Tarbert Flood Study

Phase 4: Options Appraisal Report

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Quality information

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Executive summary

Project Overview

Argyll and Bute Council (ABC) are investigating flood risk in the village of Tarbert as identified in the Argyll and Highland Local Flood Risk Management Plan (LFRMP). AECOM have been commissioned to undertake a Flood Study to identify current and future flood risk and identify potential flood mitigation options that may then be presented to SEPA for prioritisation for centralised Scottish Government funding.

For this study, significant work has been carried out to understand the flood mechanisms affecting Tarbert. Coastal flooding, as a result of still water levels, was found to be the main source of flooding, affecting properties along Harbour Street and Barmore Road during relatively frequent events. Predicted sea level rise as a result of climate change is expected to significantly increase flood risk in the future.

Once the baseline conditions were understood, a Long List of potential flood mitigation options was collated. An option screening process was undertaken on this Long List, assessing legal, environmental, cost and technical feasibility, to produce a short list of viable flood mitigation options. This process has been summarised in more detail in the previous Phase 3 report. Table 0-1 displays the short listed viable options.

Table 0-1: Short listed flood mitigation options

Type of Measure	Measure
Direct defences	Wall structure along harbour boundary
Direct defences	Wall structure along landward side of the promenade
Direct defences	Flip-up/demountable coastal flood wall structure
Direct defences	Combination of traditional/demountable/coping stones etc.
Direct defences	Tidal barrage structure in bay
Property Flood Protection (PFP)	Small scale property interventions
Self help	The measure would aim to improve understanding of flooding issues and how to cope better.
Flood resilience	The measure would aim to improve building resilience to flooding making clear up easier and cheaper. This could include waterproof render and lifting of electrical sockets
Land reclamation/direct defences	Infilling an area of intertidal mudflats in front of the existing harbour wall, to create more space, and to install a new flood wall to protect harbour front properties

The purpose of this report is to develop and appraise the shortlisted flood mitigation options through, concept design, costing, damages assessment and multi-criteria appraisal to consider the economic, social and environmental aspects of each option. The aim of this exercise is to comparatively evaluate the options so that the best solution can be identified for Tarbert.

It is proposed that the findings of this study be passed to SEPA for inclusion in the next round of SEPA FRM Strategies. The Strategies set out a prioritised list of actions for flood risk on a national scale, which may then be submitted for approval and funding to the Scottish Government.

Option Development

The short listed options from previous phases of this Flood Study were then developed and appraised through the following:

- Public consultation – with the local community and stakeholders to get feedback on options.

- Concept design – to develop a more detailed understanding of costs, how options would be constructed and identify opportunities and constraints.
- Costing – to determine the cost of each option. This has been considered over the whole 100-year design life (25 year for PFP) of the proposed scheme to include annual and intermittent maintenance costs.
- Damage assessment – to quantify economic benefits from the option in terms of damages avoided over the 100 year life of the scheme (25 year for PFP).
- Cost benefit – to establish the economic viability of each option
- Multi-criteria appraisal – to appraise options holistically in terms of social, economic and environmental.

The appraisal has allowed AECOM to assess the options against each other so that recommendations could be made based on the appraisal of economic, social and environmental impacts, whole life costs and consideration of risk and uncertainty, both present and future.

Recommendations

Preferred option for prioritisation

Weighing the economic and environmental considerations, the appraisal has determined that there is a viable scheme for Tarbert that should be presented for SEPA prioritisation. If successful, this will then be put forward for centralised Scottish Government funding.

Table 0-2 presents a summary of the options that are recommended to be taken forward as a preferred scheme and presented for SEPA prioritisation. Recommendation 1 is the preferred option for prioritisation, however recommendation 2 is presented as an additional viable scheme.

Table 0-2 Summary of Recommendations

Recommendation for prioritisation	Description	Costs	Damages Avoided (present value)	SoP (%AEP)	No. properties with reduced flood risk	BCR
1	**Direct defences: combination of traditional/demountable**	**£4,201,607.87**	£4,426,027.44	**0.5%+CC**	**73**	**1.05**
	Property Flood Protection: for properties not protected by direct defences	**£81,785.90**	£575,477.79	**4%**	**13**	**7.04**
2	**Property Flood Protection**	**£245,746.70**	£3,087,839.49	**4%**	**78**	**7.71**

Additional recommended flood resilience options

In addition to the preferred scheme that will be presented for SEPA prioritisation, the categories of Self Help and Flood Resilience have also been carried forward as recommendations. It is recommended that these options are taken forward by ABC with the aim of working towards educating the public and promoting Self Help and Flood Resilience within the community.

Recommendations for next steps

Should a scheme be taken forward through the SEPA prioritisation process, it is recommended to further develop flood protection options centred on the choice between direct defences, demountable defences and property flood protection. This would be done by the following:

- Carry out further, more, detailed consultation with affected residents and businesses, such as the Harbour Authority and businesses which use the quayside. Wider consultation has previously been undertaken but this would seek to converse with those properties directly affected.
- Develop details of direct defences to a size / height as determined from these consultations.
- Develop accurate cost estimates for direct defences with a view to ascertaining if a positive benefit cost ratio can be obtained for varying standards of protection.
- Consult with residents and businesses with regards to property flood protection.

Educate the public on flood risks, and promote self-help and flood resilience

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1. Introduction

1.1 Purpose of the report

Argyll and Bute Council (ABC) are investigating flood risk in the village of Tarbert. The Flood Risk Management (FRM) Act (Scotland 2009) provides the necessary statutory powers and potential funding to address this risk and also allows promoted measures to enhance the local area. AECOM was commissioned to undertake a Flood Study (FS) for Tarbert. The study will propose flood mitigation measures for coastal flooding. This will enable ABC to make an informed decision on the most economically, environmentally and socially viable options to alleviate coastal flooding in Tarbert.

At this point of the study, significant work has been carried out to understand the flood mechanisms affecting Tarbert and to identify constraints and opportunities with regard to potential coastal flood mitigation options. An option screening process has been carried out to produce a short list of options which has been summarised in more detail in the Phase 3 Report[1]. The short listed options resulting from the screening process are evaluated in more detail in this report.

The purpose of this report is to develop and appraise the shortlisted options through, concept design, costing, damages assessment and multi-criteria appraisal to consider economic, social and environmental aspects of each option. The aim of this exercise is to comparatively evaluate the options so that the preferred solution can be identified. The scope of this report includes:

- Summarising the process to date
- Concept design of short listed mitigation options
- Costing of short list options
- Economic, Social and Environmental Appraisal of the short list options
- Prioritise list of mitigation options
- Next steps

1.2 The process

The project is being carried out in a phased approach in line with Scottish Environment Protection Agency (SEPA) and Scottish Government Guidance[2][3]. **Figure 1.1** provides a high level overview of the study development process.

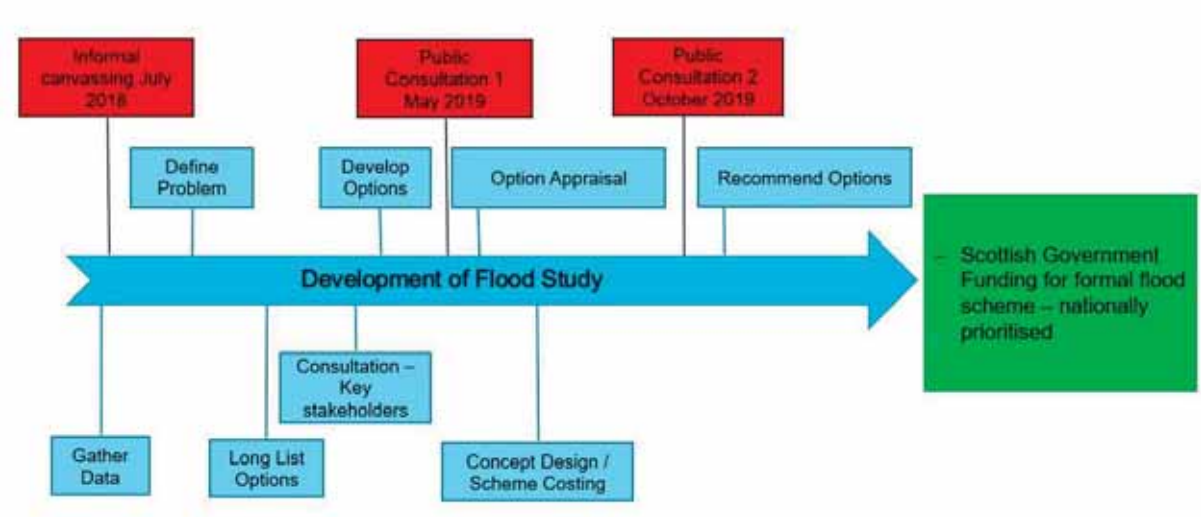


Figure 1-1 The study process

[1] *Tarbert Flood Study; Phase 3 - Options Screening Report*, AECOM, April 2019.
[2] *Options appraisal for flood risk management: Guidance to support SEPA and the responsible authorities*, Scottish Government, May 2016.
[3] *Local Authority flood study checklist, Version 2*, SEPA, June 2017.

Significant work has been carried out to understand the flood sources and mechanisms affecting Tarbert. During Phase 1 the existing available information was collated and a gap analysis undertaken to determine the quality of the data and what additional information was needed in order to undertake the assessment of flood risk.

The flood mechanisms and extents currently experienced in Tarbert were confirmed in Phase 2. Flooding from coastal sources were assessed through long-term wave transformation modelling, joint probability and wave overtopping analysis, and direct inundation form the sea during an extreme tide.

At the request of ABC, a further high-level culvert capacity assessment was undertaken in conjunction with this Flood Study, looking into flood risk from fluvial sourced. This looked at the flood risk associated with blockage or overwhelming of the culverts which carry the small burns through the town, discharging to the harbour through the harbour wall. The outcome of this assessment was not included in the reporting as it was out with the original scope. A separate technical note was produced setting out the analysis and concluding that a reasonable standard of service was provided but that they should be regularly re-evaluated.

At the start of the flood study process a public canvassing event was carried out with the residents of Tarbert, to understand their experience of flooding in the area and to identify flood hotspots. This information was then be used to sense check modelled outputs. Further public consultation was held during Phase 3 to present the findings of the long list to short list process to the community, where feedback and comments were gathered on the options identified to manage the coastal flood risk. Consultation was a key part of the Phase 3 process. As well as public consultation, statutory stakeholders such as ABC, Tarbert Harbour Authority, SEPA, and Scottish Water were involved through technical workshops

The study is currently at Phase 4; where the drivers of flooding and the scale of the problem are understood and short listed options to mitigate coastal flood risk have been proposed. The process of determining the short list has been informed by feasibility screening assessments and ecological, environmental and planning desk studies to identify constraints and opportunities for flood alleviation options.

The Scottish Government Guidance on Options Appraisal for Flood Risk Management sets out a clear approach to identify and prioritise mitigation measures. The following steps are highlighted:

- Define the purpose of the appraisal and set objectives.
- Identify “long list” of potential flood measures
- Screen to create a “short list” of flood measures
- High level appraisal of short listed flood measures

ABC and AECOM have adopted this approach for Phase 4 of this study. A short list of the most feasible and beneficial options were determined in Phase 3 and will be further assessed during this phase of the study. The short list of options will be further developed through high level design and cost benefit appraisal. The way forward will then be dependent on the option recommendations. If a formal scheme is determined to be the best option, the findings of this study would be passed to SEPA for inclusion in the next round of SEPA FRM Strategies. The Strategies set out a prioritised list of actions for flood risk on a national scale.

2. Baseline Modelling Results – Summary

Tarbert is located in a Potentially Vulnerable Area that has been identified as being primarily at risk from coastal flooding.

Flood mitigation options outlined in the Phase 3 appraisal process focused on coastal flooding only. Phase 4 looks at the whole life cost and damages of the Phase 3 shortlisted options.

2.1 Coastal flooding

Phase 3 established that the main source of flood risk is direct inundation from the tide. The coastal modelling carried out in Phase 3 modelled the nearshore extreme wave characteristics along the frontage at Tarbert. A numerical modelling study was undertaken to investigate the existing and future (up to the year 2100) wave climate. The information on wave conditions and extreme sea levels was used to assess wave overtopping volumes and to generate inundation mapping.

A regional wave model was run to establish the offshore wave heights at Tarbert, under present day conditions. The regional modelling results show that the wave climate at the entrance to East Loch Tarbert is generally small; however, maximum significant wave heights of 2.77 m are predicted over a period of 38 years; the data period available from the Met Office. An extremes analysis of wave heights shows that for present day conditions a significant wave height of 2.0 m could be expected for a 1% AEP (1 in 100 year) event.

A local wave model of Tarbert Harbour was constructed under both a present day and with climate change for the 2100 epoch using boundary conditions established in the regional model. The local wave model was used to consider the wave heights within Tarbert bay at a much higher resolution. The findings from the local model for the present-day scenario show that wave conditions within Tarbert bay are negligible, with a 1% AEP (1 in 100 year) event producing wave heights in the region of 0.4m. The small waves are attributed to the shallow bathymetry and island structures in the harbour.

Due to the small wave heights, wave overtopping is not considered a significant issue. Increases in still water levels, as predicted in climate change scenarios, represent the greatest source of flooding to the lower lying areas surrounding the harbour. Therefore, when developing shortlisted options extreme still water levels are used to inform the design.

In the current day scenario tidal flooding is seen to affect areas around the harbour wall and seafront from the 50% AEP event. As event magnitude increases, sections of Harbour Street, Barmore Road, Brunswick Street and Cambeltown Road, as well as the docking areas, all become inundated. Areas to the north of Pier Road around the ferry terminal are also seen to be at flood risk. The 0.5 % AEP (1 in 200 year) + climate change flood outline for Tarbert is shown in **Figure 2-1** below.

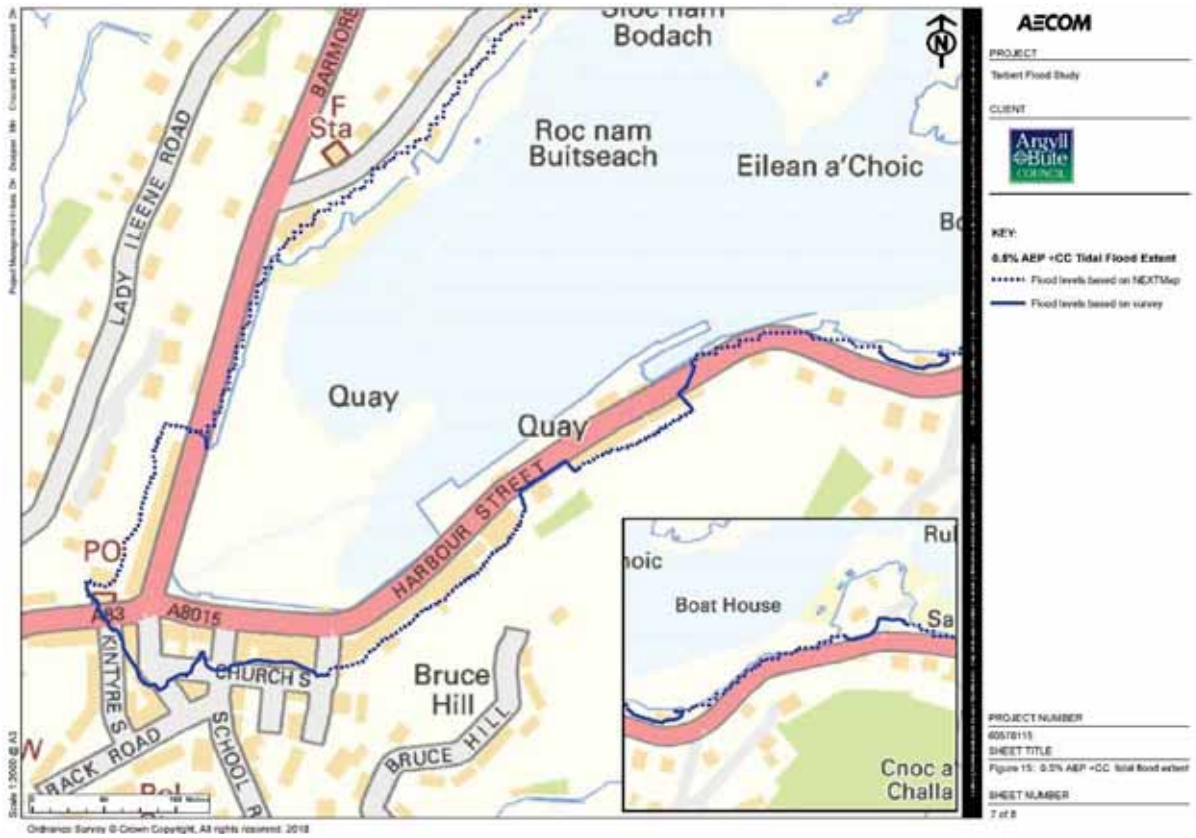


Figure 2-1: Baseline 0.5% AEP + climate change flood extents from Tarbert coastal modelling

During the climate change scenario, many of the same areas are affected that were in the current day scenario albeit more frequently. Due to the increase in sea levels of approximately 600mm, the current day 0.5% AEP event (a rare event) is seen to correspond to a 10% AEP event in 2100 meaning that the frequency of disruptive flooding will increase considerably in the future. Extreme water levels in Tarbert for varying AEP events (both present day and predicted 2100 levels) are shown in **Table 2-1** below.

The present day extreme water levels are factored with UKCP09 95th percentile high emission scenario (including surge) sea level rise projections. The UKCP18 data was not available and SEPA had not issued any guidance on the use of these updated projections at the time of writing.

Table 2-1: Coastal Flood Boundary extreme water levels

% Annual Exceedance Probability (return Period)	Present Day (2018) Level m AOD	Future (2100) High Emission Level m AOD
50 (2)	2.86	3.47
20 (5)	3.03	3.65
10 (10)	3.16	3.78
5 (20)	3.31	3.94
2 (50)	3.48	4.11
1 (100)	3.62	4.26
0.5 (200)	3.77	4.41
0.1 (1000)	4.13	4.78

3. Short Listing Process

Following baseline modelling and flood inundation mapping, option screening was carried out based on guidance in the Flood Risk Management (Scotland) Act 2009. An initial long list of all possible flood protection options was developed through an internal workshop with ABC. The long list of options was then screened for technical, financial, legal and environmental feasibility.

The full Long List to Short List screening process is detailed in 'The Tarbert Flood Study Options Screening Report' (Phase 3). The report outlines our initial long list of flood mitigation options and summarises the short list process which was informed by the following inputs:

- External workshops with ABC and statutory stakeholders such as SEPA and Tarbert Harbour Authority to integrate their feedback to shortlisting process
- Public consultation event to gain feedback on options and factor this into appraisal
- Preliminary Ecological Appraisal to identify constraints to further inform appraisal

These inputs were layered up to either include or discount options based on their feasibility and produced the short list which is set out in **Table 3-1**.

Table 3-1 Short List Options

Type of Measure	ID	Flood receptor (location)	Measure
Direct defences	2.1	Low lying property on Barmore Road, Harbour Street and the quay and ferry terminal	Wall structure along harbour boundary
Direct defences	2.2	Low lying property on Barmore Road, Harbour Street and the quay and ferry terminal	Wall structure along landward side of the promenade
Direct defences	2.3	Low lying property on Barmore Road, Harbour Street, the quay and ferry terminal	Flip-up/demountable coastal flood wall structure
Direct defences	2.4	Low lying property on Barmore Road, Harbour Street, the quay and ferry terminal	Combination of traditional/demountable/coping stones etc.
Direct defences	2.5	Entire harbour area	Tidal barrage structure in bay
Property Flood Protection (PFP)	3.1	Address flooding caused by extreme water levels on Barmore Road, Harbour Street and the quay.	Small scale property interventions
Self help	6.1	All affected properties in Tarbert.	The measure would aim to improve understanding of flooding issues and how to cope better.
Flood resilience	8.1	All affected properties in Tarbert.	The measure would aim to improve building resilience to flooding making clear up easier and cheaper. This could include waterproof render and lifting of electrical sockets
Land reclamation/direct defences	10.1	Address flooding caused by extreme water levels on Barmore Road, Harbour Street and the quay. The ferry port could also be protected by traditional defences	Infilling an area of intertidal mudflats in front of the existing harbour wall, to create more space, and to install a new flood wall to protect harbour front properties

4. Refining Options

The shortlisted options provided an overview of the type of option and its indicative location. The next stage was to refine these measures to specific locations and details.

The final list of flood protection options is shown in **Table 4-1**.

The additional categories of Self Help and Flood Resilience will also be carried forward to the scheme recommendations. These options will not form part of a formal scheme but will provide general recommendations that can be undertaken in combination with the preferred scheme design to further increase resilience and awareness.

Table 4-1 Options and associated measures

Option No.	Description	Flood cell	Description of Measures
2.1	Direct defences: Existing defence line wall	1	Coastal wall along existing harbour wall on Barmore Road and Harbour Street. Coastal wall along landward side of harbour promenade. Runs along the south side of the harbour buildings Three pedestrian flood gates (at existing slipways on Barmore Road, west side of Harbour Street and west side of Harbour). Two vehicle flood gates (at south side of harbour).
2.2	Direct defences: Set back wall	1	Coastal wall set back from existing defence line on Barmore Road and Harbour Street. Set back to follow kerb line on the harbour side of both roads. Coastal wall along landward side of harbour promenade. Runs along the south side of the harbour buildings. Three pedestrian flood gates (at existing slipways on Barmore Road, west side of Harbour Street and at entrance to Earra Gael bar). Two vehicle flood gates (both at south side of harbour).
2.3	Direct defences: Flip up/demountable coastal flood wall	1	Demountable coastal wall set back from existing defence line on Barmore Road and Harbour Street. Set back to follow kerb line on the harbour side of both roads; same alignment as option 2.2. No flood gates. Demountable defences are a simple stoplog type, stored locally on site, with mounting frames pre-installed.
2.4	Direct defences: Combination of traditional/demoun table	1	Coastal wall with demountable upper part, set back from existing defence line on Barmore Road and Harbour Street. Set back to follow kerb line on the harbour side of both roads; same alignment as option 2.2. Demountable defences are a simple stoplog type, stored locally on site, with mounting frames pre-installed. Three pedestrian flood gates (at existing slipways on Barmore Road, west side of Harbour Street and at entrance to Earra Gael bar). Two vehicle flood gates (both at south side of harbour).
2.5	Direct defences: Tidal Barrage	1-5	Two tidal barrage structures;

Option No.	Description	Flood cell	Description of Measures
			A revetment structure with no opening, from a peninsula (North East of Tarbert) to Eilean a' Choic And a wall structure with gated opening, from Eilean a' Choic to the Tarbert Ferry Terminal 10m wide vertical sector gate opening to allow marine access to the harbour
3.1	PFP	1-7	Measures for protecting individual buildings from flooding, by blocking flow entry routes through openings/defects in the building Various measures are available; airbrick covers, flood proof doors/screens, waterproof sealant etc. Each PFP candidate property should be assessed further, to determine the most beneficial measure (or combination of measures) for each property
10.1	Land reclamation and direct defences	1	Land reclamation area over intertidal mudflats between slipway on Barmore Road and the most south-westerly point of the harbour. Reclaimed land set level with existing harbour wall. Coastal wall along sea-front of reclaimed land, creating potential for amenity behind on new land. Coastal wall along landward side of harbour running along the south side of the harbour buildings. Two vehicle flood gates (both at south side of harbour).

5. Modelling and Development of Short-Listed Options

5.1 Modelling of coastal flooding options

Hydraulic modelling of the shortlisted options has not been undertaken because, wave overtopping from flood events below the design level is taken to be negligible because of the small wave heights, and flood events in excess of the design event are assumed to fully inundate the area behind the defence. The design of the coastal defences is simply set against the predicted tide and wave level.

No breakdown of how varying Standards of Protection (SoP) impact damages or residuals has been carried out. A change in the design flood and defence height (standard of protection) is expected to give a relatively small change in the cost of the defence given a significant proportion of the cost is associated with the foundations and ground works rather than the height of the wall. However, were any options deemed worthy of being taken forward for detailed consideration, then the SoP could be investigated further to achieve the most viable option.

5.2 Design defence level and standard of protection

The main purpose of the coastal flooding defence is to protect properties within the town, both residential and commercial. Direct defences up to approximately 2.0m high would be required to protect Tarbert and all properties along the A83 and A8015 to a 0.5% AEP (1 in 200 year) + climate change event. This defence height would allow for 0.2m freeboard; the actual defence height could change slightly depending on the freeboard applied. The highest defences are required in the centre of the town near the Barmore Road and Harbour Street junction.

Freeboard is the difference between design flood level and flood defence height; this is to accommodate waves and a factor of safety against general uncertainties in the determination of the design flood level.

Direct defences to a 0.5% AEP + climate change standard would provide protection to 78 properties. However, the defence heights would create significant negative visual impact.

Because Tarbert harbour and East Loch Fyne are very sheltered from the open sea and estimated wave heights concurrent with extreme tides are very low it is expected that wave overtopping of any sea defence will be small to negligible and a suitably low freeboard can be applied. For the purpose of this flood study the flood defences are based on applying a freeboard allowance of 0.2m on top of the maximum still-water flood level. It has been applied for simplicity and does not materially influence the appraisal of the options. The actual freeboard applied to the final defence design should a scheme go ahead should be chosen specifically for the wall type and location against a determination of tolerable wave overtopping.

Indicative sections of the defences were drawn against the 0.5% AEP (1 in 200 year) + climate change event and the different extreme flood levels shown alongside to gain an understanding of the SoP that varying wall heights could provide to the properties at risk.

Although flood embankments are often preferable as defences in terms of cost, the required physical space based on the heights of defence required is not available. A minimum footprint of 12m width is considered necessary for a sea defence embankment of this height: 2.0m crest width, with 4.0m wide shoulders either side. This space is unavailable given the proximity of the A83 and A8015 to the sea front. Therefore, flood walls are more appropriate to provide direct defence in Tarbert. Flood walls are therefore considered for all direct defence options below (except for ‘Option 2.5 – direct defences: tidal barrage’ as this would be built in the bay).

Projected increase in extreme sea levels caused by climate change has a considerable influence on the SoP over the lifespan of the defence. In general, the difference between extreme flood levels is relatively small, the variation in defence level between a 5% AEP (1 in 20 year) event and 0.5% AEP (1 in 200 year) event is 460mm. Therefore, a small reduction in the defence height has a significant influence on the SoP provided. Irrespective of the defence level, the SoP provided is expected to reduce considerably as higher tide levels become more frequent by the influence of climate change over the next century.

Reducing the height of defences to a lower design SoP should be explored further to determine if a significant reduction in costs is achievable which would make the option more economically viable, as well as reducing the potential visual impact of defences.

Because of the topography at either end of the harbour, the length of required flood-wall barely changes with design flood level and standard of protection (SoP). The overall length of flood-wall varies more with the chosen alignment.

5.3 Option 2.1 - direct defences: existing defence line wall

Direct defences on the existing sea wall would require to extend along the existing sea wall parallel to the A83 (Barmore Road) from high ground near the marina and extending along the A8015 (Harbour Street) to just east of the Harbour. This requires a total length of up to approximately 560m of direct defence flood-wall.

It is estimated that approximately 30m of flood gates would be required to provide access to slipways and to provide vehicle access to the quayside and harbour; 3 No. pedestrian gates and 2 No. vehicle gates. The location of wall and gates can be seen in Figure 5-1. For detailed plan and indicative section, refer to sheet number '**60578815_SHT_20_G_OP2.1-A'** in Appendix A- Option Plans and Indicative Sections.

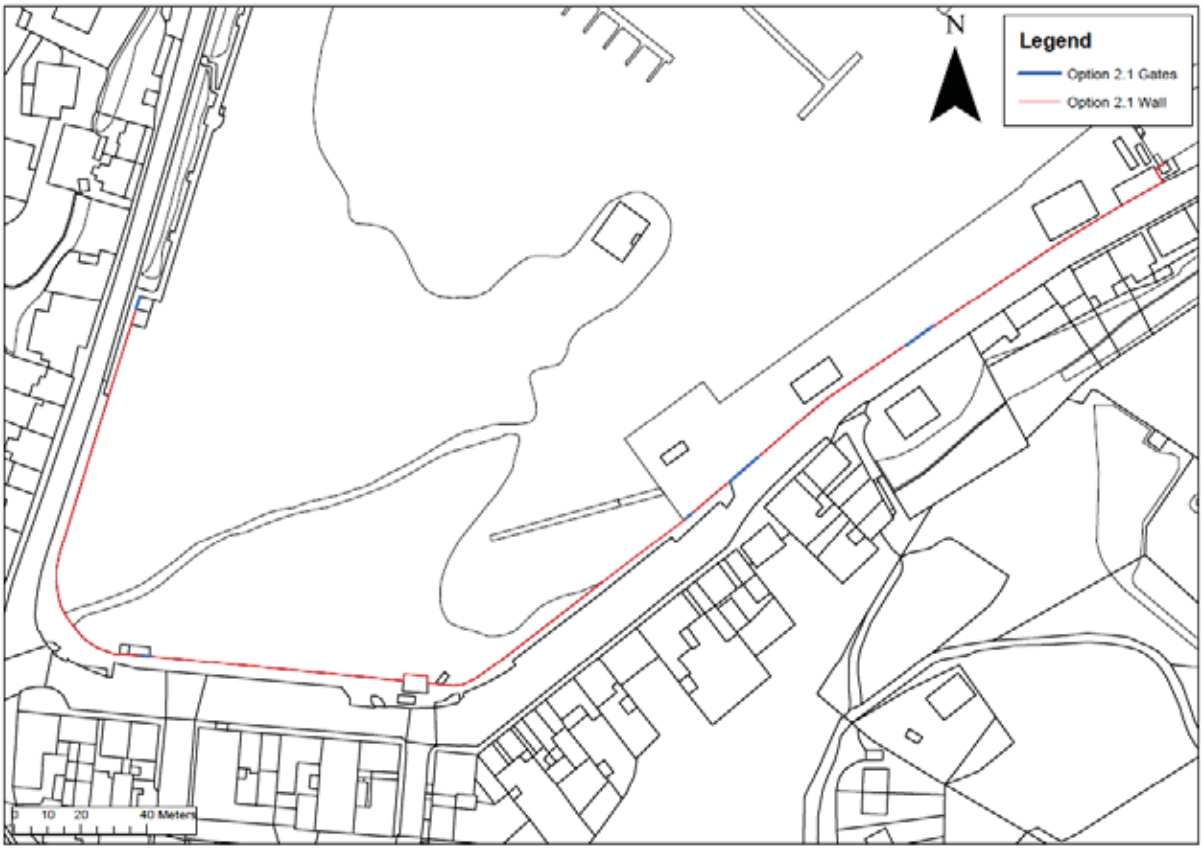


Figure 5-1: Option 2.1: Direct defences on existing harbour wall

The defence height required would have significant influence on the appearance of Tarbert and may cause extremely adverse visual impact.

Reducing or increasing the SoP the defence provides should be explored during the outline design stage if the scheme is taken forward. At outline design stage, more detailed cost estimates will be undertaken, and hence a range of SoP's could be considered to determine the most viable defence height in terms of economic benefit. No breakdown of how varying Standards of Protection (SoP) impact damages or residuals has been carried out at this stage

Direct defences could provide protection for up to 78 properties, residential and commercial, for the 1 in 200 year SoP.

5.4 Option 2.2 - direct defences: set back wall

Direct defences set back from the existing sea wall would require tying in with high ground parallel to the A83 (Barmore Road) from near the marina and extending along the A8015 (Harbour Street) to just east of the Harbour. The alignment shown adds up to approximately 515m length of defence.

It is estimated that approximately 30m of flood gates would be required to provide access to slipways and to provide vehicle access to the landward side of the harbour; 3 No. pedestrian gates and 2 No. vehicle gates. The location of wall and gates can be seen in **Figure 5-2**. For detailed plan and indicative section, refer to sheet number '**60578815_SHT_20_G_OP2.2-A'** in Appendix A- Option Plans and Indicative Sections.

Figure 5-2 Option 2.2: Direct defence set back from existing harbour wall

The defence height required would be slightly lower than Option 2.1 because the flood wall would be located on slightly higher ground set back from the top of harbour wall. However, the chosen defence height will still have significant influence on the appearance of Tarbert and may cause extremely adverse visual impact.

Reducing or increasing the SoP the defence provides should be explored during the outline design stage if the scheme is taken forward. At outline design stage, more detailed cost estimates will be undertaken, and hence a range of SoP's could be considered to determine the most viable defence height in terms of economic benefit. No breakdown of how varying Standards of Protection (SoP) impact damages or residuals has been carried out at this stage.

Direct defences could provide protection for up to 73 properties, residential and commercial, for the 1 in 200 year SoP.

5.5 Option 2.3 - direct defences: demountable coastal flood wall

It is considered than demountable sea defences would be better suited set back from the top of the harbour wall, this allows access to both sides of the defence for easier construction and installation. Demountable defences are taken to be simple stop-log type structures which are manually installed before a flood event.

Direct defences set back from the existing sea wall would require tying in with high ground parallel to the A83 (Barmore Road) from near the marina and extending along the A8015 (Harbour Street) to just east of the Harbour, approximately 515m length of defence.

No flood gates would be required as demountable defences are not a permanent feature. They will be stored locally and erected during times of expected flood events. The location of wall can be seen in **Figure 5-3**. For detailed plan and indicative section, refer to sheet number '**60578815_SHT_20_G_OP2.3-A'** in Appendix A- Option Plans and Indicative Sections.

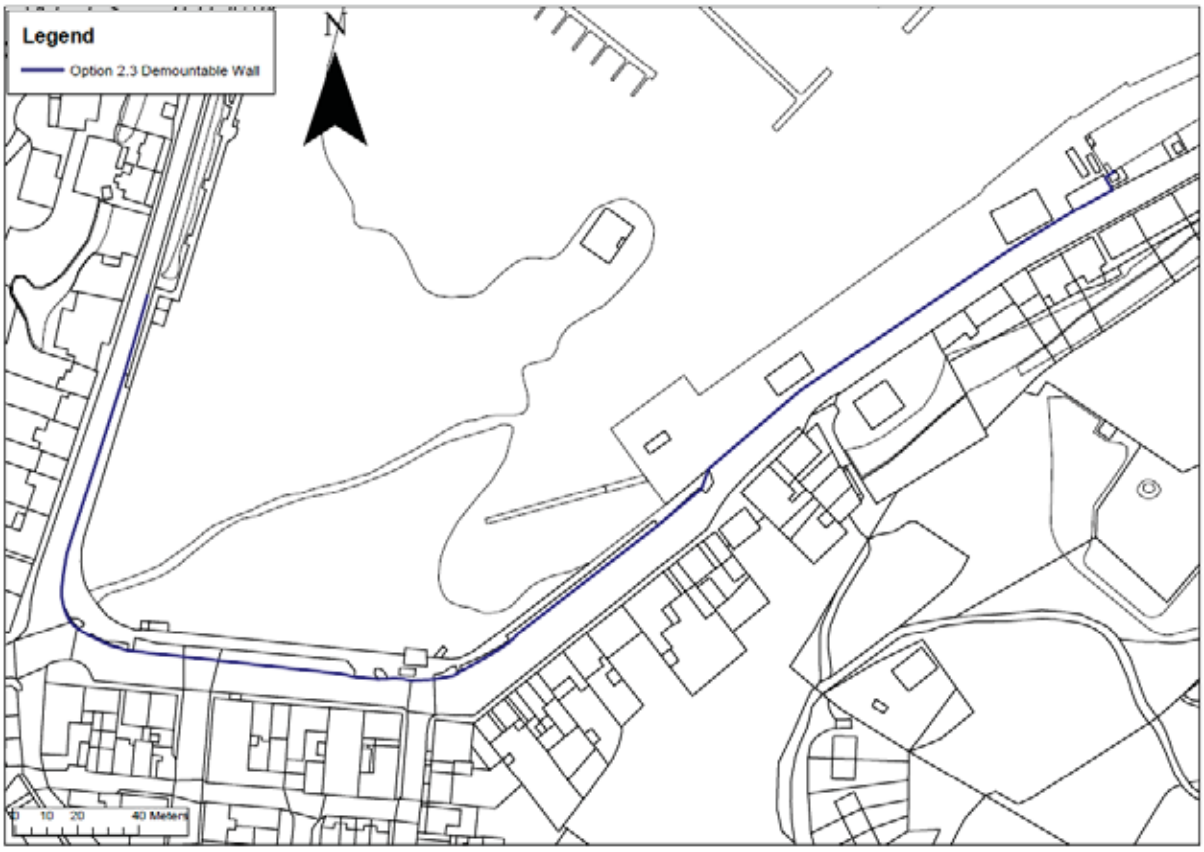


Figure 5-3 Option 2.3: Demountable direct defence set back from existing harbour wall

The defence heights required could cause extremely adverse visual impact. However, demountable defences would lower visual impact, as they are only in place during predicted high sea levels.

Reducing or increasing the SoP the defence provides should be explored during outline design stage if the scheme is taken forward. At outline design, more detailed cost estimates will be undertaken, and hence a range of SoP's could be considered to determine the most viable defence height in terms of economic benefit. No breakdown of how varying Standards of Protection (SoP) impact damages or residuals has been carried out at this stage.

The demountable defences considered in this option are simple frame and barrier structures, similar in concept to a series of stoplogs, which are manually mounted and demounted from permanent footings. However, upon consultation with ABC, the need to install 500m of demountable barrier would require significant staffing resources for each flood warning and hence would present considerable resourcing and logistical challenges. It is considered unlikely that installation would be achievable. Automatic barriers are considerably more expensive. Initial discussion with suppliers suggest the cost for a fully automated, powered, tilting flood-barrier could cost as much as ten times the cost estimated

for a manual installation barrier. High maintenance costs are also likely due to the aggressive coastal environment.

Direct defences could provide protection for up to 73 properties, residential and commercial, for the 1 in 200 year SoP.

5.6 Option 2.4 - direct defences: combination of traditional/demountable

This option would entail a lower lying permanent wall, with the ability to erect demountables if a larger event was forecast.

Direct defences set back from the existing sea wall would require tying in with high ground parallel to the A83 (Barmore Road) from near the marina and extending along the A8015 (Harbour Street) to just east of the Harbour, approximately 515m of defence.

It is estimated that approximately 30m of flood gates would be required to provide access to slipways and to provide vehicle access to the landward side of the harbour; 3 No. pedestrian gates and 2 No. vehicle gates. The location of wall and gates can be seen in **Figure 5-4**. For detailed plan and indicative section, refer to sheet number '**60578815_SHT_20_G_OP2.4-A'** in Appendix A- Option Plans and Indicative Sections.

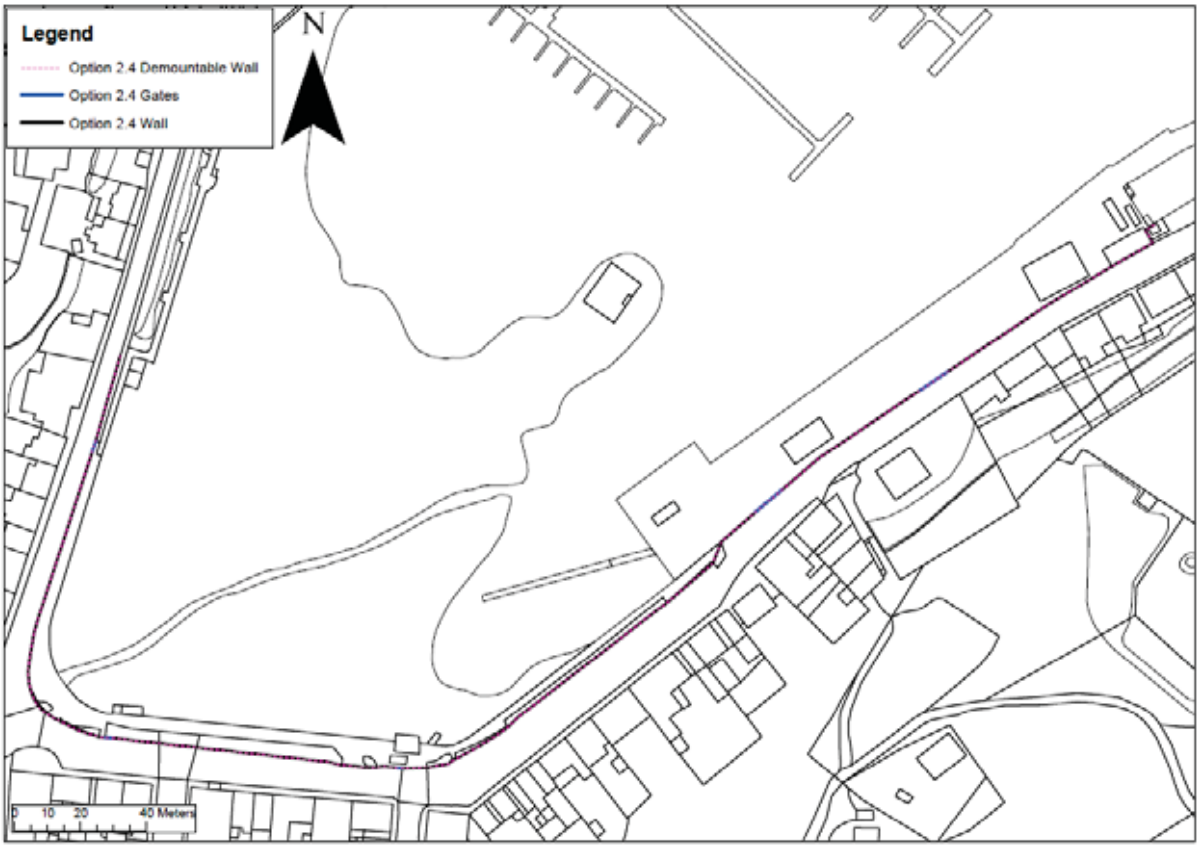


Figure 5-4 Option 2.4: Direct defence set back from existing harbour wall. Combination of permanent and demountable defences

The combination of permanent and demountable defences is considered to lessen the visual impact. Demountable direct defences would provide additional defence height to the permanent coastal wall, without restricting views for the majority of the time. They would be stored locally and erected during times of expected extreme flood events.

Reducing or increasing the SoP the defence provides should be explored during the outline design stage if the scheme is taken forward. At outline design stage, more detailed cost estimates will be undertaken, and hence a range of SoP's could be considered to determine the most viable defence height in terms of economic benefit. No breakdown of how varying Standards of Protection (SoP) impact damages or residuals has been carried out at this stage.

Direct defences could provide protection for up to 73 properties, residential and commercial, for the 1 in 200 year SoP.

5.7 Option 2.5 – direct defences: tidal barrage

This option would entail direct defences that form a barrier into the bay to protect the entire harbour area from extreme water levels. The barrage would be split into two structures, a northern and southern structure. The northern structure would consist of an approximately 80m long revetment with no opening. The structure would run from a peninsula to the north-east of Tarbert, to the Eilean a' Choic island. The southern structure would consist of an approximately 105m long wall with gated opening. It would run from Eilean a' Choic island to just west of the Tarbert Ferry Terminal.

It is estimated that as a minimum, an approximately 20m wide vertical sector flood gate would be required to provide access for boats entering the harbour and marina. The locations of the barrage structures can be seen in **Figure 5-5**. For detailed plan and indicative section, refer to sheet number '**60578815_SHT_20_G_OP2.5-A'** in Appendix A- Option Plans and Indicative Sections.

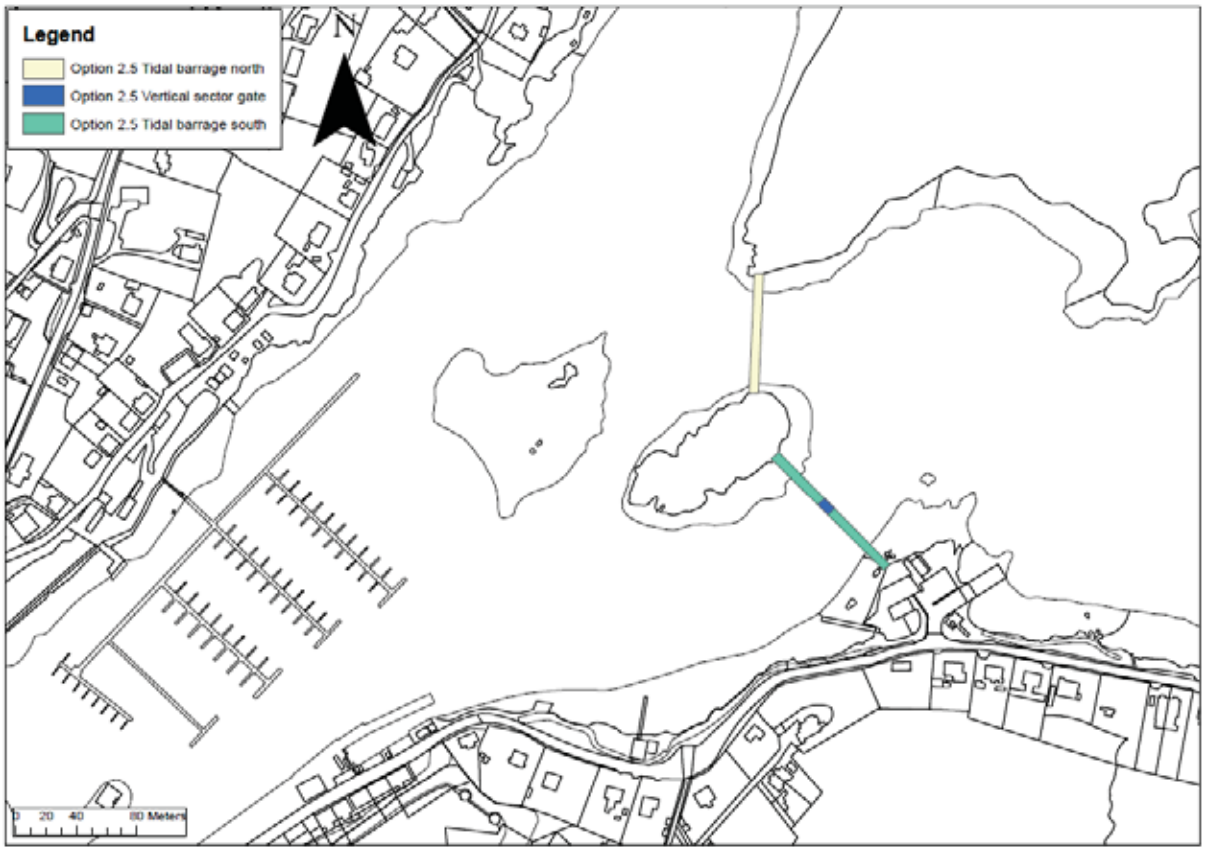


Figure 5-5 Option 2.5: Tidal barrage direct defence to protect whole harbour area

The cost and complexity of these engineering works required merit a high SoP. Reducing the SoP of the defence is unlikely to prove beneficial in terms of economic benefit.

Permanent direct defences from a tidal barrage would provide 1 in 200 year + climate change SoP to 91 properties, for the 1 in 200 year SoP.

5.8 Option 3.1 - property flood protection (PFP)

Property Flood Protection (PFP) are measures for protecting individual buildings from flooding, focusing on blocking flow entry routes into the building through things like air bricks, doorways, drainage pipes, defects in building fabric and building foundations / subsoil. In cases where a formal flood protection scheme may not be viable, a strategy of resilience to targeted properties affected by flood depths which are optimal for PFP measures may offer more benefit in comparison to a capital scheme.

This measure has not been modelled but has been taken into account in the economic damages assessment by removing damages up to an assumed effective level.

Property Flood Protection includes measures such as:

- Airbrick covers to prevent ingress into the solum.
- Flood-proof doors to prevent water ingress to the property when water levels exceed the floor level.
- Flood-proof door screen adjacent to door where door opening is wider than single door width.
- Flexible waterproof sealant around cables / pipes to seal holes created for pipes and cables entering the building.
- Automatic non-return valves on drainage pipes entering the building. These reduce the risk of internal flooding should the sewer network become surcharged.
- Non-return valve on boiler pressure release pipe / drain pipe. Although there is expected to be an internal valve on this pipe.
- Facade repairs to minimise water ingress through defects.
- Sealing of cracks in render to minimise water ingress through cracks.
- Over-render - new layer of external render over full property facade.
- Sump pump to drain the solum should water enter. This is the only measure listed which addresses the potential for flood water to flow through the ground and into the solum.

Depths of flooding below 0.6m is generally considered to be the limit of operation for PFP. Above this depth, seepage is likely to occur and above 1m it is generally accepted that the structural integrity of buildings can be affected, and it is thereafter better to allow inundation of the property to allow water levels to equilibrate.

The protection provided by a single PFP installation will vary from property to property depending on the level it is installed at. Where there is a block of properties, the whole block has been assumed to require PFP measures to block flood entry routes. For the purpose of simplicity, it is assumed that a total of 78 properties (**Figure 5-6**) could be protected from internal flooding up to a 4.0% AEP (1 in 25 year event). When considering climate change uplifts, this is equivalent to protecting up to a 50% AEP + CC event.

Given that flood risk to Tarbert is coastal, and flood warning is expected in advance of such events, it is considered that flood resistance can be achieved through features such as flood doors, airbrick covers, etc. ABC's preference is to use passive automated systems where possible, as the risk of defences not being deployed is reduced. These are lower cost than fully automated systems, and do not require power to activate the mechanism.

The impact of this measure has been assessed by removing damages associated with flooding up to the 4.0% AEP event. This simple assessment assumes that if floodwater cannot enter property there will be no damages associated. It should be noted that additional work would be required to specify PFP for each property, including property surveys, as it is likely a bespoke approach will be required for each property.

The benefit of PFP is measured over a 25 year period; the expected lifespan of the installed products. It must be noted that manufacturers' stated service lives for protection measures is typically of the order of 20-30 years, however poor maintenance and inappropriate storage can significantly reduce

these timescales. It is therefore essential that education is undertaken to achieve optimal performance from PFP.

Another challenge to this measure is how this is implemented from a legal standpoint in terms of ownership, purchase, and maintenance of the equipment. This measure would require significant community engagement and communication. However, based on the economics this option could offer a significant improvement in flood damages in Tarbert.

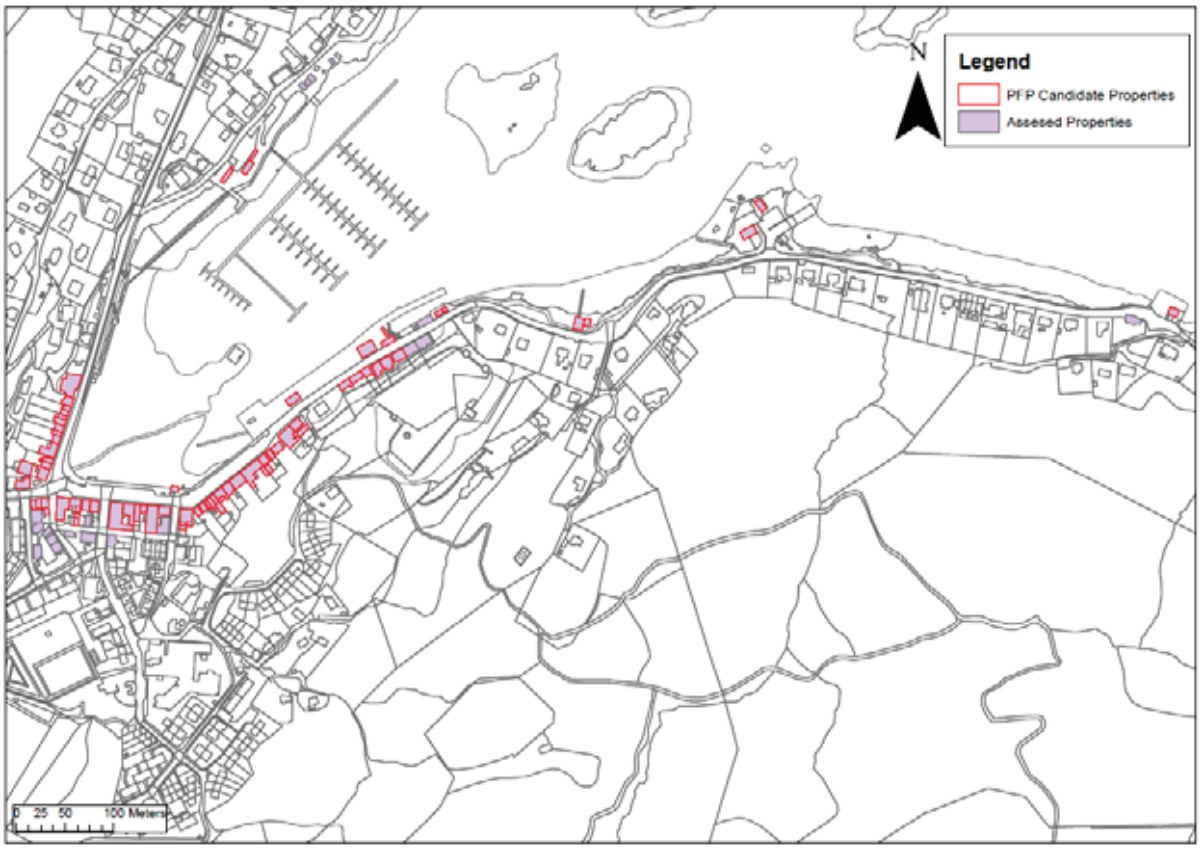


Figure 5-6 PFP locations: 78 Properties protected to 1 in 20 year event

It should be noted that for this stage of the appraisal of options PFP is considered appropriate and effective for all properties; understandably this assumption may not prove correct for all. Because the estimated cost of PFP is relatively inexpensive in all but the lowest damages, minor flooding in rare events, a positive benefit cost benefit ratio would be expected.

Where formal flood defences do not protect all properties at risk, it is considered appropriate to look into how PFP may help those outside the protected area. This is recommended but not explored in any detail and the cost of interventions and the flood damages avoided are not included in formal flood options. The incidental cost, and cost-benefit, of this PFP is not considered to be a determining factor in the comparison of options. The cost, and associated BCR, of providing PFP for properties not covered by the preferred flood protection option was latterly included for this option only in order to derive a more comprehensive assessment of this option.

5.9 Option 10.1 – land reclamation and direct defences

Direct defences set in front of the existing sea wall on reclaimed land is considered by request from ABC. For an outline option, approximately 7750 m^3 of fill over an approximate area of 2800m^2 would be required, tying in with high ground parallel to the A83 (Barmore Road). The wall would run along the coastal side of the reclaimed land before re-joining existing ground just south-west of the harbour. It would then run along the landward side of the harbour, as in Option 2.2. This adds up to approximately 480m of defence.

It is estimated that approximately 20m of flood gates would be required to provide vehicle access to the landward side of the harbour; 3 No. pedestrian gates and 1 No. vehicle gate. The location of the reclaimed land, wall and gates can be seen in **Figure 5-7**. For detailed plan and indicative section, refer to sheet number '**60578815_SHT_20_G_OP10.1-A'** in Appendix A- Option Plans and Indicative Sections.

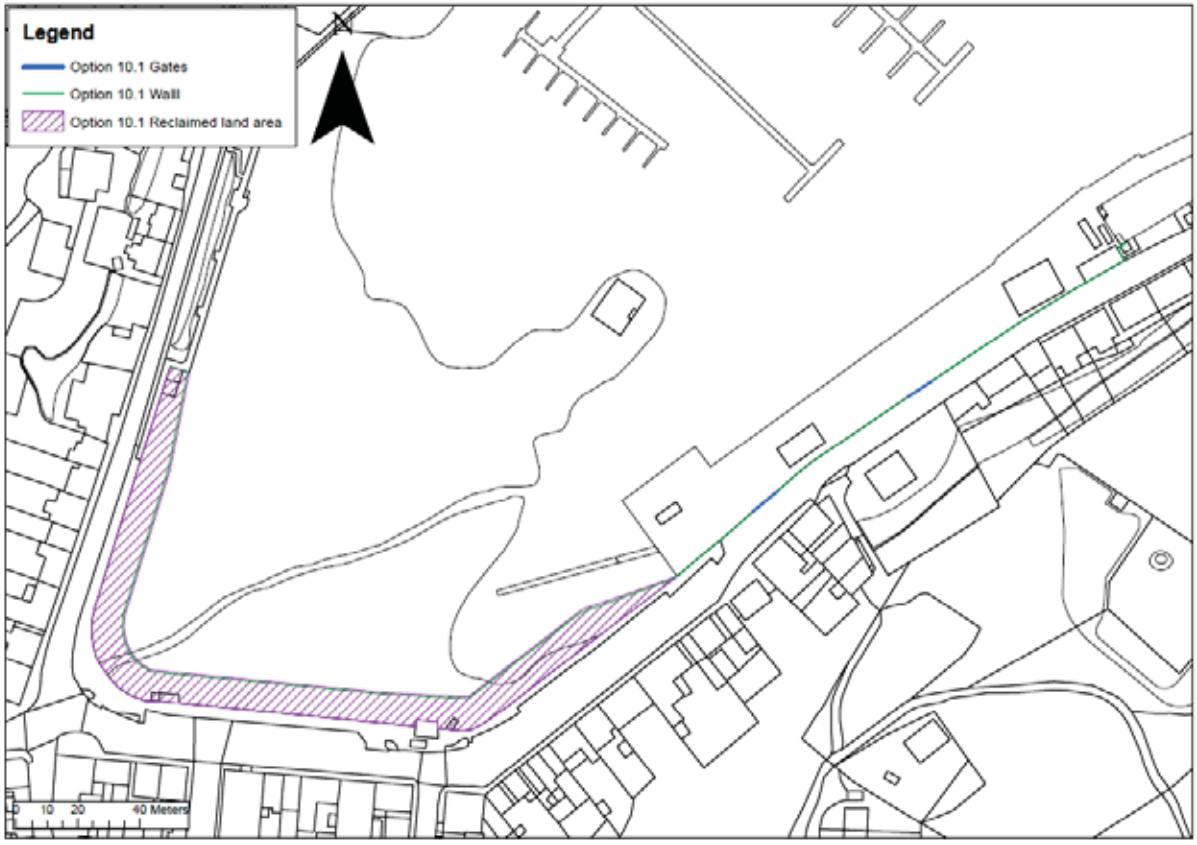


Figure 5-7 Option 10.1: Land reclamation and direct defence. Defence wall runs along the coastal side of reclaimed land, and landward side of harbour

These defences could still cause extremely adverse visual impact; this is somewhat offset by the land area which could be used to increase amenity in the area. However, the amount of fill required for the reclaimed land area is substantial and will incur significant cost.

There is a great deal of variability inherent in this option and many variations on the extent, width, and position of the flood-wall and below ground cut-off are possible. The arrangement shown is considered indicative of the concept.

Reducing or increasing the SoP the defence provides should be explored during the outline design stage if the scheme is taken forward. At outline design stage, more detailed cost estimates will be undertaken, and hence a range of SoP's could be considered to determine the most viable defence height in terms of economic benefit. No breakdown of how varying Standards of Protection (SoP) impact damages or residuals has been carried out at this stage as it is out with the scope of this feasibility study.

Direct defences could provide protection for up to 74 properties, residential and commercial.

6. Economic Appraisal

The economic appraisal has been used to assess the monetised benefits of each option as flood damages avoided over the appraisal period. In addition to a purely economic appraisal, the social and environmental benefits for each option will also be reviewed on a qualitative basis. The economic appraisal has been carried out over a 100 year period (25 year period for PFP due to associated design life). This reflects the standard physical life (with maintenance) of a conventional flood scheme and allows benefits to be assessed over the lifetime of the scheme.

6.1 Baseline damages summary

The baseline economic impacts (flood damages), used in this economic appraisal are presented under separate cover: reference should be made to the baseline economic impact assessment report[4].

6.2 Benefits of options

It should be noted that it is not possible to completely prevent flooding from happening; not all of the above damages can therefore be mitigated using a flood scheme since there will always be some residual risk associated with more extreme events. This is demonstrated in **Figure 6-1** below. The shaded area in the graph shows the theoretical residual damages expected in a 1% Annual Exceedance Probability (1 in 100yr) flood scheme.

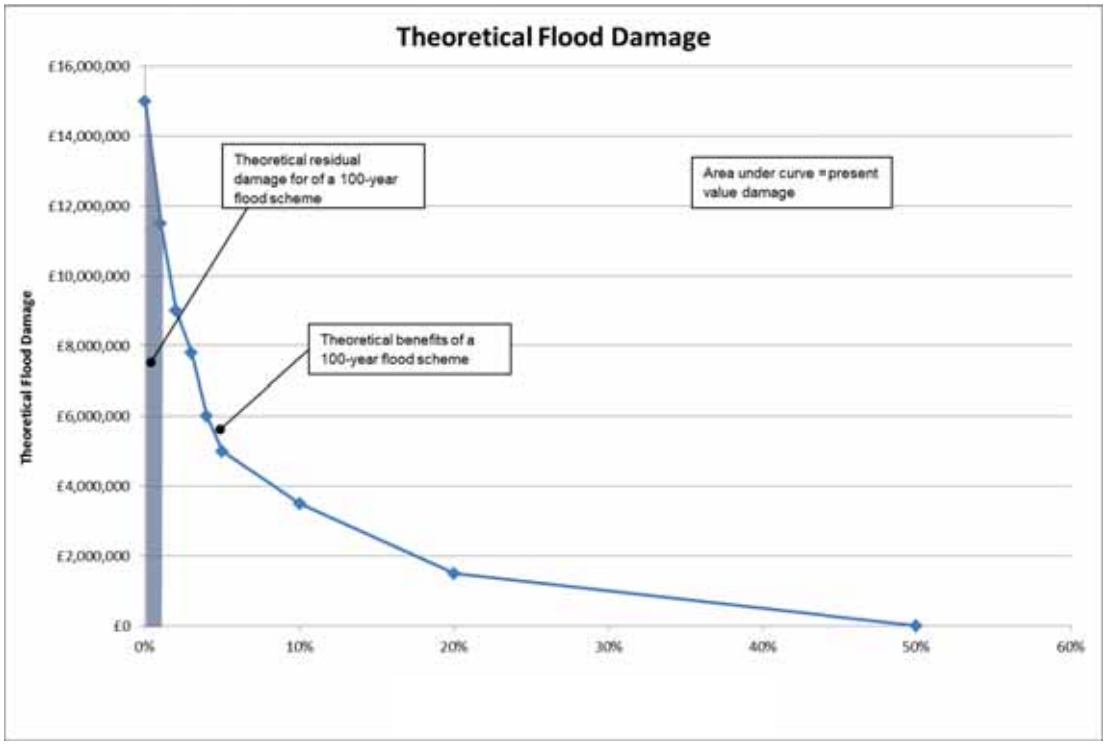


Figure 6-1 Theoretical representation of simplified residual damages[5]

For example, for direct defence schemes, residual damages are dependent on flood characteristics during an exceedance event. Once exceedance occurs damages quickly return to, or surpass, the pre-scheme damages. Residual damages and benefits for each of the scheme options are shown in **Table 6-1**: below.

[4] *Tarbert Flood Study Baseline Economic, Social and Environmental Impact Assessment – Technical Report*, AECOM, April 2019
[5] The annual exceedance probability is the inverse of the return period e.g. a 100 year return period is equivalent to an annual exceedance probability of 1/100 = 1%.

Table 6-1: Residual Damages

Option No.	Option	Baseline	SoP (%AEP)	Residual	Total benefit	Additional economic benefits
2.1	Direct defences; coastal wall	£5,576,172.93	**0.5%+CC**	£915,192.26	£4,660,980.67	Reduced flood depth and velocity on A83 and A8015
			0.5%	£2,578,625.44	£2,997,547.49	
			2%	£3,664,203.57	£1,911,969.36	
2.2	Direct defences; landward flood wall	£5,576,172.93	**0.5%+CC**	£1,150,145.49	£4,426,027.44	Reduced flood depth and velocity on A83 and A8015
			0.5%	£3,070,320.30	£2,505,852.63	
			2%	£3,691,023.92	£1,885,149.01	
2.3	Direct defences; demountable flood wall	£5,576,172.93	**0.5%+CC**	£1,150,145.49	£4,426,027.44	Reduced flood depth and velocity on A83 and A8015
			0.5%	£3,070,320.30	£2,505,852.63	
			2%	£3,691,023.92	£1,885,149.01	
2.4	Direct defences: Combination of traditional/demountable	£5,576,172.93	**0.5%+CC**	£1,150,145.49	£4,426,027.44	Reduced flood depth and velocity on A83 and A8015
			0.5%	£3,070,320.30	£2,505,852.63	
			2%	£3,691,023.92	£1,885,149.01	
2.5	Direct defences; Tidal Barrage	£5,576,172.93	**0.5%+CC**	£915,192.26	£4,660,980.67	Reduced flood depth and velocity for whole harbour area
3.1	PFP	£3,577,307.81*	**4%**	£489,468.32	£3,087,839.49	N/A
10.1	Land reclamation with direct defences	£5,576,172.93	**0.5%+CC**	£1,150,145.49	£4,426,027.44	Reduced flood depth and velocity on A83 and A8015
			0.5%	£3,070,320.30	£2,505,852.63	
			2%	£3,691,023.92	£1,885,149.01	

**Note baseline differs for PFP properties where appraisal period is 25 year rather than 100 year*

6.3 Option costs

Option costs have been developed using the Environment Agency's guidance and cost estimation information set out in the references below. For this project we have used the environment agency costing information for all options so that the consistency of approach allows costs to be more reliably compared against each other.

The cost estimates provided are indicative costs only, to help compare the conceptual options and appraise the options against the benefits from the flood damages avoided. These options have not been developed to outline design stage so there is significant variability in the option itself and therefore uncertainty in the costs. Option costs should be reviewed in tandem with the social and environmental options appraisals to help appraise and recommend options to manage flood risk in Tarbert. Where more detailed estimates are needed (i.e. for the preferred option), we would strongly recommend further development of the design to at least outline design and potentially involving a contractor in costing.

A number of sources were used to guide the costing of options. These include:

- Long term costing tool: summary of evidence on cost estimation, Report –SC080039/R1, Environment Agency, March 2015

- Cost estimation for fluvial defences – summary of evidence, Report –SC080039/R2, Environment Agency, March 2015
- Cost estimation for control assets – summary of evidence, Report –SC080039/R5, Environment Agency, March 2015
- Cost estimation for coastal protection – summary of evidence, Report –SC080039/R7, Environment Agency, March 2015
- Cost estimation for managed realignment – summary of evidence, Report –SC080039/R8, Environment Agency, March 2015
- Cost estimation for temporary and demountable defences – summary of evidence, Report – SC080039/R10, Environment Agency, March 2015
- Cost estimation for household flood resistance and resilience measures – summary of evidence, Report –SC080039/R11, Environment Agency, March 2015
- Cost estimation for flood warning and forecasting – summary of evidence, Report – SC080039/R13, Environment Agency, March 2015
- Flood Prevention Schemes - Guidance for Local Authorities, Scottish Government
- HM Treasury Green Book; Appraisal and Evaluation in Central Government, HM Treasury, March 2018

6.3.1 Capital Cost

6.3.1.1 Traditional engineering works – unit rates

Flood protection measures have been developed to a level appropriate for outline costing, whereby the main elements only are determined in approximate size and extent. It should be noted that only the core elements of the flood protection measures (and necessary ancillary works) have been included in the economic assessment, with engineering solutions such as flood defences costed using rates extracted from the various EA guidance documents as listed above.

The EA unit rates have been determined using actual construction costs from flood risk management projects across the UK from 1985 – 2015. The guidance has taken this data and attempted to standardise unit rates based on the kind of element being implemented e.g. flood embankment, defences, culverts etc. This unit rate can then be scaled based on the size of the proposed measure. Each rate is specific to the type of element employed and are graded in terms of the geometry and length of the element.

For example, in the case of a floodwall a wall of height 1.2-2.1m over a length of 50-100m would generate a unit rate of £2,905 per m length of wall. For example, in the case of a direct defence wall of 1.5m high over 50m this would generate a capital cost of 2,905 x 50 = £145K. Each unit rate factors in total construction cost of each feature including temporary and associated works.

These benchmarked or unit cost estimates are broadly typical or representative of the type of works. However, for civil engineering works the tremendous variety of project conditions and complexities make the straightforward use of these rates less reliable. The prices given can only be taken as a guide to actual cost. The various Environment Agency guidance documents state that the rates are suitable for initial appraisal of options which is the purpose of this study. Given that the level of design is at the feasibility stage at present, these benchmarked costs provide broad estimates to compare options to aid the selection of preferred options which could then be designed in full in outline and detail stages.

For construction costs, it is necessary to be cognisant of the chosen method of executing the work, drawing up a detailed programme and then costing the resources needed. Scale, site difficulties, locale, tender climate are all factors in the actual sum tendered. For this reason, more detailed cost estimation carried out using unit rates from industry guidance which are broken down to material, plant and labour rates for each item of construction was not deemed to be appropriate at this stage as the construction details of the options are not known at this time.

6.3.1.2 PFP Measures

If PFP is taken forward as an option, property surveys by a manufacturer or qualified staff will be required at individual properties to determine a bespoke flood protection strategy. As PFP will be tailored to individual properties based on flood entry routes, a simplistic assumption has been made for costing. In line with EA costing guidance, passive measures which offer a "premium" standard of protection have been assumed for residential properties as these are the most vulnerable receptors. This includes two flood-proof doors, two airbrick covers and external wall render/bricks (20 m). For non- residential properties a standard protection was deemed suitable so measures would not impact the operation of business as they are demountable. This includes two demountable door guards and multiple airbrick covers.

6.3.2 Acquisition or enabling costs (pre-construction)

EA guidance is unclear as to what costs such as construction preliminaries, accommodation works and such like that are included in the core capital cost data on which the unit rates are based. Guidance is included for enabling costs: scheme development, design, planning, and project management etc. Enabling costs are very variable and for complex projects are clearly higher.

In the absence of any additional data the values recommended for use in the EA guidance are used. For local authority projects of >£1m an allowance of 10% the capital costs is recommended estimate for the enabling cost. For PFP, 5% of the capital cost is assumed.

6.3.3 Optimism bias

Optimism Bias relates to the unavoidable tendency for project appraisal cost estimates to be overly optimistic; this is inherent in early stage cost estimates because major project risks are not known or are not quantifiable at this stage. Optimism Bias is intended to account for uncertainty over project costs and the likely increase between the current project stage, i.e. capital expenditure review, and completion. Through a review of the current stage inputs, assumptions and remaining project risks, risks can be factored into an overall uncertainty for Optimism Bias.

For most flood studies the options considered are similar in terms of their construction requirement and therefore associated risks. This is broadly the case for the engineering options; the options for Tarbert fall into 2 distinct categories including:

- Direct Defences – large scale engineering measures
- PFP – local resilience intervention

Advice from Scottish Government's Project Appraisal Guidance[6] on the application of optimism bias to flood protection costs for Strategic and Scheme costs has been applied to this study.

This flood study presents an appraisal of potential flood protection costs at a strategic level. The appraisal guidance recommends 60% optimism bias is taken as a starting point for this level of assessment. An assessment is then made as to whether the valuations of different risk components contributing to the overall optimisation bias can be reduced based on the information available or through demonstratable actions that would minimise the risk. The risk components include; project specific risks, client risks, environmental issues and external influence risk. In line with the appraisal guidance different optimism bias has been calculated for each option category to provide a more realistic quantification of uncertainty.

Risks were reviewed for the two categories of options. For direct defences there was no strong case to reduce any of the risk items therefore optimisation bias of 60% is applied. For PFP a reduction could be made because external influence risks generally associated with large scale construction such as ground investigation, construction materials and plant are less relevant and an optimism bias of 40% is considered appropriate. These biases were applied to the Whole Life cost of options in line with Scottish Government Guidance.

[6] Flood protection schemes - assessment of economic, environmental and social impacts: guidance, Scottish Government, February 2012

6.3.4 Uncertainty and limitations of the method

There are several uncertainties identified within the current costing. These include:

- Costs have been based on conceptual design sizing.
- Costs are based on standardised unit rates and research.
- No significant geotechnical design requirements will be required as ground investigation is unavailable at this stage e.g. contamination, groundwater issues, seepage etc. There have been recurrent comments from public consultations regarding water coming under the existing harbour wall at high tide. There is some thought that the wall may be permeable, and that a cut off foundation may be required. This requirement cannot be confirmed until a ground investigation has taken place. Although this would add cost to an option, it is anticipated that any additional costs be covered through the conservative optimism bias.
- Land purchase costs have not been considered as these costs are highly uncertain. This is difficult to quantify as it will require individual landowners and organisations working together in partnership to deliver a joint vision. This uncertainty can skew the benefit cost assessment of options significantly which should not be the case at options appraisal stage.

There are further limitations of the EA costing guidance in particular for coastal defences. The data on which the costs of coastal defences have been derived is minimal and provides little certainly that these costs are representative of wider schemes.

In the EA costing guidance, coastal defence costs are also not linked to defence height in the same way as fluvial defences are. This means that it is not possible to derive different costs representing variations in standard of protection. For the purpose of this flood study a single cost has been derived for each defence option which is considered to be representative of the defence option irrespective of standard of protection provided.

6.3.5 Operation and maintenance costs

Flood risk management measures require ongoing maintenance to ensure the system remains in good working order and the design life of the system is extended as long as possible. Operation and maintenance activities include:

- Monitoring and post-construction inspection;
- Regular, planned maintenance (annual or more frequent); and,
- Intermittent, refurbishment, repair/remedial maintenance;

It is recommended that these long terms costs are considered as part of the initial benefit cost assessment so a full “whole life” cost of an option is considered to allow transparent appraisal of options and budget accordingly.

Environment Agency guidance has been used to inform our estimate of the likely maintenance and operational activities associated with the different elements of the scheme, the frequency of these activities and cost per metre of a feature or cost per visit has been used to determine annual maintenance costs as well as account for intermittent maintenance costs. These are included in the whole life cost build up.

Generally, flood defence maintenance will come under the remit of ABC, which will include vegetation or debris clearance and inspection of flood walls which is expected to be minimal.

PFP measures will require a degree of maintenance costs to minimise the risk of operational failure during a flood. The degree of maintenance required will depend on the type of measure implemented but may require intermittent or annual inspections and maintenance by qualified personnel to ensure that all elements are in good working order. Costs for this work should be defined through discussions with the manufacturer, however EA guidance recommends a typical cost for this to be around 1% of the purchase cost of the measures; this cost is not included in the overall whole life cost because it is envisaged that PFP measures would be handed over to property owners and it would be their responsibility to use and maintain these assets.

6.3.6 Whole Life Cost

Whole life costing is defined as 'the systematic consideration of all relevant costs associated with the acquisition and ownership of an asset'. A schematic of whole life costs is shown in **Figure 6-2** below.

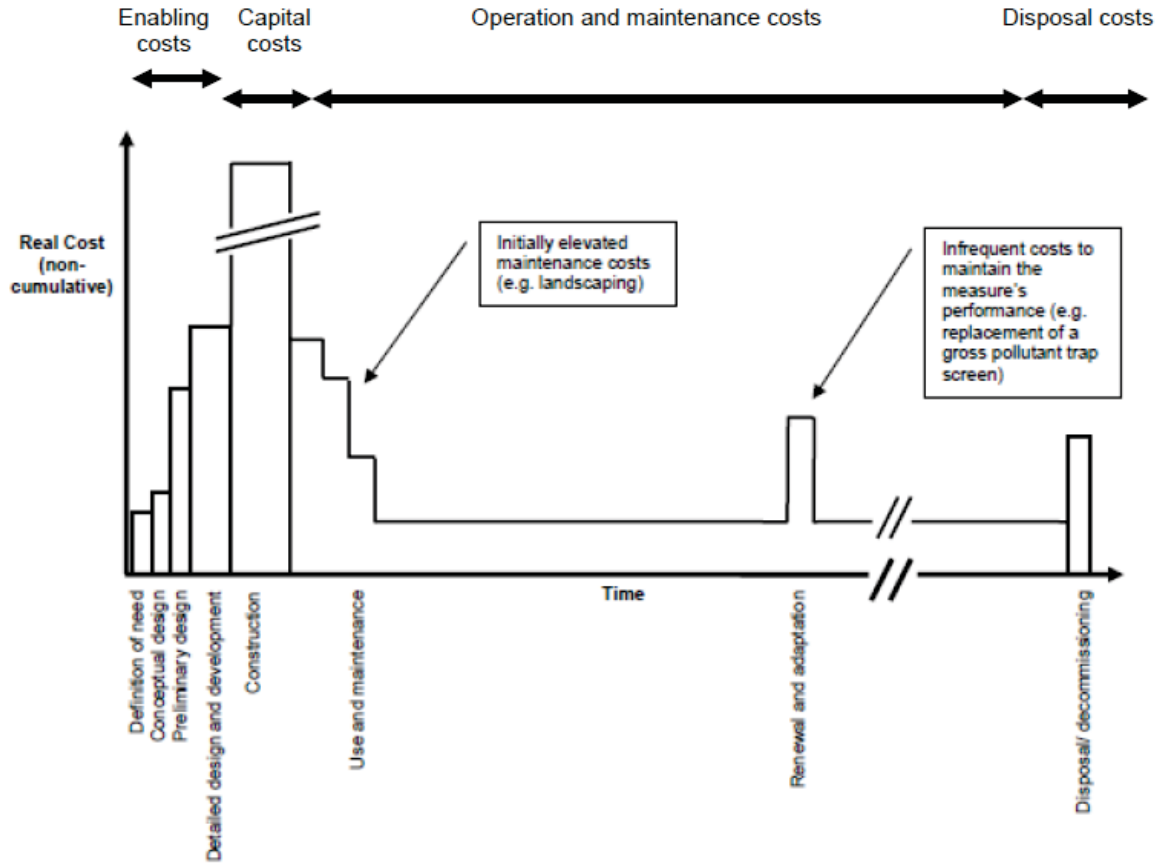


Figure 6-2 Conceptual schematic of whole life costs[7]

Each option has been considered for its whole life cost; expressed in terms of present value (PV). Present value is a single figure representing all the future costs and incomes at their equivalent present value. Discounting is an important part of the present value calculation as it offers a way to compare the value of costs and benefits over different time periods relative to their present values. This allows the depreciation of money in the future to be accounted for; to factor in its reduced capacity for generating a return through interest because of inflation. Discounting is a means of assessing how much less an amount is worth in the future than it is now.

Whole life costs of each option over the life of the scheme are brought to a present value (PV), using a 2018 base year. This allows a direct comparison with flood damages which are also priced to 2018. The current discount rates specified in the HM Treasury Green Book; Appraisal and Evaluation in Central Government, Treasury Guidance have been adopted. An appraisal period of 100 years has been used, as recommended by Scottish Government for Flood Prevention works, therefore the Green Book recommended discount rate of 3.5% reducing to 2.5% over the appraisal period is used.

It should be noted that the economic appraisal has assessed PFP over a 25 year design life. This is due to the complexities regarding ownership and liability of these elements. Current ABC policy is that ABC can provide advice and potentially purchase and facilitate initial installation of these measures as part of a scheme funded by Scottish Government, but PFP would then become the property owner's responsibility over which ABC would have no control over. It is likely a PFP would be re-evaluated again in 25 years to determine its viability as a scheme at this point in the future. Argyll and Bute Council's current view is that a PFP scheme would be implemented on a grant basis with homeowner

[7] reproduced from: *Cost estimation for fluvial defences – summary of evidence, Report –SC080039/R2*, Environment Agency, March 2015

maintenance obligations, but it remains to be seen on what basis any Scottish Government funding would be provided.

The addition of cut-offs have not been included in the direct defence costing as the requirements for them is an unknown at this stage. This requirements cannot be confirmed until a ground investigation has taken place. Although this would add cost to an option, it is anticipated that any cut-off would be relatively shallow and any additional costs could be accounted for the in conservative optimisation bias applied to the capital costs.

6.3.7 Summary of Cost

Table 6-2 Summary of Costs

Option no.	Description	Items costed	Enabling Cost[8] (% of capital cost)	Capital Cost	Operation and Maintenance Cost[9] (100 years)	Whole Life Cost (Present Value)	Whole life with Opt Bias 60% (40% for PFP)
2.1	**Direct defences: Existing defence line wall**	• 315m of coastal defence with wave / retaining wall • 185m of flood-wall up to 2.0m high at harbour • 3 Pedestrian gates for existing slipways & 2 twin-leaf vehicle flood-gates for access to harbour	£228,590.10 (10%)	£2,289,900.98	£452,050.47	£2,560,596.04	£4,096,953.66
2.2	**Direct defences: Set back wall**	• 515m of flood-wall up to 2.0m high • 3 Pedestrian flood-gates (for existing slipways etc.) • 2 twin-leaf vehicle flood-gates for access to harbour	£177,332.45 (10%)	£1,773,324.90	£674,262.20	£2,073,483.91	£3,317,574.26
2.3	**Direct Defences: Demountable flood wall**	• 515m of demountable wall up to 2.0m high	£120,453.35 (10%)	£1,210,533.50	£2,034,600.00	£1,860,294.36	£2,976,470.97
2.4	**Direct defences: Combination of traditional/demountable**	• Combination of Option 2.2 and Option 2.3 • 515m of flood-wall up to 1.0m high • 515m of demountable wall up to 1.0m high	£211,284.59 (10%)	£2,117,845.88	£1,335,650.16	£2,626,004.92	£4,201,607.87
2.5	**Direct defences: Tidal Barrage**	• 80m of coastal revetment • 105m of tidal barrage wall • 10m of vertical sector gate	£486,170.14 (10%)	£4,876,702.16	£18,989.52	£5,688,174.80	£9,101,079.67
3.1	**Property Flood Protection – 25yr SoP**	• 14 residential properties provided with Two flood-proof doors, two airbrick covers and external wall render/bricks. • 64 non-residential properties provided with two demountable door guards and multiple airbrick covers.	£48,587.30 (5%)	£245,746.70	£0	£286,023.80	£400,433.32
10.1	**Land reclamation and direct defences**	• 2768 m^2 of reclaimed land over intertidal mudflats • 275m of coastal defence with wave / retaining wall • 185m of flood-wall up to 2.0m high at harbour • 3 Pedestrian gates for existing slipways 2 twin-leaf vehicle flood-gates for access to harbour	£276,079.81 (10%)	£2,764,798.12	£523,969.27	£3,085,203.16	£4,936,325.06

[8] Enabling costs are estimated at 10% of capital cost not including incidental 1st year "other-costs", e.g. training, promotion, etc.
[9] Note this figure represents typical total operation and maintenance costs over a 100 year lifespan which can be averaged to an annual maintenance cost although more intermittent recommended maintenance has been included e.g. significant repairs and replacement of elements at 10 to 25 year intervals.

6.4 Cost benefit ratio

The cost benefit ratio for each option has been summarised in **Table 6-3** below. This is a useful parameter which feeds into the appraisal process but should be considered alongside the non-monetised benefits and limitations as part of the overall economic, social and environmental appraisal. A figure illustrated flood cells is shown in **Figure 6-3**.

Table 6-3: Benefit Cost Ratio

Option No.	Description	Costs	Main Flood Cells Affected	SoP (%AEP)	Damages Avoided (present value)	No. properties with reduced flood risk	Benefit-Cost Ratio
2.1	**Direct defences: Existing defence line wall**	£4,096,953.66	**1**	**0.5%+CC**	**£4,660,980.67**	78	**1.08**
				0.5%	**£2,997,547.49**	69	0.61
				2%	**£1,911,969.36**	63	0.46
2.2	**Direct defences: Set back wall**	£3,317,574.26	**1**	**0.5%+CC**	**£4,426,027.44**	73	**1.33**
				0.5%	**£2,505,852.63**	64	0.76
				2%	**£1,885,149.01**	58	0.57
2.3	**Direct Defences: Flip up/demountable coastal flood wall**	£2,976,470.97	**1**	**0.5%+CC**	**£4,426,027.44**	73	**1.49**
				0.5%	**£2,505,852.63**	64	**0.84**
				2%	**£1,885,149.01**	58	0.63
2.4	**Direct defences: Combination of traditional/demountable**	£4,201,607.87	**1**	**0.5%+CC**	**£4,426,027.44**	73	**1.05**
				0.5%	**£2,505,852.63**	64	0.60
				2%	**£1,885,149.01**	58	0.45
2.5	**Direct defences: Tidal Barrage**	£9,101,079.67	**1,2,3,4,5**	**0.5%+CC**	**£4,660,980.67**	91	0.51
3.1	**Property Flood Protection**	£400,433.32	**1,2,3,4,5,6,7**	**4%**	**£3,087,839.49**	78	**7.71**
10.1	**Land reclamation and direct defences**	£4,936,325.06	**1**	**0.5%+CC**	**£4,426,027.44**	74	0.90
				0.5%	**£2,505,852.63**	65	0.51
				2%	**£1,885,149.01**	59	0.38

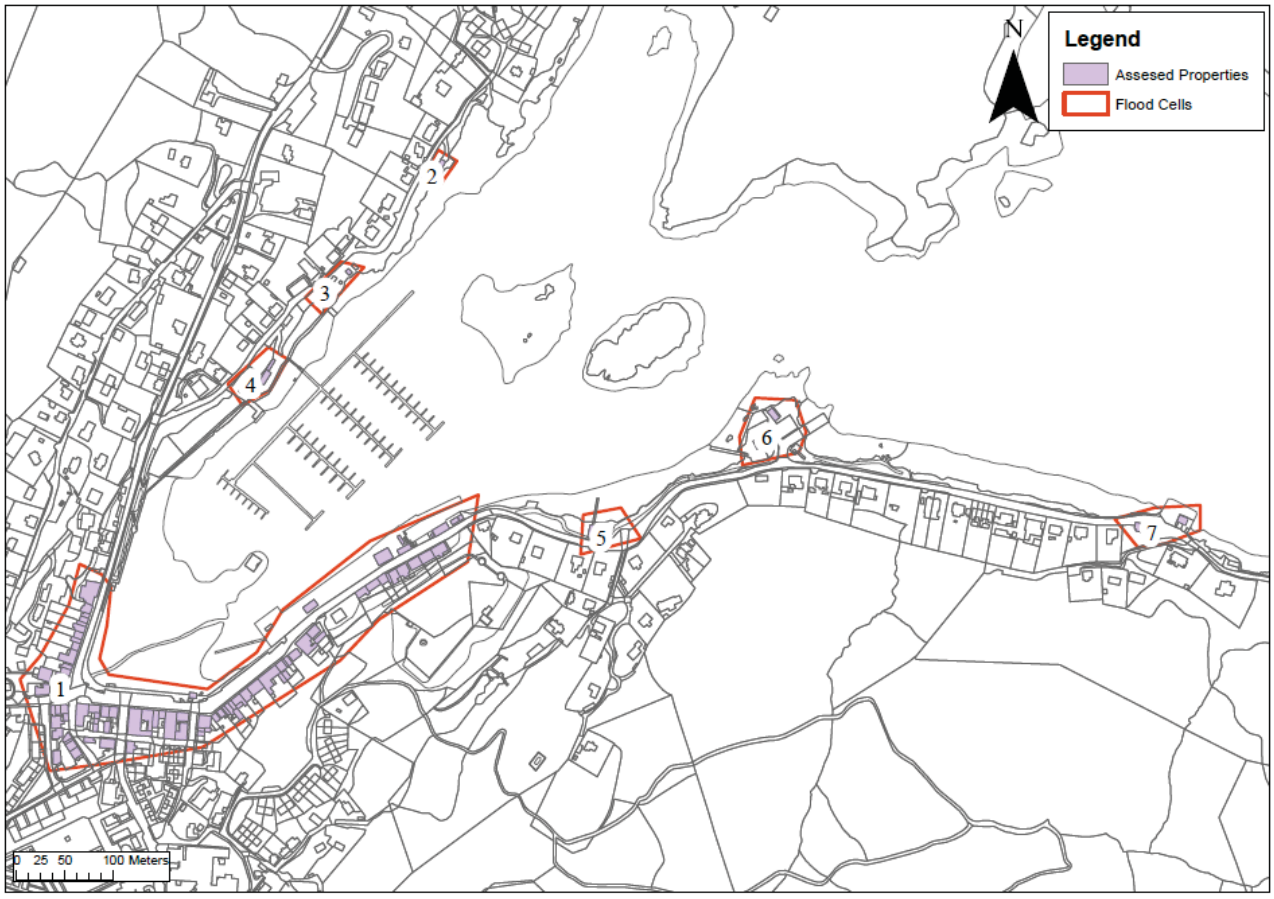


Figure 6-3: Tarbert Flood Cells

7. Environmental and Social Appraisal

Historically, appraisals of flood protection options were often focussed on cost-benefit analysis. The cost benefit ratio is a useful metric to compare the monetised benefits and impacts of options. However, to ensure focus is not solely placed on those parameters which have been monetised, an environmental and social appraisal has been carried out for this study. The baseline assessment is set out in the *'Tarbert Baseline Economic, Social and Environmental Impact Assessment – Technical Report'.*

Options involve four categories: Direct Defences; Property Flood Protection; Tidal barrage and Land Reclamation.

7.1 Overview

7.1.1 Environmental

The environmental impacts of the baseline have been assessed over the 100yr appraisal period. It is understood that at present there are no pressing environmental issues associated with flooding. However, over 100 years, under the influence of climate change, environmental pressures may arise. Impacts included in this assessment are:

- Water environment
- Biodiversity, flora and fauna
- Air and soil
- Climatic factors
- Landscape
- Cultural heritage

The primary requirements for environmental appraisals are to identify opportunities for environmental enhancement and to assess environmental impacts associated with any flood mitigation options (thus allowing for impacts to be mitigated). For this appraisal, the environmental impacts are described; this is considered adequate for this appraisal unless there is an indication that impacts will be significant, in which case a formal Environmental Impact Assessment may be required.

7.1.2 Social

Flooding and flood risk have a significant impact on society before, during and after a flood event has occurred. Werritty et al.[10] carried out a study into the social impact of flooding and flood risk in Scotland. The feedback from surveys carried out as part of the study highlight that the intangible impacts of flooding are significant, and it is therefore important to consider such impacts. Impacts included in this assessment are:

- Risk to life
- Health
- Social vulnerability
- Recreation, community and way of life

It should be noted that social impacts are often interlinked; for example, a heritage feature could be a source of recreation which in turn could have benefits in terms of well-being.

There are a number of stakeholders and groups in Tarbert. Stakeholders such as SEPA and Scottish Water have been consulted during the shortlisting process and two public consultations have been held.

[10] Werritty et al, *Exploring the Social Impacts of flood Risk and Flooding in Scotland*, Scottish Executive Social Research, Edinburgh, 2007

7.2 Results

Table 7-1 Results of social and environmental appraisal

Project name		Tarbert Flood Study				
Element		**Baseline**	**Flood Wall – Direct Defences**	**Property Flood Protection**	**Tidal Barrage – Direct Defences**	**Land reclamation – Direct Defences**
Element Description		Do-nothing - No intervention	Approximately 515-557m of flood walls ranging height up to 2.2 m high for different options.	PFP installed at 14 res properties and up to 64 NRP. Mix of passive and demountable features.	Approximately 80m of coastal revetment and 105m of wall. 10m gated opening in the wall for harbour use. Approximately 5m in height above sea level	Approximately 7750 m^3 of fill in front and 480m of flood wall. Wall is approximately 1.7m high
Approaches to adaption		None	One-off intervention	One-off intervention	One-off intervention	One-off intervention
Category		**Description and quantification of impacts**	**Description and quantification of impacts**	**Description and quantification of impacts**	**Description and quantification of impacts**	**Description and quantification of impacts**
Social	Risk to life	Low to moderate hazard, with flood hazard increasing for the more severe floods	Reduction of flooding leads to reduced risk to life	Higher residual risk to life as flooding is only reduced within properties.	Reduction of flooding leads to reduced risk to life	Reduction of flooding leads to reduced risk to life
	Health and well-being	Anxiety associated with flooding, physical health effects due to contact with flood water, worry about future flooding. It should be noted there is uncertainty in this developing area of research.	Reduction of flooding leads to reduced expected health impacts. However residual impacts will remain.	High residual health and well-being impacts as flooding is only reduced within properties.	Large defences may provide more reassurance during flood event. Reduction of flooding leads to reduced expected health impacts. However residual impacts will remain.	Amenity created on reclaimed land may encourage outdoor activity which in turn could positively effect health and well-being Reduction of flooding leads to reduced expected health impacts. However residual impacts will remain.
	Social vulnerability	Local assets at risk of flooding increasing flood disadvantage	Reduction of flooding would reduce social disadvantage	High residual social vulnerability as local assets may not be protected.	Reduction of flooding would reduce social disadvantage	Reduction of flooding would reduce social disadvantage
	Recreation, community and way of life	Community features are at risk of flooding include local businesses. flooding impacts the village centre, flooding would seriously impact the recreation, community and way of life for most residents.	Reduction of flooding would increase access to the village, therefore improving way of life. This not only affects the people of Tarbert, but people in the wider community who rely on the services and businesses with the village.	High residual impacts to recreation, community and way of life as local amenity and transport (roads) may not be protected. Could enhance community and way of life through development of a local partnership group to manage and install proposed measures	Reduction of flooding would increase access to the village, therefore improving way of life. This not only affects the people of Tarbert, but people in the wider community who rely on the services and businesses with the village.	Reduction of flooding would increase access to the village, therefore improving way of life. This not only affects the people of Tarbert, but people in the wider community who rely on the services and businesses with the village. Reclaimed land may be used for recreational enhancing the way of life

Environmental	Water	Pollution of watercourses during a flood event from contact with backed-up sewers and flood debris. Loch Fyne outer basin has an overall water status of 'Good' from 2007 to 2017.	General reduction of flooding reduces the risk of contaminants.	Higher residual risk - flooding is only reduced within properties so contaminant risk is not reduced.	General reduction of flooding reduces the risk of contaminants.	General reduction of flooding reduces the risk of contaminants.
	Flora and fauna (biodiversity including fisheries)	Not considered to be significantly affected by current flood risk	No significant impacts expected.	No significant impacts expected.	May create barrier to ecological corridors.	Reclaiming land may have some adverse impact by altering habitat.
	Air and soil	Not considered to be significantly affected by current flood risk	No significant impacts expected.	No significant impacts expected.	No significant impacts expected.	No significant impacts expected.
	Climatic Factors	Greenhouse gas emissions associated with flood response and post-flood recovery	Emissions reduced through reduction of flooding. Works will have climatic costs.	Emissions reduced through reduction of flooding.	Emissions reduced through reduction of flooding. Works will have significant climatic costs.	Emissions reduced through reduction of flooding. Works will have climatic costs.
	Cultural heritage	Flooding of Tarbert conservation area and listed buildings. Possibility that flood risk is discouraging investment in maintaining the area.	Reduced risk of flooding to listed buildings. Potential change and loss of heritage of listed harbour walls (unless demountable). Walls will change character of area by impeding connection to harbour (unless demountable).	Locally no loss of heritage.	Reduced risk of flooding. Locally no loss of heritage. Barrage will change character of area.	Reduced risk of flooding to listed buildings. Potential loss of heritage of listed harbour walls. Walls will change character of area by impeding connection to harbour as well as its footprint.
	Landscape	Not considered to be significantly affected by current flood risk.	Walls will change character of area by impeding connection to harbour (unless demountable).	No significant impacts expected.	Visual impact, which can be minimized by sensitive design, however size and height will be very significant which may be considered intrusive and not in keeping with local landscape.	Walls will change character of area by impeding connection to harbour and changing the landscape of the seafront.

7.3 Summary

7.3.1 Environmental

In general, Tarbert would experience environmental benefit through the reduction of flood risk from each option. Different options however have different wider benefits and disadvantages associated which add or detract from their value.

Direct defences and land reclamation have the most negative environmental impact. Walls would have a negative visual impact, cut off community connection to the sea and may adversely impact heritage value of the existing harbour walls. These impacts can be reduced through sensitive design to the existing landscape using materials which are similar with locally used materials. Improvements to the existing walkway could also be made as part of a scheme which would further improve the visual elements.

PFP offers no significant environmental benefit or loss out with those gained by reducing flood risk.

A tidal barrage would avoid adverse impacts directly on the harbour but would have significant visual impact to the wider area.

Baseline flood scenarios have carbon emissions associated with flood response and post-flood recovery. Flood defence options reduce these emissions to varying degrees, for example direct defences around specific properties or PFP still require some clear up and flood response. All works have associated climatic costs however these vary in magnitude. Direct defences would require more fuel and imported materials increasing climate costs.

7.3.2 Social

In general, the options assessed provide social benefits associated with their impact on flood risk. The reduced flood risk offered by direct defence options increases access to the village which enhances community way of life. This not only allows residents of Tarbert access to the village and the amenities, but also those living in the wider community. Tarbert is a hub for a number of more isolated properties in the surrounding area, who rely on the services and businesses within the village. Flood affected properties include banks, shops, hotels and restaurants. Protecting these properties reduces the frequency at which they will be forced to close and therefore benefits Tarbert and the wider community. It should also be noted that the main road around the harbour is the key access route for the Kintyre peninsular and closure of this road has the potential to affect communities out with Tarbert. Direct defences are usually considered to offer the greatest social benefit by providing the best standard of protection to properties. Land reclamation can provide additional amenity to the area, whilst large defences such as a tidal barrage can reduce social anxiety around flood risk.

It is also considered that set back defences could improve the existing walkway and parking safety around the harbour. The improved walkway and safety would feed into the enhancement of the area as a key social location in Tarbert.

Some types of local flood defences, demountable and PFP, could enhance community and way of life through development of a local partnership group to manage and install to proposed measures.

8. Public Consultation

A public consultation event was held in Tarbert Village Hall on the 23rd of May 2019 after the Phase 3 report had been issued. The event was well attended with 14 members of the community present. Those attending gave insight into flood events and flood risk in Tarbert and provided feedback on the shortlisted options. A further consultation event was help on the 23rd of October 2019 to present the preferred option.

8.1 Comments in relation to flooding

In general, there was agreement that Tarbert would benefit from a coastal flood protection scheme, with the following accounts of flooding recorded:

- Recurrent comments that water comes under and through the harbour wall at high tide. Harbour wall appears to be very permeable. This primarily effects properties along Barmore Road. This will be considered further if direct defences along the wall are to be considered.
- There are also issues with waste pipes becoming tide locked which also effects properties on Barmore Road.
- Confirmation that waves are not a significant issue. Flooding is caused by a combination of high tides and surge up Loch Fyne.
- Water levels come up to the top of the harbour wall approximately every year.
- Tidal flooding generally recognised as an issue and understood that flooding would become more severe and frequent in the future.

8.2 Feedback on shortlisted options

The following feedback was provided regarding options that had been considered for Tarbert:

- PFP was considered by several people to be a reasonable short term solution. It was noted that Scottish Water had provided PFP measures to a small number of properties to protect against surface water flooding.
- A tidal barrage was considered by most as an unlikely and undesirable solution although there were a couple of people that thought it would be reasonable.
- Reasonable feedback on land reclamation options– the idea of providing a community area as part of the flood defence works was well liked and fills a need of the village.
- Some concern over direct defences changing the character of the area and visual appeal. However, the majority of people spoken to understood that something had to be done and that direct defences provided a solution. Interest in flip up defences and glass top wall options as a means of reducing the visual impact.
- No strong opinions noted on the location of the direct defences i.e. on the current wall or set back during the long list to short list consultation.
- Parking noted as an issue and an option of land reclamation with underground parking was raised.
- Residents were very supportive of the preferred option presented, with many commenting that this would provide the protection they required without adversely affecting the visual appeal of the village.
- It was suggested that the permanent wall of the preferred option could be clad or decorated to make a feature of it or to blend it in as much as possible.
- THA were in attendance and also supported the preferred option.
- Concern expressed over the porosity of the Telford harbour wall – this would be assessed fully if a scheme were to go ahead.

9. Option Recommendations

The options have been assessed in a holistic manner to include social, environmental and economic factors together to ensure the option selection process is not unfairly weighted towards economics.

9.1 Appraisal Summary

When considering the benefit cost ratio (BCR) alongside environmental and social benefits, the tidal barrage (Option 2.5) and land reclamation with direct defences (Option 10.1) can be deemed less viable than their alternatives. These options have low BCR due to the significant costs, and when compared to other options there is no great difference in environmental or social benefit.

The tidal barrage has the highest capital costs of any option and this may be a conservative estimate due to limitations in the EA costing tool.

A demountable coastal flood wall (Option 2.3) and PFP (Option 3.1) would provide the greatest BCR by a significant margin and although they have limited environmental benefit, they can enhance community and way of life through development of a local partnership group to manage and install the proposed measures. However, it must be noted that upon consultation with ABC, the need to install 500m of demountable barrier would require significant staffing resources for each flood warning and hence would present considerable resourcing and logistical challenges which are unlikely to be achievable.

PFP may provide the greatest BCR, but this is at a reduced SoP and carries increased uncertainties in relation to deployment.

At the 0.5% +CC SoP both the existing defence line and set back walls (Options 2.1 and 2.2) would provide greater BCR, however the visual impacts (and hence loss of connection with the harbour) due to the size of wall would be significant. The character of the area and visual appeal was picked up as a community concern at the public consultations in May and October 2019. A combination of traditional defences with demountable defences on top (Option 2.4) allows for a permanent wall of reduced SoP, with additional demountable walls, providing the same SoP as Options 2.1 and 2.2, at reduced visual impact.

Flood risk appraisal guidance now recognises the value in wider environmental and social benefits which are not explicitly included in the BCR calculation but have been assessed qualitatively in this study. In the case of the short-listed options for Tarbert, three options stand out in terms of environmental/social benefits highlighted in **Section 7** which would partner with the reduced impact of flood events. PFP (Option 3.1) and demountable defences (Options 2.3 and 2.4) stand out from other options because they are considered to be far less visually intrusive than more traditional direct defences, which is noted as a concern in the community in Tarbert. Of the three, Option 2.4 provides the highest SoP whilst still being practical in operation. This option would also protect the main road which option 3.1 would fail to do so.

Direct defence offers reduced flooding to the village, increasing its access to not only residents, but those in the wider community who rely on Tarbert's businesses and services.

The combination option allows for an adaptable defence which can be later re-evaluated and altered. As part of this option, PFP could be deployed to protect isolated properties out with the formal scheme. Our assessment predicts that up to 13 properties could benefit from PFP up to the 4% AEP event.

Table 9-1 below presents the recommended options, and their associated BCR. Recommendation 1 is the preferred option for prioritisation, however recommendation 2 is presented as an additional viable scheme.

Table 9-1 Summary of Recommendations

Recommendation for prioritisation	Description	Costs	Damages Avoided (present value)	SoP (%AEP)	No. properties with reduced flood risk	BCR
1	**Direct defences: combination of traditional/demountable**	**£4,201,607.87**	£4,426,027.44	**0.5%+CC**	**73**	**1.05**
	Property Flood Protection: for properties not protected by direct defences	**£81,785.90**	£575,477.79	**4%**	**13**	**7.04**
2	**Property Flood Protection**	**£245,746.70**	£3,087,839.49	**4%**	**78**	**7.71**

9.2 Standard of Protection (SoP)

Three separate standards of protection are shown for the shortlisted options where it is considered appropriate to look at the variability in BCR. It must be recognised that a 2.0% AEP (1 in 50 year) event decreases to a 1 in 2 year event with climate change based on predictions for the year 2100 and therefore reduces the benefit of this SoP.

The proposed standard of protection chosen for the shortlisted option 2.4 is the 0.5% AEP (1 in 200 year) plus allowance for climate change event. This higher SoP is due to option 2.4 providing a 2% AEP SoP before the additional protection of demountable defences are added. The significant capital costs of option 2.5 merit a high SoP. Option 3.1, Property Flood Protection, has an assumed SoP of 1 in 25 year return period; this is the same as the typical stated design life for PFP products.

In events exceeding the SoP, inundation behind the defences will occur. It is recommended that foundations are designed to ensure that during these exceedance events, the walls remain structurally sound.

9.2.1 Sensitivity of SoP

High level sensitivity testing of varying the standard of protection a permanent wall could offer was undertaken to determine if improvements could be made on the BCR. In general, the difference between still water levels, and therefore AEP events, is relatively small. Because of this, wall heights required for different standards of protection are not seen to vary by a significant amount.

The EA costing guidance used within this study does not provide a specific cost per height of flood walls, and instead costs are grouped into three bands; walls < 1.2m tall, walls between 1.2m and 2.1m tall, and walls > 2.1m tall. Due to the small variation in extreme still water levels, walls offering a significantly different SoP are grouped within the same EA wall height costing band and therefore produce the same cost.

The damages avoided (benefits) due to defences with a high SoP will always be greater than those at a lower SoP. Consequently, using the EA guidance costing, the BCR reduces as SoP becomes lower for any given flood wall option. In order to gain a better understanding of achievable BCR's at varying standards of protection, a more detailed cost assessment would need to be carried out which is not proportional in this feasibility stage. It is suggested that this be undertaken at outlie design stage should a scheme for Tarbert be taken forward.

10. Conclusions and Next Steps

This report details the Option Appraisal process carried out on short-listed options to manage flood risk in Tarbert. A preferred solution has been identified and the process and main conclusions have been outlined below.

10.1 Summary of findings

10.1.1 Summary of phase 4 process

A long list of options was developed and then short listed by assessing the feasibility of options from a technical, legal, financial and environmental perspective with input from statutory stakeholders and local residents.

The short listed options were then developed and appraised through the following:

- Public consultation – with the local community and stakeholders to get feedback on options.
- Concept design – to develop a better understanding of costs and how options would be constructed and identify opportunities and constraints.
- Costing – to determine the cost of each option. This has been considered over the whole 100-year design life (25 year for PFP) of the proposed scheme to include annual and intermittent maintenance costs.
- Damage assessment – to quantify economic benefits from the option in terms of damages avoided over the 100 year life of the scheme (25 year for PFP).
- Cost benefit – to establish the economic viability of each option
- Multi-criteria appraisal – to appraise options holistically in terms of social, economic and environmental.

The appraisal has allowed AECOM to assess the options against each other so that recommendations could be made based on the appraisal of economic, social and environmental impacts, whole life costs and consideration of risk and uncertainty, both present and future.

10.1.2 Flood risk

Coastal flood risk in Tarbert is overwhelmingly as a result of extreme sea levels.

Wave modelling of Tarbert Harbour and East Loch Fyne shows that wave action is very small. The concurrent significant wave heights that are expected in combination with extreme high tide events are not expected to exceed 0.4m

Freeboard allowance used in this options appraisal is 0.2m; this is a relatively arbitrary figure used to demonstrate the expected height of defences and has no influence on the benefit / cost ratio for options.

10.1.3 Climate change

An uplift to account for predicted sea levels in 2100 due to climate change should be applied where achievable to any flood defence for the study area so that it is future proof. In the climate change scenario, essentially the same areas are affected as are at risk in the current day scenario albeit more frequently. This is due to the topography in the area.

Due to the predicted increase in sea levels of approximately 600mm by the year 2100, the current day 0.5% AEP event (a rare event) is seen to correspond to a 10% AEP event in 2100. This means that the frequency of disruptive flooding will increase considerably in the future which in turn will reduce the standard of protection that a defence provides over its life.

10.1.4 Benefit Cost Ratio

When evaluating BCR, it is very typical for PFP to come out with a very high benefit cost ratio, higher than all others. Although providing a low SoP, the PFP costs are also very low, and the damages avoided are relatively high because capping and write-offs limit the build-up of damages over longer appraisal periods. It is also assumed that PFP is 100% effective for the stated SoP.

Demountable defences show good benefit cost ratio because the demountable defences are relatively inexpensive. It must be noted that the demountable defences are taken as simple manually installed stoplogs and powered or automatic systems are considerably more expensive; perhaps as much as 10 times the cost of stoplogs. Large scale demountables could be deemed unpractical to deploy at short notice.

Further work should be carried out to determine if a greater BCR could be achieved through delaying installation of the demountable defence to sometime in the future. The permanent wall presented in Option 2.4 will provide a relatively high SoP to Tarbert, and demountables would only need deployed during more extreme events. Planned future investment is discounted to present value and by delaying installation, greater understanding of the impact climate change will have on extreme sea levels should be available. The cost difference between the future investment and its present value, together with a greater understanding of climate change impact, could better inform the height of defence required and potentially yield a better BCR.

The tidal barrage (Option 2.5) is not reliably costed because the guidance only covers such works with very limited information. It is considered that the option cost given here may underestimate the actual likely cost for a significant marine structure such as this and therefore may overestimate the BCR.

The EA costing guidance does not give any means of adjusting the cost of sea defences based on defence height. Because of this, and the relatively limited difference in cost expected from small changes in defence heights, it is considered appropriate to use a single option cost to compare against the residual damages of different SoP.

10.1.5 Defence options and standard of protection

The 0.5% annual exceedance probability (1 in 200 year) water level including allowance for future climate change is approximately 4.41mAOD; top of the existing harbour wall is around 2.65 mAOD, Barmore Road and Harbour Street are typically around 2.95 mAOD. Permanent flood protection to this level is unlikely to be a favourable option for the people of Tarbert because the flood defences will completely block the view of the harbour and cut the town off from the sea.

It is recommended to investigate further and consult with the public as to the size of permanent flood defences that would be seen as acceptable, and the design flood level and standard of protection established through collaborative discussion with the affected parties.

10.1.6 Standard of Protection (SoP)

For a permanent installation on the seafront we would envisage a SoP of 2.0% AEP (1 in 50 year) event, this decreases to a 50% AEP (1 in 2 year) event with climate change based on predictions for the year 2100. This represents our interpretation of the inevitable compromise between flood risk and the visual intrusion of a flood wall whilst still providing a worthwhile SoP. Our recommended option allows for additional SoP up to 0.5% AEP (1 in 200 year) plus climate change event through demountable defences, which would only be in place during extreme events.

High level sensitivity of how varying standards of protection offered by the permanent wall affects BCR has been undertaken. It was found that, using the EA costing guidance, walls between 1.2m and 2.1m tall have the same capital costs, with significantly varying benefits for varying SoP. Therefore, to gain a better understanding of achievable BCR’s at varying standards of protection, a more detailed cost assessment would need to be carried out during outline design stage.

10.1.7 Environmental and social

The area of flood risk within Tarbert is a conservation area and the harbour wall itself and two seafront hotels are listed structures. There are recognisable benefits of providing flood protection to such social heritage. However, direct defences risk adversely altering the harbour and harbour wall; these negative effects could outweigh the positive.

Direct defences are usually considered to offer the greatest social benefit by providing the best standard of protection to properties and improving access to the village through reduced flooding. In Tarbert, this means that not only residents of the village, but those in the wider community will benefit from increased access to amenity, businesses and services. It should also be noted that the main road around the harbour is the key access route for the Kintyre peninsular and closure of this road has the potential to affect communities out with Tarbert. Property flood protection and demountable defences stand out from other options because they are considered to be far less visually intrusive than more traditional direct defences.

10.2 Preferred scheme recommendations

10.2.1 Preferred option for prioritisation

Weighing the economic and environmental considerations, the appraisal has determined that there is a viable scheme for Tarbert that should be presented for SEPA prioritisation. If successful, this will then be put forward for centralised Scottish Government funding.

The following options are recommended to be taken forward as a preferred scheme and presented for SEPA prioritisation:

> Combination of Option 2.4 and PFP – Direct defences; combination of permanent and demountable flood wall with PFP at isolated properties (not protected by the direct defence)

The option described above is the preferred option for Tarbert to be taken forward to SEPA prioritisation. However, it is noted that Option 3.1 - Property Flood Protection at 78 properties - is presented as an additional viable scheme. The preferred scheme allows for future adaption through the use of demountable components which could be changed, improved or replaced as permanent.

10.2.2 Additional recommended flood resilience options

In addition to the preferred scheme that will be presented for SEPA prioritisation, the additional categories of Self Help and Flood Resilience have also been carried forward to the recommendations. It is recommended that these options are taken forward by ABC with the aim of working towards educating the public and promoting Self Help and Flood Resilience within the community.

The EA costing guidance used throughout this study does cover costing of Flood Resilience and can be used to gauge an expected cost, and thereby quantify some benefit for this type of work. This cost estimate was not undertaken as it is assumed that flood resilience work would be carried out by individual property owners and not ABC. Flood resilience work is not included as part of other formal flood protection options and as such have not been assessed against their economic, environmental or social impact.

10.3 Recommendations for next steps

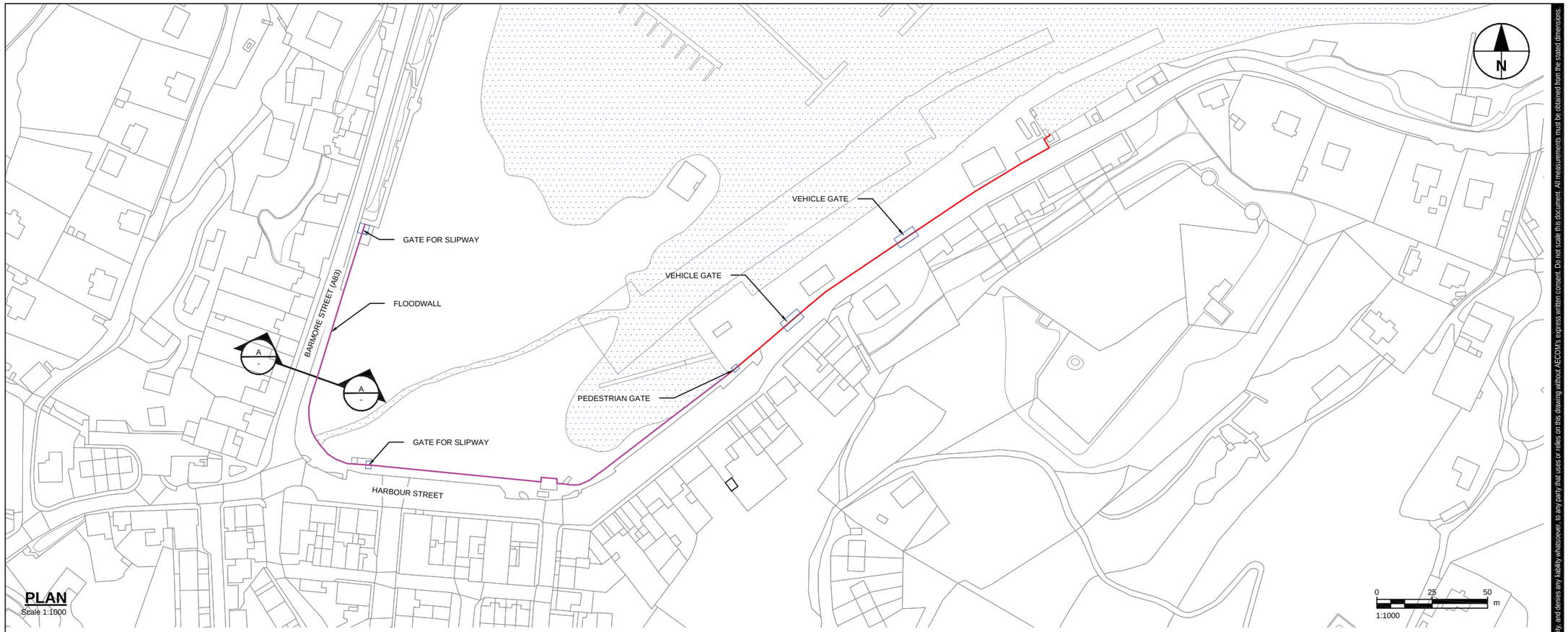
Should a scheme be taken forward through the SEPA prioritisation process, it is recommended to further develop flood protection options centred on the choice between direct defences, demountable defences and property flood protection. This would be done by the following:

- Carry out further, more, detailed consultation with affected residents and businesses, such as the Harbour Authority and businesses which use the quayside. Wider consultation has previously been undertaken but this would seek to converse with those properties directly affected.
- Develop details of direct defences to a size / height as determined from these consultations.
- Develop accurate cost estimates for direct defences with a view to ascertaining if a positive benefit cost ratio can be obtained for varying standards of protection.

- Consult with residents and businesses with regards to property flood protection.

Educate the public on flood risks, and promote self-help and flood resilience

Appendix A – Option Plans and Indicative Sections



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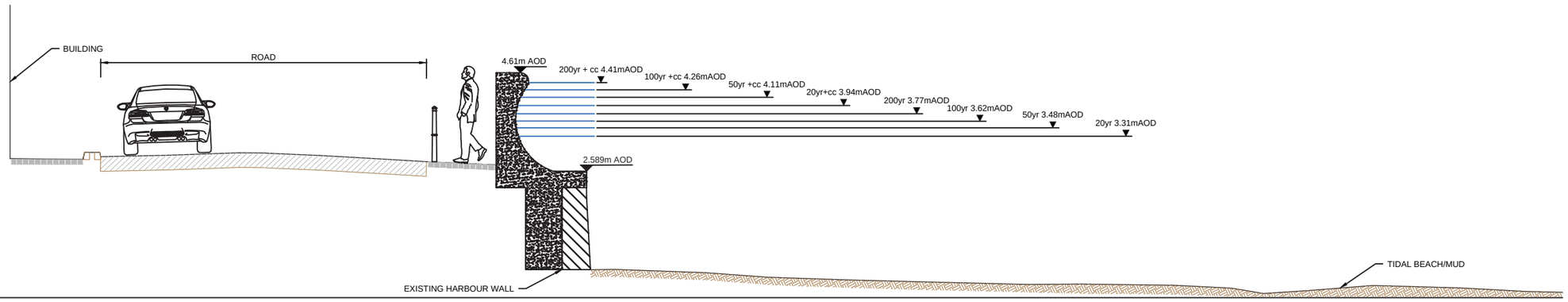

A | **SECTION A OPTION 2.1 - DEFENCES ON HARBOUR WALL**
G-#####
1:50

0 1.25 2.5 m
1:50

AECOM

PROJECT

TARBERT FLOOD STUDY - PHASE 4 OPTIONS APPRAISAL

CLIENT

ARGYLL AND BUTE COUNCIL

CONSULTANT

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LEGEND

- Option 2.1 Existing defence line coastal wall
- Option 2.1 Flood wall on landward side of harbour
- Option 2.1 Flood Gates

ISSUE/REVISION

I/R	DATE	DESCRIPTION
B	2019-10-21	FOR INFORMATION
A	2019-10-03	FOR INFORMATION

KEY PLAN

PROJECT NUMBER

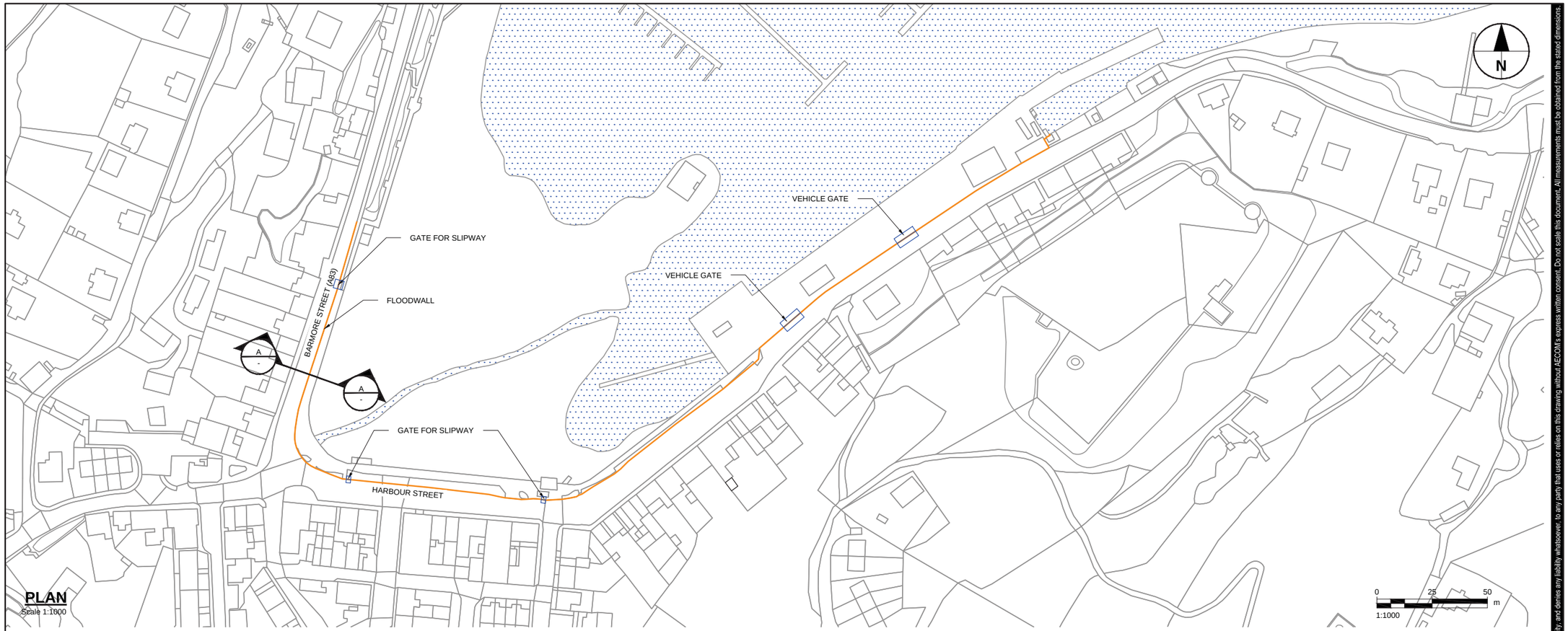
60578115

SHEET TITLE

TARBERT FLOOD STUDY
Option 2.1
DIRECT DEFENCES ON HARBOUR WALL

SHEET NUMBER

60578115_SHT_20_G_OP2.1-A



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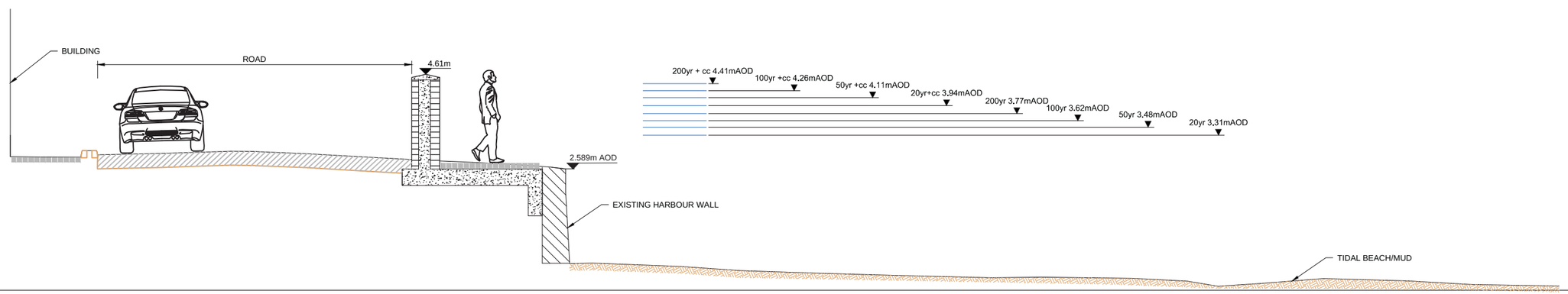

A G-#### **SECTION A OPTION 2.2 -SET BACK DEFENCES**
1:50

0 1.25 2.5 m
1:50

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PROJECT

TARBERT FLOOD STUDY - PHASE 4 OPTIONS APPRAISAL

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LEGEND

- Option 2.2 Wall set back from defence
- Option 2.2 Flood Gates

ISSUE/REVISION

I/R	DATE	DESCRIPTION
A	2019-10-03	FOR INFROMATION

KEY PLAN

PROJECT NUMBER

60578115

SHEET TITLE

TARBERT FLOOD STUDY
Option 2.2
DIRECT DEFENCES SET-BACK WALL

SHEET NUMBER

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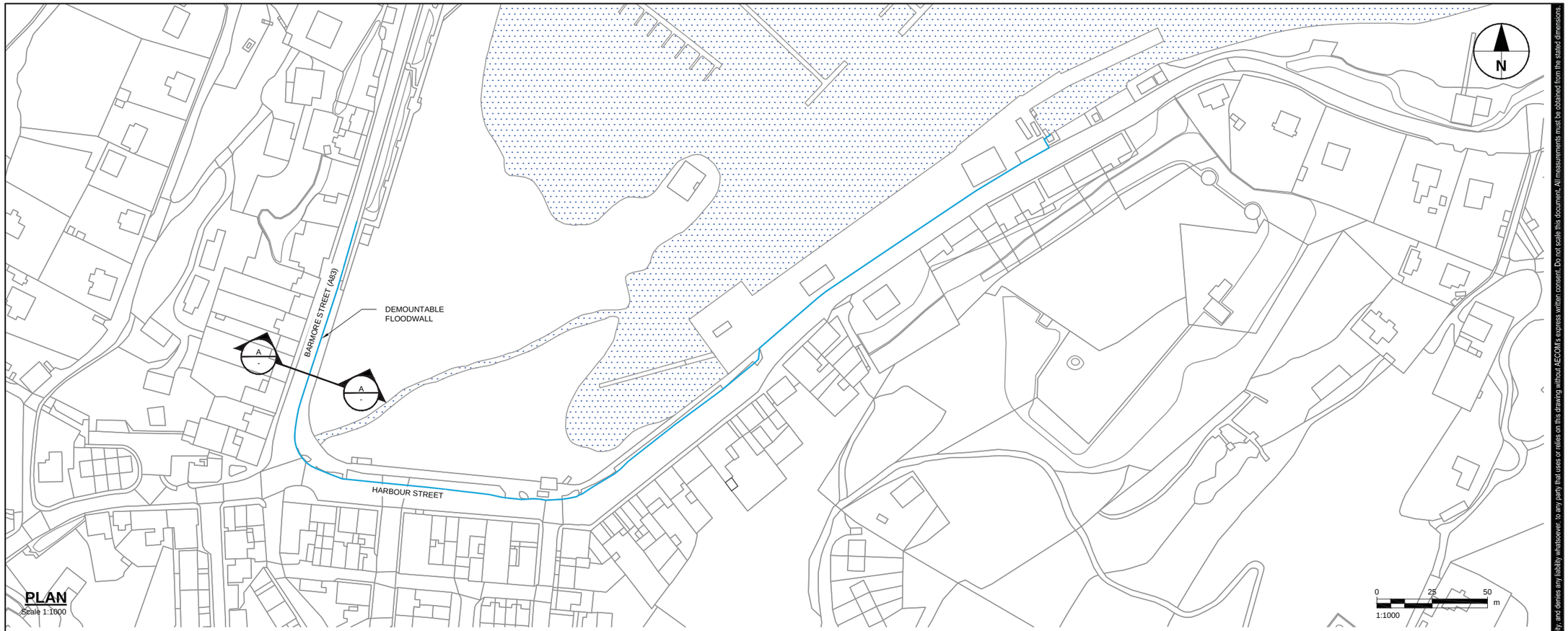

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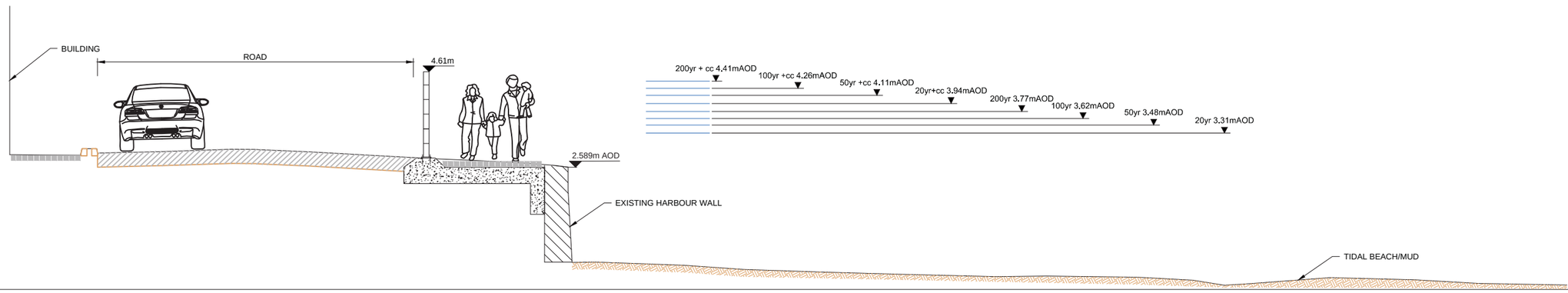

A G-#### **SECTION A OPTION 2.3 DEMOUNTABLE DEFENCES**
1:50

0 1.25 2.5 m
1:50

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PROJECT

TARBERT FLOOD STUDY - PHASE 4 OPTIONS APPRAISAL

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LEGEND

Option 2.3 Demountable Wall

ISSUE/REVISION

I/R	DATE	DESCRIPTION
A	2019-10-03	FOR INFROMATION

KEY PLAN

PROJECT NUMBER

60578115

SHEET TITLE

TARBERT FLOOD STUDY
Option 2.3
DEMOUNTABLE DEFENCES

SHEET NUMBER

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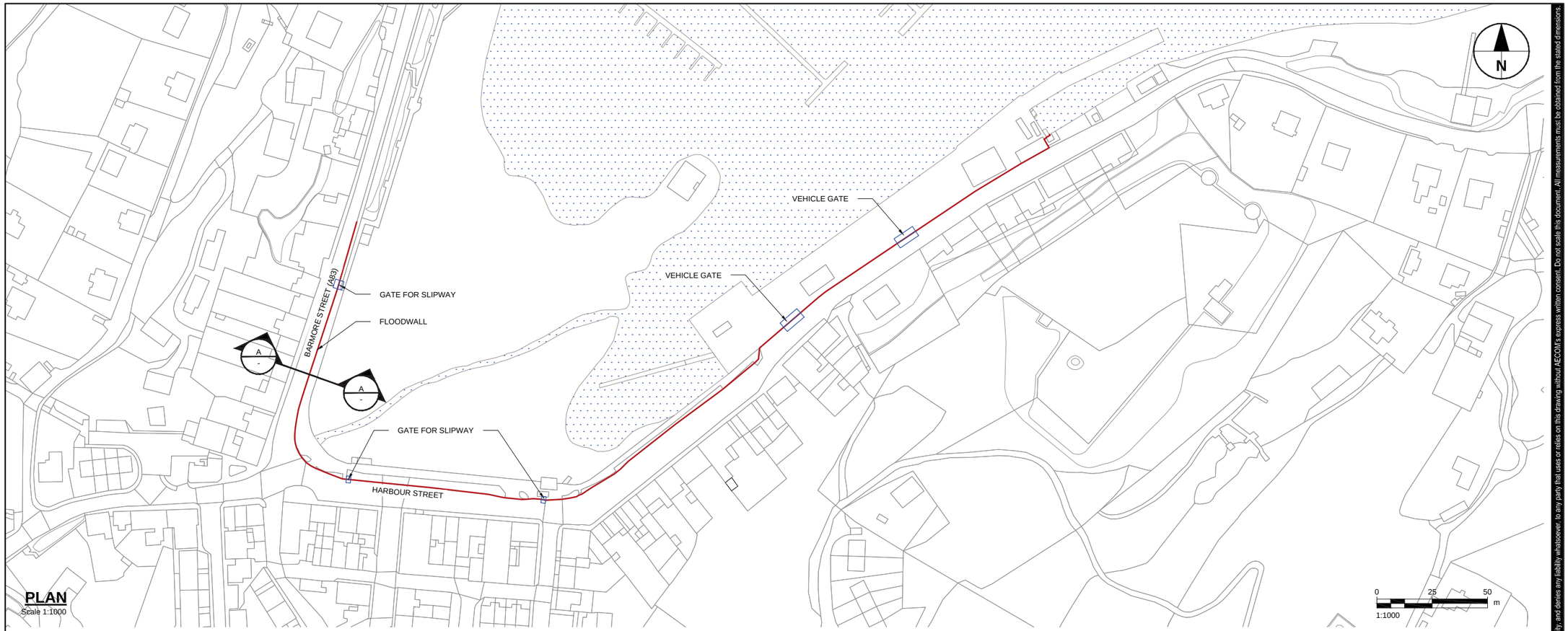

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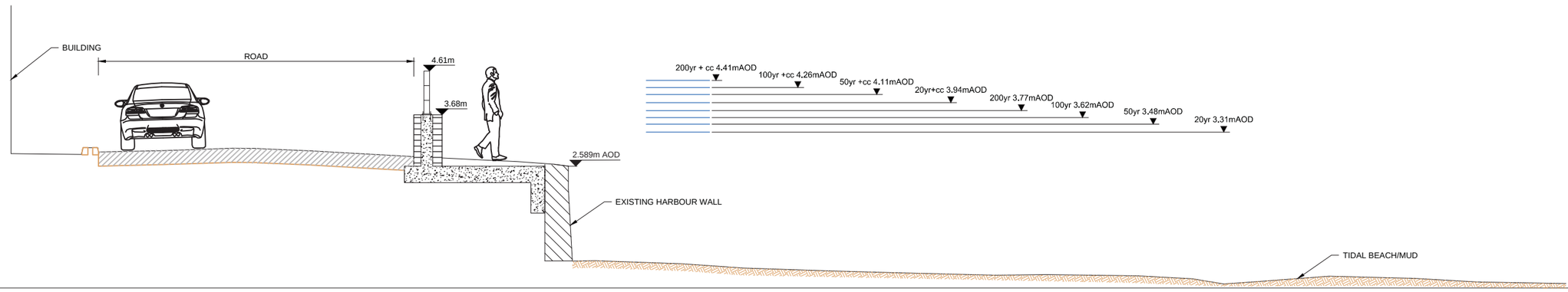

A | **SECTION A OPTION 2.4 - COMBINED PERNAMENT & DEMOUNTABLE**
G-#### | 1:50

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TARBERT FLOOD STUDY - PHASE 4 OPTIONS APPRAISAL

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LEGEND

- Option 2.4 combination of traditional/demountable wall
- Option 2.4 Flood Gates

ISSUE/REVISION

I/R	DATE	DESCRIPTION
A	2019-10-03	FOR INFROMATION

KEY PLAN

PROJECT NUMBER

60578115

SHEET TITLE

TARBERT FLOOD STUDY
Option 2.4 - COMBINATION OF PERNAMENT/DEMOUNTABLE

SHEET NUMBER

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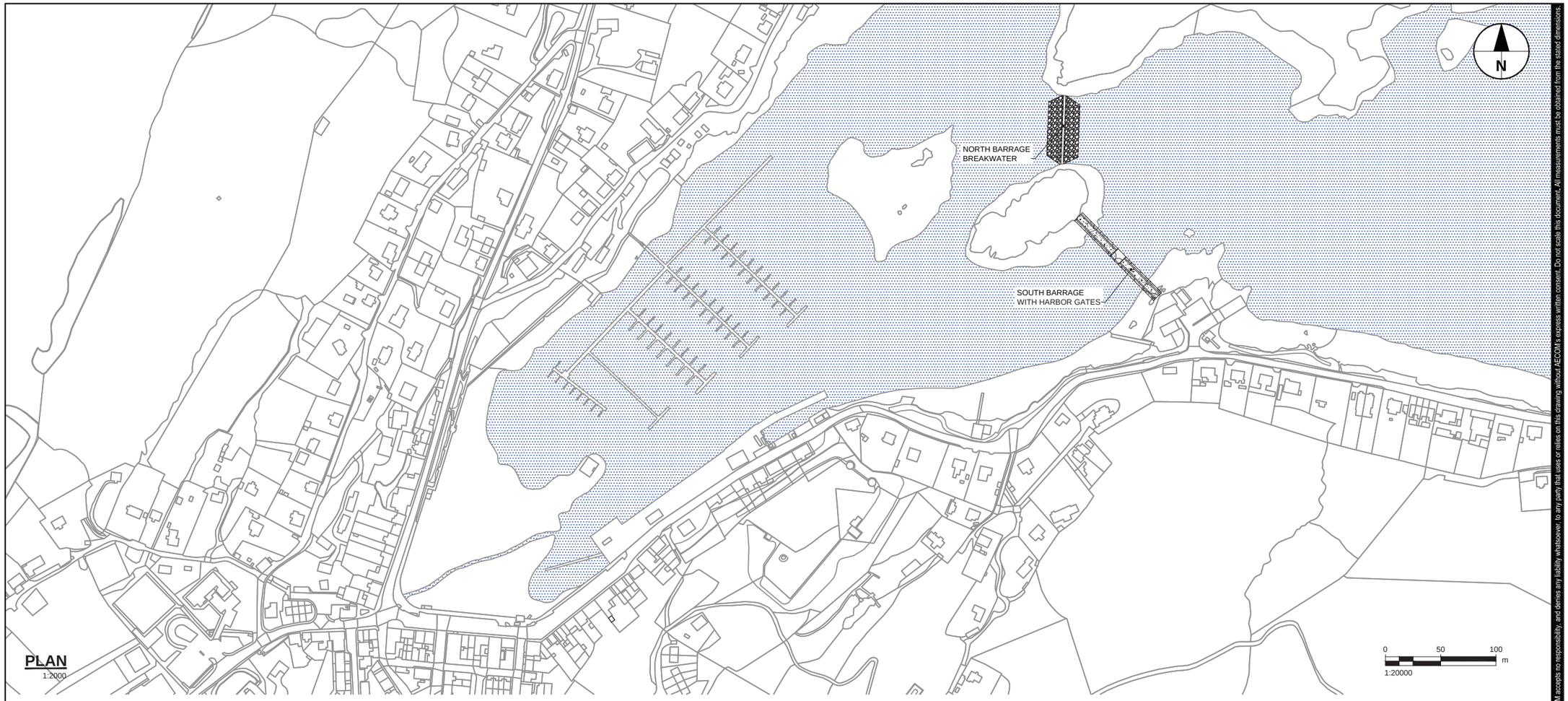

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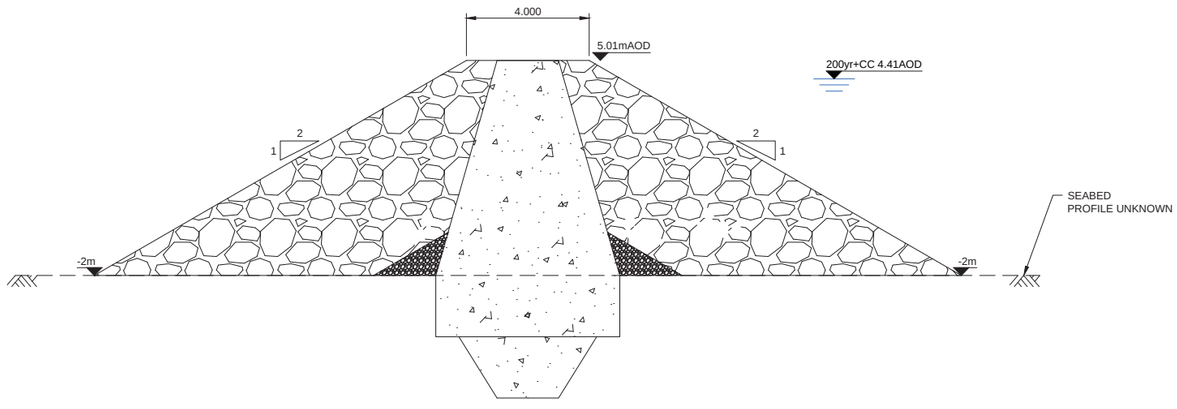
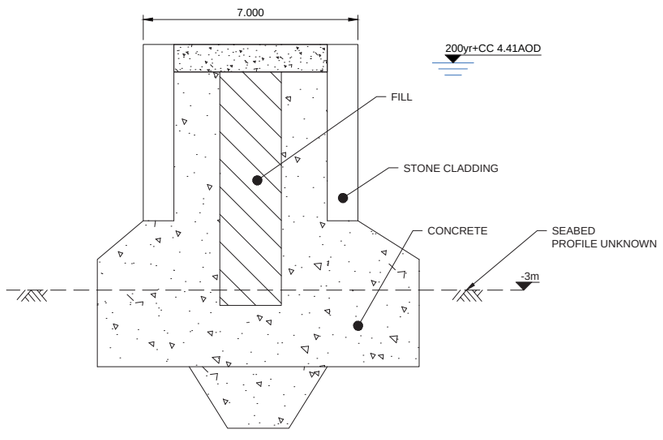


A | **TYPICAL SECTION OF NORTH BARRAGE**
G-#### | 1:100



A | **TYPICAL SECTION OF SOUTH BARRAGE**
G-#### | 1:100

0 2.5 5 m
1:100

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PROJECT

TARBERT FLOOD STUDY - PHASE 4 OPTIONS APPRAISAL

CLIENT

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LEGEND

NORTH BARRAGE
SOUTH BARRAGE
HARBOUR GATES

ISSUE/REVISION

I/R	DATE	DESCRIPTION
A	2019-10-03	FOR INFORMATION

KEY PLAN

PROJECT NUMBER

60578115

SHEET TITLE

TARBERT FLOOD STUDY
OPTION 2.5
DIRECT DEFENCES: TIDAL BARRAGE

SHEET NUMBER

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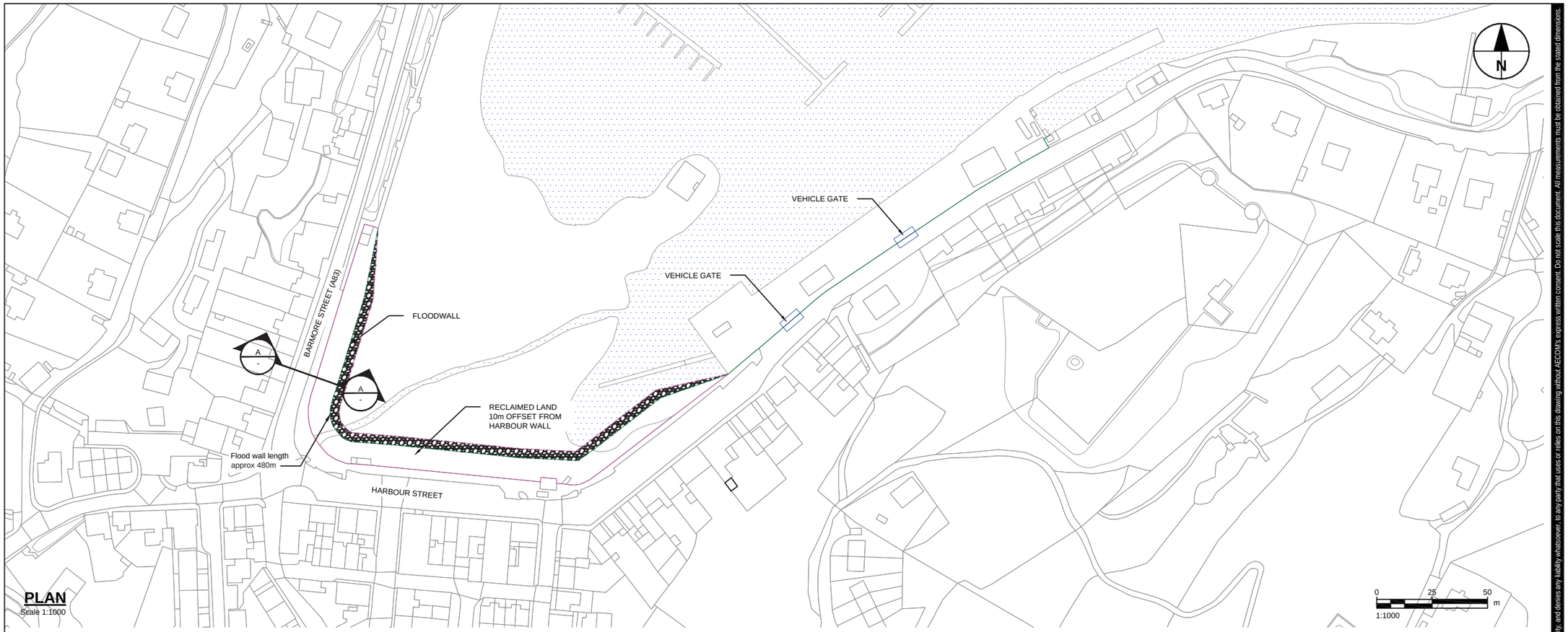

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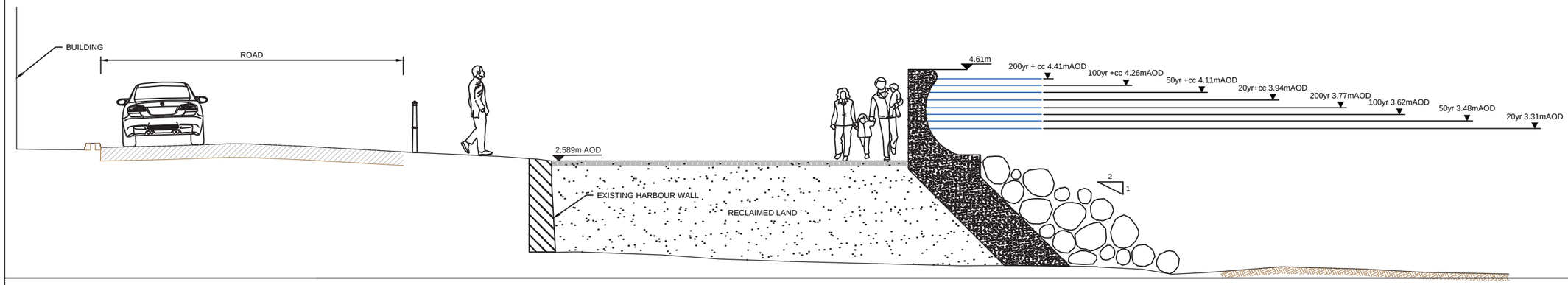

A | **SECTION A OPTION 10.1**
G-#### | 1:50

PROJECT

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LEGEND

- Option 10.1 Reclaimed Land area
- Option 10.1 Wall
- Option 10.1 Flood Gates

ISSUE/REVISION

B	2019-10-21	FOR INFORMATION
A	2019-10-03	FOR INFORMATION
I/R	DATE	DESCRIPTION

KEY PLAN

PROJECT NUMBER

60578115

SHEET TITLE

TARBERT FLOOD STUDY
Option 10.1 - LAND RECLAMATION AND DIRECT DEFENCES

SHEET NUMBER

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