of climate change are realised.

The table below highlights the preferred option (medium and long term) for each benefit zone, along with the number of properties protected.

Benefit Zone	Initial option	Adapted option
Rhu	PFR – 5 properties	New sloped revetment
Sailing Club	PFR – 7 properties	New set-back walls
West Clyde St	PFR – 26 properties	New set-back walls
East Clyde St	PFR – 39 properties	New rock revetment*
Craigendoran	PFR – 9 properties	New set-back walls
* Considers 190m of set-back walls in the green open space between Lomond St and Glenfinlas St		

The present value damages for the entire study area are **£10,520k**, and the preferred option includes an initial cost of £1,681k, enhanced maintenance and a future capital cost to adapt to climate change of £7,723k. It is proposed that these costs be realised approximately 25-years after installing the PFR (i.e. one cycle). This results in a total present value cost of **£6,888k** over the appraisal period.

Present value benefits for the preferred option are estimated to be **£9,183k**; resulting in a BCR of **1.33**.

A series of short-term recommendations are also made; these aim to address existing coastal risk prior to the design and construction of a Flood Protection Scheme (FPS).

Additional benefits

While the primary benefit associated with the proposed scheme is from flood protection, many secondary benefits will be realised along the frontage.

Tourism and recreation in Helensburgh are key contributors to the local economy with the proposed scheme providing valuable protection to existing businesses along the front through PFR and investment in existing defences.

By setting a design standard of 1 in 200 years, they will support development under the requirements in Scottish Planning Policy, thus supporting the possibilities for sustainable regeneration and economic growth for Helensburgh.

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Abbreviations

2D	Two Dimensional (modelling)
AAD	Annual Average Damages
AEP	Annual Exceedance Probability
BCR	Benefit Cost Ratio
BS	British Standard
BZ	Benefit Zone
CaLL	Clyde and Loch Lomond
EA	Environment Agency
FPS	Flood Protection Scheme
FRMS	Flood Risk Management Strategy
HMNB	Her Majesty's Naval Base
HSDP	Helensburgh Seafront Development Partnership
JONSWAP	JOint North Sea WAve Project
LDP	Local Development Plan
LFRMP	Local Flood Risk Management Plan
LPD	Local Plan District
MCM	Multi-Coloured Manual
NFM	Natural Flood Management
PFR	perty Flood Resistance and Resilience
PV	Present Value
PVA	Potentially Vulnerable Area
Ramsar	The intergovernmental Convention on Wetlands, signed in Ramsar, Iran, in 1971
RBMP	River Basin Management Plan
SEPA	Scottish Environment Protection Agency
SNH	Scottish Natural Heritage

SoP	Standard of Protection
SPA	Special Protection Area for birds, protected under the EU Habitats Directive
SSSI	Site of Special Scientific Interest
TUFLOW	Two-dimensional Unsteady FLOW (a hydraulic model)

1 Introduction

JBA Consulting were commissioned by Argyll and Bute Council in April 2018 to undertake an appraisal of a coastal Flood Protection Study for the frontage at Helensburgh.

1.1 Study extent

The study covers the village of Rhu, the town of Helensburgh itself, and Craigendoran, as shown within Figure 1-1. A number of small burns drain into the Firth of Clyde within the study extent.

Figure 1-1: Location plan

1.2 Objective

In terms of flood risk management, Helensburgh is part of the Clyde and Loch Lomond (CaLL) Local Plan District (LPD), with Glasgow City Council designated the Lead Local Authority. The Clyde and Loch Lomond Local Flood Risk Management Plan (LFRMP) for 2016-2022, which supplements the local Flood Risk Management Strategy (FRMS)[1] developed by the Scottish Environment Protection Agency (SEPA), identifies 'Helensburgh to Loch Long' as a Potentially Vulnerable Area (PVA). The Helensburgh to Loch Long PVA is designated 11/02 and is deemed to be at risk of flooding from pluvial, fluvial and coastal sources and identifies Annual Average Damages (AAD) of £390,000. Of concern to this study is the risk from coastal flooding to the town of Helensburgh, Rhu and Craigendoran.

The objective of this project is to deliver a flood protection study to consider options to reduce coastal flood risk within Helensburgh.

1 Helensburgh to Loch Long: Flood Risk Management Strategy http://apps.sepa.org.uk/FRMStrategies/pdf/pva/PVA_11_02_Full.pdf

1.3 Guidance

Scottish Government guidance specifies that an "adaptive" rather than "precautionary" approach to flood risk should be considered[2]. This is to combat the uncertainties surrounding the changes in flood risk in the future (i.e. climate change, natural processes, demographics, etc.) where the design of climate change upfront (precautionary) may not prove to be the best option[3]. This entails looking at a long-term solution that could be changed as the implications of climate change are realised. Managed adaptive approaches enable risk to be monitored at periodic intervals, and are usually more sustainable long-term as they facilitate benefits for the environment and society, along with cost savings. The flexibility surrounding a managed adaptive approach allows for new innovations to be used, to help cope with future climate change projections.

1.4 Report overview

This report is laid out so as to follow the process undertaken for the project:

Chapter 2 – Information Review and Baseline Studies

Chapter 3 – Flood Modelling

Chapter 4 – Long List of Options and Multi-Criteria Analysis

Chapter 5 – Short Listed Options and Appraisal

Chapter 6 – Preferred Option, Environmental Screening and Business Case

[2] Scottish Government (2016). Options appraisal for flood risk management: Guidance to support SEPA and the responsible authorities. First Edition.

[3] SEPA (2018) Local Authority Flood Study Checklist. Version 3.

2 Information review and baseline studies

An information review was undertaken to identify gaps in information regarding coastal flooding in Helensburgh. Baseline studies were then undertaken in areas where more information was required.

2.1 Information Review

Coastal flooding in Helensburgh results from a combination of high-water levels and wave action. SEPA's coastal flood mapping suggests East and West Clyde Streets, Rhu village, the Sailing Club and Helensburgh Pier are all at risk from coastal flooding. Previous assessments of flood risk at Helensburgh have been carried out and are discussed within the Information Review report in **Appendix A**, along with a comprehensive review of historic flood events.

Historical flood information is important to develop an understanding of local flood mechanisms, as well as providing an evidence base for model development and calibration. The most significant events in recent years are those of January 2012 and January 2014, both of which resulted in flooding.

Figure 2-1: January 2012 – flooding along East Clyde Street

Figure 2-2: January 2014 - flooding over the esplanade at Henry Bell Monument

Helensburgh, Craigendoran and Rhu are fronted by a range of coastal defences, including gabion baskets, sea walls and rock armour. Full details, including photographs and location maps are included within the Information Review report in **Appendix A**.

2.2 Baseline studies

A number of baseline studies were undertaken to fill gaps in the information available. A summary of each of these studies is provided below, with full details available in the relevant appendices.

2.2.1 Topographic Survey

JBA undertook a 3D laser scan survey of the Helensburgh, Craigendoran and Rhu coastline at a resolution of 15cm in September 2018. This was used to develop a surface model, utilised within the flood modelling and within the concept design and appraisal process. A threshold survey of buildings within the 200-year climate change flood extents was undertaken and levels used within the economic analysis.

2.2.2 Structural Inspection Reports

A series of reports into the condition of assets, ascertained through visual inspections, are provided within **Appendix C**. The reports assess each defence along the frontages, assigning it an overall condition score grade, which is then converted into the predicted lifespan of that defence. A log of defects and recommendations for repairs to defences are also detailed within the reports.

2.2.3 Baseline Environmental Report

An investigation into the presence and importance of different habitats within the coastal frontages at Helensburgh, Craigendoran and Rhu was undertaken within the Baseline Environmental Report, provided in **Appendix D**.

Of particular note is that the eastern edge of the study extent at Craigendoran lies within the Inner Clyde Special Protection Area (SPA), Site of Specific Scientific Interest (SSSI) and Ramsar; these designations are due to the wintering population of Redshank, which is one of the largest populations in Britain. Recommendations and considerations for future work are provided within the report.

2.2.4 Baseline NFM and RBMP Report

The baseline Natural Flood Management (NFM) and River Basin Management Plan (RBMP) report, which assesses the current condition of the watercourses and coastal water bodies located within the study extent as well as considering the potential NFM options relevant to the study area is provided within **Appendix E**.

The Rhu coastal strip is classified as being in High morphological condition, whilst Helensburgh is considered Moderate. This is due to the presence of hard coastal defences along the entire frontage of Helensburgh acting as the primary form of coastal flood protection, with opportunities to remove these being limited. The main suggestion to improve the morphological status is to remove the dilapidated piers at Craigendoran, along with the degraded and redundant defences in certain areas along the front.

Two primary NFM opportunities are detailed within the report to restore more natural habitat: saltmarsh expansion and shingle recharge.

2.2.5 Baseline Sediment Processes Report

Local sediment processes were analysed within the Baseline Sediment Processes Report provided in **Appendix F**.

The report concludes that the area experiences little longshore drift due to the predominant waves approaching the beach perpendicular to the shore and the tidal velocities in the area being low. A review of historical maps showed that the shoreline has varied very little, with significant changes only occurring due to the construction of piers and defences. Volumetric analysis showed that the overall sediment budget has varied very little between 2011 and 2018, with only small areas of sediment loss occurring at piers and defences from localised

scour. Overall, new defence works are unlikely to affect sediment movement, but appropriate allowance for localised toe scour should be considered.

2.2.6 Baseline GI Report

An assessment of the geotechnical and geo-environmental risk within the study area is included in the Baseline Geotechnical Report provided in **Appendix G**.

The report recommends undertaking a targeted ground investigation to determine the ground conditions, the classification of soils and identify the risk of contaminated land, obstructions, dense strata and settlement. Service plans have also been obtained for the coastal frontage.

2.2.7 Baseline Landscape Report

A report reviewing landscape policies and character assessments can be found within **Appendix H**.

Consideration must be taken of the Core Paths and National Cycle Network Route, designated sites within the area, the policies within the Argyll & Bute LDP and it is recommended to update the SNH Landscape Character Assessment for the area.

2.2.8 Baseline Heritage Report

The Baseline Heritage Assessment report can be found within **Appendix I**.

Helensburgh and Rhu are both designated Conservation Areas, with a large number of Listed Buildings within them. The report recommends that the local Conservation Officer be consulted regarding necessary consents if the designated heritage assets are to be impacted. For non-designated heritage assets including Helensburgh Pier, Craigendoran Steamer Pier and Craigendoran Ferry Pier, it is recommended that the remains of these are retained so the historical value of these structures are not harmed.

Careful design should ensure the historical significance of the Henry Bell monument and the bust of John Logie Baird remain appreciable within their setting. A large number of buildings are orientated towards the shore and have views across the Clyde, and therefore care should be taken to ensure new works are sympathetic to their historic context and employ an appropriate palette of materials. Where works require excavation, it may be appropriate for archaeological mitigation to be in place.

3 Flood modelling

The flood modelling process involved multiple steps to develop and combine a suite of numerical models in order to simulate coastal flood risk effectively. A summary of these steps is provided below, with a detailed report of the flood modelling methodology found within **Appendix J**. The modelling does not take into account proposed development along the frontage. SEPA's feedback on the interim modelling report is provided within **Appendix P**; the report has been updated to reflect this feedback.

3.1 Extremes analysis

Due to the geometry of the inner Firth of Clyde, coastal flood risk within Helensburgh, Craigendoran and Rhu is predominantly controlled by a combination of sea levels and local wind waves. The joint probability of extreme surges and wind from multiple directional sectors were modelled through an extreme value model in order to estimate the flood risk at Helensburgh from the combination of wave overtopping and extreme sea levels.

3.2 Wave estimation

Wave action is a complex process controlled by several factors. Waves are generated in deep water and then propagate towards land. As they do so, they enter shallower bathymetry where wave transformation processes occur. The consequence of these processes is that the properties of the waves when they reach the base of coastal defences are quite different to those in deep water. In terms of coastal flood risk, it is these nearshore waves that are of the greatest importance, as it is these that interact with beaches and defences and ultimately lead to wave overtopping and inundation.

A number of methods were assessed in order to calculate appropriate nearshore wave characteristics for the frontages, with the JONSWAP method being considered as the most suitable. Overall, wave heights increased west to east (from 0.43m to 1.40m for a 2 year event) within the study extent due to the increase in fetch lengths.

3.3 Wave overtopping

Wave overtopping was modelled to consider how the waves at the toe of the defences interact with the beach and defence structures (more detail on the defences can be found in **Appendix C**). 33 different sections were assessed based on different defence types along the frontage (Figure 3-1). The calculations were undertaken using the EurOtop II Neural Network tool, which is considered the most suitable method for the range of defences present within the study extent. The defences were schematised and then calibrated using historical events (Jan 2012 and Jan 2014), WaveWatchIII hindcast data and recorded water levels. The calibrated sections were subsequently used to provide extreme overtopping rates using the design conditions for each return period. The largest rates occurred at the Sailing Club, along West Clyde Street, at Helensburgh Pier, along East Clyde Street and at the railway line in Craigendoran. It should be noted that sections 11-13 at Helensburgh Pier represent the existing defence.

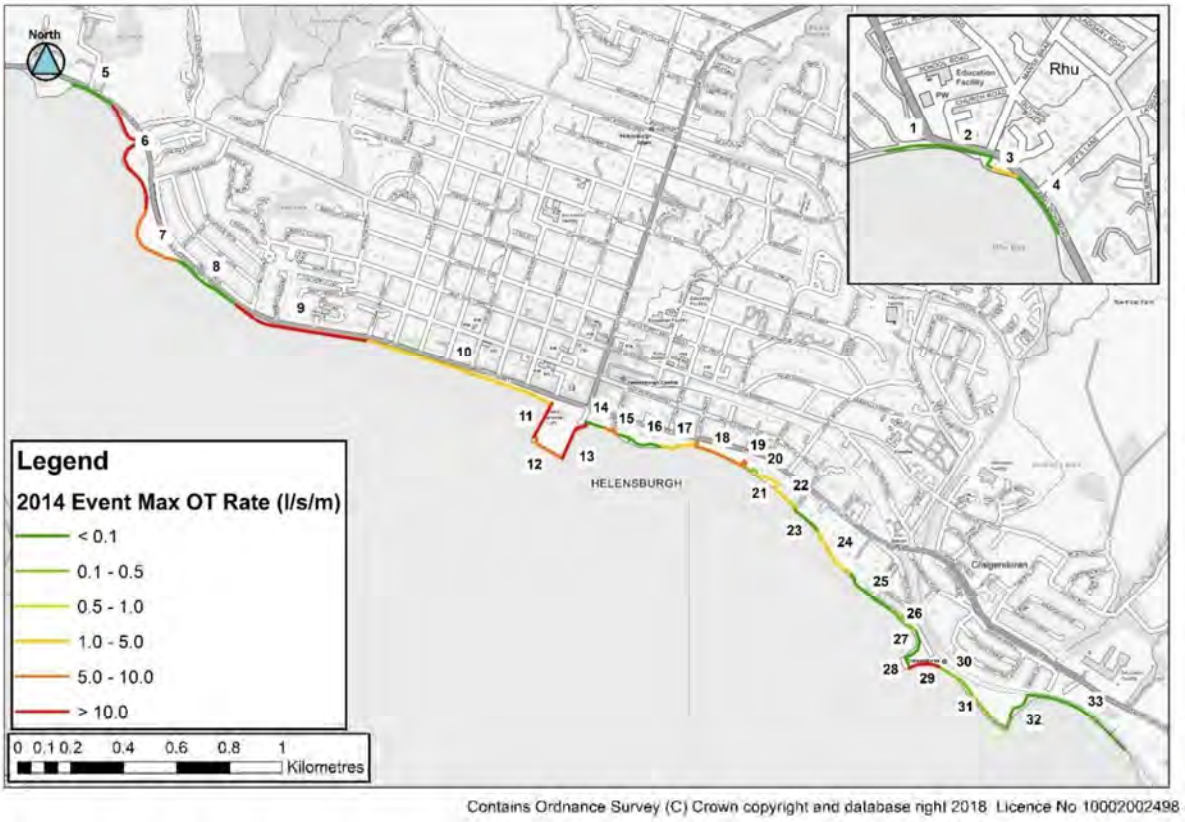

Figure 3-1: January 2014 calibration event overtopping rates (l/s/m)

3.4 Inundation modelling

A TUFLOW model was developed to estimate inundation along the coastal frontage during simulated floods. It was forced by an offshore tidal graph and overtopping inflows in order to produce flood extents that include the risk from both wave overtopping and extreme storm surges. The model was calibrated for both the 2012 and 2014 events using anecdotal evidence. Extreme events were then modelled to inform the baseline flood damage calculations.

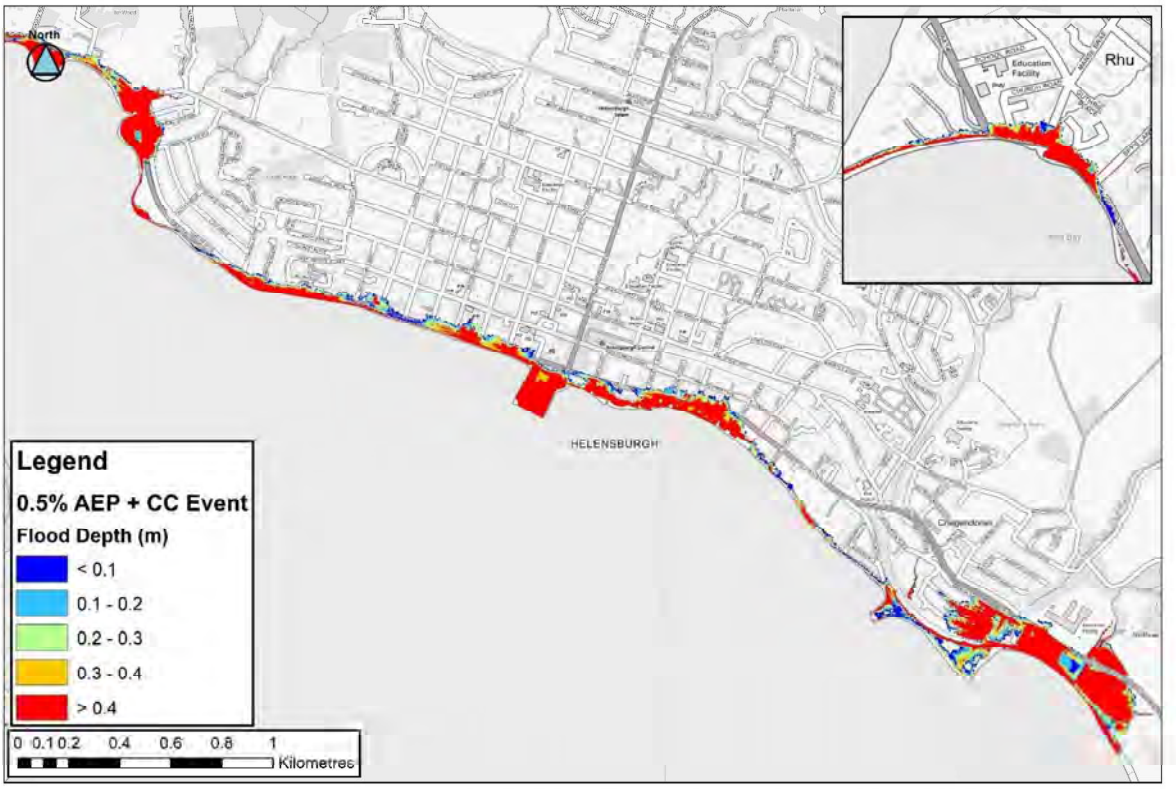

Figure 3-2: 200-year plus climate change flood extent

4 Long list and multi-criteria analysis

In order to consider options that may be appropriate to reduce coastal flood risk, the frontage of the study area was split into five benefit zones (BZs) (Figure 4-1); Rhu, Helensburgh Sailing Club, West Clyde Street, East Clyde Street and Craigendoran. A long list of potential flood risk management options was drawn up and the validity of the options for each of the zones assessed; this provided an initial screening of the options (Table 4-1). Further analysis was subsequently undertaken to assess the remaining options against a series of technical, economic, environmental, social, political and legal criteria (Table 4-2), with each option/category assigned a score (Table 4-3) based on whether the option met the aims of the assessment criteria. A summary of the total scores is provided in **Appendix K**, with those taken forward to the short list phase for further assessment highlighted in green.

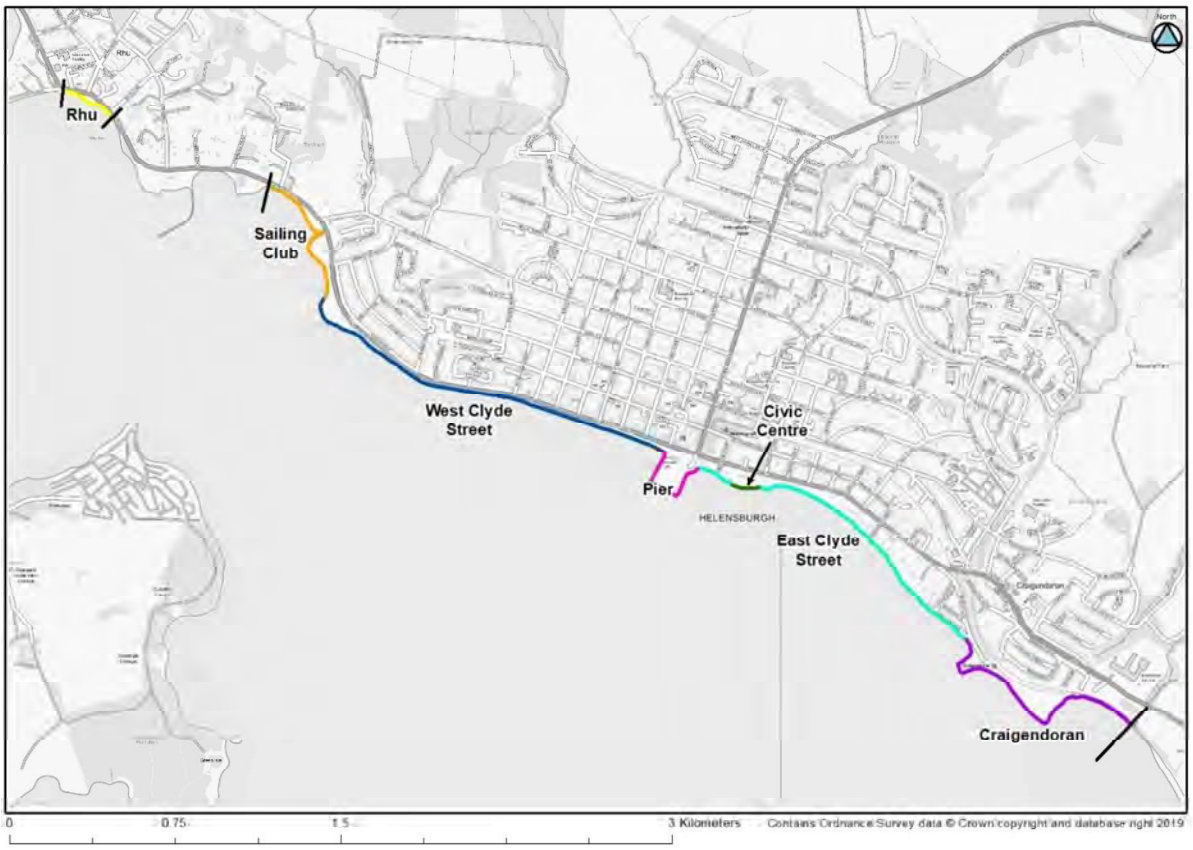

Figure 4-1: Helensburgh Benefit Zones (N.B. the defences at Helensburgh Pier and the Civic Centre are not being developed as part of this study)

Table 4-1: Long list of options considered

Options and Description	Benefit zone				
	Rhu	Sailing Club	West Clyde Street	East Clyde Street	Craigendoran
Do nothing	✓	✓	✓	✓	✓
No maintenance of existing defences.					
Do minimum	✓	✓	✓	✓	✓
Maintain existing defences.					
New sea wall	✓	✓	✓	✓	✓
A new wall could be built of concrete, steel piles or masonry. This option would seek to replace the existing defence or could be placed seaward of the existing defence in order to advance the line. To adapt to climate change, the wall would need to be taller than the current defence.					
Raise existing defences	✓	✓	✓	✓	✓
Raising the existing defence would increase the flood protection performance of the defence in the short to mid-term. However, as this option relies on the existing structure it can only practically be raised so far without a complete re-build. In areas where the existing structures are currently in poor condition a concrete 'face', 'backing' or 'shroud' could be used to enhance or strengthen the existing defence.					
Rock armour revetment	✓	✓	✓	✓	✓
Rock armour could be installed at the base of the existing defence to increase flood protection performance. This option may or may not include a wall on top.					
Setback walls with flood gates	x	✓	✓	✓	✓
Flood protection walls could be installed set-back from the existing coastal defences. This option would help prevent flooding to the town through a secondary defence line; while it does not help reduce wave overtopping, it would prevent flood water from inundating roads and properties. In the long-term this option will be less effective due to the extreme sea levels expected and it does not seek to improve the condition of existing defences. However, if used in conjunction with other defence improvements it could effectively work into the long-term scenario.					
New stepped or sloping revetment	✓	✓	✓	✓	✓
A new stepped revetment or similar modular blockwork structure could be constructed. All solutions could be designed such that their wave overtopping performance is suitable into the long-term scenario; this may or may not include a wall on top. This option would seek to replace the existing defence or could be placed seaward of the existing defence in order to advance the line seaward.					

Options and Description	Benefit zone				
	Rhu	Sailing Club	West Clyde Street	East Clyde Street	Craigendoran
Beach recharge + control structures	x	x	x	x	x
The beach in front of the existing defences could be recharged, increasing both the beach crest width and height. To prevent the beach mobilising and moving around beach control structures would also likely be required. The beach would likely require replenishment over time if it is shown that material is lost, or the beach migrates. Due to the risk from still water levels, the benefit of this as a stand alone option is likely to be limited within the study area.					
Managed realignment	x	x	x	x	✓
In some areas partial realignment of the existing defences could be considered. Within a partial realignment scenario, a secondary defence may be required to be set-back from the existing coastal defences.					
Property relocation	✓	✓	✓	✓	✓
Properties at immediate flood risk behind the current coastal defences could be relocated, reducing potential flood damages while also providing additional space for flood protection improvement schemes behind the existing defences.					
Property Flood Resilience and Resistance (PFR)	✓	✓	✓	✓	✓
PFR measures could be a valuable option to incorporate into those properties at risk of flooding. This could be in conjunction with automated traffic signs to advise of diversions on roads.					
Helensburgh Seafront Development Partnership (HSDP) lagoon	x	x	✓	x	x
HSDP have a proposal to create a lagoon to the west of Helensburgh pier. This would be formed by a series of breakwaters and offer protection to part of the West Clyde Street benefit zone.					
Saltmarsh regeneration	✓	✓	x	x	✓
Small areas of existing saltmarsh have been identified along the frontage, and these could be developed to encourage the dissipation of wave energy. This measure would need to be combined with direct defences to provide an appropriate standard of protection in the long term.					
Self raising or demountable barriers	x	x	x	x	x
As an alternative to fixed hard structures (e.g. set-back flood walls) self-raising or temporary demountable barriers can be used to offer flood protection to vulnerable areas. While temporary or demountable defences can be very effective in emergency situation, the can also be incorporated into FPS where new defences are not acceptable of difficult to construct. Self raising defences are a permanent solution and are well suited to short frontages such as bridging gaps between wall types as an alternative to a fixed flood gate.					

Options and Description	Benefit zone				
	Rhu	Sailing Club	West Clyde Street	East Clyde Street	Craigendoran
Offshore breakwater	x	x	x	x	x
A breakwater built typically of rock armour can be installed offshore of a coastline and acts to dissipate larger waves as they propagate towards the shore, reducing overtopping rates from wave action. As these defences do not increase the height of the existing defences on the coastline, they do not offer a protection against rising still water levels.					
Tidal barrier	x	x	x	x	x
A tidal barrier could be installed further out toward the Firth of Clyde, potentially bridging the gap between Dunoon and Gourock. A barrier of this scale would prevent extreme water level storm surges from traveling up towards Helensburgh. However, given the scale, design challenges and extreme cost, the option is considered unviable.					
Advance the line	x	x	x	✓	x
Advancing the line by building new coastal defences seaward of the existing provides a good opportunity for remodelling the coastal frontage and improving amenity space. This option has been identified as a feasible solution for the East Clyde Street frontage where introducing a new coastal promenade would also improve construction difficulties associated with other Hold the Line options.					

Table 4-2: Multi-criteria assessment criteria

Category	Assessment criteria	Aims
Technical	**Technical performance and adaptability**	Provides desired standard of protection throughout the design life of the scheme or is easily adaptable to allow for modifications for climate change through time. Provides protection to full extent of benefit zone.
	Buildability	Safe to construct, local sources of appropriate material for construction, suitable ground conditions and would not conflict with existing services, primarily the sewer main along the front.
Environmental	**Capital cost**	Low capital cost.
	Maintenance and monitoring	Minimal ongoing maintenance and/or monitoring requirements and costs.
	Environment	No environmental impact on local habitats, geology and ecology, including local designations.
	NFM and RBMP	Works with nature to provide natural protection and does not downgrade the existing classifications.
	Landscape and Heritage	Works with the existing landscape and is sensitive to listed buildings and heritage designations.
	Tourism	Maintains access to beaches, considers local views and provides connectivity along the frontage.
Legal	**Strategic alignment**	Aligns with local strategies.
	Stakeholder views	Supported by stakeholders and the local community.
	Waste management and contamination	Minimal waste disposal requirements or contamination risks.
	Regulatory consenting and approvals	Regulatory framework would be readily achievable.

Table 4-3: Multi-criteria assessment scoring

Score	Description
1	Option has significant potential to negatively affect achievement of aims
2	Option likely to conflict with aims
3	Option not likely to contribute or conflict with aims
4	Option likely to contribute to achieving aims
5	Option has significant potential to meet aims

5 Short list and appraisal

The short-listed options underwent a detailed appraisal to test the economic viability of each, with the appraisal processes implemented for each benefit zone (BZ) individually. Outcomes were subsequently combined to form the most appropriate option for an FPS for the frontage as a whole. For the purposes of the economic assessment, it is assumed that the BZs are independent of one another. As such, no residual risk of backdoor flooding is expected, should the decision be taken not to progress with a scheme at any of the respective BZs.

5.1 Baseline scenario

The baseline scenario for this assessment is the Do Minimum. Under this scenario, it is assumed that the existing defences will be maintained at their current level of investment, with a residual life as indicated in the visual asset condition surveys undertaken as part of this study. In this scenario, when the residual life is exceeded, the defences are assumed to have failed.

Figure 5-1: An example of failure of concrete revetment face at Craigendoran.

Analysis and modelling of the undefended scenarios indicates that there is no inherent benefit in attempting to incorporate these end of life losses into the damage calculations. The economic cost of exposure and erosion of assets after failure could be included in the 2118 flood damage estimates at future design stages; however, these have not been included in the damage calculations at this stage.

5.2 Short list options

The below sections provide a summary of the short-listed options for each Benefit Zone.

Although there is no design standard required to receive government grant, options have been developed and appraised for a 200-year standard of protection (SoP) with an allowance for climate change in 2118. This aligns with the current planning guidance[4] and will therefore allow for additional wider benefits in terms of long-term regeneration of Helensburgh, Craigendoran and Rhu.

4 Argyll and Bute Local Development Plan

Property Flood Resistance and Resilience (PFR) is to be appraised as an option across all BZs.

Table 5-1: Rhu short-listed options and timescale over which they are applicable

Option	SoP	Timescale
PFR	Varies	Medium
Sea wall	200-year + CC	Long
Sloped revetment	200-year + CC	Long

Table 5-2: Helensburgh Sailing Club short-listed options and timescale over which they are applicable

Option	SoP	Timescale
PFR	Varies	Medium
Sea wall	200-year + CC	Long
Set-back walls*	200-year + CC	Long
*This requires capital injections to maintain the existing primary defences throughout the appraisal period.		

Table 5-3: West Clyde Street short-listed options and timescale over which they are applicable

Option	SoP	Timescale
PFR	Varies	Medium
Sea wall	200-year + CC	Long
Set-back walls*	200-year + CC	Long
*This requires capital injections to maintain the existing primary defences throughout the appraisal period.		

Table 5-4: East Clyde Street short-listed options and timescale over which they are applicable

Option	SoP	Timescale
PFR	Varies	Medium
Rock armour revetment	200-year + CC	Long
Advance the line	200-year + CC	Long

Table 5-5: Craigendoran short-listed options and timescale over which they are applicable

Option	SoP	Timescale
PFR	Varies	Medium
Rock armour revetment	200-year + CC	Long
Set-back walls*	200-year + CC	Long
*This requires capital injections to maintain the existing primary defences throughout the appraisal period.		

Property Level Resistance and Resilience is a medium-term option, protecting the 200-year present day flood zone from depths up to 600mm, whereas the longer-term options discussed above protect to a 200 year plus climate change standard.

It is assumed most products installed as part of a flood protection scheme will operate automatically and will normally have a service life of 25-30 years. The study assumes PFR will be replaced by structural measures as the effect of climate change takes place. The design life of PFR is uncertain with longevity relying on individual property owners

maintaining measures. For this to be a viable long-term option, the responsibility would potentially have to be passed to multiple homeowners. This, combined with the uncertainty in funding multiple installations has led to the decision to appraise PFR as solely a medium-term option.

5.3 Concept designs

Concept designs were developed for the above short-listed options to assess their feasibility. These included the general arrangement of defences, typical section, engineering materials and key structure dimensions and are included in full in **Appendix L**, along with the design risk assessment and supporting technical note. The defence geometries have been optimised by extreme wave conditions and extreme sea levels.

All options have been designed with a 200-year event standard of protection, plus an allowance for climate change up to 2118.

The Environment Agency (2017) freeboard guidance[5] has been adopted, from which a 4-star confidence rating has been assumed to be achieved during the detailed design stage. As such, a minimum 450mm freeboard has been designed to achieve zero still water level flooding during the design event, and events with lower return periods.

The tolerable overtopping discharge threshold proposed for all shortlist options is to be less than 1 l/s/m for the 0.5% AEP event as this is considered to be safe for pedestrians, according to the European Wave Overtopping Manual[6].

No allowance for settlement and consolidation has been made within the designs, and therefore all the levels presented in the concept designs represent post-settlement and post-consolidation levels.

All of the shortlisted options have been optimised to achieve the best balance between the required design performance standards and minimising material usage and, hence, carbon footprint as to develop a sustainable design.

The shortlist options have been designed to protect from tidal inundation and from the risk of wave overtopping. The typical sections were assessed within the latest release of the Artificial Neural Network overtopping tool. A range of revetment crest levels, wall crest levels, crest widths and revetment slopes were assessed. The wave climate data used to develop the shortlist designs was the 2118 0.5% AEP overtopping. The final defence geometries are included in **Appendix L**.

5.4 Options appraisal

The appraisal has considered each shortlisted option in turn for each benefit zone. The appraisal undertaken was reviewed by SEPA as part of this study, with the feedback received included within **Appendix P**.

Due to the uncertainty in the long-term viability of PFR, this option has only been appraised over a 25-year period, (i.e. one instalment, as the design life of elements of property level protection is considered to be 25-30 years[7]).

For each BZ, an additional option has been appraised which combines PFR at the start with a longer-term option of improved defences in the future, thus resulting in a long-term solution overall. This has been undertaken with the most economic defence option within each benefit zone.

5 Environment Agency. 2017. Accounting for residual uncertainty - updating the freeboard guide (SC120014)

6 EurOtop. 2018. Manual on wave overtopping of sea defences and related structures.

7 JBA, 2014. Assessing the Flood Risk Management Benefits of Property Level Protection

Table 5-6: Rhu appraised options: the approach and type of capital investment required

Option	Initial	Final	Investment
1	PFR	NA	Upfront – medium
2	Sea wall	Sea wall	Upfront – long
3	Sloped revetment	Sloped revetment	Upfront – long
4	PFR	Sloped revetment	Upfront and delayed*
* Delayed investment represents additional capital costs that may or may not be eligible for government grant. However, a scheme where investment is delayed until the effects of climate change are being realised is in line with the Scottish Government's managed adaptive approach.			

Table 5-7: Helensburgh Sailing Club appraised options: the approach and type of capital investment required

Option	Initial	Final	Investment
1	PFR	NA	Upfront – medium
2	Sea wall	Sea wall	Upfront – long
3	Set-back walls	Set-back walls	Upfront and delayed*
4	PFR	Set-back walls	Upfront and delayed*
* Delayed investment represents additional capital costs that may or may not be eligible for government grant. However, a scheme where investment is delayed until the effects of climate change are being realised is in line with the Scottish Government's managed adaptive approach. The set-back walls option also has delayed costs as it would require capital injections to maintain the existing primary defences throughout the appraisal period.			

Table 5-8: West Clyde Street appraised options: the approach and type of capital investment required

Option	Initial	Final	Investment
1	PFR	NA	Upfront – medium
2	Sea wall	Sea wall	Upfront – long
3	Set-back walls	Set-back walls	Upfront and delayed*
4	PFR	Set-back walls	Upfront and delayed*
* Delayed investment represents additional capital costs that may not be eligible for government grant. However, a scheme where investment is delayed until the effects of climate change are being realised is in line with the Scottish Government's managed adaptive approach. The set-back walls option also has delayed costs as it would require capital injections to maintain the existing primary defences throughout the appraisal period.			

Table 5-9: East Clyde Street appraised options: the approach and type of capital investment required

Option	Initial	Final	Investment
1	PFR	NA	Upfront – medium
2	Rock armour revetment[†]	Rock armour revetment	Upfront – long
3	Advance the line	Advance the line	Upfront – long
4	PFR	Rock armour revetment	Upfront and delayed*
[†] Considers 190m of set-back walls in the green open space between Lomond St and Glenfinlas St. * Delayed investment represents additional capital costs that may not be eligible for government grant. However, a scheme where investment is delayed until the effects of climate change are being realised is in line with the Scottish Government's managed adaptive approach.			

Table 5-10: Craigendoran appraised options: the approach and type of capital investment required

Option	Initial	Final	Investment
1	PFR	NA	Upfront – medium
2	Rock armour revetment	Rock armour revetment	Upfront – long
3	Set-back walls	Set-back	
4	PFR	Set-back	

5.5 Public consultation

A public consultation at the Helensburgh
short list of options. For each benefit zone
defence designs were displayed for discussi -
met for the option to be taken forward. T
importance of maintaining and creating public spaces and rights of way.

Options that delivered these outcomes were therefore preferred, such as a new sea wall at West Clyde Street, which creates a new public space by the coast and Advance the Line at East Clyde Street which includes a new walkway along the seafront. A summary of feedback from the public consultation is included within **Appendix M**.

5.6 Costs

Broad assumptions regarding the cost of each defence based on height, construction materials and expected lifetime can be taken from the 'Flood Risk Management Estimating Guide'[8]. Costs of construction for the options have been developed using realised costs associated with previous JBA design and construction projects along with national guidance. Outcomes from these have been used to develop unit costs for each option, which are then applied across the length of frontage being considered. In addition to the construction costs, the following uplifts are applied:

- On-costs – 19% of construction costs to account for:
    - Designer fees
    - Argyll and Bute Council staff costs
    - Contract supervision
    - Cost consultants fee
    - Legal costs
    - Land purchase
- Optimism bias – 60% to account for concept design stage

For each option, maintenance costs were estimated using Environment Agency databases[9]. The costs used assume efforts are made to maintain assets at condition grade 2 (Good) using the grading system described in the Environment Agency's asset condition assessment manual[10]. Higher estimates have been used to account for the fact the defences will suffer direct wave loading.

8 Flood Risk Management Estimating Guide Unit Cost Database, Environment Agency, 2007

9 Appendix B Maintenance Standards – SC060078 FRCM Assets: Deterioration Modelling and WLC Analysis

10 Condition Assessment Manual (CAM) (Environment Agency, 2012)

Costs of PFR have been estimated assuming automatic measures and taken from Scottish Government Guidance[7].

Whole life (present value) costs have been estimated based on the above enabling, capital and maintenance costs. The following assumptions have been made:

- The life span of the scheme and appraisal period is 100 years.
- Discounting of costs are based on the standard Treasury discount rates as recommended by the 2018 revision to the HM Green Book.
- Delayed costs of Option 4 are assumed to occur 30 years later (coinciding with the estimated life of one PFR instalment and the residual life of existing coastal defences).

5.7 Flood damages

Flood damages have been estimated using the best practice approach outlined in the Multi-Coloured Manual[11] (MCM) using 2017 depth damage curves, uplifted to 2018. It includes quantification of the economic costs associated with:

- Direct property damages
- Indirect property damages
- Intangible damages including increased vulnerability
- Transport disruption on the A814 – divided equally across all BZs
- Railway disruption at Craigendoran – applied to Craigendoran only

Transportation disruption on the A814 has been estimated following the MCM's *Diversion-Value method* and the following assumptions:

- The average travelling speed is 40 kph
- The total diversion is 27km – Helensburgh to Faslane via A82 and A817
- There are 1,050 vehicles per hour on average[12]
- The average resource cost is 0.46 £/km
- Duration of road closure varies depending on flood depth from 3 hours (0.3m) to 12 hours (1+ m)

Damages associated with the flooding to the railway at Craigendoran have been estimated following the MCM's *Value of Time* and *Compensation Payments* methods and the following assumptions:

- A total of 86 trains per day use the line at Craigendoran on average
- There are 50 passengers per train on average
- Delay / cancellation durations are based on overtopping rate; flood mechanism and water depth. These vary from 6 hours (overtopping only) to 96 hours (still water level flooding)
- Given the duration and source, services are always cancelled
- Medium estimates for cancellation compensation have been used

Flood damages will increase over time in response to rising sea levels and this has explicitly been accounted for in the analysis. Annual Average Damages (AAD) have been estimated using the modelled results for 2018 and 2118 and interpolated linearly through the appraisal period.

11 Penning-Rowsell el al., 2013. Flood and Coastal Erosion Risk Management – A Manual for Economic Appraisal

12 https://roadtraffic.dft.gov.uk/#6/55.254/-6.053/basemap-regions-countpoints

The table below shows a breakdown of AAD (for both the current situation and at 2118) and the total present value damages (PVD) for each benefit zone, and the study area (Table 5-11). The figures demonstrate the breakdown in AAD for each BZ and the contribution of each BZ to the total (Figure 5-2 and Figure 5-3).

A total PVD **£10.5 million** is estimated for the entire study area, based on a 100-year appraisal period.

Table 5-11: Flood Damages in Helensburgh

Benefit Zone	No. of properties at risk	2018 AAD (£k)	2118 AAD (£k)	Total PvD (£k)
Rhu	32	£2	£38	£350
Sailing Club	38	£11	£91	£982
West Clyde St	173	£26	£173	£1,969
East Clyde St	192	£41	£257	£2,969
Craigendoran	167	£6	£104	£971
A814	NA	£65	£105	£2,270
Railway	NA	£25	£57	£1,010
NB: "properties at risk" indicate those that have been assessed as being at risk of internal flooding.				

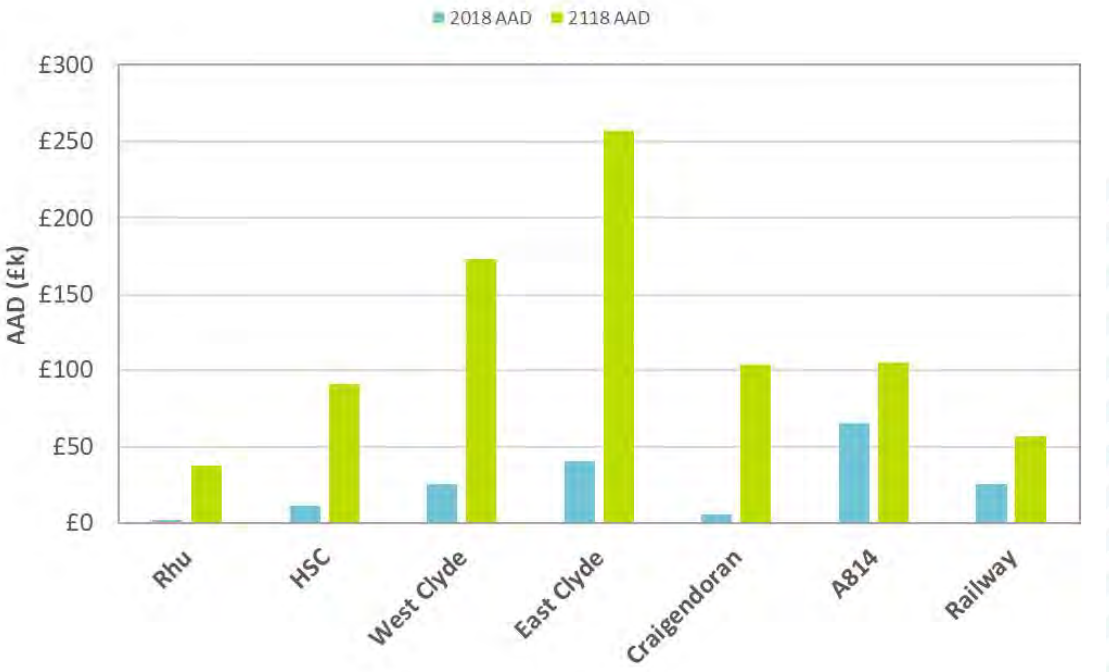

Figure 5-2: Present day and 2118 Annual Average Damages

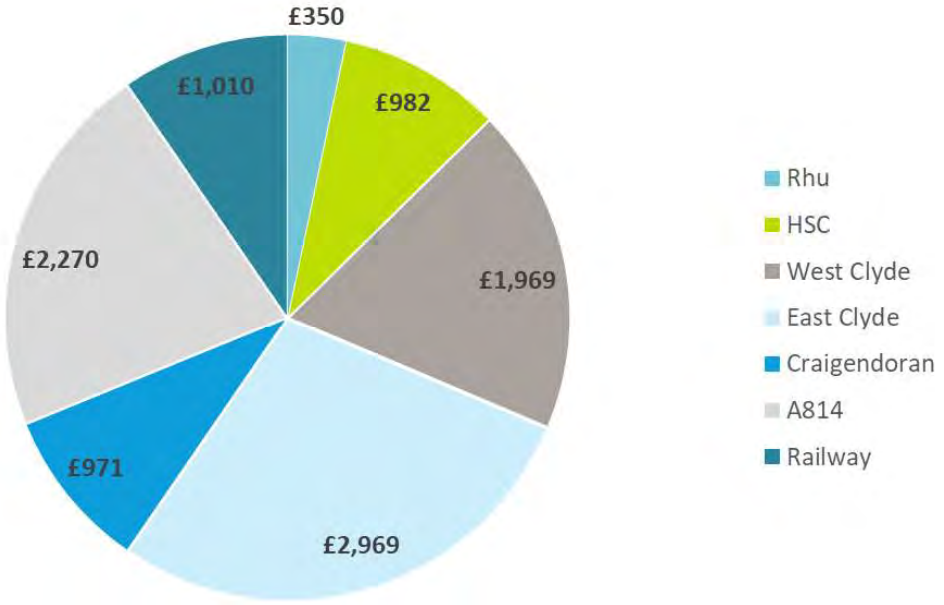

Figure 5-3: AAD breakdown for each BZ

5.8 Economic analysis

Due to the uncertainty surrounding the application of certain methods in establishing accurate benefits, the following assumptions have been applied:

- Only 84% of the estimated benefit from PFR measures have been claimed, as recommended in the guidance;
- 100% of the railway disruption benefits have been claimed. While it is acknowledged that there is potential that the railway can be interrupted by coastal flooding further along the line; and some of the benefit may be attributed to adjacent local authorities; there is no definitive guidance on the strategic distribution of such benefits.

5.8.1 Rhu benefit zone

The options outlined in the tables in Section 5.4 were appraised in order to establish their economic viability. The table below provides the results from this analysis, with the economically viable options highlighted in green.

Table 5-12: Rhu economic analysis

Option	Name	PV Costs (£k)	PV Benefits (£k)	BCR
1	**PFR**	£128	£56	0.44
2	**Sea wall**	£2,577	£888	0.34
3	**Sloped revetment**	£1,345	£888	0.66
4	**PFR + sloped revetment**	£597	£618	1.04

From the results presented above it can be seen that only the delayed investment in new defences, construction of a new sloped revetment after 30 years, achieves a BCR>1.

All options that consider a new structure initially are shown to be not economically viable. Option 2, which considers a new sea wall structure initially is shown to be the least

economically viable option with a BCR of 0.34. Similarly, option 3 which considers a new sloped revetment initially is shown to be not economically viable with a BCR of 0.66. This is because the capital cost of investment in a new sea wall and sloped revetment is £2,577k and £1,345k respectively, yet there are only a possible 32 properties that could benefit from the defence, as such the costs significantly outweigh the benefits.

As sea level rise increases the damages associated with coastal flooding increase substantially (Figure 5-2), which, combined with the discounting applied to the delayed cash investment, results in a BCR > 1.0.

The medium-term option of only PFR for 25 years is also not considered economically viable; the capital cost is £128k yet the potential benefit of implementing the scheme is only £56k.

5.8.2 Helensburgh sailing club benefit zone

The options outlined in the tables in Section 5.4 were appraised in order to establish their economic viability. The table below provides the results from this analysis, with the economically viable options highlighted in green.

Table 5-13: Helensburgh sailing club economic analysis

PFR	£91	£234	2.57
Sea wall	£8,448	£1,500	0.18
Set-back walls	£1,701	£1,500	0.88
PFR + set-back walls	£885	£1,242	1.40

From the results presented above it can be seen that the medium-term option of only PFR for 25 years has the highest BCR (2.57), and this demonstrates the case for immediate investment in some form.

A delayed investment in new defences, construction of a new set-back walls after the residual life of the existing structures has been exceeded, achieves a BCR > 1. The initial capital cost of investment is significantly higher for Option 3 with respect to Option 4, suggesting that Option 4 is more economically viable.

The other option that considers a new sea wall structure initially is shown to be not economically viable. This is because the capital cost of investment in a new sea wall is £8,448k yet the potential benefits only equates to £1,500k.

5.8.3 West Clyde Street benefit zone

The options outlined in the tables in Section 5.4 were appraised in order to establish their economic viability. The table below provides the results from this analysis, with the economically viable options highlighted in green.

Table 5-14: West Clyde Street economic analysis

Option	Name	PV Costs (£k)	PV Benefits (£k)	BCR
1	**PFR**	£569	£646	1.14
2	**Sea wall**	£10,144	£2,390	0.24
3	**Set-back walls**	£2,690	£2,390	0.89
4	**PFR + set-back walls**	£2,131	£2,185	1.03

From the results presented above it can be seen that the medium-term option of only PFR for 25 years has the highest BCR (1.14) and demonstrates the case for immediate investment in some form.

A delayed investment in new defences, construction of a new set-back walls after the residual life of the existing structures has been exceeded, as well as investing in new set-back walls initially achieves a BCR > 1. The initial capital cost of investment is significantly higher for Option 3 with respect to Option 4, suggesting that Option 4 is more economically viable.

The other option that considers a new sea wall structure initially is shown to be not economically viable. This is because the capital cost of investment in a new sea wall is £10,144k yet the potential benefits only equates to £2,390k.

5.8.4 East Clyde Street benefit zone

The options outlined in the tables in Section 5.4 were appraised in order to establish their economic viability. The table below provides the results from this analysis, with the economically viable options highlighted in green.

Table 5-15: East Clyde Street economic analysis

Option	Name	PV Costs (£k)	PV Benefits (£k)	BCR
1	**PFR**	£462	£847	1.24
2	**Rock revetment**	£4,047	£3,353	0.83
3	**Advance the line**	£10,066	£3,353	0.33
4	**PFR + rock revetment**	£1,924	£3,168	1.65

From the results presented above it can be seen that PFR followed by delayed investment in new defences, advance the line after the residual life of the existing structures has been exceeded, achieves the highest BCR (1.65), which demonstrates the case for investment in new coastal defences of this kind.

The medium-term option of only PFR for 25 years has a positive BCR (1.24) and supports the case for initial investment in some form.

Option 3, which considers advancing the line initially is shown to be not economically viable. This is because the capital cost of investment in advancing the line is £10,066k yet the potential benefits only equates to £3,353k.

5.8.5 Craigendoran benefit zone

The options outlined in the table in Section 5.4 were appraised in order to establish their economic viability. The table below provides the results from this analysis.

Table 5-16: Craigendoran Economic Analysis

Option	Name	PV Costs (£k)	PV Benefits (£k)	BCR
1	**PFR**	£188	£49	0.26
2	**Rock revetment**	£11,830	£1,955	0.17
3	**Set-back walls**	£2,008	£1,955	0.97
4	**PFR + set-back walls**	£1,350	£1,529	1.13

From the results presented above it can be seen that PFR followed by delayed investment in new defences achieves that highest BCR (1.13).

Option 2, which considers a new rock revetment structure initially is shown to be the least economically viable option (BCR = 0.17).

5.8.6 Combination

Upon analysis of the individual BZ results, the most economically viable were taken forward to assess as options across the entire frontage. The table below provides a summary of the options, with the subsequent table outlining the results from the appraisal. Options that include new defences have been developed solely on those with the lowest PV cost.

Table 5-17: Combination options summary

Name	Description
Do Minimum	Continue with current maintenance and reactive repairs of defences
PFR	PFR across all BZs over a 25-year appraisal period
PFR + Delayed Defences	PFR across all BZs for 25 years then: New sloped revetment – Rhu New set-back walls – HSC New set-back walls – WCS New rock revetment – ECS New set-back walls – Craigendoran
Upfront Defences	New sloped revetment – Rhu New set-back walls – HSC New set-back walls – WCS New rock revetment – ECS New set-back walls – Craigendoran

The results from this analysis are presented below, with the economically viable options highlighted in green.

Table 5-18: Combination economic analysis

Name	PV Costs (£k)	PV Benefits (£k)	BCR
PFR	£1,438	£1,831	1.27
PFR + delayed	£6,888	£9,183	1.33
Upfront	£11,791	£10,086	0.86

From the results presented above it can be seen that the PFR only option and the PFR with delayed investment in coastal defences option are both economically viable, achieving BCR > 1. Of these, adopting PFR for 25 years followed by delayed investment in new defences is shown to be the most cost beneficial (BCR = 1.33).

The final option, which considers new coastal defence structures initially is shown to be the least economically viable option with a BCR of 0.86.

The analysis above was repeated, removing the Craigendoran BZ for the appraisal. This was done due the uncertainty in asset ownership between Argyll and Bute Council and Network Rail. The results from this analysis are presented below, with the economically viable options highlighted in green.

Table 5-19: Combination economic analysis wi

Name	PV Costs (
PFR	£1,250
PFR + delayed	£5,537
Upfront	£9,784

This shows a similar pattern as the previous analysis but with an increase in BCR for PFR only, which is now shown to be the most cost beneficial option (BCR = 1.43).

6 Preferred option

6.1 Short-term recommendations

As part of the "managed adaptive approach", short term recommendations are outlined to manage existing flood risk prior to a FPS being implemented. These include promotion of SEPA's Flood Warning Service, which is in operation 24/7, providing live flooding information using a forecasting system for the Firth of Clyde that was updated in 2017. The structural assessment at Helensburgh found defects were present on defences along the whole frontage and it is recommended these are considered for repairs under ABC's coastal protection programme. It is also recommended that community engagement is encouraged through the setting up of a local flood action group and the update of an emergency plan for the town. This would be set up and managed by residents but supported by ABC through engagement like that undertaken with existing community development groups.

6.2 Medium to long term options

6.2.1 Business case

The results and analysis summarised in this document have demonstrated how the short-listed options have been developed and appraised. This was undertaken for each BZ and subsequently for the whole study area in combination.

Helensburgh Coastal Flood Study was identified in the SEPA strategies as the full length of Helensburgh seafront. The options for each of the benefit zones are put forward as one single scheme to benefit the whole Helensburgh community and not individual at risk pockets.

Based purely on economics this identifies PFR over 25-years as the preferred option in most locations and for the frontage overall.

The table below indicates the top two economic options for each BZ and for the whole study area in combination. Options highlighted in red indicate where the BCR < 1. Full details of the economic analysis are included in **Appendix N**.

Table 6-1: Two economically best options for each benefit zone

Benefit Zone	Preferred Option	Second Option
Rhu	PFR + sloped revetment	Sloped Revetment
Sailing Club	PFR	PFR + set-back walls
West Clyde St	PFR	PFR + set-back walls
East Clyde St	PFR + rock revetment	PFR
Craigendoran	PFR + set-back walls	Set-back walls
All	PFR + delayed	PFR

From these, the most economically viable option for each BZ varies between medium and long-term options. Considering the frontage as a whole, PFR and delayed investment in defences comes out on top economically. It has been agreed that the following approach should be taken forward as the preferred option to be considered for prioritisation by SEPA in the 2022 – 2028 cycle:

PFR for 25 years then a combination of new structures along the front

This option is shown to have a BCR of **1.33** over the appraisal period.

This option has been chosen for the following reasons:

- It provides a solution to effectively manage flood risk for Helensburgh, Craigendoran and Rhu in the long-term. Given the demonstrated increase in risk through rising sea levels, this is deemed to be the most sensible option.
- It is in line with the Scottish Government guidance that promotes adaptive management of flood risk in response to climate change.
- Existing defences along the front are in varying degrees of disrepair, as established in the Structural Inspection Reports, and substantial capital investment over the next few years is desirable. For the long-term options these costs are included along with the investment required for PFR.
- The analysis has demonstrated the risk to critical local infrastructure (A814 and the railway line) and Argyll and Bute Council are committed to developing a proactive management plan to minimise the damage and disruption which is set to increase with sea level rise.
- There are opportunities to use NFM to supplement and increase the resilience of the defences and extend habitat, notal

Works would take into account the restrictions within the Inner Clyde SPA, in particular for wintering birds, and a Marine License will be obtained from Marine Scotland once the nature and extent of the works have been confirmed. This would also be necessary before any targeted ground investigations take place.

Sediment movement is minimal along the shoreline and therefore any works are unlikely to affect the sediment budget. However, upon finalisation of any defence works it is recommended that an assessment be included to establish any adverse effects.

Policies within the Argyll and Bute Local Development Plan will be adhered to, as recommended in the Landscape Assessment Report (**Appendix 0**), in particular *Supporting the Protection, Conservation and Enhancement of our Environment* and *Supporting the Sustainable Development of our Coastal Zone*.

Following the recommendations from the Heritage Assessment (**Appendix 0**), the Conservation Officer will be consulted regarding consent if direct impact to listed buildings is anticipated. Care will be taken to ensure the Henry Bell monument and the bust of Logie Baird remain appreciable in their setting at West Clyde Street when designing the defence structures.

A second public consultation was held to discuss the preferred option at Helensburgh Civic Centre on 25th June. The main issue was that the proposed walls were too high, which would block views of the sea for passing traffic. Feedback from this consultation is included in **Appendix M**.

6.2.2 Support for Cycle 2 investment

The practicalities and process for the funding and delivery of adaptive and staged FPS is yet to be finalised and, as such, there is uncertainty around whether the preferred option can be delivered.

From all of the individual appraisals undertaken and presented above, the results for alternative options provide further support for the investment in Helensburgh in the next funding cycle.

- PFR for 25-years alone has a BCR of 1.27 for the entire area, demonstrating the requirement for immediate management of flood risk. Removal of Craigendoran from the analysis (onset of flooding is at a much lower probability) further increases this, demonstrating the benefit can be further enhanced when it comes to deciding on the appropriate implementation. Should circumstances change

and the funding mechanism does not support an adaptive approach, it demonstrates a FPS could be promoted now.

- The BCR for upfront investment in new defences is close to 1.0 (0.86). It is likely that further refinement of the economic analysis in Cycle 2 would be able to justify the immediate case for new defences. Namely focusing on the following:
  - Additional recreational benefit from protecting the sailing club
  - Additional social benefit from increasing safety along West Clyde Street and creating additional landscaping opportunities
  - Additional tourist benefit from protecting the commercial properties on West Clyde Street and enabling economic growth
  - Wider national benefit from the protection of critical access routes to and from HMNB Faslane
- It should be noted that the economic case has been developed based on Do Minimum and the assumption that degradation of the existing frontage will not increase flood risk, should ABC continue to maintain the defences. If a Do Nothing approach was adopted it is likely that additional flood damage would be realised as defences would not function as intended. Quantifying the impact of Do Nothing for coastal sites is difficult and highly uncertain and comes with the risk of biasing the BCR based on the assumptions made.

Going ahead with PFR as part of a long-term plan will allow for the flood risk to be effectively managed in the short to medium-term and the details of direct defences be revisited in the future. Inclusion of capital investment for improvement/repair to the existing defences will put Helensburgh in a much better position when it comes to the optimisation of further defences in response to sea level rise.

It should be noted that a sensitivity test claiming 40% of the railway benefits (like the allowance of a non-strategic assessment under EA guidelines) still shows the preferred option to be cost beneficial (**BCR = 1.21**).

It is also acknowledged that the creation of new coast flood defences may potentially exacerbate surface water flood risk to properties along the front. This is particularly pertinent along West Clyde St, where issues with the sewer network are known to exist. Given that the ultimate recommendation of this report is to delay investment in new defences, and the level of complexity required to fully understand the network, no assessment of this has been conducted at this stage. However, to test the economic case, an additional cost of £1 million was added to West Clyde St for pumping requirements. This still showed the preferred option to be cost beneficial (**BCR = 1.04**).

6.2.3 Option details

The preferred option is for PFR across the whole frontage, followed by direct defences 25 years later to provide a long term solution. The PFR would provide protection up to a 0.5% AP (200-year) present day event, and properties at risk from an event of that magnitude would qualify for PFR. **Appendix O** includes onset of flooding maps for each benefit zone, outlining at which event, up to the 0.5% (200-year) event, each property is modelled as flooding, and therefore the locations of properties that would be covered by PFR.

Following a cycle of PFR, the preferred option is for the construction of new direct defences. The form of these defences varies along the frontage; these are detailed within Table 6-2. These options have been designed to the 0.5% AP (200 year) plus a climate change standard.

Within the multi-criteria analysis, natural flood management options (**Appendix E**) were dismissed as an option in their own right. However, it is recommended that the potential to incorporate localised NFM measures, such as expanding areas of existing saltmarsh, be further assessed in the future design stages.

The below provides a summary of the details of the preferred option including PV and cash costs associated with the adaptive implementation. Cost breakdowns can be described as follows:

- **Upfront Capital costs –** Cash value of the cost of implementing PFR at the start and necessary capital investment to existing defences where set-back walls are the preferred adapted option.
- **Delayed Capital Cost –** Cash value of the future costs to adapted to the preferred long-term option. Includes additional capital injection to existing defences where set-back walls are the preferred adapted option.

Table 6-2: Preferred option details

Benefit Zone	Initial option	Adapted option
Rhu	PFR – 5 properties	New sloped revetment
Sailing Club	PFR – 7 properties	New set-back walls
West Clyde St	PFR – 26 properties	New set-back walls
East Clyde St	PFR – 39 properties	New rock revetment*
Craigendoran	PFR – 9 properties	New set-back walls
* Considers 190m of set-back walls in the green open space between Lomond St and Glenfinlas St		

Table 6-3: Preferred options costs

Benefit Zone	PV Cost	Upfront Capital Cost	Delayed Capital Cost (cash)
Rhu	£575k	£64k	£831k
Sailing Club	£885k	£188k	£1,186k
West Clyde St	£2,131k	£772k	£1,657k
East Clyde St	£1,924k	£263k	£2,510k
Craigendoran	£1,350k	£394k	£1,539k
All	**£6,865k**	**£1,681k**	**£7,723k**

6.3 Environmental screening

The process of Environmental Impact Assessment (EIA) ascertains the likely significant environmental effects from a proposal. An EIA screening opinion for the preferred option will be prepared and submitted to the Argyll and Bute Council since the proposal comprises a project described in Annex II of the 2011/92/EU 'EIA' Directive - "*10(f) Inland-waterway construction not included in Annex I, canalisation and* ***flood-relief works***'

There are several sets of EIA Regulations which transpose the Directive and proposed developments should be considered in relation to the most applicable regulations. For the preferred flood protection scheme option f the Helensburgh Flood Study, the screening will be undertaken under The Flood Risk Man (Flood Protection Schemes, Potentially Vulnerable Areas and Local Plan Districts) (Scotland) Amendment Regulations 2017.

Whilst the preferred option includes works at the coast, the powers within the Marine (Scotland) Act 2010 for management of Scotland's seas extend from the Mean High Water Spring (MHWS) to the seaward limits of the Scottish territorial waters. Since, at the time of the preparation of the screening report, none of the drawings for the preferred option for each of the five areas extend beyond the MHWS, the Helensburgh Flood Study will be screened under the above EIA Regulations rather than The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017.

6.4 Key beneficiaries

The preferred option intends to provide PFR measures to all properties within the present-day 1 in 200-year flood zone, reverting to formal defences that will maintain that standard until 2118. The onset of flooding maps provided in **Appendix O** therefore highlight the individual properties along the front that are likely to benefit, with the below summarising key receptors within each benefit zone.

- **Rhu**
  - The Rhu Inn and adjacent residential properties
  - A814
- **Helensburgh Sailing Club**
  - Helensburgh Sailing Club
  - Residential properties at the junction with Rhu Road Higher, Dalmore Crescent and Cumberland Avenue
  - A814
- **West Clyde Street**
  - Commercial and residential properties between Campbell Street and James Street
  - A814
- **East Clyde Street**
  - Residential properties at the bottom of Maitland Street
  - Residential properties at the bottom of Charlotte Street
  - Commercial and residential properties at Glenfinlas Street
  - A814
- **Craigendoran**
  - Residential properties on Dennistoun Crescent
  - Railway line

6.5 Additional benefits

While the primary benefit associated with the proposed scheme is from flood protection, many secondary benefits will be realised along the frontage.

Tourism and recreation in Helensburgh are key contributors to the local economy with the proposed scheme providing valuable protection to existing businesses along the front through PFR and investment in existing defences.

By setting a design standard of 1 in 200 years, they will support development under the requirements in Scottish Planning Policy, thus supporting the possibilities for sustainable regeneration and economic growth for Helensburgh.

Appendices

Appendix A – Information Review Report

Appendix B – Survey

Appendix C – Structural Inspection Reports

Appendix D – Baseline Environmental Report

Appendix E – Baseline NFM and RBMP Report

Appendix F – Baseline Sediment Processes Report

Appendix G – Baseline GI Report

Appendix H – Baseline Landscape Report

Appendix I – Baseline Heritage Report

Appendix J – Interim Modelling Report

Appendix K – Multi-criteria Assessment

Appendix L – Engineering Drawings, Technical Notes and Designers Risk Assessment

Appendix M – Public Consultation Feedback

Appendix N – Economic Analysis

Appendix O – Onset of Flooding Maps

Appendix P – SEPA Feedback