Clachan Flood Study

Phase 4 Options Appraisal Report

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Quality information

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Executive Summary

Project Overview

Following a number of significant flood events in the village of Clachan in Argyll in recent years, a catchment group was set up to address flood risk. The group was made up of different authorities responsible for flood risk including SEPA, Scottish Water, Argyll and Bute Council (ABC), Scottish Forestry and community representatives. The discussions from this group partnered with the Flood Risk Management Act (Scotland 2009) has given Argyll and Bute the power and funding to commission a Flood Study for Clachan. AECOM Ltd was commissioned in June 2018 to undertake this study.

The objective of the study is to understand flood risk and its mechanisms more fully. The outcomes from this study will enable ABC to make an informed decision on the most economically, environmentally and socially viable options to alleviate flooding in Clachan.

Significant work has been carried out to understand the flood mechanisms affecting the village and to identify constraints and opportunities around potential flood mitigation options. River flooding from the Clachan Burn, driven by lack of channel capacity and backwater effect from an existing weir, has been shown to impact a number of properties along the river corridor. The A83 and Filling Station at the north end of the village are also impacted. Overtopping from the Allt Mor is also a significant source of flooding impacting properties along its right bank and travelling overland towards Clachan Burn.

Once flood risk in the area was understood, AECOM developed a long list of measures to address flood risk for fluvial flooding. These ranged from Natural Flood Management, formal upstream storage, flood diversion channels etc. Client and stakeholder workshops were used to derive a Short List of options based on assessment of measures taking account of Technical, Legal, Environmental and Economic perspective. The resultant Short List is shown in **Table 0-1** below.

Table 0-1 Short List Options

No.	Option	Description
1	Catchment wide Natural Flood Management (NFM)	Targeted NFM measures at key subcatchments to include installation of leaky barriers in ditches, upland ditch blocking and installation of leaky barriers to create 4 areas of wetland storage, hillslope planting and riparian planting. Features will slow flows entering watercourses.
2	Removal of Clachan Burn weir	Removal of redundant weir on Clachan Burn with associated erosion protection at river banks
3	Direct Defences	610m of flood wall along river banks of Clachan and Allt Mor Burns ranging from 1.2 – 2.4m high
4	NFM and weir removal	Combination of Option 1 and Option 2
5	NFM and direct defences	Combination of Option 1 and 546m of floodwall along river banks of Clachan and Allt Mor Burns ranging from 0.8 – 2.4m high
6	Weir removal and direct defences	Combination of Option 2 and 510m of floodwall along river banks of Clachan and Allt Mor Burns ranging from 0.7 – 2.4m high
7	NFM, weir removal and direct defences	Combination of Option 1, Option 2 with no bank protection and 225m of flood wall along river banks of Clachan and Allt Mor Burns ranging from 0.9 – 1.6m high
8	Property Level Flood Protection (PFP) 200year SoP	Passive flood resilience measures on 9 properties including flood doors, airbrick covers and repointing of brick. 3 non residential properties provided with demountable door guards and multiple airbrick covers.
9	Property Level Flood Protection (PFP) 200year+CC SoP	Passive flood resilience measures on 15 properties including flood doors, airbrick covers and repointing of brick. 4 non residential properties provided with demountable door guards and multiple airbrick covers.
10	Weir removal and PFP	Combination of Option 2 and Option 8

Option Development

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

- Hydraulic modelling – to understand impact of a measure on flood risk
- Public consultation – with the local community 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 if an option is value for money. This has been considered over the whole 100 year design life of the proposed option 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.
- Multi-criteria appraisal – to appraise options holistically in terms of social, economic and environmental impacts

The appraisal has allowed AECOM to assess the options against each other so that recommendations could made based on the appraisal of economic, social and environmental impacts, whole life costs and consideration of risk and uncertainty, both present and future. Weighing these considerations together, the appraisal has determined that the options shown in **Table 0-2** to be most viable:

Table 0-2 Short List Options

Option No.	Description	Costs	No. of properties with reduced flood risk	Benefit-Cost Ratio	Standard of Protection	Non-monetised benefits
2	Weir removal	£170,318.00	15	1.06	10yr - 25yr	• increased in-stream biodiversity • improved fish migration and habitat • restoration of channel morphology and sediment transfer processes
4	NFM and weir removal	£335,709.37	23	0.59	2yr - 25yr	• climate regulation, • habitat provision, • improvement in water quality, • betterment to channel morphology, • improved fish habitat, • erosion regulation, • reduced risk of structural damages of A83 maintaining link to community in long term • improved fish migration and habitat • etc.
8	Property Flood Protection – 200 year SoP	£80,433.23	13	1.03	200yr	• petrol station/post office building protected protecting key community building
10	Weir removal and Property Flood Protection – 200 year SoP	£237,214.52	21	1.11	25yr – 200yr	• petrol station/post office building protected protecting key community building • increased in-stream biodiversity • improved fish migration and habitat • restoration of channel morphology and sediment transfer processes

The options above (except for Option 4) have a BCR greater than one, demonstrating value for money even before considering non-monetised social and environmental benefits. On this basis any of these options could be submitted to SEPA for prioritisation for Scottish Government Funding on a national level. Option 4 could also be promoted for prioritisation based on the non-monetised benefits providing a feasible boost to it's BCR.

Option 10 offers the best solution in terms of standard of protection and economic return with gains also achieved within the water environment for morphology and fish habitat. Option 4 offers the best solution from a wider benefit perspective.

Recommendations

Based on the findings in this report, the following next steps are recommended to allow this Flood Study to be used as a driver for ongoing flood risk management in Clachan:

- Submit Option 10 (weir removal and targeted PFP) to SEPA for national prioritisation as the best economic option,
- Submit Option 4 (weir removal and NFM) to SEPA for national prioritisation as the best holistic option,
- Establish a Local Flood Action Group/Catchment Partnership to include community representatives and the different public bodies responsible for flood risk management. This should be used to identify interventions long term, examine for potential external funding and communicate maintenance/planning issues. Funding sources such as Scottish Forestry's Community Fund could be used to drive this,
- Engage with landowners affected by NFM options identified. This is vital for an NFM strategy to succeed as it involves changing how land is managed and incentivising/educating landowners to do this. This should be driven by the Local Flood Action Group/Catchment Partnership,
- ABC and SEPA should work in partnership to progress potential funding for a weir removal option either through a shared mechanism, direct ABC funding, Scottish Government funding in Cycle 2 of FRM cycle (2022 – 2028) or through other alternative funding sources.
- ABC to explore sharing river monitoring data through LFAG,
- ABC to follow up offline actions as budget permits e.g. maintenance of trees along bank, maintenance of road verge,
- SEPA to continue to monitor any reservoir works on Loch Ciaran as the regulator,
- Scottish Forestry to continue to work with commercial forestry in the area to ensure best practise is followed as the regulator.

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1. Introduction

1.1 Purpose of the report

Argyll and Bute Council (ABC) are investigating flood risk in Clachan and the Flood Risk Management Act (Scotland 2009) has given them the power and potential funding to address this risk but also to enhance the local area with proposed measures. AECOM Ltd was commissioned to undertake a Flood Study (FS) for Clachan. The objective of the study is to understand flood risk and mechanisms more fully as well as develop/appraise potential flood mitigation measures to reduce fluvial flooding. This will enable ABC to make an informed decision moving forward on the most economically, environmentally and socially viable options to alleviate flooding in Clachan.

At this point of the study, significant work has been carried out to understand the flood mechanisms affecting the village and to identify constraints and opportunities with regard to potential 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 Section 3. The short listed options resulting from the screening process have been developed in more detail in this report.

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

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

1.2 Summary of Project Objectives

Flood risk objectives aim to provide a common goal and shared ambition for managing floods. As Clachan was not included as a PVA in the first round of SEPA FRM Strategies, no flood risk objectives for the area have yet been set. As such this study has attempted to set objectives based on assessment of the underlying evidence of the causes and impacts of flooding. The short listed options will be appraised and the preferred option(s) selected based on the primary and secondary objectives set out below.

Primary Objectives for the Clachan area are:

- Reduce overall flood risk
- Reduce flood risk in Clachan from river flooding

Secondary Objectives are:

- To highlight surface water flooding as a separate source and set out catchment management strategies for future assessment
- To make the public more aware of causes of flood risk
- To encourage the community to develop a “community flood action group” to improve flood planning and resilience locally
- To allow the environmental enhancement of the waterbodies
- To improve wider catchment management practices

1.3 The process

The project is being carried out in a phased approach in line with Scottish Environment Protection Agency (SEPA) and Scottish Government Guidance[1][2]. **Figure 1.1** provides a high level overview of the study development process.

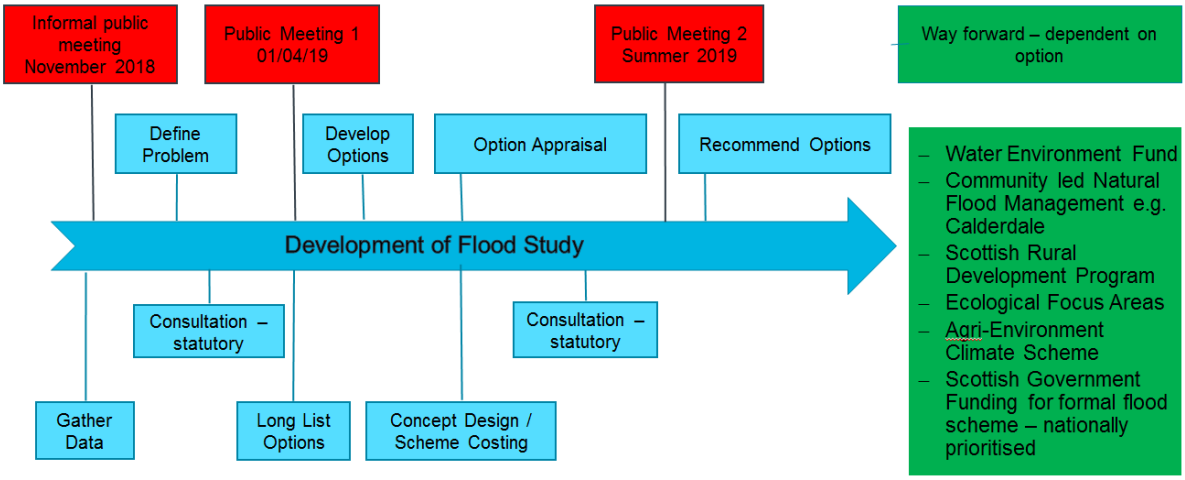


Figure 1-1 The study process

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 measures
- Screen to create a “short list” of measures
- High level appraisal of short listed measures

AECOM have adopted this approach for the study, and this report covers the high level appraisal of short listed measures. 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. If the scheme is prioritised for funding, it will then be submitted for approval to Scottish Government and the scheme details presented to the public for comment. Given the scale of flooding and level of economic damages that may be offset, it may be difficult to secure funding through this mechanism alone to provide significant reduction in flood risk. Alternative funding sources may be targeted where appropriate depending on the options which are shown to offer the most benefit through the appraisal.

[1] Options appraisal for flood risk management: Guidance to support SEPA and the responsible authorities, Scottish Government, May 2016.
[2] Local Authority flood study checklist, Version 2, SEPA, June 2017.

2. Baseline Modelling Results - Summary

There are two mechanisms of flooding affecting Clachan; pluvial and fluvial, and these are a result of the topography of the area and the nature of the river catchments. Pluvial flooding is caused by direct surface runoff flowing overland and ponding in low areas, and causing flooding before reaching a watercourse. The steep topography of the village and its surrounding area is such that during high rainfall events, there is little infiltration and high runoff is generated. In the past, this has caused problems of flooding and damage for the A83 road, the old road on the north side of the village and some properties.

Fluvial flooding is caused when a river overtops its banks. The village lies on the banks of the Clachan Burn and Allt Mor , which can both be prone to bank overtopping due to a lack of capacity in Clachan Burn channel and steep topography of the Allt Mor. Both catchments have extensive commercial forestry cover, with a programme of cyclical felling and replanting in operation.

In order to investigate the nature of the fluvial flood risk to Clachan, a 1D-2D model of the Clachan Burn and Allt Mor has been developed. This baseline model was run for a series of storm events to determine existing flood conditions. The inflows to this model are fed by a second fully 2D model of the whole catchment which was also constructed in Tuflow to assess the impact of forestry management of fluvial flows downstream and to allow for testing of Natural Flood Management (NFM) options as the study progressed. This model was run for a series of storm events to determine flows reaching downstream channels. Although sufficient data was not available to fully calibrate the catchment model, historic flood records and rainfall have been used for high level verification of the model. This work is fully detailed in the Phase 2 Report.[3]. The 1 in 200 year + climate change flood outline for Clachan is shown in Figure 2-1 below.

Baseline assessment indicated that fluvial flooding in Clachan is driven by a lack of capacity in the channels as well as a backwater/sedimentation effect from the weir downstream of the village.

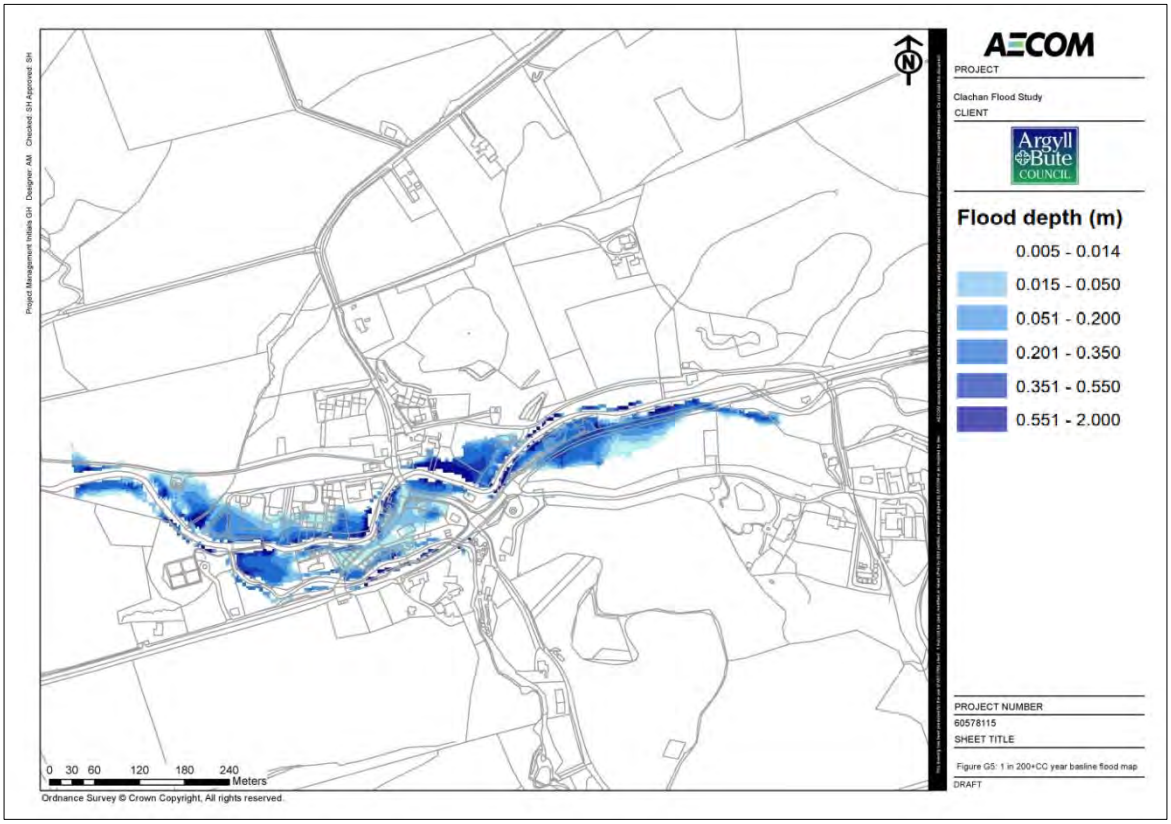


Figure 2-1 Baseline 200 year plus climate change flood extents (1D-2D model output for Clachan and Allt Mor burns)

[3] Clachan Flood Study, Baseline Modelling Report, December 2018

2.1 Clachan Burn catchment

Flooding from the Clachan Burn is shown to affect farmland upstream of Clachan, roads and several properties and gardens within the village. Overtopping of the burn occurs first at the Filling Station, on the A83 road and into the fields upstream during a 1 in 2 year event. This is likely related to a lack of capacity in the channel at this location, with a low left bank and steep right bank, allowing water to spill out of the channel. The topography in this location is such that floodwater cannot escape and builds up at the Filling Station and on the road. The field to the east of the confluence of the Clachan Burn and Allt Mor is also affected by flooding during this magnitude of event.

During the 1 in 5 year flood event, water spills from the Clachan burn to gardens on the left bank, downstream of the road bridge within the village and on the right bank into gardens at Mansecroft and the caravan park.

2.2 Allt Mor catchment

The Allt Mor is a very steep watercourse, but is impacted by the regulation of flows from Loch Ciaran. Flooding from this burn is shown to occur from the 1 in 2 year event on mainly the left bank downstream of the A83 and around its confluence with the Clachan burn. This is likely due to the sudden reduction in gradient of the burn downstream of the road. At the 1 in 5 year event, flooding around the confluence covers a wider area and there is some increase in inundation on the left bank downstream of the A83. A relatively large number of properties are predicted to be affected during the 1 in 200 year + climate change event.

2.3 Pluvial Flooding

Pluvial flooding has been experienced on at least two occasions in Clachan (August 2012 and February 2016) and is related to the steep fields surrounding the village. Key locations where this mechanism has been seen are:

- on the north side of the village where flow has exceeded road culverts and is routed down the old road;
- on the south side of the village where flow is generated from the steep fields to the west of the Allt Mor and flows onto the A83 and down the local road into Clachan;
- the slopes above Balinakill House are also very steep and rapid runoff is generated here, leading to flow through the grounds of the properties in this area and across fields towards the A83;
- the hillslopes along the A83 to the east of the village (on the north side) are very steep and runoff can lead to overtopping of roadside ditches and subsequent flooding of the road.

Surface water management planning is outwith the scope of this study. However, site visits and historic information have helped identified pluvial flooding as a separate source and options will be recommended to better manage the catchment from this aspect. At present, the level of detail required to model and test the potential pluvial options with a degree of confidence is not available due to the low quality of ground model data and lack of survey for key drainage routes. As such high level recommendations were made in the Phase 3 Options Screening Report[4] for pluvial options rather than a full assessment. These should be considered by ABC for future management of surface water flood risk in Clachan.

[4] Clachan Flood Study, Phase 3, Options Screening Report, AECOM,

3. Short Listing Process

Following baseline modelling, an option screening was carried out based on guidance in the Flood Risk Management (Scotland) Act 2009. An initial long list of options with the potential to reduce flood risk in Clachan was developed through an internal workshop to identify feasible options from a flood risk performance, constructability, engineering and economic perspective. Significant work was then carried out to assess the feasibility of options in order to screen the list.

The full Long List to Short List screening process is detailed in 'The Clachan Flood Study Options Screening Report'[5]. 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 Scottish Water to integrate their feedback to shortlisting process
- Public consultation event to gain feedback on options and factor this into appraisal
- High level modelling to target subcatchments for intervention
- Natural Flood Management assessment to identify potential NFM solutions
- Ecological Preliminary Appraisal Study and Planning and Environmental Constraints Study to identify constraints to further inform appraisal and to be taken into account when developing short listed options

These inputs were layered up to discount options and obtain a short list which is set out in Table 3-1.

Figure 3-1 below illustrates the Clachan Village Study area and gives locations used as reference points through out this report.

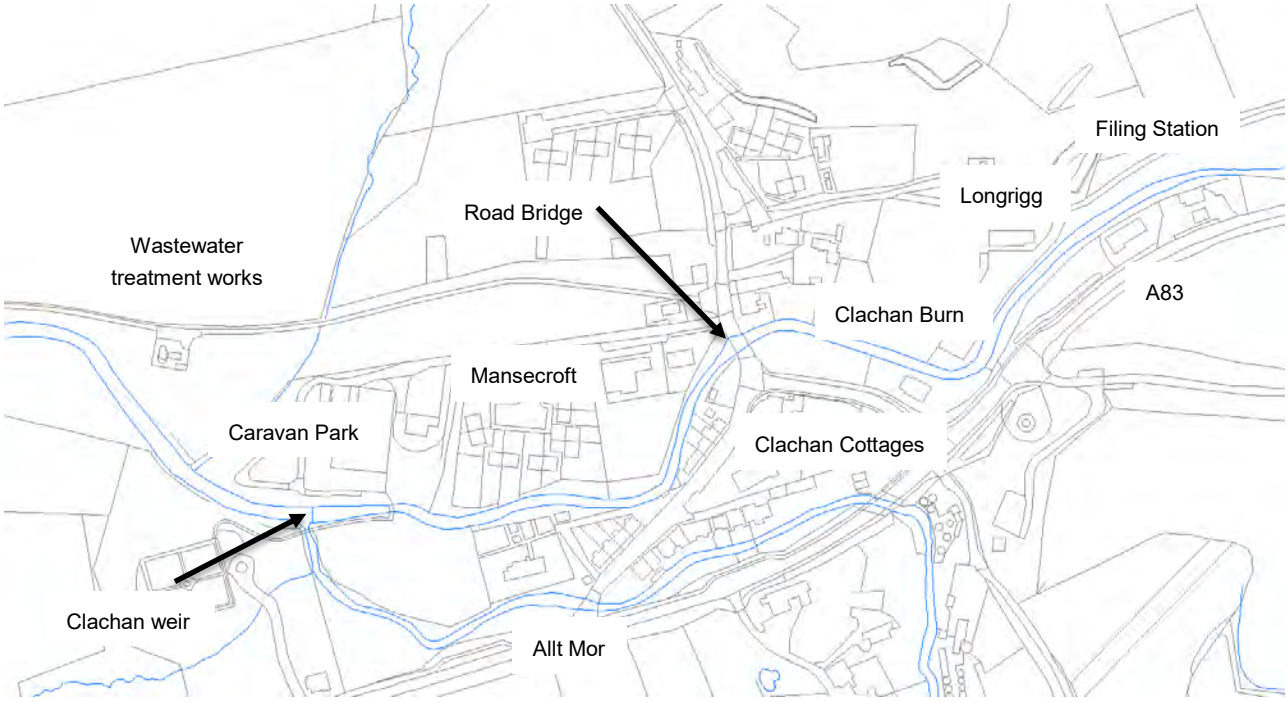


Figure 3-1 Study area

[5] Clachan Flood Study, Options Screening Report, AECOM, April 2019

Table 3-1 Short list of options

Measure Category	Type of Measure	Measure	ID
Local Options	Property Flood Protection	Assess properties within 0.6m flood depth as optimum for PFP as a resilience rather than prevention technique.	1.2
	Self Help/ Local Flood Action Group (LFAG)	This includes preparing a flood plan and flood kit, possibly installing property level protection, signing up to Floodline and Resilient Communities initiatives, and ensuring that properties and businesses are insured against flood damage.	1.4
Clachan Burn – NFM options	Wetland enhancement to south east of Balinakill	Provide storage and attenuation to reduce flows entering Clachan Burn higher in catchment	2.6
	Wetland enhancement & ditch blocking to north of Scotmill	Provide storage and attenuation to reduce flows entering Clachan Burn higher in catchment	2.7
	Riparian woodland	To increase roughness higher in catchment to create restriction and storage for flood water	2.8
	Wetland enhancement & ditch blocking to south west of Loch nan Gad	Provide storage and attenuation to reduce flows entering Clachan Burn higher in catchment	2.9
Hard engineering options	Weir modification/or removal	Weir modification/or removal	3.1
	Flood defences – embankment or wall	Flood defences along the Clachan Burn at vulnerable locations in the village	3.3
Allt Mor Options	Natural Flood Management	Tree planting and leaky barriers on tributary	4.4
	Wetland enhancement	Wetland/ storage area on right bank of Allt Mor	4.5

4. Modelling and Development of Short Listed Options

The short list options to be technically assessed were grouped, where appropriate and renamed for clarity:

- Option 1 – catchment wide natural flood management (NFM)
- Option 2 – removal of Clachan Burn weir
- Option 3 – direct defences
- Option 5 – NFM catchment wide with defences
- Option 6 – removal of Clachan Burn weir and defences
- Option 7 – NFM, weir removal and defences
- Option 8 – Property Level Flood Protection

4.1 Option 1 NFM catchment wide

As part of the initial option screening exercise carried out in Phase 3 an assessment for potential natural flood management options was undertaken. The catchments are already heavily forested as well as being influenced by several loch's. Both elements provide attenuation benefits and limit the potential opportunities to reduce runoff further. However, carrying out a subcatchment analysis to assess contributions from different areas of the catchment using the 2D catchment model allowed us to identify where the greatest opportunities were to place features that could slow the flow entering the Clachan and Allt Mor watercourses. Subcatchments CB8, CB9, CB10, CB11,CB12, AM11 and AM12, highlighted in Figure 4-1, were shown to have the highest contributions of flow to the village per km^2 so the assessment of measures has been focused here.

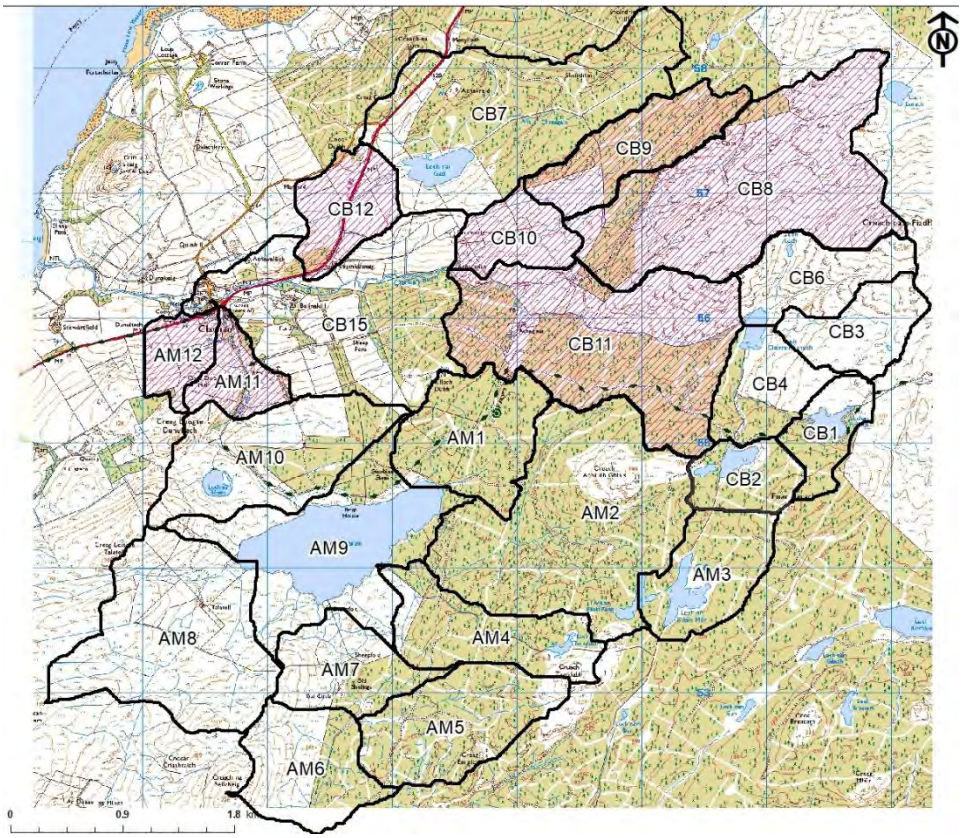


Figure 4-1 Subcatchments within study area

This process combined with site walkovers and analysis of desktop information such as topographic maps identified a selection of NFM interventions which could have a flood risk benefit.

4.1.1 Clachan Catchment NFM measures

For the Clachan catchment these options included:

- **Riparian planting** along the banks of the upper reaches of the Clachan Burn (**Option 2.8**). These would be buffer strips 15 -20m wide of broadleaf planting. This offers the benefits of infiltration and evapotranspiration to provide increased floodplain storage upstream. The main benefit in Clachan is to increase hydraulic roughness to slow and restrict flows higher in the catchment
- **Installation of leaky barriers in ditches** in this steep part of the catchment near Balankill House (Figure 4-6) would slow flows rather than provide storage. These features would be robust wooden dams on steep watercourses. Leaky barriers (Figure 4-2, Figure 4-3) can be constructed by hand and are a relatively simple structure. Two posts are knocked into the toe of the bank and sections of tree trunk of branches are placed against them with smaller branches and brash added, then secured with wire. The height of the structure should be positioned so that water is encouraged onto the floodplain during high flows.

Figure 4-2 Cumrew beck, Eden Rivers Trust

Figure 4-3 Newly constructed woody debris dam in Yorkshire Dales

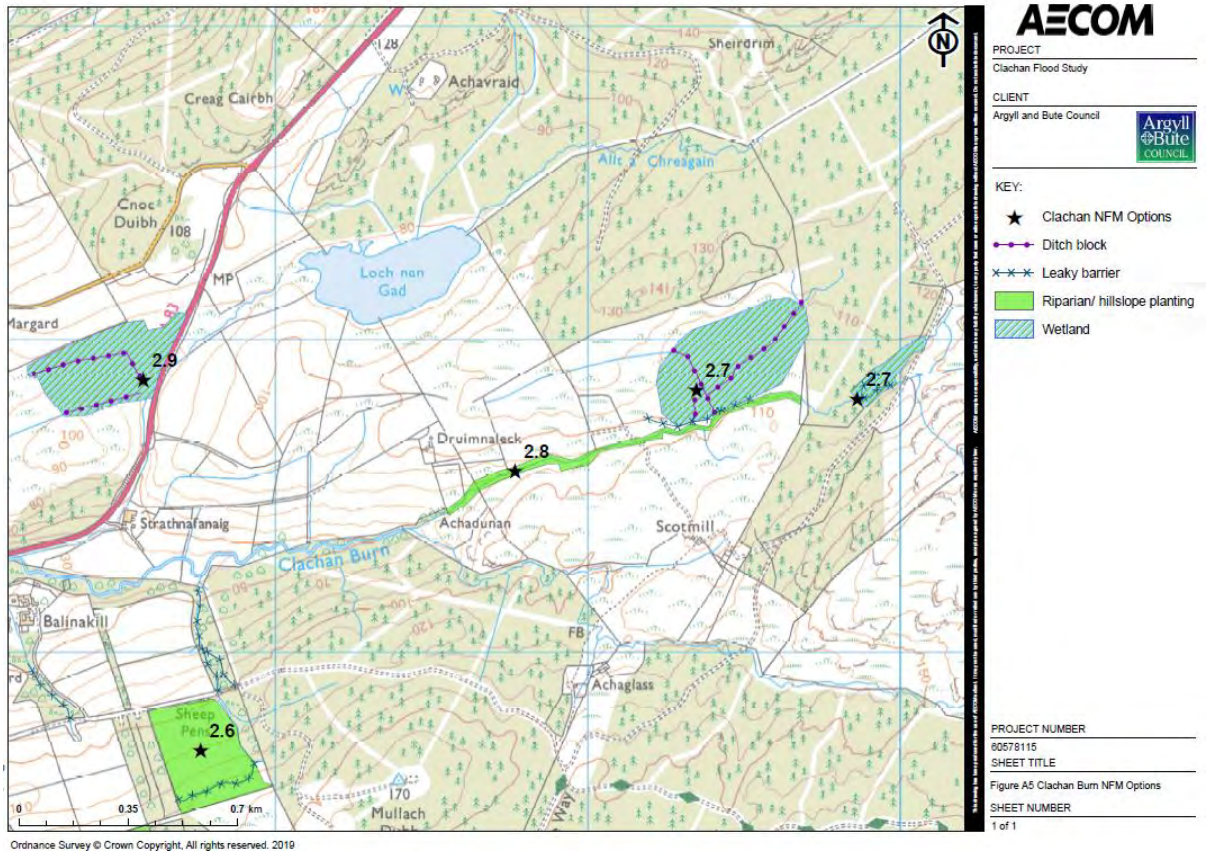
- **Upland ditch blocking and installation of leaky barriers to create wetland storage** in pockets across the Clachan Burn catchment (Options 2.7 and 2.9). This will provide small scale upstream storage. The areas identified as wetlands on the Clachan catchment are flat areas which are naturally boggy but appear to be heavily artificially drained. Ditches would be blocked with heather bales to utilise more natural and low cost materials (Figure 4-5). This forces water to be retained and spread out over this naturally flat and boggy area. A more engineered structure would then be installed prior to the ditches' confluence of the Clachan Burn. This would be in the form of wedged logs. To construct these four strainer posts would be driven into ditch banks parallel to each other and locally sourced timber logs placed between them. Plain wire is then used to secure the timber in place and prevent them moving. This creates a more robust flow constriction and reduces the risk of debris becoming loose. Engineered leaky barriers would be constructed with a crest level slightly higher than that of the top of bank of the ditch to encourage excess water to be redistributed back out onto the moorland surface. The leaky barrier then allows water to slowly pass through it reducing velocity and runoff of water entering Clachan Burn during heavy rain. These interventions were targeted at subcatchments CB12,CB8, CB9 and CB10 which are high contributors to flow.

Figure 4-4 Engineered Leaky Barrier

Figure 4-5 Heathbale ditch blocking

- **Hillslope planting** on steep slopes partnered with leaky barriers north of Balankill House to slow flow within smaller feeder tributaries/ditches within the Clachan Burn (Option 2.6).

Figure 4-6 Clachan Burn NFM Options



4.1.2 Allt Mor Catchment NFM measures

For the Allt Mor catchment there is much less opportunity given the dominating attenuation impact of Loch Ciaran and the steep nature of the remaining catchment limiting both the impact and technical capacity to install NFM measures. For the Allt Mor the NFM options include:

- **Ditch restriction** using leaky barriers higher in the catchment partnered with hillslope planting to attenuate flows (Option 4.4). As this area is steeper, robust leaky barriers would be required to block ditches due to the likely force of overland flows.
- **Wetland creation** to provide small scale storage and attenuation of flows through in-channel leaky barrier (Option 4.5). The crest of this in channel wedged log structure would sit above channel bank level to encourage high flows to flow onto the flat topographic area identified as potential wetland. The leaky barrier would then act as a barrier in the channel so that flow must dissipate and settle on the surrounding area, creating the wetland.

Figure 4-7 in channel engineered leaky barrier (Pickering)

Figure 4-8 Riparian planting (Lake District)

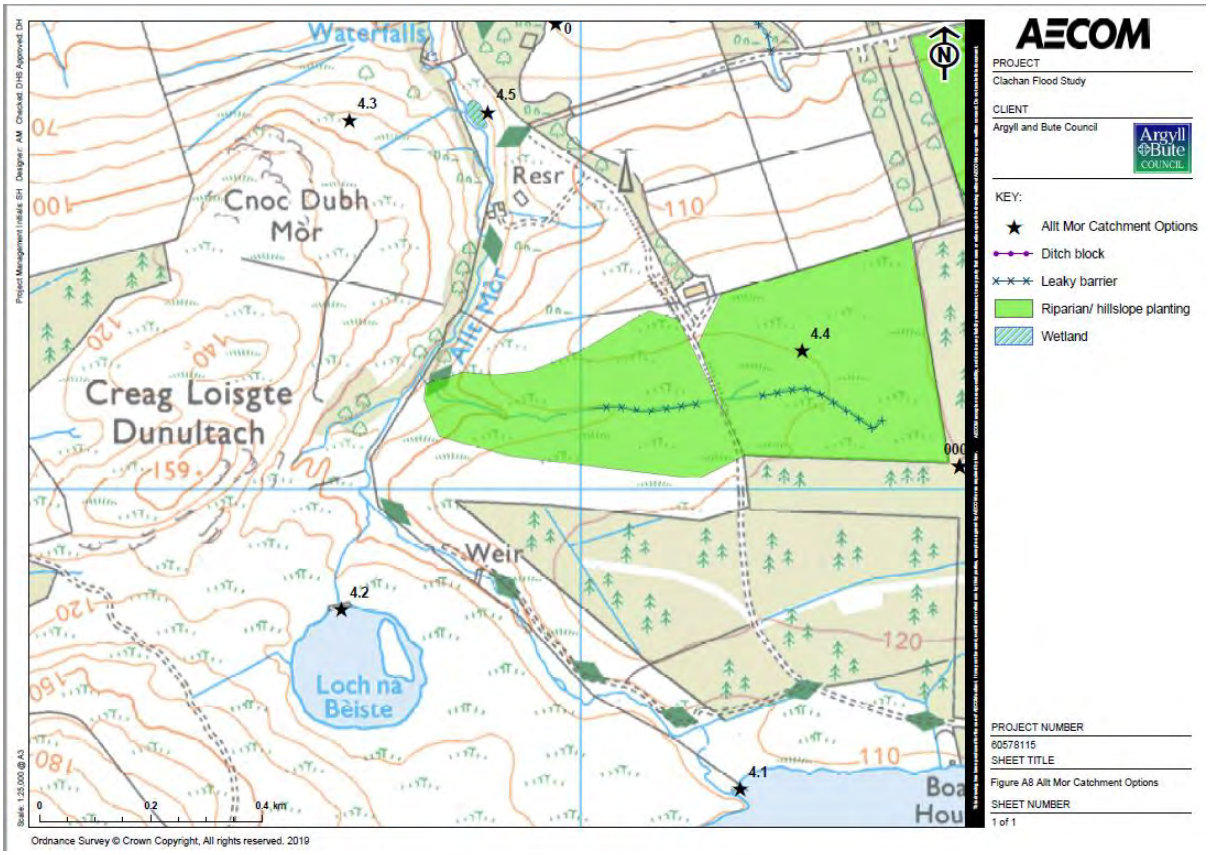


Figure 4-9 Allt Mor NFM Options

4.1.3 Testing of NFM measures

NFM on a catchment wide scale was tested using the 2D hydraulic model of the catchment to test how the physical changes to the catchment would impact the runoff generated in terms of flow and time. Given the small scale nature of the interventions, one localised measure is unlikely to have a discernible impact even during small magnitude flood events. NFM works best when it is utilised on a catchment wide scale to allow incremental gains in terms of attenuation and timing of floods across the catchment to maximise the downstream benefit. On this basis, NFM solutions were tested together as a single option.

Ditch blockages at wetlands on the Clachan Burn were modelled in TUFLOW by modifying the underlying ground model. This involved raising the height of the ditch line to block flow from entering this route. A leaky barrier was then represented along the confluence of ditch and watercourse using a flow restriction layer with soffit of the restriction set above bank level to represent the restriction a leaky barrier would place on flow. A 70% blockage factor[6] was chosen based on research into similar modelling approaches of leaky barrier implementations developed by Forestry Commission Hydrologists. The wetland area identified in the Allt Mor catchment was represented in the same manner although this leaky barrier would be installed within the watercourse, rather than at a tributary.

The impact of riparian and hillslope planting on surface flows was represented by applying a flow restriction through each grid cell, which was considered to produce a more realistic hydraulic response over modification of Manning “n” roughness values. This is consistent with our representation of commercial forestry tree stands as detailed in the baseline modelling report[7]. A factor of 25% was applied to represent the more naturally spaced nature of the planting compared to the 40% chosen for commercial forestry.

In-channel leaky barriers identified at steep areas of both catchments were represented by 70% blockage function to the top of bank level of the ditches. These leaky barriers were spaced approximately 1 grid cell apart (10m), assuming the ditch was a maximum width of 1m. This was

[6] THOMAS, H. AND NISBET, T., 2012. Modelling the hydraulic impact of reintroducing large woody debris into watercourses. Journal of Flood Risk Management, 5 (2), 164-174.
[7] Clachan Flood Study, Baseline Modelling Report, AECOM, December 2018

based on a design guide developed by the Yorkshire River Dales Trust which indicates barriers should be spaced at approximately 7 times the channel width. This suite of options was tested for a range of return periods to understand what flood risk benefit could be achieved.

As discussed previously, subcatchment analysis was used to identify focus areas for NFM potential. Outputs from the catchment model at key subcatchments were again analysed to determine the impact of NFM measures on these lower lying areas of the catchment. Analysis of the 1 in 25 year event is shown in Table 4-1 for key parts of the catchment.

At this level of event, flow contribution from CB8 and CB9 is reduced by 8% and 60% respectively due to wetland creation. CB9 is a much smaller catchment so the impacts are more pronounced than on CB8 which covers an area 5 times larger. The combined impact of both wetlands has a small overall influence reducing peak flow in the Clachan Burn downstream by 4%. However, these interventions are shown to slow the flow of water increasing the individual times to peak by 40mins and 15mins respectively for these subcatchments. This equates to an increase in time to peak in the watercourse downstream of 15mins. Further downstream, additional wetland storage at Strathnafanaig reduces flow contribution from this subcatchment (CB12) by 14% increasing this subcatchment's time to peak by 10mins. The impact of leaky barriers downstream on steeper ditches is also shown to reduce contribution from these areas by 5%.

The combined influence of wetlands and leaky barriers are shown to have cumulative impact downstream within Clachan. At CB15 peak flows are reduced by a small amount (5%) but the time to peak is increased by 25 mins. The impact on peak flows is small due to fact the modelled measures offer limited storage volumes and influence only 10% of the total catchment area of the Clachan Burn. However, the impact on storm response time is significant. By slowing the flow to the Clachan Burn, this allows the capacity of the Clachan Burn channel to be utilised more effectively during storm events so flow can pass through the village in a more controlled manner reducing the volume of overtopping, and reducing flood risk.

On the Allt Mor catchment, there are two peaks in the storm (Figure 4-11), the first is due to the normal response of the watercourse downstream of Loch Ciaran, and the second is due to the flow from the catchment upstream of Loch Ciaran, attenuated by the loch. NFM measures are shown to provide some storage in the lower reaches of the Allt Mor catchment, reducing the first peak flow by 18%. Given the steep nature of this catchment at this location, a reasonable volume of storage can be achieved over a small area. The time to peak is unchanged limiting the effectiveness of this measure. This is again due to the steep nature of topography - the area would fill very quickly at the start of the storm meaning there would be no available storage at the peak of the storm, limiting the attenuation impact on flow response.

Overall, catchment modelling indicates a 7% reduction in peak flow and increase of 20 mins in time to peak in the Clachan Burn within Clachan up to a 1 in 25 year event as shown in Figure 4-10. At higher return period events such as a 1 in 200 year event, the impacts of NFM measures are minimal with a 3% reduction in flood peak and no real impact on time to peak. For the Allt Mor catchment, generally the initial peak in flow is reduced by 20% with no real impact on time to peak up to a 1 in 25 year event. At higher return periods the NFM impacts are significantly reduced with flows reduced by around 4%. Modelling indicates NFM has a positive influence on flows on small magnitude storm events.

Table 4-1 Subcatchment analysis of NFM Measures (1 in 25 year event)

Location	Subcatchment	Base Time to peak (hours)	Peak flow Baseline (m^3/s)	NFM Time to peak (hours)	Flow NFM (m^3/s)	Increase in time to peak within individual subcatchment (mins)	% reduction in peak flow within individual subcatchment
Smaller Scotmill Wetland (2.7)	CB8	3.2	10.8	3.5	9.9	15	8
Larger Scotmil Wetland (2.7)	CB9	3.0	1.7	3.7	0.7	40	60
Dowmstream Scotmill Wetlands (2.9)	CB10	3.1	3.3	3.3	3.1	15	4
Downstream Strathnafanaig wetland	CB12	2.6	2.1	2.8	1.8	10	14
Within Clachan	**CB15**	**2.7**	**33.3**	**3.6**	**31.6**	**25**	**5**
Downstream Allt Mor wetland	**AM12**	**2.8**	**5.6**	**2.8**	**4.6**	**0**	**19**

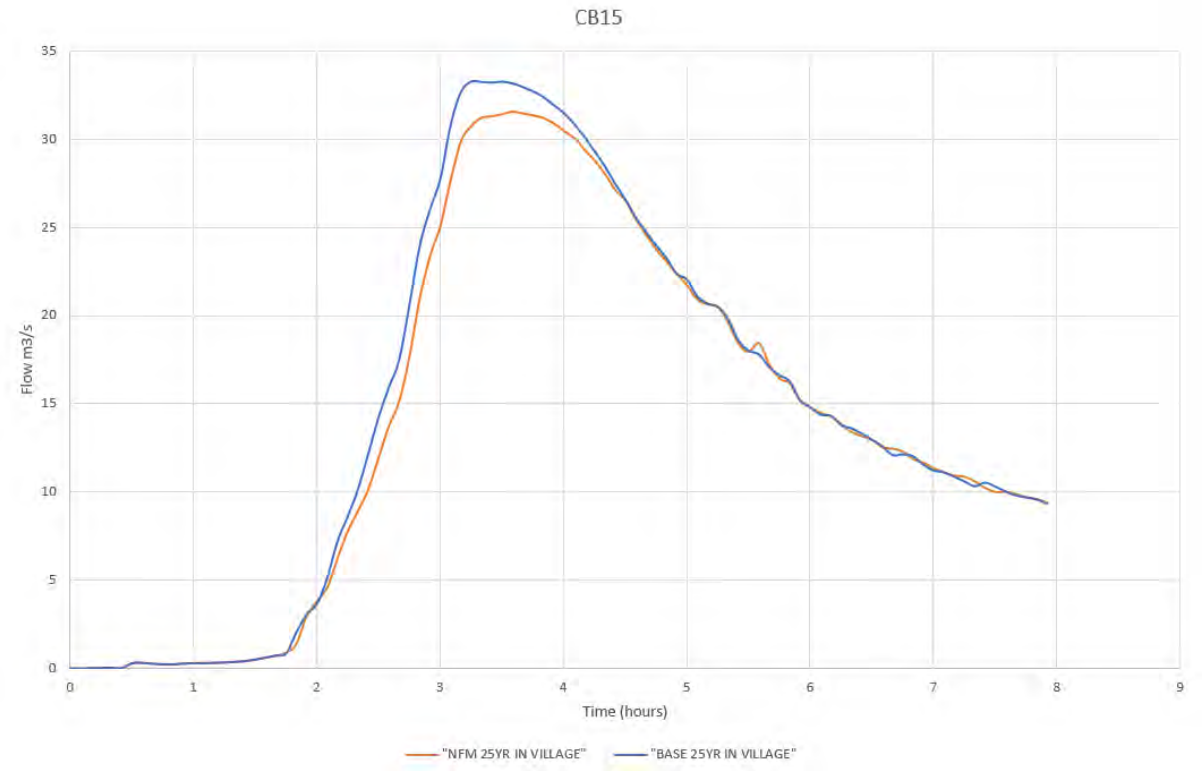


Figure 4-10 1 in 25yr hydrograph comparing flows in Clachan Burn

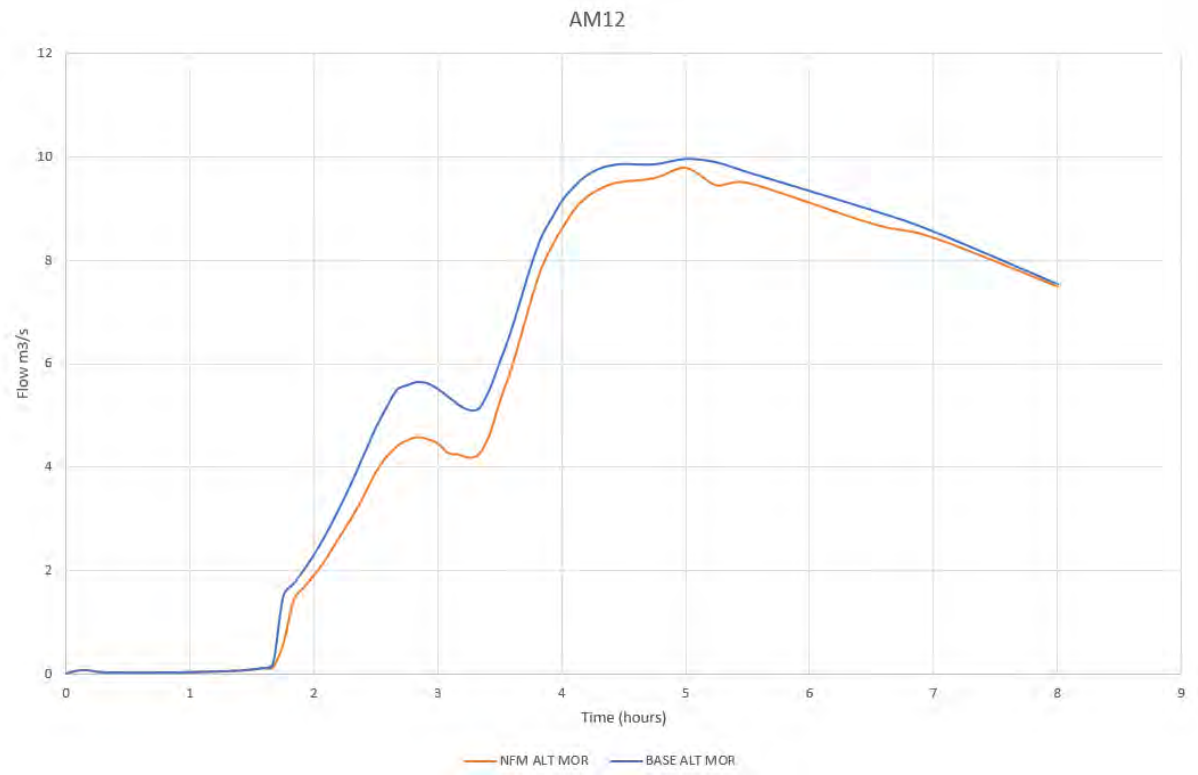


Figure 4-11 1 in 25 year hydrograph comparing flows in Allt Mor

Inflow hydrographs for the Clachan Burn and Allt Mor were extracted from the catchment model outputs and run through the more detailed 1D model of the watercourses within the village in order to understand how NFM would impact flood response in the village.

At a 1 in 2 year event, the only flooding is at the A83, Filling Station and the adjacent property to the south. NFM is shown to reduce flood depths here by 30mm. Although this is minor, the residential property in this area is no longer predicted to flood at this frequent event. During baseline conditions, flooding from the Clachan Burn was predicted to impact gardens at cottages downstream of the old road bridge and buildings at Longrigg from a 1 in 10 year event. With NFM measures in place these locations are no longer impacted by flooding at this return period. Overtopping is still predicted to impact gardens at Mansecroft though flood depths are reduced by 30mm. At the Filling Station, A83 and cottages on the left bank of the Clachan Burn there is a negligible difference in flood risk for this event. On the Allt Mor the impacts of NFM are minor with no change to flood extent but reduction of flood depth of 30mm at a in 1 in 10 year event.

At a 1 in 25 year event, again the flood impacts to receptors are small with depths to gardens at Mansecroft and adjacent to the road bridge reduced by 20 - 40mm. At more extreme events such as a 1 in 200 year event, the impacts are similar with the flood extent largely unchanged but a reduction in flood depths of 40mm at Mansecroft, Clachan cottages and Allt Mor cottages whilst the risk to the A83 and Filling Station is unchanged.

The assessment of NFM indicates flood alleviation betterment is achievable events up to a 1 in 25 year event through low intensity and low cost measures. This is consistent with other NFM studies which have been carried out. It is generally accepted in the industry that NFM will not solve flood risk problems alone as it is a small scale measure, however pairing this with an engineering solution could enhance the potential benefit. Furthermore, although NFM will not prevent flooding it can reduce its impact and deliver increased resilience. It must be stated that as with any modelling exercise undertaken, there is a level of uncertainty associated with the results. In this case, uncertainty is greater compared to hydraulic modelling and design of traditional engineered solutions as the science

and modelling methods behind natural flood management is still developing. Post implementation monitoring and assessment of a small number of existing schemes is being carried out by the Environment Agency and should be taken into account during the development of any NFM measures.

NFM measures are low cost compared to an engineered scheme and require minimal maintenance except for inspection and small works by land managers. The key challenge in implementing NFM will be identifying funding sources and engaging landowners in a catchment management approach.

4.2 Option 2 Weir removal

As stated in the Phase 2 modelling report[8], the weir structure immediately upstream of the Allt Mor and Clachan Burn confluences is shown to have a backwater effect on the Clachan Burn. In addition, the structure itself has led to sediment build up within the channel, restricting its already limited capacity. This weir is redundant and therefore could be removed. However, clearly a geomorphology assessment would be required to ensure this is done in a way that channel banks and associated structures along the Burn are not placed at risk of erosion due to increased flows and velocities. Argyll and Bute Council will be responsible for this risk, careful consideration must be taken when looking at options to remove the weir

A scenario was run in the 1D-2D model with the weir removed to test the impact on water levels and velocity in the reach upstream. Bed levels were also lowered in sections up to the road bridge to follow the natural gradient of the Burn where there was evidence of sedimentation. The removal of the weir is expected to release this sediment and allow the river processes to return to their natural state.

Figure 4-12 Weir adjacent to caravan park

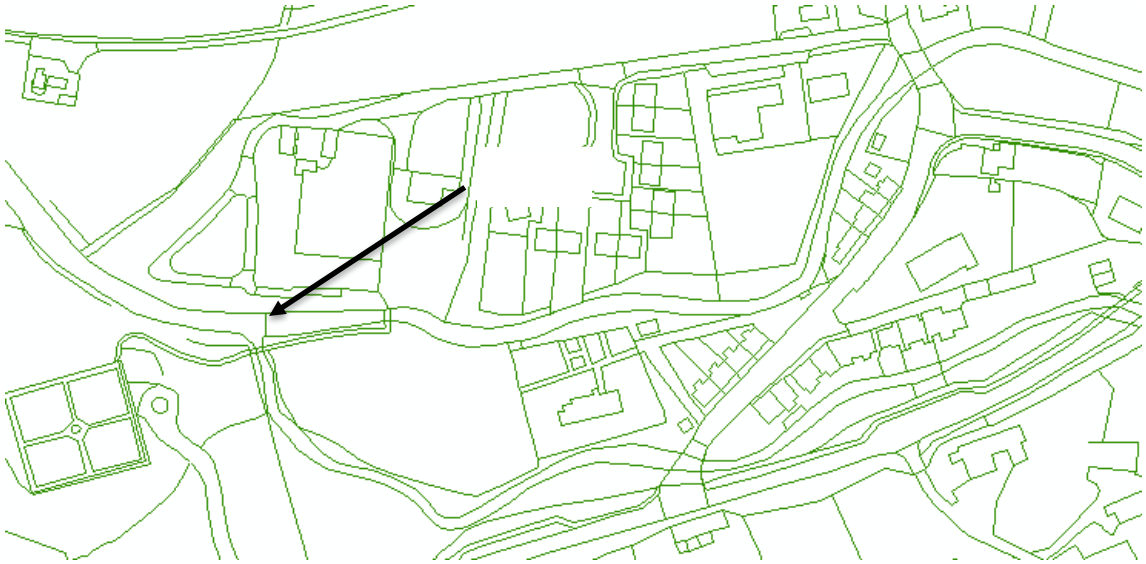


Figure 4-13 Weir Location

[8] Clachan Flood Study, Baseline Modelling Report, AECOM, December 2018

The removal of the weir was shown to have a positive impact on flood risk. At a 1 in 10 year event, the removal of the weir removes flooding at the gardens of Clachan Burn cottages and prevents overtopping at the caravan park. Flooding at the gardens at Mansecroft is also reduced in depth by 120mm. This is due to the increased capacity of the Clachan Burn channel in this location. At a 1 in 25 year event, flood extent is shown to be reduced at Mansecroft and flood depths are also substantially reduced from 0.3m to 0.1m. The gardens of cottages downstream of the road bridge are still affected by flooding at this return period but to a lesser extent and flood depths are reduced by 100mm. During more extreme events such as 1 in 200 year, the impact of weir removal is limited. The flood extent is largely unchanged, however there are reductions in flood depth of up to 50mm around Clachan cottages and Mansecroft, likely due to slightly increased capacity of the channel as a result of removal of sediment.

Flood risk upstream of the road bridge is unchanged as the backwater impact of the weir does not extend this far upstream. Flood risk at properties along the Allt Mor is unchanged as the weir has no influence on the Allt Mor.

Modelling indicates removal of the weir would result in a localised increase in velocity in the reach from the weir to approx. 45m upstream. This has the potential to generate bank erosion and a full assessment would need to be carried out to determine if any erosion protection needs to be provided. Greenbank protection could be utilised to avoid hard engineering measures which would limit the capacity of the channel.

The works would fall under Controlled Activities Regulations (CAR) and a licence would be required from SEPA. It is likely that temporary isolation of the channel would be required so that sediment released during construction works would not be washed downstream. Given the short duration of works and complexity of working at a confluence, full isolation with a by-pass pipe arrangement is likely to be necessary. Construction would need to be timed based on consultation with SNH and appropriate fish rescue provided.

Testing of this option has shown it can provide a positive flood benefit. This measure would be simple from a constructability and cost perspective and could also improve the water environment as well as improve fish migration in the river channel. As a small scale intervention this measure will not solve the flooding problem in Clachan alone, but it could provide a reduction in flood risk for more frequent storm events.

4.3 Option 3 Direct Defences

Direct defences were explored at four key areas, Clachan Filling Station, downstream of the road bridge, Mansecroft and Allt Mor where overtopping originates. The main purpose of the defences is to protect properties.

Direct defences were tested in the 1D-2D hydraulic model and represented as a ground model modification with an assigned elevation to represent the defence height and location in the 2D domain of the model. An iterative approach was used to test defence heights in the model using the 1 in 200 year flood level as a start defence level working upstream to downstream. This was to ensure that any potential movement of flood risk downstream was accounted for and included in additional defences. This level was chosen to limit visual intrusion at properties as most walls would be lower than 1.8m high, whilst still providing a high standard of protection (SoP).

Although flood embankments are preferable as defences in terms of visual amenity and cost, the required physical space based on the heights of defence required is not available. A minimal footprint of 12m would be required for the smallest defence. This space was either unavailable due to existing properties or would significantly encroach on garden areas. In addition, given the constrained nature of the bank areas of the Clachan Burn, the removal of floodplain storage through the construction of a bund is likely to increase flood risk on the opposite bank. On this basis, flood embankments are not appropriate for Clachan.

240m of direct defence ranging from 1.8 – 2.4m high would be required to protect the Filling Station and A83 to a 1 in 200 year event, resulting in significant felling of trees on the left bank. Further downstream, the required defence height is 1.8m high over a length of 68m at the cottages downstream of the road bridge at the Clachan Burn. At Mansecroft a length of195m , at 1.5m high

defence is required. At the Allt Mor a 1.5m high defence would be required over an 84m length. These locations are illustrated in Figure 4-14.

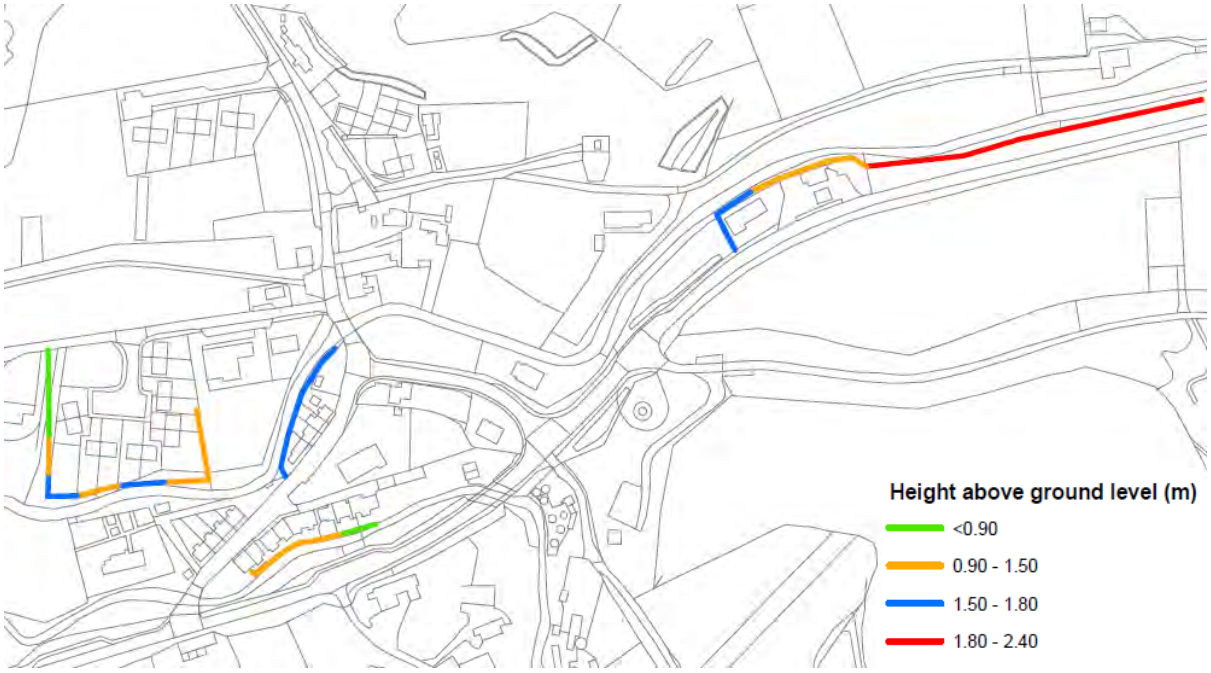


Figure 4-14 Option 3 Direct Defences

All defence heights allow for 0.6m freeboard in line with SEPA Guidance[9]. Freeboard is the difference between design flood level and flood defence height to add a factor of safety to cover the inherent uncertainties in flood estimation. Defences would provide a 1 in 200 year standard of protection to properties. Downstream, flood levels at the caravan park are shown to increase by 5mm so this can be deemed a negligible increase in flood risk.

The defence heights required are significant. Given the order of economic damages to be offset, direct defences are unlikely to create a positive cost benefit. Reducing the standard of protection the defence provides was also explored to determine if a significant reduction in costs was achievable which would make the option more economically viable, as well as to reduce the potential visual impact of defences.

In general, the variation in defence level between a 1 in 25 year event and 1 in 200 year event is 200-400mm. This would have a minimal reduction in the cost of defence required given most of the cost is associated with ground works (i.e. foundations) rather than the height of the wall. Reducing the standard of protection would reduce costs by around £220K. In the context of a capital cost above £1 million as well as damages which are well below this value, this SoP is not worth exploring further.

Upstream of the road bridge, the Filling Station, adjacent property to the south and A83 are predicted to flood from a 1 in 2 year event. Given the frequency of this flooding a lower standard of protection in this area was investigated to potentially provide a significant betterment in a more cost proportionate manner. The difference in flood level between a 1 in 200 year and lower return period storm events is minor in this location except for a 1 in 10 year event and below. On this basis a high level check on the damages avoided when providing a 1 in 10 year defence in this location was assessed and shown that the capped damages avoided (£64K) would still be far below the approximate £200K cost of a flood wall to provide a 1 in 10 year SoP in this location. This indicates a lower standard of defences is not worth exploring in this location.

Based on the assessment of different standard's of protection, the most appropriate configuration of direct defences alone for Clachan would be to provide a 1 in 200 year standard of protection to 18 properties and the A83. However, these works would incur significant design and construction costs

[9] Technical Flood Risk Guidance for Stakeholders, SEPA, May 2019

which are unlikely achieve a viable benefit cost ratio. As well as this, the defence heights and tree felling required would create significant negative visual impact as illustrated in Figure 4-19.

Figure 4-15 Flood Wall Visualisations

4.4 Option 4 NFM catchment wide with weir removal

NFM and weir removal (Option 1 and Option 2) have been assessed in isolation. Both options showed small scale positive impact on flood risk. It was therefore deemed appropriate to determine if combining these options could boost the potential flood risk benefit to be gained. This was tested by combining the schematisations for Option 1 and Option 2 into one model.

With NFM alone there is no benefit in desynchronization of peaks between the two burns as the Allt Mor joins the Clachan Burn downstream of the weir which is the dominant impact on flow regime. However, when combining NFM with weir removal, peaks flows are now 1.25 hours apart, meaning the peak flow at the Allt Mor now occurs when discharge to the Clachan Burn is decreasing, rather than peaks of both watercourse coninciding and exacerbating flooding. .

At frequent storm events, combining these options is shown to have a positive impact with the flood extent at the A83 reduced at a 1 in 2 year event through a reduction in flood depth of 40mm compared to baseline on the road and removal of property adjacent to the Filling Station from the flood extent. At a 1in 10 year event, flooding to the access at Longrigg adjacent to the Burn is no longer predicted and flood depths at Mansecroft are reduced by an additional 100mm compared to weir removal alone.

At a 1 in 25 year. flood depths are reduced from 200mm to 25mm at cottages downstream of the road bridge and from 300 to 100mm at Mansecroft compared to baseline. From a 1 in 50 year event onwards, there is limited flood risk benefit with flood depths generally reduced by around 50mm compared to baseline around Mansecroft and Clachan cottages. At the A83, flood risk is unchanged. Combining weir removal with NFM makes no change to flood risk on the Allt Mor compared to NFM alone with flood depths typically reduced by 50mm as a result of NFM up to the 1 in 25 year at properties here.

Combining these options would provide reduced flood risk from the Clachan Burn at events up to a 1 in 25 year event by partnering the attenuating impact of NFM upstream with the removal of the weir increasing conveyance capacity of the channel. It would also reduce to need to provide bank protection, increasing the viability of removing the weir. This is because NFM measures have slowed flows entering the channel meaning there is no uplift in channel velocity due to the weir removal. Combining these options would also allow wider environmental benefits to be boosted, enhancing the overall value of this option.

4.5 Option 5 NFM catchment wide with defences

There is a general understanding in the industry that NFM measures complement rather than replace traditional engineering solutions in terms of the standard of protection that can be achieved. On this basis it was deemed necessary to determine if combining NFM with defences could reduce water levels, in order that lower defence heights would be required. Given the heights required to achieve a 1 in 200 year standard of protection, it was decided the target SoP would be reduced to 1 in 100 year also. This would balance a higher standard of protection with less visual impact.

Combining defences with NFM and accepting a slightly reduced SoP allows 60m of the required defences at Clachan Filling Station to be lowered by 400mm. Downstream of the road bridge, defences at the Clachan cottages are reduced by 400 – 500mm. At Mansecroft, reduction of flood levels reduces the extent of flood wall required from 190m to 130m as well as reducing the height of defence by 300mm. At the Allt Mor, the impact of NFM is less significant with defence levels dropped by only 100mm. These locations are show in Figure 4-16.

Figure 4-16 Option 5 NFM + Direct Defences

Lowering the target SoP slightly to 1 in 100 year and combining direct defences with NFM reduces defence heights to a more acceptable level. With the exception of the A83, defences are typically 1.3m or less above present ground level compared to 1.8m defence height. This is much more likely

to be acceptable to residents, as a 1.5m high wall is generally the maximum wall height that will still allow some view of the river. This will also allow a reduction in cost, although as discussed previously, based on the foundation requirements of flood walls this is likely to be minimal. Combining these options would provide a 1 in 100 year SoP to properties whilst reducing the long term visual impact and also providing wider environmental benefits to the catchment. The benefits of NFM include habitat creation and improved water quality which will be discussed in more detail in the environmental section of the appraisal.

4.6 Option 6 Weir + Defences

Removing the weir from the Clachan Burn was shown to provide positive flood risk benefit therefore the potential to boost this through defences was tested. The reduction in backwater effect as a result of the weir removal could reduce the extent and height of defence required, which may improve the cost benefit ratio of measures. This was tested in the 1D-2D hydraulic model by determining the required defence heights on a iterative basis following the removal of the weir and associated sediment build up. Again, based on the significant defence level required or a 1 in 200 year event the SoP was reduced to 1 in 100 year to balance flood risk protection, economic benefit and visual impact.

Combining defences with weir removal allows wall heights downstream of the road bridge to be reduced. At cottages on the left hand bank of the Clachan Burn defences are reduced by and 300-400mm. At Mansecroft, the reduction of flood levels reduces the extent of flood wall required from 190m to 130m as well as reducing the height of defence by 300mm. At the Allt Mor, the impact of NFM is less significant with levels dropped by only 100mm. Wall heights upstream of the road bridge remain unchanged as the backwater impact of the weir does not extend this far upstream. This is illustrated in Figure 4-17 below.

Hydraulic modelling indicates combination of direct defences and weir removal would reduce defence heights to a more acceptable level downstream of the road bridge. With the exception of the A83, defences are typically 1.4m or less above present ground level compared to 1.8m high defence height for a 1 in 100 year SoP. This again is more likely to be acceptable from a visual impact perspective and will allow some reduction in cost.

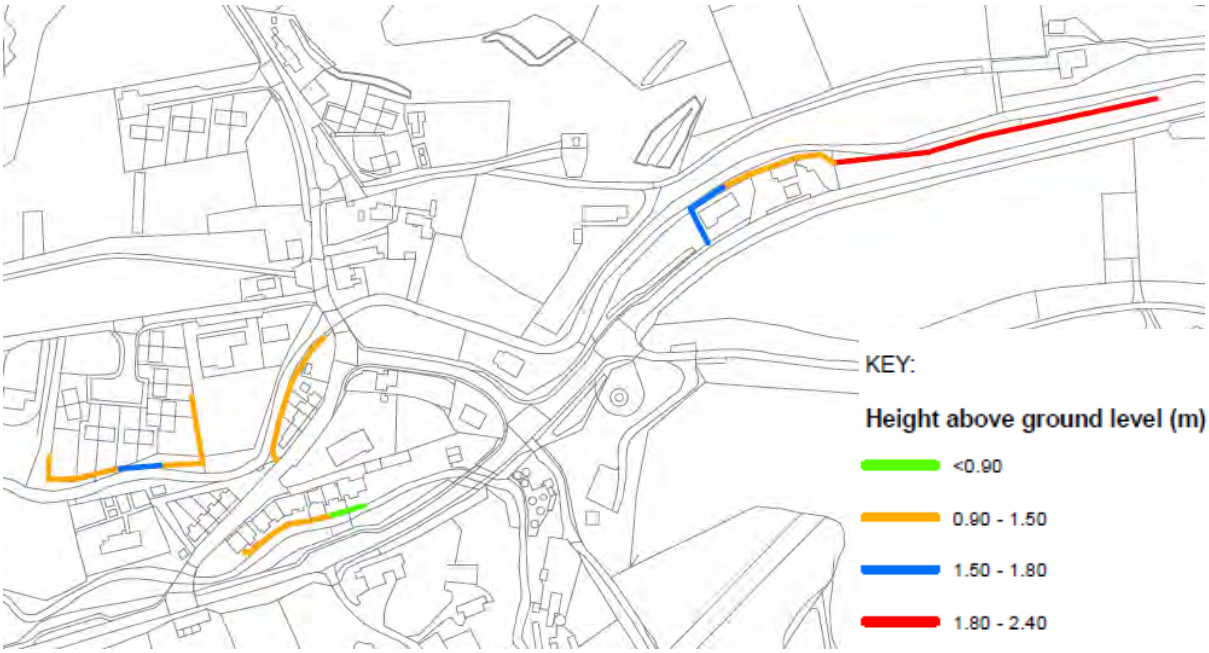


Figure 4-17 Option 6 Weir Removal + Direct Defences

4.7 Option 7 NFM + Weir+ Defences

A final combination option was developed to optimise the features which were shown to provide positive flood risk benefit to Clachan. Based on the significant defence requirements upstream of the road bridge, partnered with the limited number of receptors in this location, it was deemed appropriate to focus defences where there was the greatest potential to balance cost and benefit and at the most vulnerable receptors. Flood defences were therefore focused at residential properties downstream of the road bridge. NFM measures and weir removal were also modelled in tandem with the defences in order to maximise the potential reduction in extent and height of defences required to provide a SoP to properties of 1 in 100 year. It was hoped that combining these smaller scale interventions could help offset the capital cost of defences as well as reduce their impact on the character of the village.

Downstream of the road bridge, defences at the Clachan cottages are reduced by and 500 – 600mm. At Mansecroft, reduction of flood levels reduces the extent of flood wall required from 190m to 72m as well as reducing the height of defence by 700mm. At the Allt Mor, the impact of NFM is less significant with levels dropped by 200mm.

Figure 4-18 Option 7 Weir removal + NFM + Direct Defences


Mansecroft


Clachan Cottages


Allt Mor

Figure 4-19 Flood Wall Visualisations, Option 7

4.8 Option 8, 9, 10 Property Level Flood Protection

In some cases a formal engineered flood protection scheme may not be the best solution. This can be due to technical constraints around available space or ground conditions or environmental factors including negative visual impact and disruption of ecological corridors. Economic reasons may also make a formal scheme unviable where the cost of an engineered scheme is are not balanced by the benefits gained.

In such cases 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. PFP focuses on blocking flow entry routes into properties through things like air bricks, doorways, drainage pipes, defects in building fabric and building foundations / subsoil. This measure has not been modelled but has been taken into account in the economic damages assessment by removing damages up to their effective depth.

Property Level Flood Protection includes measures such as:

- Airbrick covers to reduce the risk of water ingress into the solum. These can be permanent with an automatic mechanism to shut during flood conditions or a fixed cover can be installed prior to flood event and then removed following the event.
- Flood-proof doors to reduce the risk of 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, further measures are needed to reduce the risk of debris entering the 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. A render over only the lower part of the property would create a small ledge which could result in dampness problems and may not be aesthetically attractive.
- 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.

The depths of flooding affecting properties in this area are below 0.6m which is generally considered to be the limit for the operation of 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 equalisation of loadings. On this basis, all affected properties within Clachan are suitable for PFP measures. 1 in 200 year flood mapping was used to identify candidate properties. This was then sense checked against threshold surveys obtained as part of the study to determine if internal property flooding was likely.

Following this technical assessment, baseline economic damages were used to identify the properties at greatest risk. Properties where the calculated damages were greater than the cost of PFP measures were identified. A total of 10 properties (Figure 4-20) could be protected from internal flooding up to a 1 in 200 year event with this measure over a 25 year period (Option 8). When considering climate change uplifts 18 properties (Option 9) could be protected up to a 1 in 200 year +

CC event (Figure 4-20). PFP was also combined with weir removal (Option 10). Based on the residual damages 6 properties were identified as most economically viable for PFP. Where there is a block of properties, the whole block has been assumed to require PFP measures to block flood entry routes.

Given the short response time of the Clachan catchment to storms (6 hour critical duration) and the lack of flood warning in place, passive/permeant features have been assumed for residential properties which are deemed to be more vulnerable receptors. This would include measures such as flood-proof doors, automatic airbrick covers and external wall render/bricks. For Clachan Filling Station, standard resistance achieved through demountable features such as door guards and airbrick covers were deemed to be more appropriate as these are more economically viable against the damages accrued for this receptor.

The impact of this measure has been assessed by removing damages associated with flooding up to the 1 in 200 year 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.

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 therefore education is essential to achieve optimal performance from PFP. On this basis PFP has only been considered over a 25 year design life. 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 Clachan.

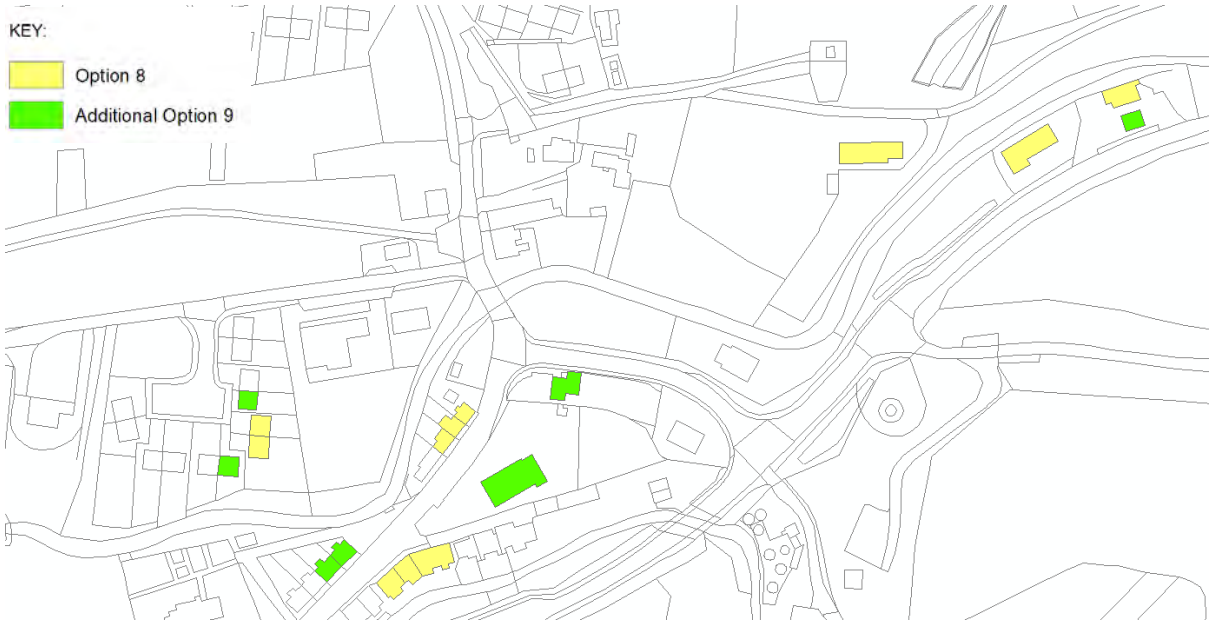


Figure 4-20 PFP Locations, Option 8 and 9

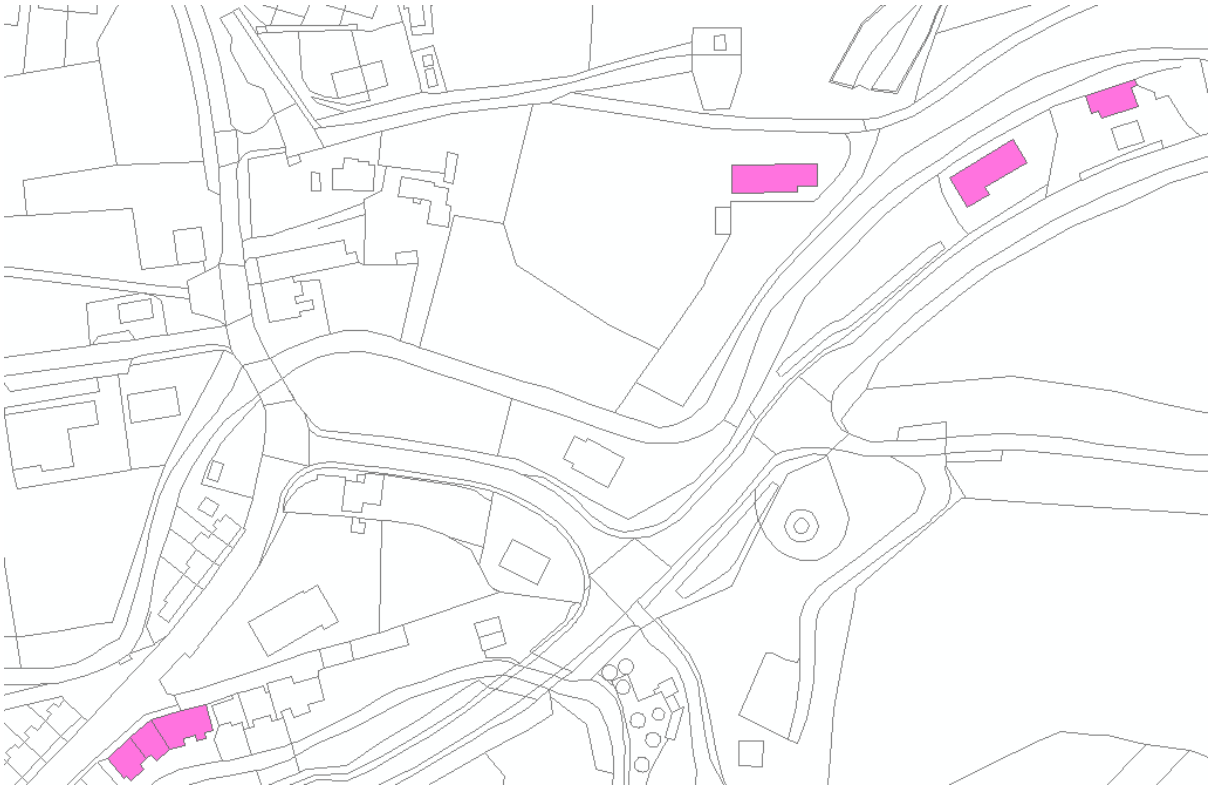


Figure 4-21 PFP locations, Option 10

5. Economic Appraisal

The economic appraisal has been used to assess the monetised benefits of each option, with regards to damages avoided. In addition to a purely economic appraisal the social and environmental benefits for each option will also be assessed on a qualitative basis. The economic appraisal has been carried out over a 100 year period. 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.

5.1 Baseline Damages Summary

The baseline economic impacts (flood damages), used in this economic appraisal are presented under separate cover: reference should be made to *'Baseline Economic, Social and Environmental Impact Assessment- Technical Report*[10]*'.*

5.2 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 concept is demonstrated in **Figure 5-1** below. The shaded area in the graph shows a theoretical residual damage expected in a 1 in 100yr (1% Annual Exceedance Probability) flood scheme.

[10] Clachan Flood Study Baseline Economic, Social and Environmental Impact Assessment- Technical Report, AECOM, April

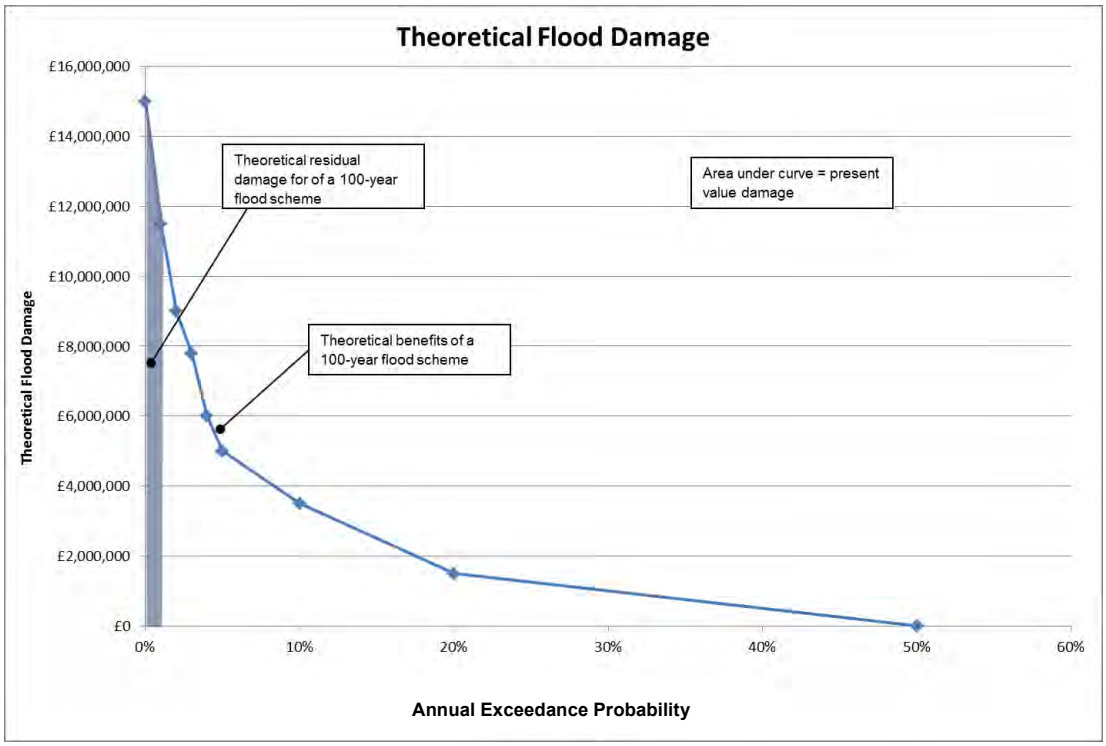


Figure 5-1 Theoretical representation of simplified residual damages[11]

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. Storage schemes, on the other hand, provide some benefit even to events which exceed the top water level of the storage area. In Clachan, as many of the viable options would manage lower exceedance events, residual damages will remain. Residual damages and benefits for each of the scheme options are shown in **Table 5-1**: below.

Table 5-1: Residual Damages

Option No.	Option	Baseline	Residual	Total benefit	Additional economic benefits
1	NFM	£508,838.28	£383,864.95	£124,973.33	Reduced flood depth and velocity on AB3
2	Weir Removal	£508,838.28	£327,471.13	£181,367.15	
3	Flood Walls	£508,838.28	£363,953.85	£144,884.43	Protection of A83
4	NFM and Weir Removal	£508,838.28	£310,946.48	£197,891.80	Reduced flood depth and velocity on AB3
5	NFM and Flood Walls	£508,838.28	£277,450.16	£231,388.12	Protection of A83
6	Weir and Defences	£508,838.28	£257,731.10	£251,107.18	
7	NFM and Weir and Flood Walls	£508,838.28	£251,157.10	£257,681.18	Protection of A83
8	Property Level Flood Protection 200yr+CC SoP	£275,177.59*	£192,449.82	£82,727.77	
9	Property Level Flood Protection 200yr SoP	£259,279.82*	£173,104.64	£86,175.17	
10	Weir Removal and Property Level Flood	£456,544.74*	£193,506.99	£263,037.75	

[11] 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%.

	Protection 200yr SoP*				

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

5.3 Option Cost Estimates

This cost estimate build up provided is an indicative cost 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 even to outline design stage, so there is significant uncertainty in the estimated costs. Option cost estimates should be reviewed in tandem with the social and environmental options appraisals to help appraise and recommend options to manage flood risk in Clachan. Where more detailed estimates are needed (i.e. for the preferred option), we would strongly recommend Contractor Involvement and completion of the outline design.

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

- Cost estimation for SUDS - summary of evidence Report –SC080039/R9, Environment Agency (EA), March 2015
- Cost estimation for fluvial defences – summary of evidence Report –SC080039/R2, Environment Agency, March 2015
- Cost estimation for channel management Report summary of evidence – SC080039/R3, Environment Agency, March 2015
- Cost estimation for household flood resistance and resilience measures – summary of evidence, SC080039/R11, Environment Agency, March 2015
- Cost estimation for habitat creation – summary of evidence SC080039/R14, 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
- Spon's Civil Engineering and Highway Works Price Book 2019, updated by AECOM, Oct 2018

5.4 Capital Cost Estimate

5.4.1 Traditional engineering works

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. These have been developed to a reasonable level for cost estimation and will make up the main elements of capital cost. Traditional engineering solutions such as flood defences have been costed using rates extracted the various EA Guidance Documents for Costing Flood Risk Management Elements 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. In the case of the direct defence on the Allt Mor for a 1 in 200yr SoP a wall of 1.5m high over 53m would be required. This would generate an estimated capital cost of £154K. 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 stage of feasibility assessment 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 to 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.

However, for removal of the weir, EA guidance does not provide appropriate detail as this is a bespoke and small scale measure. In this case the SPONS price book for Civil Engineering and Highway Works has been used. This provides detailed rates for labour, plant and material for different work items. This price book as well as past project experience for weir removal and fish passage works have been used to generate cost estimates.

5.4.2 Natural Flood Management

Natural Flood Management is still developing as a technique and as such there is a much smaller body of evidence to use for costing purposes in comparison to traditional engineering works. However, in recent years both SEPA and the Environment Agency have gathered a body of case studies which can be used as reference. It is generally accepted the capital costs of NFM measures are low as they require minimal plant and labour for installation and use natural locally sourced materials. Research into guidance documents and project case studies has been used to estimate costs for NFM measures including:

- Constructed Farm Wetlands, Wildfowl and Wetlands Trust, March 2015
- Natural Flood Management, A Farmers Guide, SAC Consulting and the Tweed Forum, 2018
- Natural Flood Management Handbook, SEPA, December 2015
- 'Working with Natural Processes: Evidence Directory', Environment Agency, October 2017
- Cost estimation for land use and run-off – Report summary of evidence - SC080039/R12, Environment Agency, March 2015
- Yorkshire Dales River Trust Natural Flood Management Resources

Key case studies used for cost estimation include Pickering, Yorkshire and Eddleston Water, Scottish Borders. In Pickering the measures included 1 large flood storage bund plus 2 timber bunds, 167 large woody debris dams, 187 heather bale check dams, 29ha of riparian woodland and 15ha of farm woodland planted.

In Eddleston Water, measures include 142 ha of newly planted woodland, 22 upstream off-line “leaky” ponds and 101 large woody structures. Both projects have been heavily documented and consist of a range of NFM measures which are relatable to the measures assessed for Clachan and therefore provide a good evidence base for costing.

5.4.3 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 cost estimation. 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 based on the

vulnerability of the receptor to flood damage and to provide as a lower cost solution. This includes two demountable door guards and multiple airbrick covers.

5.5 Overhead, Profit and Professional Services (OHPs)

EA guidance is unclear as to whether construction overhead and profits as well as construction preliminaries are included in the core capital cost data on which the rates are based; therefore to be conservative, a 15% uplift for construction overheads costs has been included in line with Spon's Civil Engineering Price Book Guidance. A 10% uplift has also been applied to estimated capital costs to account for likely design/professional services fees.

5.6 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 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; project risks are factored into an overall uncertainty for Optimism Bias.

Unlike most flood studies where many of the options are similar in terms of their construction requirement and therefore associated risks, the options for Clachan fall into 4 distinct categories including:

- Defences – large scale engineering measures
- Weir removal – small scale engineering measure
- NFM – natural small scale intervention
- PFP – local resilience intervention

Advice from Scottish Government's Project Appraisal Guidance[12] gives 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 recommended 60% optimism bias is taken as a starter 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.

This assessment was carried out for the four 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 NFM and weir removal options environmental impact risks and external influence risks generally associated with large scale construction such as lack of Ground Investigation (GI), reliance of materials and plant could be reduced due to smaller scale nature of interventions resulting in an optimism bias of 45% and 40% respectively. For PFP, again reduction could be made as this is not influenced by GI, construction materials and plant. This resulted in an optimism bias of 40%. These biases were applied to the estimated Whole Life cost of options in line with Scottish Government Guidance.

5.6.1 Uncertainty

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

- Cost estimates have been based on conceptual design sizing.
- Cost estimates are based on standardised unit rates and research.

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

- No significant geotechnical considerations for design and construction will be required as GI investigation is unavailable at this stage e.g. contamination, groundwater issues, seepage etc.
- Land purchase costs have not been considered as these costs are highly uncertain. This uncertainty applies particularly to NFM as these measures require a change in how land is managed on a catchment wide basis rather than simply purchasing land to construct a flood mitigating measure. 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.

5.7 Operation and Maintenance Cost Estimates

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 will include the following:

- 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 determine 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 estimate.

Generally flood defence maintenance will come under the remit of ABC, which will include inspection of flood walls which is expected to be minimal. For the weir removal, ongoing maintenance will be minimal also with an ongoing inspection regime required.

The majority of NFM options are considered low maintenance, which would require routine inspections and low-grade management such as possible debris removal. This would be considered general maintenance by the land manager therefore has not be included in the costing. Wetlands would require a medium level of maintenance in that they require expert advice or equipment to be brought in occasionally. Yorkshire Dales River Trust guidance[13] indicates this would be at intervals of 10 years and would require removal of sediment, which has been allowed for in the whole life cost estimate.

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 estimate for this to be around 1% of the purchase cost of the measures. The mechanism for this maintenance responsibility and cost is still to be determined within ABC policy.

5.8 Whole Life Cost

Each option has been considered for its whole life cost; this requires the whole life cost of the option to be 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 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

[13] Practical Guidance for Farmers – Natural Flood Management, Yorkshire Dales Rivers Trust, 2017

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 2019 as the base year. 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 2.5% is adopted. Some elements, such as landscape or planting, may have a shorter lifespan and would therefore need to be replaced during the appraisal period. Where reasonable estimates can be made for these cases replacement costs have been included in the Present Value calculation. These costs are summarised in Table 5-2.

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 it's viability as a scheme at this point in the future.

5.9 Summary of Cost Estimates

Table 5-2 Summary of Cost Estimates

Option No.	Description	Items costs	Capital incl OHPs	Typical Maintenance[14]	Whole Life	Whole life with Opt. Bias 40%-60%
1	**Natural Flood Management - Catchment Wide**	• 34 ha woodland planting • 658 ditch block heather bales • 70 leaky barriers • 4 engineered/wedged log leaky barriers • 22.8ha wetland planting, 30% reduction assumed that farmers would carry out work in own fields • 28ha of field scraping at wetland areas to maximise habitat potential	£198,526.28	£266.00	£207,020.41	£300,179.59 (45%)
2	**Weir removal**	• Site set up, labour and plant for 1.5 weeks • 2 temporary river diversions to access weir in dry conditions (conservative assumption) • Excavation and disposal of 5m^3 material for weir • Excavation and disposal of 189m^3 sediment build up • 90m green bank protection • Riprap protection to footbridge at Allt Mor	£118,673.59	£100.00	£121,655.71	£170,318.00 (40%)

[14] Note this figure represents typical average annual maintenance cost for option though for some options more intermittent recommended maintenance has been included in the Whole Life Cost e.g. removal of sediment from wetlands at 10 year intervals.

Option No.	Description	Items costs	Capital incl OHPs	Typical Maintenance[14]	Whole Life	Whole life with Opt. Bias 40%-60%
3	**Direct Defences**	• 170m of walls >2m high • 343m of 1.5 – 1.8m high walls • 96m of flood wall <1.2m high	£2,001,838.35	£511.56	£2,017,093.70	£3,227,349.91 (60%)
4	**Natural Flood Management - Catchment Wide and weir removal**	• Combination of Option 1 and Option 2 with need for green bank protection removed	£223,847.18	£366.00	£239,792.40	£335,709.37 (45%)
5	**Natural Flood Management - Catchment Wide and direct defences**	• Option 1 • 170m of flood wall >1.8m high • 136m of flood wall 1.4-1.8m high • 240m of flood wall<1.3m high	£1,542,256.28	£724.64	£1,568,896.59	£2,510,234.54 (60%)
6	**Weir removal and direct defences**	• Option 2 • 173m floodwall >2m high • 151m flood wall 1.4 – 1.5m high • 185 high floodwall <1.2m high	£1,499,424.66	£527.56	£1,515,157.14	£2,196,977.86 (60%)
7	**Natural Flood Management - Catchment Wide, weir removal and direct defences**	• Option 1 • Option 2 with no bank protection • 178m flood wall <1.2m high • 47m of floodwall 1.6m high	£656,855.54	£555.00	£678,436.97	£949,811.76 (60%)
8	**Property Flood Protection – 200 year SoP**	• 9 residential properties provided with Two flood-proof doors, two airbrick covers and external wall render/bricks (20 m). • 3 non residential properties provided with two demountable door guards and multiple airbrick covers.	£49,080.05	£490.80	£57,452.31	£80,433.23 (40%)
9	**Property Flood Protection – 200 year+CC SoP**	• 15 residential properties provided with Two flood-proof doors, two airbrick covers and external wall render/bricks (20 m). • 3 non residential properties provided with two demountable door guards and multiple airbrick covers.	£73,406.30	£734.06	£87,331.56	£122,264.18 (40%)
10	**Weir removal and Property Flood Protection – 200 year SoP**	• Option 2 • 4 residential properties provided with Two flood-proof doors, two airbrick covers and external wall render/bricks (20 m). • 2 non residential properties provided with two demountable door guards and multiple airbrick covers.	£146,297.67	£776.00	£169,438.94	£237,214.52 (40%)

5.10 Cost Benefit Ratio

The cost benefit ratio for each option has been summarised in Table 5-3 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 5-2.

Table 5-3 Benefit Cost Ratio

Option No.	Description	Damages Avoided (present value)	Costs	Main Flood Cells Affected	No. of properties with reduced flood risk	Benefit-Cost Ratio	CBR Rank
1	Natural Flood Management - Catchment Wide	124,973.33	£300,179.59	1,2,3	18	0.42	7
2	Weir removal	181,367.15	£170,318.00	1	15	1.06	2
3	Direct Defences	144,884.43	£3,227,349.91	1,2,3	18	0.04	11
4	Natural Flood Management - Catchment Wide and weir removal	197,891.80	£335,709.37	1,2,3	20	0.59	8
4a	Natural Flood Management - Catchment Wide, weir removal and Property Flood Protection 200yr	£388,011.08	£537,421.11	1,2,3	24	0.72	4
5	Natural Flood Management - Catchment Wide and direct defences	231,388.12	£2,510,234.54	1,2,3	18	0.09	10
6	Weir removal and direct defences	£251,107.18	£2,196,977.86	1,2,3	18	0.11	9
7	Natural Flood Management - Catchment Wide, weir removal and direct defences	£251,447.05	£949,811.76	1,2,3	18	0.26	7
8	Property Flood Protection – 200 year SoP	£82,727.77	£80,433.23	1,2,3	13	1.03	3

7	Natural Flood Management - Catchment Wide, weir removal and direct defences	£251,447.05	£949,811.76	1,2,3	18	0.26	7
8	Property Flood Protection – 200 year SoP	£82,727.77	£80,433.23	1,2,3	13	1.03	3
9	Property Flood Protection – 200 year+CC SoP	£86,175.17	£122,264.18	1,2,3	22	0.7	5
10	Weir removal and Property Flood Protection – 200 year SoP	£263,037.75	£237,241.52	1,2,3	21	1.11	1

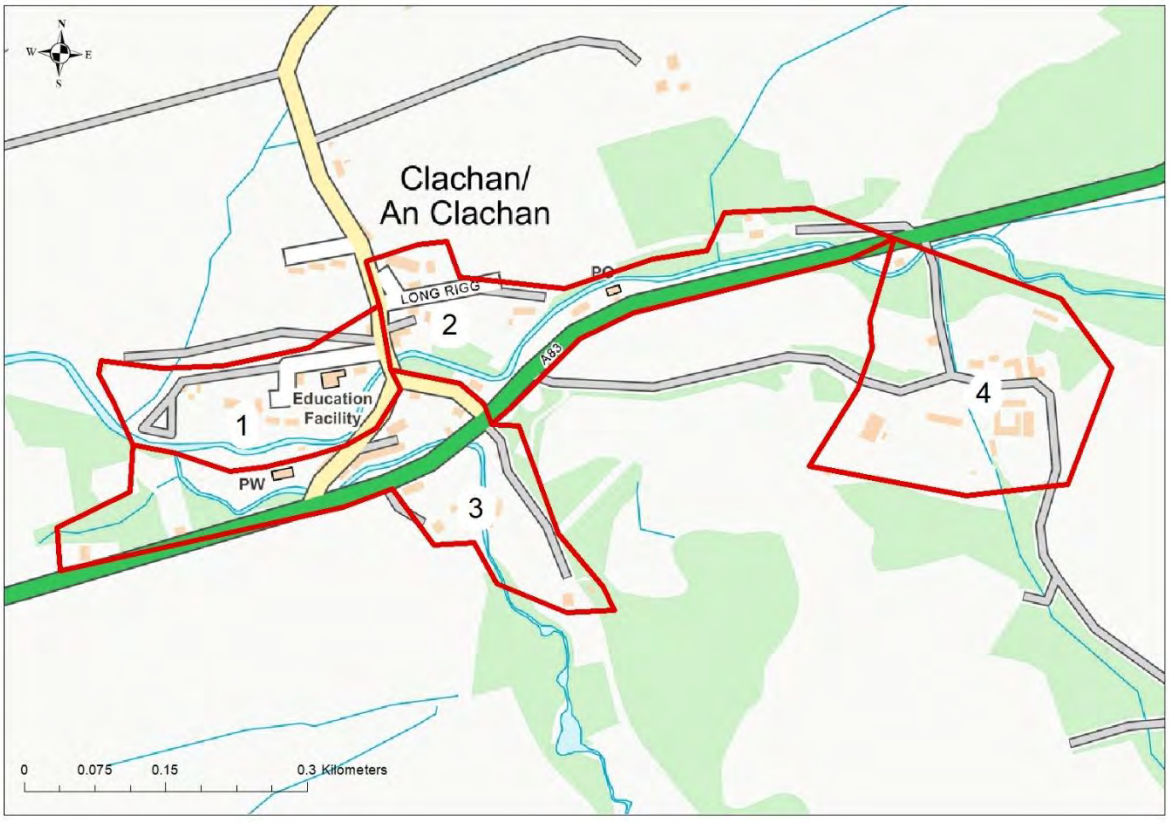


Figure 5-2 Clachan Flood Cells

6. 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 included in the *'Clachan Baseline Economic, Social and Environmental Impact Assessment – Technical Report'.*

Options involve four categories: Natural Flood Management; Weir; Direct Defences; and Property Flood Protection.

6.1 Overview

6.1.1 Environmental

The environmental impacts of the baseline have been assessed over the 100yr appraisal period. It is understood that the main environmental issue associated with flooding in Clachan presently is the potential for high water level in the Clachan Burn to damage the gravity sewer line which runs across the channel. This could cause significant pollution and disrupt the sewerage treatment plant Over 100 years, under the influence of climate change, further 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 appraisal are to identify opportunities for environmental enhancement and 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.

6.1.2 Social

Flooding and flood risk has a significant impact on society before, during and after a flood event has occurred. Werrity et al. 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 Clachan. Stakeholders such as SEPA and Scottish Water have been consulted during the shortlisting process and two public consultations have been held.

6.2 Results

Project name	Clachan Flood Study				
Element	**Baseline**	**Natural Flood Management**	**Weir Removal**	**Walls – Direct Defences**	**Property Flood Protection**
Element Description	Do-nothing - No intervention	4 wetlands constructed from leaky barriers, ditch blocking on Allt Mor and Clachan Catchments, riprairan and hillslope planting	Removal of small weir structure direct upstream of Allt Mor/Clachan Burn confluence with erosion protection	Up to 609m of flood walls ranging from 0.5-2.4m high for different combination of options.	PFP installed at 12-18 res properties and up to 4 NRP. Mix of passive and demountable features.
Approaches to adaption	None	Adaptable	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 led to reduced risk to life. Poor installation can lead to them detaching, causing blockage and risk to public safety.	Reduction of flooding led to reduced risk to life	Reduction of flooding led to reduced risk to life	High residual risk to life as flooding is only reduced within properties.
Social – 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. Risk of sewer fracture due to high flows in Clachan Burn, creating heath risk	Floodplain trees 'scavenge' pollutants from the air improving air quality and reducing health impacts. Reduction of flooding led to reduced expected health impacts particularly regarding reduced risk of sewer fracture by attenuating flows. However residual impacts will remain.	Reduction of flooding led to reduced expected health impacts. However residual impacts will remain. Low but possibly increased risk of sewer pipe fracture, though this should be accounted for in recent erosion protection installation in 2019.	Direct defences may provide more visual reassurance during flood event. Reduction of flooding led to reduced expected health impacts. However residual impacts will remain.	High residual health and well-being impacts as flooding is only reduced within properties.
Social – Social vulnerability	Local assets at risk of flooding increasing flood disadvantage	Reduction of flooding would reduce social disadvantage	Reduction of flooding would reduce social disadvantage	Reduction of flooding would reduce social disadvantage	High residual social vulnerability as local assets may not be protected.
Social – Recreation, community and way of life	Community features are at risk of flooding including the petrol station, town hall, church and primary school. flooding impacts the village centre, flooding would seriously impact the recreation, community and way of life for most residents.	Creating a catchment partnership working group would improve community links and provide recreation and education. Reduction of flooding would increase access to the village, therefore improving way of life.	Reduction of flooding would increase access to the village, therefore improving way of life.	Reduction of flooding would increase access to the village, therefore improving way of life. Protects Filling Station and A83 from flooding maintain access to village	High residual impacts to recreation community and way of life as local assets may not be protected. Petrol station/post office building protected protecting key community building

			Reduces flood depths and velocity on road reducing risk of any structural damage maintaining access Reduced flooding at petrol station key community building.			
Environmental	Water	Pollution of watercourses during a flood event from contact with sewage and flood debris. The Clachan Burn and the Allt Mor tributary have an overall water status of 'Poor' from 2007 to 2017. The Poor status is due to its ecological status; in particular fish.	Creation of hillslope planting and riparian buffers will improve soil structure increasing the rate of infiltration, reducing runoff and topsoil erosion being washed into the watercourse. Wetlands would allow improvements in water storage and conveyance, these measures restore the natural functioning of the watercourse, make the watercourse more resilient to subsequent pressures and stabilise channel morphology. Upland drain blocking can reduce excessive loss of sediment high up the catchment improving water quality. Reducing runoff also reduces the amount of agricultural chemicals reaching the watercourse. Reconnection of wetlands, riparian and hillslope planting and leaky barriers can manage high nutrient loads e.g. phosphates and nitrates and prevent their runoff to watercourses improving levels in water. Floodplain woodland helps to restore natural hydrological processes. Low river flows can be boosted by the slow release of water stored in pools, side channels and floodplain soils	Removal of weir in the Clachan Burn will improve fish passage and therefore may improve the overall water status. Removal of the weir will restore natural geomorphological processes particularly sediment transfer to be restored improving water environment Reduces potential scour downstream of weir in high flows reducing risk of sediment pollution and maintaining banks. Potential scour of banks predicted 45m upstream	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	Wetlands lead to increased ecosystem sustainability and habitat. Creating multiple wetlands not only improves biodiversity at the site but potentially improves the connectivity of wetlands, in effect improving the ability of plants and animals to move between these	Weir removal will improve fish passage and habitat. Increase in biodiversity by removing uniform habitat potential of impoundment upstream and naturalising river	May create barrier to ecological corridors Significant tree feeling required upstream removing habitat	No long-term significant impacts expected

			habitats for a range of species including specialised vegetation, fungi, birds, amphibians and water mammals. Woodland planted along river banks can increase plant species richness. It also provides nesting sites for birds and shelter for pollinators and can enhance biodiversity in other water environments such as wetlands. Bank stabilisation from trees decreases soil erosion and sedimentation, which has a positive effect on macroinvertebrate populations Riparian shade helps fish such as trout and salmon survive hot temperatures. Leaky barriers provide habitat diversity by creating pools and varied channel morphology. They support fish and macroinvertebrate life cycles and provide nutrients for aquatic organisms. They also provide basking and perching sites for reptiles and birds. Care needs to be taken with placement so as not to disrupt fish passage during low flows.			
	Air and soil	Not considered to be significantly affected by current flood risk	Creating of wetlands through upland drain blocking can significantly improve air quality through carbon sequestration. Leaky barriers can also provide this impact to a much smaller degree. Floodplain trees 'scavenge' pollutants from the air improving air quality Riparian and hillslope planting can also offer protection from soil erosion and slope failure. Natural flood management measures that improve soil structure reduce the loss of valuable topsoil and can increase productivity (e.g. by increasing the amount of oxygen reaching crop roots).	No significant impacts expected	Removal of trees will reduce carbon storage benefits and cleaning of local air quality.	No significant impacts expected

	Climatic Factors	Greenhouse gas emissions associated with flood response and post-flood recovery	NFM provides increased resilience to climate change by regulating temperature and water level. Many NFM measures can deliver more resilient ecosystems in that they increase the capacity of the ecosystem to respond to disturbance and damage, including that brought about by climate change. Wetlands and woodlands are particularly efficient at accumulating and storing carbon reducing emissions. Drain blocking reduces runoff and raises water table which can lessen the impact of droughts. Emissions reduced through reduction of flooding. Works will have climatic costs.	Emissions reduced through reduction of flooding. Works will have climatic costs	Emissions reduced through reduction of flooding. Works will have climatic costs Removal of trees will reduce carbon storage benefits	Emissions reduced through reduction of flooding. Works will have climatic costs
	Cultural heritage	Two Scheduled Monuments and Listed Buildings, some of which are at risk of flooding. Possibility that flood risk is discouraging investment in maintaining the area.	Reduced risk of flooding	Reduced risk of flooding Locally no loss of heritage in removal and landowner is supportive	Reduced risk of flooding Walls will change character of area by removing connection to river	Reduced risk of flooding
	Landscape	Not considered to be significantly affected by current flood risk other than that mentioned under cultural heritage.	Wetland restoration through land drainage management and floodplain planting creates landscape diversity, returning it to a more ‘natural’ and aesthetically pleasing state.	Restoration of natural river profile will increase aesthetic quality of Clachan Burn	Visual impact, which can be minimized by sensitive design, however height will be at least 1m in most places which may be considered intrusive and not in keeping with local landscape. No significant impacts expected	No significant impacts expected

6.3 Summary

6.3.1 Environmental

In general Clachan 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.

Natural flood management has the most significant environmental advantages. The ecosystem services provided by the different measures include climate regulation, carbon sequestration, flood regulation, habitat provision, improvement in water quality from both sediment runoff and nitrates/phosphates, betterment to channel morphology and bank stability, improved fish migration and habitat, community engagement, improvement in landscape character, and education/knowledge.

Weir removal would also offer significant environmental benefit by restoring the natural geomorphological processes and reducing potential scour downstream of weir. Further to this, re-naturalising the river would promote in-stream biodiversity and reduce obstruction to fish migration. There is a risk of negative impact from scour of banks upstream of the weir but this would be assessed in a geomorphology study and offset through green bank protection measures.

Direct defences have the most negative environmental impact. Walls would be a minimum of 1m in most places which would have a negative visual impact and cut off ecological corridors and community connection to the watercourse. These impacts would be reduced through sensitive design to the existing landscape using materials which are similar with locally used materials. Further to this, felling of trees would be required around A83 which would reduce baseline air and water quality as well as carbon sequestration.

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

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 PLP still require some clear up and flood response. All works have associated climatic costs such as carbon footprint of materials, emissions from construction etc., however these vary in magnitude. NFM measures would have limited climatic cost as they require local materials and require small input of plant for installation. Direct defences would require more fuel and imported materials, increasing climate costs.

6.3.2 Social

In general, the options assessed provide social benefits associated with their impact on flood risk. Additional benefits and disadvantages are also specific to each option. There would be social benefit associated with NFM measures through community engagement. This could be enhanced through development of a catchment partnership group/Local Flood Risk Action Group to manage and install the proposed measures. This would also provide recreation and education. NFM would reduce flood depths and velocities on A83, reducing the risk of long-term delays on this route by reducing risk of structural damage.

Direct defences offer the greatest social benefit by providing the best standard of protection to properties, the A83 and the Filling Station which would protect access to the community.

7. Public Consultation

Community engagement has been an important part of this project. Previous engagement has included quarterly community update newsletters distributed to Clachan Filling Station. Two previous meetings have also been held. An informal meeting was held in November 2018 with key representatives in the community where an update on baseline modelling and potential options was provided. A representative from the community was also in attendance at the stakeholder workshop in February 2019 where the representative fed back comments on the baseline report and potential options.

The second community meeting was held on 1st April 2019 and involved a public “drop-in” session followed by an AECOM led presentation explaining the baseline modelling and long list of potential options.

The final formal public consultation event was held on 28th August 2019 in Clachan Village Hall. The event was well attended with 22 members of the community attending. Again, most attendees were residents of Clachan who had been impacted by past flooding.

This third event was run with the same format as it had worked well previously. The public event comprised a public “drop-in” session between 6pm and 7pm followed by an AECOM led presentation and a Q&A session between 7pm and 8pm and further ‘drop-in’ session from 8pm- 9pm. 3 AECOM staff, 3 ABC staff and 1 representative from Scottish Forestry were on hand to explain the process and answer queries.

Figure 7-1 Informal drop in a public consultation 3

7.1 Key messages

In general there was support for the flood study and attendees were encouraged at the progress. There were several key messages that emerged from the informal discussions:

- There were support for the NFM catchment measures and understanding of how these could work. There was also positive response for the habitat benefits from wetlands.
- There was strong support for the removal of the weir. The community generally felt anything this restricts channel capacity and could help Clachan Burn manage storm events better.
- There was concern from attendees on the delivery of a solution from a funding perspective and the time scale for implementation. Particular concern that coming to the end of the flood study process that the findings will not be put into action.
- There was still a small appetite for direct defences from a small number of community members but the vast majority, particularly those living adjacent to the watercourse felt the scale of defence would destroy amenity and “cause more stress than the flood”.

- There was concern over the impact on stability of banks and structures along it if the weir was removed
- There was positive response to the fact SEPA are looking into the Clachan weir removal as part of their River Basin Management Planning Objectives.

7.2 Summary of Q&A Session

Following the AECOM led presentation (introduced by Graham Nash of ABC and delivered by Sally Homoncik and Aisling McGilloway of AECOM, the Q&A session considered the following raised points:

Q – How was Benefit cost ratio worked out? Is there ability to improve? In particular is there scope to raise the combined option (NFM + weir removal + direct defences, Option 7) to something more viable?

A – Given that the option is in the order of millions rather than thousands and is a hard engineering measure and is so far away from a positive BCR it is unlikely these wider benefits would be acceptable to boost the overall value of the option to an acceptable level for Scottish Government funding. Furthermore, even if this was put forward as the preferred solution for Clachan with such a low BCR it would be a very low priority in the context of national prioritisation and the limited funding available through this route.

Q – If the Water Environment Fund (WEF) could be used to remove the weir is shown to viable through SEPA's work and goes ahead could this cost be taken out of Option 7 to boost the BCR ratio further?

A – FRM funding and WEF funding have very strict requirements and need to be viewed separately. The benefits achieved by the weir removal (and possibly NFM if included for wider benefit under WEF) would then be lost to the overall option so this would reduce BCR of the combined option. Under FRM Act you cannot be reliant on additional funding as it may not happen. Furthermore, the weir is small proportion of the combined option cost so this is unlikely to make a significant difference..

Q – Is the largest cost associated with Op 7 is the direct defences?

A – Yes this is correct. Public and particularly homeowners directly impacted by defences were concerned about changing character of river and lost visual amenity. There was a view that this would cause more stress than the flooding.

Q – Concern raised around Lodge woods which were cleared 3-4 years ago but a crack has appeared in the wall, what is being done to prevent the failure of this wall during a flood?

A – ABC Operations continue to monitor this crack for any changes and where a risk is identified repair works will be carried out. GN to pass comments to operations team to investigate local view that crack is getting larger.

Q – What is being done about old road drainage where the culvert became overwhelmed in 2016 flood event causing deep and fast flowing water to flow through village, severely damaging road?

A – This was identified as a maintenance action at the long list short list stage of this study which was discussed at the last meeting. It has been taken away from the flood study as a ongoing maintenance action to be carried out by ABC. Verges continue to be kept down to ensure that when drainage infrastructure becomes overwhelmed the exceedance flow is directed away from village and towards green space. This is a low cost option which would obviously offset the need for costly resurfacing work accrued in 2016 event so will continue to be a priority.

Q – What is being done around trees upstream of Balinakill House which are destabilised and will soon wash into river? Perception from landowner higher in the catchment that the flooding is caused by trees being washed into the watercourse and blocking bridges causing overtopping. Concern that this will re-occur based on his visual inspection of trees. This was a large factor in the last major river flooding event. Perception that the Clachan Burn is shifting its alignment.

A – Agree that this was a significant factor impacting the 2015 flood which exacerbated overtopping. This was considered when verifying model results against historic events based on photos provided by residents showing this blockage. However, there is a flood problem outside of this blockage scenario. The maintenance of these areas lies with individual riparian landowners and they have a responsibility to maintain these areas. In terms of ABC responsibilities and enforcement that can be brought this will be taken away as an action to be looked at. This could be something which is discussed at a multiple partner

Q – Can ABC remove all these trees as a preventative measure?

A – EJ from Scottish Forestry suggested that Forestry Commission hydrologists could investigate this. She explained that although removing trees from one area may help, those upstream may be providing benefit and are likely stabilising banks and it can be a tail chasing exercise to remove trees which may undermine banks and make channel capacity worse. FRM funding couldn't be used for these maintenance measures it would have to come from ABC maintenance budget which is limited.

Q – What is the history of the weir? Was it put in to stabilise the watercourse?

A – The weir was constructed to encourage fish up the Allt Mor. The steepness of this channel and other obstructions means this was never successful so the weir holds no function and can be taken out. It is recognised there is a risk of destabilising walls along the banks of the river by removing the weir and sediment which has been in place for many years but this will be fully assessed before any removal is carried out. Bank protection would also be provided where necessary. AECOM also noted combining the weir removal with NFM measures would de-risk this by slowing flows in the channel.

Q – Will removing weir and sediment being washed out/increased velocities undermine new SW sewer pipe?

A – ABC and AECOM advised SW in the depth of foundation when designing erosion works with this potential option in mind so this has been considered prior to construction and no significant risk is anticipated.

Q – Desire to reinvigorate Clachan Catchment Study Group. There was a feeling in the community that they do not want the study to end and then be forgotten about. Clear message that this will require a multi-agency response.

A – This is a recommendation in the report and ABC agrees this is needed and needs to be a two way street between public bodies and communities. Group may need to take a different form with people such as SFF brought in. ABC highlighted resources are in short supply and some thought needs to be put into what form this group takes and how this can be used to deliver an action for Clachan to improve flooding. A separate meeting with agencies around the table and reps for a Local Flood Action Group is needed to determine the next steps. ABC would be supportive of this.

Q – Is there an end date for gauging on both watercourse?

A – ABC made the investment in equipment to gauge flows on Clachan Burn and Allt Mor. This has very low operating costs such as battery replacement and small subscription to maintain access to data. There will be a replacement cost in the future, assuming equipment would last 5 – 10 years. There is also an element of good faith that landowners have allowed us to install will allow this to continue. If that were to change this would need to be re-examined but at this point no end date in sight.

Q – What is done with this data?

A – ABC would be open to letting community have access to data. It would not be a formal flood warning but could provide some level of resilience more so on the Clachan Burn than Allt Mor, however both catchments are flashy so this is difficult. Where a flood event occurs this data can be used to validate models.

Q – What are ABC's responsibilities to look after properties?

A – View is that individual property owners must do what they can to protect themselves from flooding. ABC have a responsibility to help communities where they can under FRM Act but budgets are finite so limitations in what can be done and where budgets are prioritised.

Q – When will report be issued to community for comment?

A – This is being finalised following ABC review and should be issued in the next month.

Q – Which of prioritised options would be put forward?

A – There was strong support for NFM, weir removal and PFP. Weir removal was particularly popular. Community wanted to know what would be put forward to SEPA. ABC will basically assess the option which has the greatest benefit from cost and holistic sense to make sure Clachan is in the best position to be prioritised. ABC will also continue to liaise with SEPA regarding potential WEF funding. AECOM met with SEPA RBMP prior to this meeting and have been told this options appraisal is to be scoped assessed in the next few months with potential funding in the new year or next financial year if scoping is successful.

8. 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. The findings of the appraisal are summarised in Table 8-1 below.

The benefit cost assessment has enabled clear decision making for some options. As a rule of thumb, it is generally considered reasonable to reject an option with a BCR of below 0.3. This is because a solution's costs significantly outweigh the monetised benefits to such a degree that additional benefits which have not been monetised such as environmental gains for water quality, ecology etc. would be highly unlikely to provide enough additional benefit to achieve unity in the BCR. This applies to each of the options which include direct defences (Option 3, Option 5, Option 6, Option7). Although a high standard of flood protection could be provided with this options, the high capital costs of flood wall construction vastly outweighs the economic return. On this basis these options are not viable.

Natural flood management alone combined with weir removal has BCR above 0.3 but below 1. Historically, any project with a BCR less than 1 would be rejected as not providing value for public money. However, 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 Option 4, natural flood management with weir removal, the wealth of environmental and social benefits highlighted in Section 6 partnered with the reduced impact of more frequent flood events would make this option viable from a wider perspective despite having a BCR of less than one. This solution would not fully solve flood risk in Clachan but it would reduce the impacts and increase flood resilience in the community.

The removal of the weir combined with PFP at some properties (Option 10) is the best option from an economic, social and environmental perspective. This option would provide positive flood protection benefit, improve water environment and shows value for money. On this basis Option 10 could be promoted for next cycle of FRM prioritisation.

PFP to provide protection up to 1 in 200 year is also shown to be a viable option. It has a positive CBR and there are no wider benefits with significant advantage or disadvantage in terms of additional benefits. This option is particularly relevant for properties at the Allt Mor where NFM and weir removal would have limited impact.

On this basis the following options could be promoted for the next cycle of FRM prioritisation:

- Removal of Clachan Burn weir alone (Option 2)
- Removal of Clachan Burn Weir and Catchment Wide implementation of Natural Flood Management (Option 4)
- Targeted installation of Property Level Flood Protection (Option 8)

- Removal of the weir and targeted installation of Property Level Flood Protection (Option 10)

Table 8-1 Economic, Environmental and Social Appraisal Summary

Option No.	Description	Costs	No. of properties with reduced flood risk	Benefit -Cost Ratio	Standard of Protection	Non-monetised benefits
1	Natural Flood Management - Catchment Wide	£300,179.59	18	0.42	2yr – 10yr	• climate regulation, • carbon sequestration • habitat provision, • improvement in water quality from both sediment runoff and nitrates/phosphates, • betterment to channel morphology and bank stability, • improved fish habitat, • community engagement, • erosion regulation, • improvement in landscape character, • improved education/knowledge. • Reduced risk of structural damages of A83 maintaining link to community in long term
2	Weir removal	£170,318.00	15	1.06	10yr - 25yr	• increased in-stream biodiversity • improved fish migration and habitat • restoration of channel morphology and sediment transfer processes
3	Direct Defences	£3,227,349.91	18	0.04	200yr	• protection of A83 and Clachan Filling Station maintaining community link • reduced stress due to visual comfort of defence
4	Natural Flood Management - Catchment Wide and weir removal	£335,709.37	23	0.59	2yr - 25yr	• climate regulation, • carbon sequestration • habitat provision, • improvement in water quality from both sediment runoff and nitrates/phosphates, • betterment to channel morphology and bank stability, • improved fish habitat, • community engagement, • erosion regulation, • improvement in landscape character, • improved education/knowledge. • reduced risk of structural damages of A83 maintaining link to community in long term • increased in-stream biodiversity • improved fish migration and habitat • restoration of channel morphology and sediment transfer processes
5	Natural Flood Management - Catchment Wide and direct defences	£2,510,234.54	18	0.09	100yr	• climate regulation, • carbon sequestration • habitat provision, • improvement in water quality from both sediment runoff and nitrates/phosphates,

Option No.	Description	Costs	No. of properties with reduced flood risk	Benefit -Cost Ratio	Standard of Protection	Non-monetised benefits
						• betterment to channel morphology and bank stability, • improved fish habitat, • community engagement, • erosion regulation, • improvement in landscape character, • improved education/knowledge. • reduced risk of structural damages of A83 maintaining link to community in long term • increased in-stream biodiversity • improved fish migration and habitat • restoration of channel morphology and sediment transfer processes
5	Natural Flood Management - Catchment Wide and direct defences	£2,510,234.54	18	0.09	100yr	• climate regulation, • carbon sequestration • habitat provision, • improvement in water quality from both sediment runoff and nitrates/phosphates, • betterment to channel morphology and bank stability, • improved fish habitat, • community engagement, • erosion regulation, • improvement in landscape character, • improved education/knowledge. • protection of A83 and Clachan Filling Station maintaining community link • Reduced stress due to visual comfort of defence
6	Weir removal and direct defences	£2,196,977.86	18	0.11	100yr	• increased in-stream biodiversity • improved fish migration and habitat • restoration of channel morphology and sediment transfer processes • protection of A83 and Clachan Filling Station maintaining community link • reduced stress due to visual comfort of defence
7	Natural Flood Management - Catchment Wide, weir removal and direct defences	£949,811.76	18	0.26	100yr	• climate regulation, • carbon sequestration • flood regulation, • habitat provision, • improvement in water quality from both sediment runoff and nitrates/phosphates, • betterment to channel morphology and bank stability, • improved fish habitat, • community engagement, • erosion regulation, • improvement in landscape character, • improved education/knowledge.

Option No.	Description	Costs	No. of properties with reduced flood risk	Benefit -Cost Ratio	Standard of Protection	Non-monetised benefits
						• reduced risk of structural damages of A83 maintaining link to community in long term • increased in-stream biodiversity • improved fish migration and habitat • restoration of channel morphology and sediment transfer processes • protection of A83 and Clachan Filling Station maintaining community link • reduced stress due to visual comfort of defence
8	Property Flood Protection – 200 year SoP	£80,433.23	13	1.03	200yr	• petrol station/post office building protected protecting key community building
9	Property Flood Protection – 200 year+CC SoP	£122,264.18	22	0.70	200yr+CC	• petrol station/post office building protected protecting key community building •
10	Weir removal and Property Flood Protection – 200 year SoP	£237,241.52	21	1.11	25yr – 200yr	• petrol station/post office building protected protecting key community building • emissions reduced through reduction of flooding. • increased in-stream biodiversity • improved fish migration and habitat • restoration of channel morphology and sediment transfer processes

9. Conclusions and Recommendations

This report details the Option Appraisal process carried out on short-listed options to manage flood risk in Clachan.

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

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

- Hydraulic Modelling – to understand impact of a measure on flood risk
- Public consultation – with the local community 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 if an option is value for money. This has been considered over the whole 100 year design life 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.
- 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 made based on the appraisal of economic, social and environmental impacts, whole life costs and consideration of risk and uncertainty, both present and future.

Weighing these considerations together, the appraisal has determined that the following options to be most viable:

- Removal of Clachan Burn weir alone (Option 2)
- Removal of Clachan Burn Weir and Catchment Wide implementation of Natural Flood Management (Option 4)
- Targeted installation of Property Level Flood Protection (Option 8)
- Removal of the Clachan Burn weir and targeted installation of Property Level Flood Protection (Option 10)

With the exception of option 4, the options above have a CBR greater than one, demonstrating value for money before considering non-monetised social and environmental benefits. On this basis any of these options could be fed back to SEPA for prioritisation for Scottish Government Funding on a national level. Option 4 could also be promoted for prioritisation based on the non-monetised benefits providing a boost to its BCR.

9.1 River Basin Management Planning in Clachan

SEPA are responsible for River basin management planning (RBMP). This process improves Scotland's water environment for the benefit of people, wildlife and the economy. The plans set out a range of actions to identify and address issues affecting the water environment.

As part of ongoing consultation with SEPA for this study, it has been identified that the Clachan Burn RBMP status has been re-classified as poor in 2017 due to poor ecology quality and fish passage obstruction due to the Clachan weir.

Consultation with the SEPA RBMP team indicated that work was being planned to assess the removal of the weir to improve the classification of the water body through the Water Environment Fund. The Water Environment Fund enables rivers to be restored by:

- Repairing damaged urban rivers often in deprived areas to enhance the environment for the communities that live there. The aim is to create attractive and accessible green river corridors that can be used for active travel and recreation in addition to helping flood management.
- Removing and easing barriers to migrating fish and improving vital fish stocks. The fund aims to increase the lengths of habitat accessible to native fish, helping to improve endangered populations and create new opportunities for angling, tourism and recreation, bringing economic benefits and recreational opportunities to river communities.

The findings of this flood study have been shared with the RBMP team at various stages to maximise the use of work already carried out and aid SEPA's scoping assessment for weir removal.

As part of this scoping SEPA have recently carried out Barrier Feasibility Geomorphology Assessment (October 2019) included in Appendix A. The initial findings of this scoping are that the weir is not totally impassable for fish presently due to erosion around the eastern side providing a fish ladder. On this basis, the weir removal would likely be ineligible for WEF funding as the conditions are very strict. However, further fish survey is required to fully assess the impacts on different species. The assessment did indicate the removal of the weir would likely have limited adverse effect providing further confidence in this option. The assessment has also provided options for weir removal i.e. full removal or staged which can be developed further.

It is therefore recommended engagement and partnership working continues with SEPA through a Local Flood Action Group (LFAG) and through ABC to identify potential funding opportunities to implement weir removal. This could be delivered through shared funding by SEPA/ABC or full funding by ABC. Establishment of a LFAG made up of the community and responsible authorities could also provide an opportunity to identify further alternative funding sources.

Scottish Government funding could be accessed in Cycle 2 of the FRM Planning Cycle (2022 – 2028). The likelihood of this is dependent on the outcomes of SEPA Strategies to be published December 2021. The Strategies will prioritise FRM actions nationally to allow Scottish Government to make informed investment decisions on where sustainable flood risk management actions should be taken.

9.2 Recommendations

The following next steps are recommended to allow this Flood Study to be used as a driver for ongoing flood risk management in Clachan:

- Submit Option 10 (weir removal and targeted PFP) to SEPA for national prioritisation as the preferred option,

Table 9-1 Preferred Option

Option No.	Description	Costs	No. of properties with reduced flood risk	Benefit-Cost Ratio	Standard of Protection	Non-monetised benefits
10	Weir removal and Property Flood Protection – 200 year SoP	£237,241.52	21	1.11	25yr – 200yr	• petrol station/post office building protected protecting key community building • emissions reduced through reduction of flooding. • increased in-stream biodiversity • improved fish migration and habitat • restoration of channel morphology and sediment transfer processes

- Explore potential to take forward Option 4a (weir removal, NFM and PFP) through other sources depending on prioritisation outcomes and discussion with responsible authorities,
- Establish a Local Flood Action Group/Catchment Partnership to include community representatives and the different public bodies responsible for flood risk management. This should be used to identify interventions long term, examine for potential external funding and

communicate maintenance/planning issues. Funding sources such as Scottish Forestry's Community Fund could be used to drive this,

- Engage with landowners affected by NFM options identified. This is vital for an NFM strategy to succeed as it involves changing how land is managed and incentivising/educating landowners to do this. This should be driven by the Local Flood Action Group/Catchment Partnership,
- ABC and SEPA should work in partnership to progress potential funding for a weir removal option either through a shared mechanism, direct ABC funding, Scottish Government funding in Cycle 2 of FRM cycle (2022 – 2028) or through other alternative funding sources.
- ABC to explore sharing river monitoring data through LFAG,
- ABC to follow up offline actions as budget permits e.g. maintenance of trees along bank, maintenance of road verge,
- SEPA to continue to monitor any reservoir works on Loch Ciaran as the regulator,
- Scottish Forestry to continue to work with commercial forestry in the area to ensure best practise is followed as the regulator.

Appendix A – SEPA Barrier Feasibility Assessment

Barrier Feasibility Geomorphology Assessment – Clachan Burn, Kintyre Barrier ID - 1480

Name of surveyor	Helen Reid
Site name	Clachan Burn
River Name	Clachan Burn
Grid ref	NR 76316 56080
Date/time/weather	15/10/19; 12.10; Sunny

Geomorphic Aspect	*Detail*	*Implications for Risk?*
Geomorphic Characteristics of the reach the weir is located in		
Landscape setting/valley confinement	The valley is flat and unconfined at this location, though fairly narrow.	**High – as the channel could adjust laterally**
Channel characteristics? - *Geo unit* - *Bed material* - *Energy*	The channel type is plane – riffle demonstrating that the channel has moderate energy and is not a passive lowland river. Bed material are mostly boulders and cobbles, which are discoloured black from diatoms. This indicates that this material is not transported often and is relatively stable. An active gravel layer was also present moving through the system and superimposed on bars and on the rivers margins.	**Moderate – energy is moderate reflecting energy to adjust**
Presence of bedrock or other impoundments? Extent and location? Evidence of instability?	No bedrock was visible from the site visit. The channel does not exhibit too much instability and would be likely to naturally have fairly low sinuosity. However, there is some bank protection, especially on the right bank of the channel which is in very poor condition and is crumbling (Figure 5; Figure 6). Some of it is held in place by fencing which has been strapped on to hold it in place. In contrast, the left bank is well vegetated and fairly stable. The poor state of the bank protection is more likely to reflect its age, and the fact that it is vertical so likely to fail, rather than be an indication that the river is overly mobile.	**Moderate – not overly mobile, but some bank protection is failing indicating some lateral instability**
Geomorphic Risk Assessment	The weir is only a relatively small structure (0.5 m from water level at time of visit, Figure 2; Figure 4), so its removal would not be likely to have significant impacts on the river. Firstly, there is minimal backwater impact from the structure. There is a footbridge 40 m upstream which has a steep riffle below it showing that is no impact of the structure on the bed slope at this point (Figure 7). The bed between the weir and the footbridge still has a good gradient on it, seen in the hydraulic unit of a run, indicating that the bed slope is not hugely impacted (i.e. there is not a large pool which stretches for a distance). This is also reflected in the sediment distribution of	**Mod – low – The weir is quite small and is only having a local impact upon the river, which limits the length of river that would be impacted by its removal**

	the river. Immediately upstream of the weir, the bed is coarse with large boulders evident. This indicates that this is not acting as a depositional environment (there is not a lot of sand as would be seen with a larger structure) and that the weir is likely to be having minimal impacts upon sediment transport. However, we would still expect some bed lowering immediately upstream of the weir as the channel resets its gradient to remove the step in its profile which the weir causes.	
Size, character and age of the structure	The weir is relatively small. There is 1 m present which was submerged and then the height above the water was only around 0.5 m. It is likely to be Victorian, though it doesn't appear on any of the older topographic maps (e.g. 1880 - 1910) so this may be due to the detail of the mapping. It was constructed to try and direct fish up the tributary of the Allt Mor (which is directly below the structure) to establish a fishery in Loch Ciaran	**Low – this is due to the weir being quite small**
Risk to infrastructure	There is minimal infrastructure on the site that would be impacted by the removal of the weir. Downstream is pasture, and it is unlikely that removal would release significant volumes of sediment which would have an impact downstream. Upstream on the right bank there is a field which has 5 caravans in it and a house behind. This bank would likely need to be protected as the current bank protection is already failing. There is also a footbridge 40 m upstream. This has large concrete foundations and the river has a steep gradient at this point indicating minimal impact of the weir on the channel at this location. Thus, it is unlikely modifying the weir would have an impact upon this, though it should be considered when designing actions (to be precautionary).	**Low**
Heritage Value	None, that we are aware of.	**Low**
Extent of works likely to be required if removal was feasible	Works could be done quite simply. The most likely thing that may need to be done would be works to protect the bank protection on the right bank if this is a priority for the landowner. However, regardless of what happens with the weir, this bank protection is likely to continue to fail. Bank protection works could be in the form of some boulders along the toe of the bank to protect this if the bed did lower. The impact could also be mitigated by leaving some form of step at the location of the weir. One options would be to break up the weir and leave parts of it there so that the bed lowers slowly. This could be done in stages with more material removed in the future.	**Low – but may need bank protection for right bank**
SUMMARY	In summary, the channel has moderate energy, despite its lowland location. The weir is small and is only impacting a short section of river, and has not significantly impacted processes. The only infrastructure which is potentially threatened at the site, is the already failing bank protection on the right bank upstream of the structure. Works may have to be undertaken to ensure that further deterioration isn't attributed to alterations to the weir. However, for this site, removal or direct modification to the structure is most viable options as it could be carried out relatively easily.	**Low – mod**

What options should be investigated in further detail?

Full removal	Yes, this is likely to be possible at this site. May require steps to be constructed to hold the bed level.
Partial removal	Yes, this could be done by progressively breaking up the weir and allowing the channel to stabilise in between stages. Stretches the recovery over longer timescales and means if work needs to be carried out to protect anything such as the banks it can be done.
Phased removal	Yes, similar to what is described above.
Informal easement (rock weirs)	This could be an option to raise bed levels downstream. Probably not the preferred option.
Rock ramp	Not necessary.
By-pass channel	There already is a channel which has been forming on the left side of the weir creating a by-pass channel. Flow is still relatively fast here, but this could be formalised by making it wider. However, effort would have to be made no to direct the flow towards the left bank downstream of the weir.
Fish pass options only	Not necessary.
Do nothing	The weir is likely to be passable sometimes to some species. If further fish pass surveys shows that it is passable then this may be the outcome.

What types of survey are necessary to further this assessment?

Surveys should include further investigation of the bank protection and assessment of what are the best actions to try and protection this face if the landowner deems it necessary. We would also need a plan outlining how best to modify the structure. It is likely that a fairly light touch approach could be used at this location.

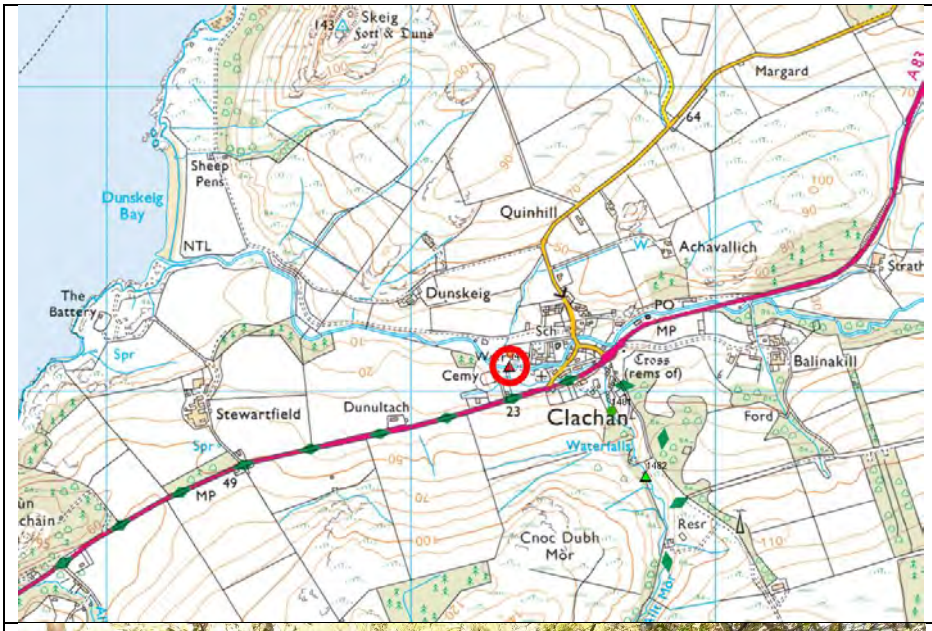


Figure 1: Location of the weir.

Figure 2: Photo looking up towards the weir.

	**Figure 3: By-pass channel which has started to form on the left side of the weir as the flow cuts around it.**
	**Figure 4: Close up of weir showing the depth of the weir pool and relative height of the weir.**

	**Figure 5: Character of the river immediately upstream of the weir, showing that the channel is not acting as a weir pool. This also shows the bank protection on the right bank.**
	**Figure 6: Section of bank which has already failed.**

Figure 7: riffle immediately upstream of the footbridge (which is 40 m upstream of the weir). This indicates that the weir has no impact on the channel slope at this point seen in the steep gradient.