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ISO 27001:2013
ISO 45001:2018

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For the attention of David Murphy, on behalf of *Scottish Borders Council*

Our Ref:SBC-JBAU-00-00-RP-C-0000-S2-P1-Erosion Mitigation Letter

18th August 2021

Dear Sirs,

2021s0445 - Scottish Borders Council - Newcastleton post flood survey

Following an e-mail, dated 11th March 2021, please find below our findings detailing the options available to address the riverbank erosion on the right-hand bank of the Liddel Water, immediately downstream of the footbridge at the north end of Newcastleton.

Please find below an executive summary of the Erosion Control Letter Report

Executive Summary

Channel velocities at each cross section along the eroded righthand bank for the 1 in 200-year event range between 1.58 to 3.55 m/s. A number of mitigation options to deal with the bank erosion problem have been considered based on Table 5.3 from CIRIA Report C551 and NERC (2021) Green approaches in river engineering.

Based on the extracted velocities the preferred option for erosion mitigation along the Liddle Water is a combination of bank re-profiling with vegetated toe and bank protection, or woody material which is considered the most appropriate solution for short-term scour protection. The use of woody material is considered cost-effective as local material can be obtained for the channel. The design life is shorter however the implementation of woody material to reduce scour would provide protection whilst a longer-term Flood Protection Scheme for Newcastleton is considered. It should be noted that this method has already been successfully implemented on the Liddle Water near Newcastleton.

Rock Armour/Stone Riprap is considered the most appropriate solution for long-term low maintenance scour protection as part of a flood protection scheme. Rock Armour is able to withstand the velocities associated with higher return periods however this form of scour protection is expensive and has a significant environmental impact.

The Environment Agency's 2015 Cost estimation for channel management – summary of evidence (SC080039/R3) report was used to determine an indicative estimation of costs for a number of options.

Please note costings listed within this report are both indicative and are for comparative purposes only at this stage

Short Term:

Woody Material along the Liddle Water (See Table 4-4)
£69,000 to £75,000.

- costing based on EA's 2015 SC080039/R3 report however it is likely that with the use of a local contractor and local supply of woody material and natural resources will dramatically decrease the cost of this option.

Long Term:

Rock Armour/Stone Riprap along the Liddle Water (See Table 4-2)
£330,000 to £468,000.

- costing based on EA's 2015 SC080039/R3 report. Based on the size of the boulders required for the Liddle Water, discussed within the 'Long-term Options' section of this report, costing for this method will likely be towards the higher end of the cost estimate.

River works are regulated by SEPA under The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended). To comply with the regulations it is likely that the short term option to use woody material would require a registration which takes 30 days to determine. Implementing the use of Rock Armour would require a complex licence due to the length of the affected reach. Based on SEPA's charging scheme fees for 2020/2021, engineering subject to a complex licence is classified as Activity Application Band 11 with a charge of £3,333 and would take up to 4 months to determine.

To complete this assessment, a review of the options to protect bank including rock armour, geotextile solutions and Bio-technical solutions is required. In order for licence submission accurate scale drawings of design structures and proposed modifications are required along with a method statement detailing how each activity is to be carried out, any temporary construction works associated with controlled activities, and details of any machinery to be used. Pre-application discussion with the local office before any application is submitted is strongly recommended. Completion of SEPA CAR licence Forms A (For all licence applicants) and Form E (For engineering activities) will also be required for the complex licence submission.

The estimated fee for undertaking the design work detailed above for the either the green bank or grey bank options would be in the region of £7,500 to

£10,000 and the study would take around 4-6 weeks to complete from commission.

Yours sincerely,

René Dobson

For and on behalf of Jeremy Benn Associates Limited

Associate Director
Rene.Dobson@jbaconsulting.com

1 SITE INSPECTION FINDINGS

The right-hand reach of the Liddle Water that is currently being eroded was inspected on the 25th February 2021, with the main observations listed below:

- There appears to be an area of fill.
- There is erosion up and downstream of the power pole.
- Consideration may be required for the whole reach due to bridge abutments and the importance of the banking up and downstream of where it effects the power pole.

View of downstream right bank erosion from right hand bank

View of downstream right bank erosion from left hand bank

View of wrack marks.

View of downstream right bank erosion from left hand bank

- Some wrack marks indicate strong and deep flows across the floodplain and re-entering the river at the point of erosion.
- Accretion of gravel material immediately upstream of the bridge

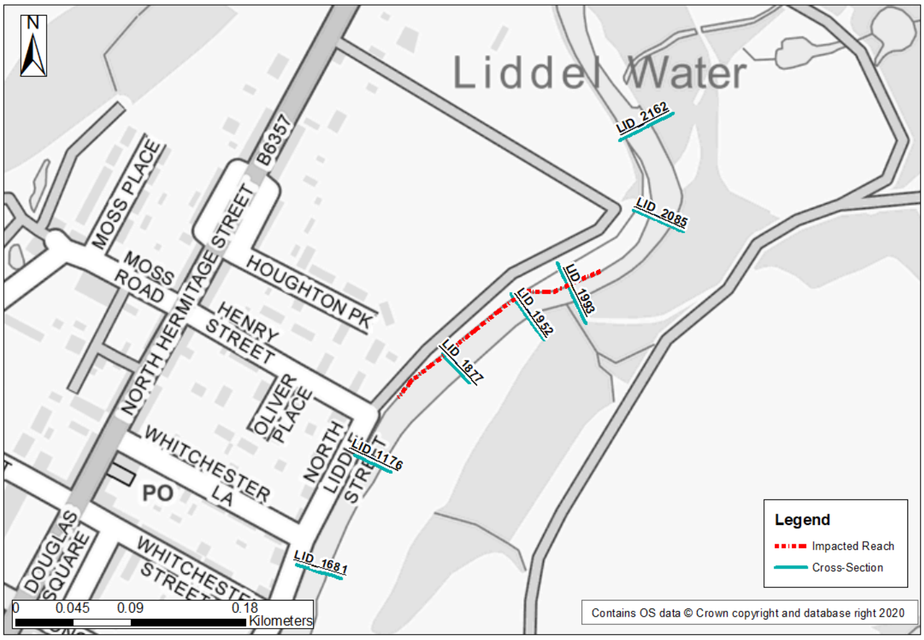

Figure 1-1: ICM model cross-section location and reach impacted by the erosion

2 HYDROLOGY AND HYDRAULIC MODELLING

An Infoworks ICM hydraulic model of Newcastleton was developed in 2017 for the purpose of a full appraisal of flood risk to Newcastleton from the Liddle Water, Charlie Sike, Short Sike and the sewer network (Study reference: JBA Consulting (2017) 2017s5526 - Mott MacDonald - Borders Flood Studies). The ICM hydraulic model included topographic survey data, consisting of coordinates and associated elevations which were used to compute a simplified representation of the Liddle Water river channel. The model also included 56 cross-sections.

The 2017 Infoworks ICM hydraulic model was used for the Newcastleton Post Flood Survey to calculate near right hand bank velocities. These velocities have been used to assess scour depths and viable options for scour management.

3 MODEL RESULTS

As detailed above, the modelling was undertaken using a number of different downstream boundary conditions. The maximum channel and bank velocities in the vicinity of the bridge for the different model scenarios and return periods are displayed within Table 3-1, Table 3-2 and Table 3-3. The cross-section locations are displayed within Figure 1-1, Figure 3-1, Figure 3-3 and Figure 3-5.

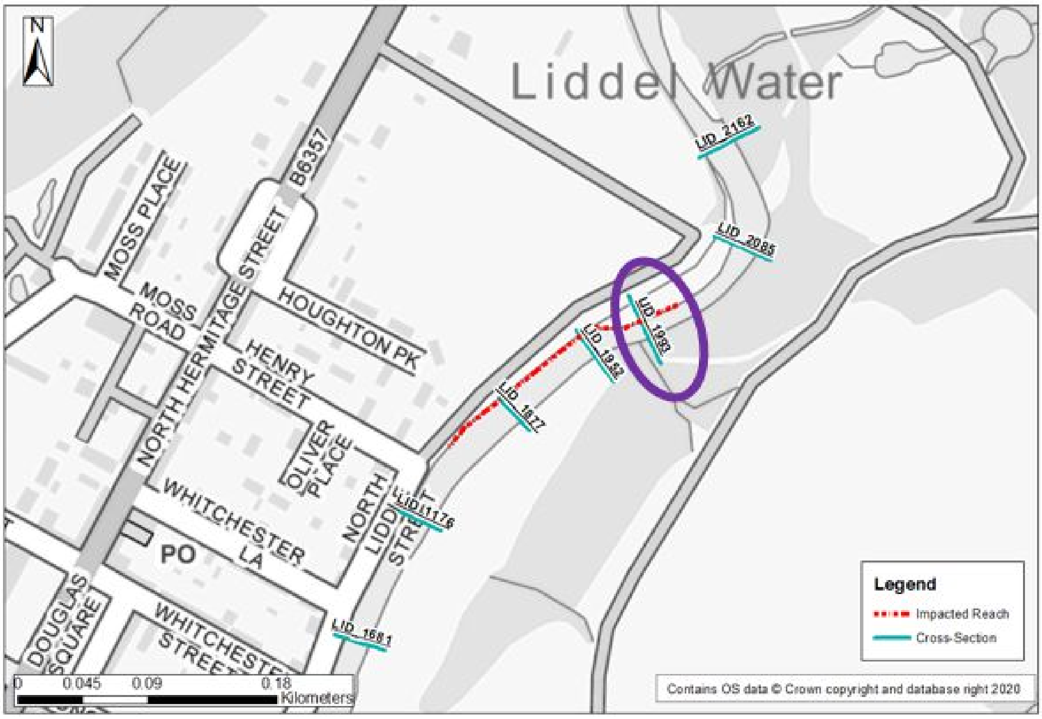

Figure 3-1: LID_1993 cross section model location

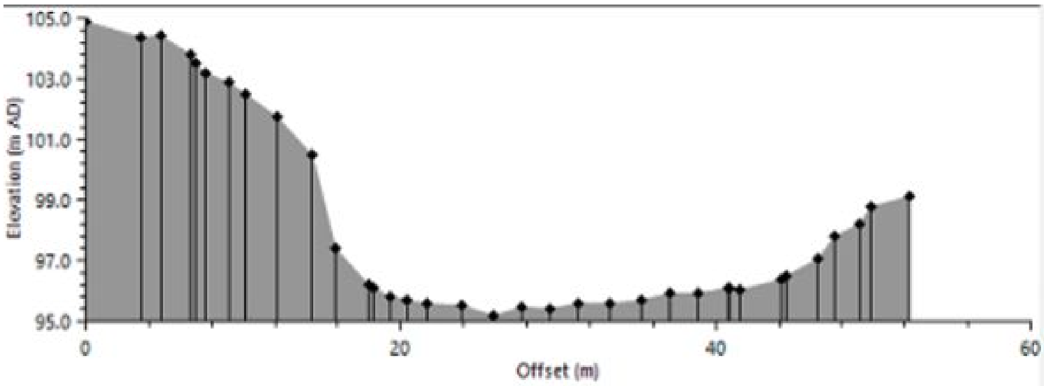

Figure 3-2: LID_1993 cross section

Table 3-1: LID_1993 model velocity results

	LID_1993 At erosion reach – upstream section	
	Velocity – Centre of Channel (m/s)	Velocity – Left Bank (m/s)
2 year	-	1.99
5 year	-	2.19
10 year	-	2.29
25 year	-	2.35
30 year	-	2.36
50 year	-	2.37
75 year	-	2.38
100 year	-	2.38
200 year	-	2.39
500 year	-	2.40
1000 year	-	2.41
	-	
30 year + Climate Change	-	2.38
200 year + Climate Change	-	2.41

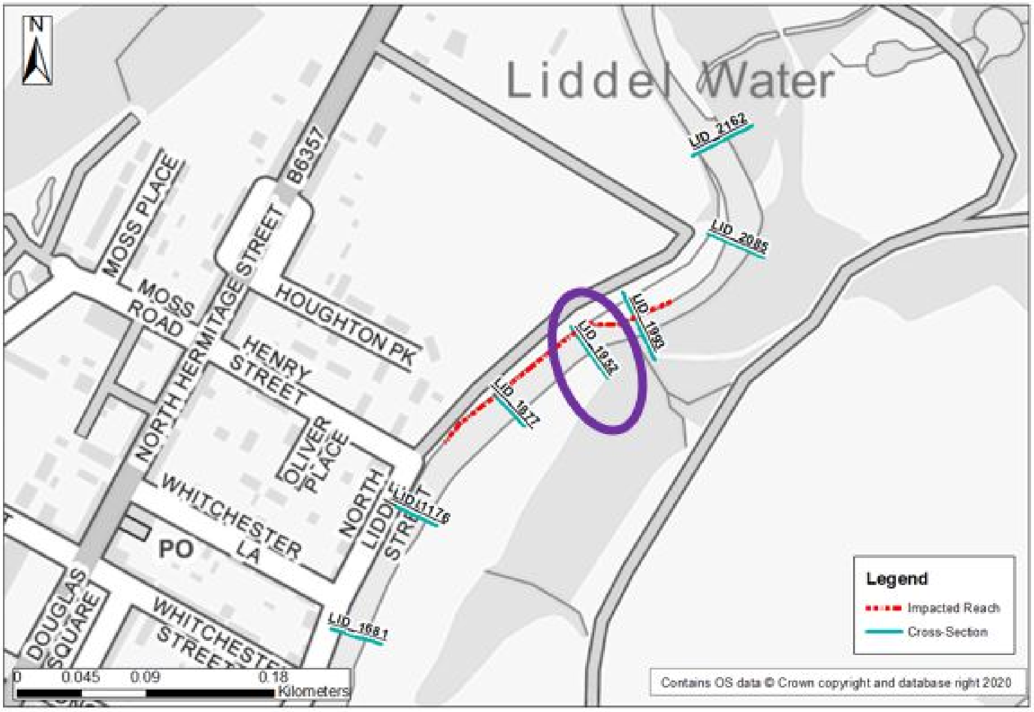

Figure 3-3: LID_1952 cross section model location

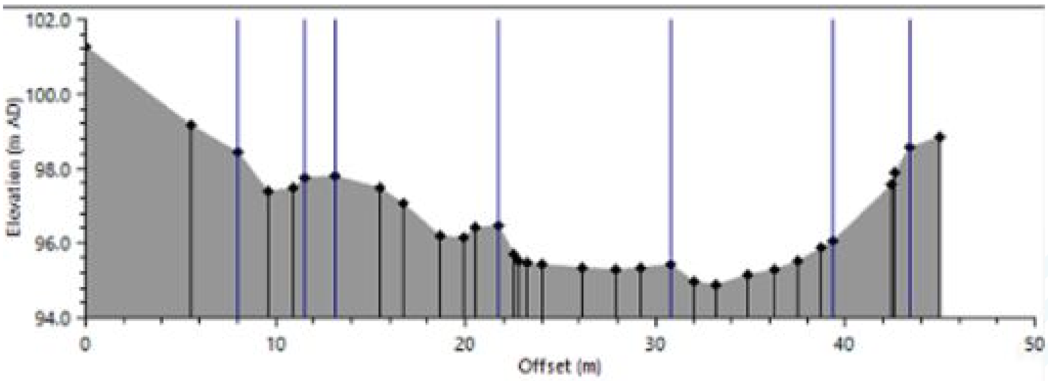

Figure 3-4: LID_1952 cross section

Table 3-2: LID_1952 model velocity results

	LID_1952 At erosion reach – middle section	
	Velocity – Centre of Channel (m/s)	Velocity – Right Bank (m/s)
2 year	16.69	1.12
5 year	16.86	1.26
10 year	16.86	1.39
25 year	16.77	1.48
30 year	16.90	1.50
50 year	17.08	1.52
75 year	17.13	1.54
100 year	16.98	1.55
200 year	16.93	1.58
500 year	17.25	1.63
1000 year	17.46	1.69
30 year + Climate Change	17.05	1.56
200 year + Climate Change	17.07	1.68

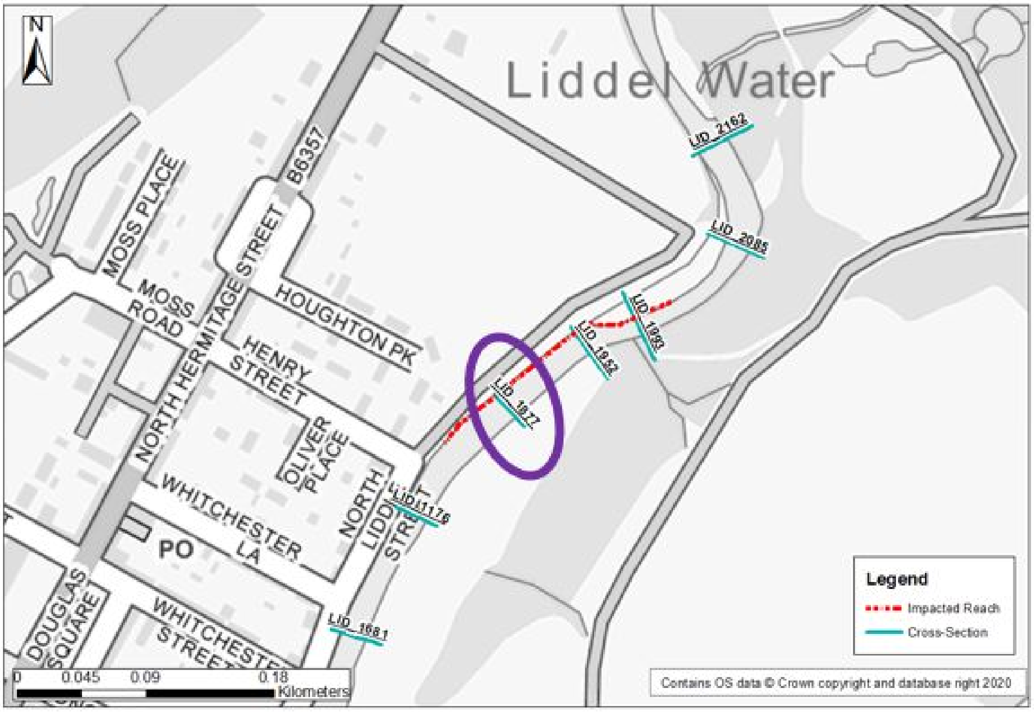

Figure 3-5: LID_1877 cross section model location

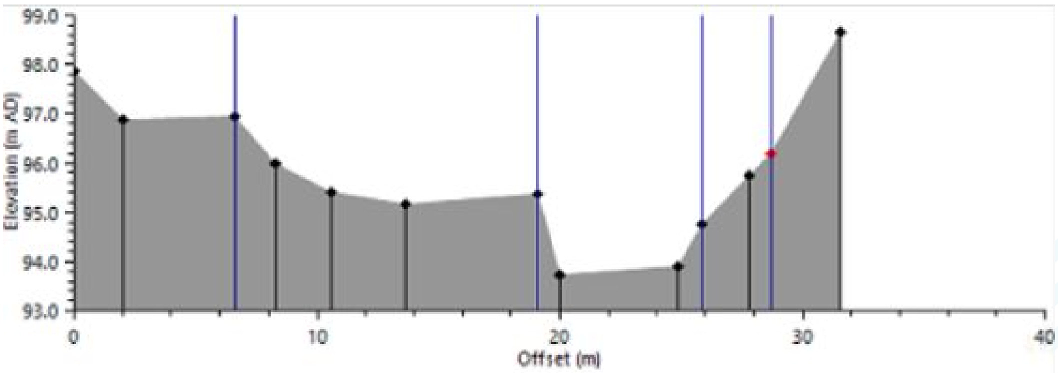

Figure 3-6: LID_1877 cross section

Table 3-3: LID_1877 model velocity results

	LID_1877 At erosion reach – downstream section	
	Velocity – Centre of Channel (m/s)	Velocity – Right Bank (m/s)
2 year	2.99	2.19
5 year	3.33	2.51
10 year	3.58	2.75
25 year	3.90	3.04
30 year	3.95	3.09
50 year	4.10	3.23
75 year	4.21	3.34
100 year	4.29	3.41
200 year	4.40	3.55
500 year	4.50	3.66
1000 year	4.55	3.73
30 year + Climate Change	4.33	3.47
200 year + Climate Change	4.56	3.73

4 SCOUR PROTECTION OPTIONS

The standard guide used for the design of scour protection is CIRIA Report C551, and recommendations made within this section are based on this standard. The design of scour protection is related to the flow velocities, turbulence, depth of water, nature and geometry of channel, as well as local features in the channel.

A range of return periods have been considered within this report. The 0.5% AP (200 year) plus climate change event is considered to be the optimal design return period to base the scour protection options on. However, designing a scour protection scheme based on the 0.5% AP (200 year) plus climate change event will likely require a grey bank solution. While a grey bank solution would provide protection to higher design return period and are considered to have a long design life, grey bank solutions are expensive and are not considered as effective in terms of cost and environmental impact.

Alternatively, green bank solutions can be implemented that use locally sourced materials and labour. Green bank solutions do generally have a shorter design life in comparison to the grey bank solutions but are considered more effective in terms of cost and environmental impact. Short-term mitigation measures, utilising green bank solutions, are considered appropriate for this reach in Newcastleton as the erosive velocities are not too high and the consequence of failure is relatively low i.e. there is no risk to life or structural damage to buildings. A possible exception to this is the right hand abutment of the foot bridge which is currently being undercut, but is believed to be founded on bedrock. However, this should be confirmed as part of any scour protection design. If at some point in the future a wider flood protection scheme is proposed, more robust erosion protection would be required as part of the scheme. The cost and ease of implementation of greenbank mitigation measures, makes it more acceptable to consider lower return periods for design purposes.

To select the most appropriate option, Table 5.3 from CIRIA Report C551[1] and Chapter 3 - Decision-support framework from NERC Green approaches in river engineering report[2] was used and a number of design options were considered. The suitability of different types of scour protection is strongly influenced by the availability of labour, plant and materials. Some types of scour protection (i.e gabions, interlocking blocks and stone pitching) require significant labour. Sheet piling requires the availability of plant, whereas other types of protection require certain materials to be available at reasonable cost, such as suitably sized rock for Rock Armour or appropriate geotextiles.

4.1 Do Nothing

The 'Do Nothing' option is not considered desirable at Newcastleton at this stage as the banks will deteriorate further and contribute to scour at the structure. The 'Do Nothing' option could be considered an option once the rate and therefore the risk of erosion have been established.

A significant flood event could result in accelerated erosion of the bank of Liddel Water. This could result in the abutment of the bridge upstream of cross-section LID_1993 becoming exposed. A significant event could also result in the loss of the track running adjacent to the right bank and undercutting of the concrete revetment which holds up North Liddle Street.

4.2 Biotechnical solutions (Green Bank)

Bio-technical solutions are suited to locations of lower flow velocities (typically up to 3m/s). As stated in Section 4, green bank solutions can be implemented that use locally sourced materials and labour. Some green bank solutions have a shorter design life in comparison to the grey bank solutions but are considered more effective in terms of cost and environmental impact. Short-term (typically 5-10 years) mitigation measures, utilising green bank solutions, are considered acceptable for Newcastleton whilst a flood protection scheme is being considered.

For a 10-year event the upstream section of the eroded bank has a bank velocity of 2.29 m/s and a downstream section velocity of 2.75 m/s. For a 25-year event the upstream section of the eroded bank has a bank velocity of 2.35m/s and a downstream section velocity of 3.04 m/s.

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[1] CIRIA (2002) C551 - Manual on scour at bridges and other hydraulic structures

[2] NERC (2021) Green approaches in river engineering - Supporting implementation of Green Infrastructure.

- Aquatic Vegetation

  Aquatic plants (for example Iris and Sedge species) can be used to reduce flow velocities by providing root reinforcements to the channel bed and lower banks. According the NERC (2021), the maximum permissible velocity of this green method is 2.4 m/s with a design life of infinity years. It is noted that this method is only suitable for banks over 1.5m.

- Coir Matting

  Biodegradable materials, constructed from natural fibres found on the outside of coconuts, can be woven and pressed into a regraded channel bank which consequentially stabilise the bank as they provide a rooting base. The rooting base allows for re-establishment of vegetation along the bank and allows vegetation to grow through. The NERC (2021), suggests the maximum permissible velocity of this green method is 2.4 m/s with a design life of 3-5 years.

- Coir Rolls

  Unlike Coir matting, Coir rolls comprise of coir shaped into rolls that are contained within an exterior mesh and are specifically used for toe bank protection. Rolls are usually used in conjunction with live vegetation and stakes. The NERC (2021), suggests the maximum permissible velocity of this green method is 1.8 m/s with a design life of 6-10 years.

- Faggots/Fascines/Brushwood

  Faggots and Fascines are bundles of untreated brushwood which are bound together with biodegradable fibres. As with Coir Rolls, Faggots and Fascines are predominately used for toe bank protection as they reduce flow velocity and trap sediment and organic matter. The NERC (2021), suggests the maximum permissible velocity of this green method is 2.0 m/s with a design life of 30->100 years. It is noted that the use of live fascines will have a higher resistance.

- Stakes (live)

  Live stakes can be used for bank reinforcement and vegetation re-growth. Stakes are usually constructed from the stem or branches of willow types to a length of 0.5-1m. The section of the stake which is set below ground is able to take root while the exposes section is able to bloom. The stakes need to be dormant when placed and this limits the period of construction to between the months of October and March. Stakes are usually used in conjunction with additional techniques. The NERC (2021), suggests the maximum permissible velocity of this green method is 1.5 m/s with a design life of 40->100 years.

- Vegetation

  Vegetation comprising of grasses, herbaceous plants and shrubs are usually used in conjunction with additional techniques. Plants established on bare soil works to reduce splash erosion, increase infiltration and reduce surface water run-off draining down the bank sides, reduce near bank flow velocity, anchor sub-soil through root reinforcement and reduction in the risk of saturated conditions. The NERC (2021), suggests the maximum permissible velocity of this green method is 2.4 m/s with a design life of infinity years.

- Willow Spilling

  Willow rods, woven around stakes, can form a fence-like structure that is backfilled with soil to provide a physical structure which provides protection against erosion. Willow hurdles can also be used to temporarily deflect flow away from the riverbank and promote near-bank deposition. The NERC (2021), suggests the maximum permissible velocity of this green method is 2.5 m/s with a design life of 40->100 years.

- Woody Material

  Material is sourced by felling trees which are subsequently used to re-direct flows and promote near-bank deposition at the toe of the eroding channel banks. Wood can be installed either as whole trees placed parallel to the flow, root wads which comprise of tree trunks and roots that are pushed into the bank, leaving the roots exposed or as engineered log jams. The NERC (2021), suggests the maximum permissible velocity of this green method is 3.0 m/s with a design life of 5-15 years.

Based on the assumption that a 10-year flood event and a 25-year flood event, would provide an appropriate standard of protection at this time, velocities obtained suggest the use of woody material or a combination of bank regrading, vegetated toe and bank protection would provide suitable short-term protection.

4.3 Bituminous systems

According to CIRIA Report C551, Bituminous scour protection can withstand velocities up to 7 m/s. However bituminous systems are not environmentally suitable for this location and cannot be constructed underwater. At this stage, the use of Bituminous systems for this site is not considered as a suitable option.

4.4 Articulated concrete blocks

Concrete block revetment construction costs is considered to be high and this method may not be environmentally suitable. Therefore, its use is not recommended.

4.5 Concrete Apron

A concrete apron is expensive, presents a risk to the environment during construction, it is not aesthetically pleasing, and is not flexible so it cannot adapt to minor erosion and tends to fail rapidly. Therefore, its use is not recommended.

4.6 Rigid grout-filled mattresses and bags

Bags, sacks and mattresses filled with cement grout or concrete are not suitable for high flow channels. Therefore, its use is not recommended.

4.7 Gabion

Gabions are wire mesh containers filled with stone. A concern with Gabion solutions is the long-term corrosion resistance of the gabion mesh however for most conditions a design life of several decades can be assumed. The use of gabion baskets is not recommended as they would be below the water level and subject to additional corrosion. Gabion baskets are also not recommended as photographic evidence in Section 1.2 indicates that bank material is comprised of stones and small boulders. Shifting stones, particularly in high velocity environment, would abrade the wires and debris carried by the river could strike the wires causing the baskets to fail prematurely. Once the basket is compromised the onset of erosion tends to be rapid. Therefore, its use is not recommended.

4.8 Rock Armour

Rock Armour (Also known as Rip-Rap) can be installed to a design standard and therefore it provides a quantifiable standard of scour protection. It is also very useful to protect small awkward locations. The advantage with Rock Armour is its ability, to a limited extent at least, to selfheal. Holes opened up by the action of scour may automatically be in filled by boulders that will provide scour protection and will naturally realign itself if there is any local settlement. In addition, it is relatively straight forward to repair any local damage. Suitably sized Rock Armour is appropriate as protection up to very high velocities and turbulence. The layout of Rock Armour protection is often designed so that there is a surplus of material at the edges, so that if there is scour adjacent to the protection, stone will fall into the scour hole but will continue to provide protection.

In terms of environmental impact, Rock Armour can provide a good habitat for invertebrates. The stone is normally inert and does not usually pose a pollution risk. Replacement of excavated material from the riverbed and banks can re-establish habitats. At this stage the use of Rock Armor for this site is considered as a suitable option. Rock Armour can be sized to provide protection against very high velocities and is therefore considered a potentially viable option.

4.9 Dredging

Dredging involves the removal of sediments such as sand and gravel and debris from the bottom of rivers. Removal of the gravel bars within the river could accelerate the scour at the right abutment of the foot bridge. The existing stone protection at the bridge will not provide any protection against scour as does not extend down into the channel and is susceptible to undercutting. Erosion and undercutting could also be accelerated further downstream of the bridge until a significant flood event re-establishes the gravel bars within the river.

4.10 Scour Protection indicative costs

The Environment Agency's 2015 Cost estimation for channel management – summary of evidence (SC080039/R3) report was developed by JBA Consulting for use in summarising the evidence on the costs of a wide range of flood and coastal risk management measures. The purpose of the study was to enable contractors to rapidly generate outline cost estimates for risk management measures.

Limited costs associated with hard and soft bank reinforcement are available within the cost estimation for channel management report, collated from a number of projects and case study examples.

Table 4-1: Indicative hard bank reinforcement costs from the Environment Agency's 2015 Cost estimation for channel management – summary of evidence (SC080039/R3) report (Table 1.14) and the Environment Agency's 2007 Flood Risk Management Estimating Guide – Unit Cost Database (SC080039/R3) report for Stone Riprap technique

Technique and source	Cost per m	Range of cost per m²		Range of cost per m³	
Stone riprap *40% uplift applied due to inflation.*	-	£ 550.00	£ 780.00	-	-
Rock rolls *AINA (2008) based on information from British Waterways (2007 data)*	£ 46.00	-	-	-	-
Stone gabions *AINA (2008) based on information from British Waterways (2007 data)*	£ 250.00	-	-	-	-
General hard *SNIFFER (2005) Generalised costs for concrete, laid stone, gabion baskets and riprap protection.*	£ 1,075.00	-	-	-	-
Gabion Baskets *SNIFFER (2007)*	-	-	-	£ 50.00	£ 65.00
Timber pilling *AINA (2008) based on information from British Waterways (2007 data)*	£ 160.00	-	-	-	-
None-live timber *SEPA (2008)*	-	£ 100.00	£ 350.00	-	-
Riprap (SEPA) *SEPA (2008)*	-	£ 60.00	£ 150.00	-	-

Based on the figures supplied in Table 4-1 and using an indicative working channel reach of a length of 120m, width of 5m and an assumption that mitigation measures such as riprap will require two layers, the following indicative costs have been calculated. However, it should be recognised that the price if materials and labour can vary significantly by location and demand, so these costs should be considered very high level and more a comparison between options that could be deployed.

Table 4-2: Indicative hard bank reinforcement costs for Newcastleton based on Table 2-2 values

Technique	Cost per m	Range of cost per m²		Range of cost per m³	
Stone riprap	£ -	£ 330,000	£ 468,000	£ -	£ -
Rock rolls	£ 55,200	£ -	£ -	£ -	£ -
Stone gabions	£ 300,000	£ -	£ -	£ -	£ -
General hard	£ 1,290,000	£ -	£ -	£ -	£ -
Gabion Baskets	£ -	£ -	£ -	£ 30,000	£ 39,000
Timber pilling	£ 192,000	£ -	£ -	£ -	£ -
None-live timber	£ -	£ 120,000	£ 420,000	£ -	£ -
Riprap (SEPA)	£ -	£ 72,000	£ 180,000	£ -	£ -

Table 4-3: Indicative soft bank reinforcement costs from the Environment Agency's 2015 Cost estimation for channel management – summary of evidence (SC080039/R3) report (Table 1.15).

Technique and source	Range of cost per m		Range of cost per m2	
Re-profiling, willow spilling, hazel faggots and willow mattress revetment *AINA (2008) based on information from British Waterways (2007 data) - Additional 30% costs required for feasibility and design*	£ 300.00	£ 900.00	-	-
Hazel faggots *AINA (2008) based on information from British Waterways (2007 data)*	£ 30.00	-	-	-
Willow hurdle revetment *AINA (2008) based on RRC case study for a 119 m length project (1995 data)*	£ 40.00	-	-	-
Coil rolls *AINA (2008) based on information from British Waterways (2007 data)*	£ 37.50	-	-	-
Plant roll *AINA (2008) based on RRC case study for a 119 m length project (1996 data)*	£ 130.00	-	-	-
Pocket fabric revetment for reed establishment *AINA (2008) based on information from British Waterways*	£ 100.00	£ 200.00	-	-
Willow spilling *RRC (2002) based on a 75 m length (1996 data)*	£ 115.00	-	-	-
Willow mattress revetment *RRC (2002) based on a 59 m length (1995 data)*	£ 164.00	-	-	-
Log toe and geotextile revetment *RRC (2002) based on a 91 m length (1995 data)*	£ 146.00	-	-	-
Grass and Reed Planting *SEPA (2008)*		-	£ 100.00	£ 200.00
Live Woody Revetment *SEPA (2008)*	£ 115.00	£ 125.00	-	-
Faggots *SEPA (2008)*	£ 50.00	£ 120.00	-	-
Geotextile *SEPA (2008)*	£ 160.00	-	-	-

Based on the figures supplied in Table 4-3 and using an indicative working channel reach of a length of 120m and a width of 5m, the following indicative costs have been calculated.

Table 4-4: Indicative soft bank reinforcement costs for Newcastleton based on Table 4-2 values

Technique	Range of cost per m		Range of cost per m²	
Re-profiling, willow spilling, hazel faggots and willow mattress revetment	£ 180,000	£ 540,000	£ -	£ -
Hazel faggots	£ 18,000	£ -	£ -	£ -
Willow hurdle revetment	£ 24,000	£ -	£ -	£ -
Coil rolls	£ 22,500	£ -	£ -	£ -
Plant roll	£ 78,000	£ -	£ -	£ -
Pocket fabric revetment for reed establishment	£ 60,000	£ 120,000	£ -	£ -
Willow spilling	£ 69,000	£ -	£ -	£ -
Willow mattress revetment	£ 98,400	£ -	£ -	£ -
Log toe and geotextile revetment	£ 87,600	£ -	£ -	£ -
Grass and Reed Planting	£ -	£ -	£ 60,000	£ 120,000
Live Woody Revetment	£ 69,000	£ 75,000	£ -	£ -
Faggots	£ 30,000	£ 72,000	£ -	£ -
Geotextile	£ 96,000	£ -	£ -	£ -

4.11 Recommended option

Short-term solution

Based on CIRIA/NERC guidance and the flow velocities derived from the Infoworks ICM hydraulic model of Newcastleton, either a combination of bank re-profiling with vegetated toe and bank protection, or woody material is considered the most appropriate solution for short-term scour protection on the Liddel Water. These green bank options are the most appropriate, cost-effective and environmentally friendly solution as a short-term option (5 to 10 years). This method is considered a short-term solution due to the design life associated with this method and the protection it offers for lower return periods.

The use of woody material is considered cost-effective as local material (such as willow or pine) can be obtained for the channel. While the design life is shorter, the implementation of woody material to reduce scour on the Liddel Water would provide protection whilst a longer-term Flood Protection Scheme for Newcastleton is considered. It is likely that with the use of a local contractor and local supply of wooded material will dramatically decrease the cost of this option. **This method has been implemented successfully on the Liddle Water near Newcastleton**.

The SEPA (2020) Sustainable Riverbank Protection: Reducing Riverbank Erosion document provides a best practice guide for protecting eroding riverbanks without increasing erosion risks to other banks downstream while improving bankside habitat. The document states that installation of protection using large wood should:

- Use a mixture of different sizes and shapes of large wood to create a complex and rough matrix.
- Starting at the bank toe, interweave the different large wood pieces so that a complex and strong matrix is created. Using at

least some live wood will help create a stronger matrix, since live branches can take root in the bank or bed.

- Willow spiling or planting native species on the bank top can be used with this technique to help stabilise the bank.
- Steel reinforcement bars (rebar) can also be used to fix large trunks into the bed or bank for additional strength or if fixing to the bank top is not possible
- Particular care should be taken to firmly secure the large wood to the non-eroding bank at the upstream and downstream ends to prevent the river going around the protection.

If required, large trees can provide good protection in high energy situations. Trees must be properly secured in place to avoid risks to structures downstream should they break free. The SEPA (2020) Sustainable Riverbank Protection: Reducing Riverbank Erosion document states that installation of protection using large trees should:

- Select the right type and size of tree. Coniferous trees such as spruce, fir or pine are most appropriate, although any locally available trees can also be used. The diameter of the tree's crown should be roughly two-thirds the height of the eroding bank face and the tree should not occupy more than one-third of the wetted channel width. Any long lengths of trunk which do not have any branches should be cut off.
- Starting from the downstream end of the eroding section, place a tree tightly against the bank face with the trunk end facing upstream. The tree's downstream end should extend over, and be securely attached to, a short section of non-eroding bank to prevent flanking.
- The tree should be anchored both at its trunk and towards its tip using one of two to secure it to the channel bed and one of two below to secure it to the bank (See SEPA (2020) Sustainable Riverbank Protection: Reducing Riverbank Erosion document for more details)
- The second tree should then be drawn into position to overlap with the first tree over about 25% of its length, ensuring no gap exists between the two. The cable used for securing the trunk of the first tree to the bank can also be used to anchor the tip of the second tree to the trunk of the first. A new cable and anchor or stake should then be used for the trunk of the second tree. Repeat along the impacted reach
- The upstream end of the cover should extend over, and be securely attached to, a short stretch of non-eroding bank to prevent the river going around the protection.

General guidance:

- Best to install protection in the later part of winter (Feb – Mar) to reduce exposure of recently disturbed ground to high flows and to provide a full first year growing season to help the establishment of vegetation.

- The first two years of establishment and settling in are often the key to success.
- Important to inspect the works following high flows and make quick repairs when required. Replanting may be necessary (Brash and large pieces of wood are good for small repairs).
- Species of willow especially suited for these techniques include osier, white and crack willow. Species highlighted are fast growing and quick to establish.
- Goat willow is also suitable and will produce lower bushy growth, however it can be slower to establish.
- Bank toe protection may be required in some situations to allow time for bank roughness to develop. This protection should be rough wood/brash or small/medium sized stones similar to what is already on the channel bed and be submerged during normal flows.
- Methods will benefit from riparian planting of trees on the banks and bank top.
- Species such as alder, aspen, hazel and willow are all considered suitable.
- Trees such as alder and willow should be coppiced after about 2 years to establish bushy growth and occasionally thereafter unless you want larger trees.

Long-term solution

Based on CIRIA/NERC guidance and the flow velocities derived from the Infoworks ICM hydraulic model of Newcastleton, Rock Armour is considered the most appropriate solution for long-term low maintenance scour protection on the Liddel Water as part of a flood protection scheme.

Rock Armour is able to withstand the velocities associated with higher return periods however this form of scour protection is expensive and has a significant environmental impact. Care is needed during placement of the filter layer to ensure adequate lap lengths and that it is well secured at the edges. Rock armour has been sized at this stage using an in-house spreadsheet which uses the Escarameia & May 1992 method based on the predicted velocities of the watercourse. The design features a double layer of rock armour as advised by CIRIA C742. The design requires excavation into the riverbank so that the final geometry of the riverbank is maintained. As previously discussed, the 0.5% AEP (200 year) plus climate change event has been utilised during the design. As stated in table 1, the peak velocity closest to the right-hand bank is 3.73 m/s. A design peak velocity of 3.73 m/s, which offers a design option which will offer protection to the bank closer to the channel bed in order to reduce the risk of undercutting of the rock armour.

Table 4-5: Rock armour design rock – peak velocity of 3.73 m/s

Proposed Design Rock Weight (mm)		
Min	Dn50	Max
468	800	996

Table 4-6: Rock armour design rock– peak velocity of 3.73 m/s

Proposed Design Rock Weight (kg)		
Min	M50	Max
256	1280	2470

For the specification of the stone itself, a standard grading from EN 13383-1:2009 should be used. To ensure fines are not washed out from behind the Rock Armour it would traditionally be placed over granular 'filter layers', each about 150 mm thick. This will provide a gradual transition from fine material to coarser material, with each layer capping the previous layer. The advantage with this approach is it is a more reliable and proven technique, whereby failure is likely to occur slowly.

The potential issue with rock armour is that size of boulders discussed in Table 4-5 will be expensive and will be intrusive in the river. The requirement of at least 2 layers for rip-rock could result in the scheme dominating most of the channel. The details provided within this report is an outline design only and is based on the information available. To carry out full detailed design, the following information would be required:

- Soil grading curves of the bed and bank material.
- Depth to bed rock.

Full detail drawings and specifications may then be produced, showing the requirements for the Rock Armour, filter layer and construction.

5 SEPA'S WATER ENVIRONMENT (CONTROLLED ACTIVITIES) (SCOTLAND) REGULATIONS LICENCE

SEPA's The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) A Practical Guide (Version 8.4 October 2019) Section 6 states:

"CAR requires authorisation for the carrying out of building or engineering works, or works other than impounding works in:
• inland surface water (other than groundwater) or wetlands;
• the vicinity of inland water or wetlands and having, or likely to have, a significant adverse impact on the water environment. (For impounding works see section 5) Engineering works in coastal and transitional waters are not regulated by SEPA under CAR, but by Marine Scotland."

The length of the eroded right-hand bank of the Liddel Water is approximately 120m and the whole eroded section will require scour management in order to ensure erosion does not creep upstream or downstream of the proposed scour protection. Under the regulations the use of wooded material would require a CAR Registration, but grey bank protection i.e. *"Grey bank protection, floodwalls and embankments greater than 100m in total length in watercourses greater than 3m wide and lochs. Grey bank protection includes the use of materials such as Rock Armour over the full height of the bank, gabion baskets, concrete, grouted stone, brick or block stonework, sheet piling, wood piling and non-biodegradable geo-textiles"* on the scale required would require a complex licence.

Table 5-1: SEPA's The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) A Practical Guide (Version 8.4 October 2019) Bank reinforcement table.

Bank reinforcement, embankments, floodwalls and other bank modifications			
GBR	Registration	Simple licence	Complex licence
Green bank reinforcement or reprofiling ≤10m or ≤ one channel width in length (whichever is greater) [GBR8].	Green bank reinforcement or re-profiling ≤50m in length All other green bank reinforcement or reprofiling	All other green bank reinforcement or reprofiling	
	The placement of trees or parts of trees in a watercourse to protect eroding banks	Grey bank reinforcement, floodwalls and embankments ≤100m in length in rivers >3m wide and lochs	All other grey bank reinforcement, floodwalls and embankments in rivers >3m wide and lochs
		All grey bank reinforcement, floodwalls and embankments in rivers ≤3m wide	
		All set-back embankments and setback floodwalls	

5.1 Complex Licence requirement

Based on SEPA's charging scheme fees for 2020/2021, engineering subject to a complex licence is classified as Activity Application Band 11 with a charge of £3,333.

In order for licence submission:

- accurate scale drawings of design structures and proposed modifications are required.
- A method statement is required which details how each activity is to be carried out, any temporary construction works associated with controlled activities, and details of any machinery to be used.
- Completion of SEPA CAR licence Forms A (For all licence applicants) and Form E (For engineering activities).

SEPA's The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended) A Practical Guide (Version 8.4 October 2019) also strongly recommends a pre-application discussion is held with the local office before any application is submitted.

5.2 Proposed scope of works to support licencing

To complete this assessment, the following tasks are anticipated:

- Review options to protect bank including rock armour, geotextile solutions and Bio-technical solutions
- Provide typical details of proposed solutions (including detailed CAD drawing)
- Review of proposed works by Hydromorphologist to determine the impact of any proposed works on adjacent lengths of the bank beyond any protection
- Report detailing the final proposed solution, details how each activity is to be carried out, temporary construction works associated with controlled activities, and details of any machinery to be used during construction
- Completion of SEPA CAR licence Forms A (For all licence applicants) and Form E (For engineering activities).

5.3 Design Fees and Timescale

The estimated fee for undertaking the design work detailed above for the grey bank options would be in the region of £7,500 to £10,000 and the study would take around 4-6 weeks to complete from commission. After completion of the design and licence application it would take 30 days for a registration or up to 4 months for a complex licence.