

# Applecross Remedial Designs

## Design Method Statement



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**CBEC Project No.:** 2150651

**Client:** Bakkafröst

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**Version:** 2.0

## 1. INTRODUCTION

cbec eco-engineering UK Ltd was commissioned by Bakkafrost to develop detailed designs for remedial works to the Russel Burn, Kishorn. The aim of the project is to remediate the existing river engineering works to comply with conditions set out by SEPA in March 2024, under the Controlled Activities Regulations (CAR). The design is based on cbec's evaluation of hydraulic, geomorphic and ecological performance, whilst ensuring that there is no increased erosion or flood risk to the development on the river right (west) floodplain and the existing infrastructure that interacts with the channel and the immediate vicinity (i.e. pipe crossing, concrete bed protection, inspection chamber and bridges).

The design site is situated along the lower course of the Russel Burn, where the bedrock channel transitions to a naturally unconfined alluvial fan environment before discharging into Loch Kishorn. Prior to modification, this unconfined ~300 m long alluvial fan would have been dominated by sediment deposition and a dynamic channel that adjusted continuously. Engineering practices have since altered the character and function of the design site, including:

- the dam installed in Loch Coire nan Arr, controlling the flow through the Russel Burn and impacting sediment supply;
- and a history of channel straightening, embankment construction and bank/ bed reinforcements along the design site, responsible for channel instability due to the steepened gradient and erodible bank material.

Prior to the commencement of any physical works, an initial on-site start-up meeting is required to ensure that all parties involved agree with the proposed construction process.

### **Assumptions**

*As with any construction that involves working in the natural environment, complete and spatially continuous supporting data sets are not always available. It is therefore not uncommon for unexpected issues to arise once the construction phase has begun. Under such circumstances, it is required to make decisions at short notice as to how designs need to be modified to solve these issues. This process is known as 'field-fitting', with this term used throughout this document where necessary.*

*CBEC, as the designer, requires representation to supervise all phases of construction to oversee the appropriate execution of the designs and ensure that any 'field-fitting' can be undertaken appropriately when it is determined necessary.*

*Accurate hydrology data could not be obtained to represent the flow controlled by the dam at Loch Coire nan Arr. Therefore, hydrology was estimated using FEH analysis, using flows that do not account for the impact of the dam or any abstraction. This decision was taken as a conservative approach which aids the development of a stable design. However, the design was modelled under overestimated flows.*

## 2. DETAILED DESIGN

The final design components are summarised below.

- Realignment of 190 m of the Russel Burn toward the river left (east), constructed as a simple ‘plane bed’ channel morphology in the upstream section of the design reach.
- Construction of a ‘step-pool’ channel morphology along 56 m of the downstream section of the Russel Burn channel.
- Removal of the existing bed level control boulder ‘weir’ structure, to be incorporated into the step-pool design channel.
- Burial of critical effluent pipes and their concrete bed casing by raising the bed level locally by 300 mm.
- Removal of existing rock armour and concrete bank protection for the construction of the designed channel.
- Installation of a total of ~310 m of setback buried (two tier) rock roll pyramids and bank reprofiling, to mitigate the potential erosion risk to assets from channel adjustments. This design replaces sections of exiting bank protection along the following extents:
  - ~35 m of rock armour bank protection on the river right bank between NG 8210 4054 and NG 8212 4051. The existing bank protection will remain in place but will be buried under the designed floodplain.
  - ~60 m of concrete bank protection on the river right bank between NG 82157 40478 and NG 82197 40434. The existing bank protection will remain in place but will be buried under the designed floodplain.
  - ~15 m of rock armour bank protection on the river left bank between NG 82209 40434 and NG 82219 40426. The existing bank protection is to be removed.
- Replacement of a total of ~55 m of rock armour and concrete bank protection with a total of ~70 m rock roll pyramids, pre-vegetated coir rolls and bank reprofiling. Extents of existing bank protection to be replaced with this method are as follows:
  - ~15 m of concrete bank protection on the river right bank between NG 82190 40441 and NG 82200 40429. The existing bank protection will remain in place but will be buried under the designed floodplain.
  - ~35 m of rock armour bank protection on the river right bank between NG 82197 40434 and NG 82222 40410. ~10 m of the existing bank protection, between NG 82213 40417 and NG 82222 40410, will be removed for the installation of rock roll pyramids and pre-vegetated coir rolls. The remaining existing bank protection will remain in place but will be buried under the designed floodplain.
  - ~15 m of rock armour bank protection on the river left bank between NG 82219 40426 and NG 82228 40415. This bank protection will be removed for the construction of the designed channel.

- Construction of a total of ~30 m of rock armour bank protection (comprising three sections) with rock roll pyramids, rock mattresses and gripples and coir rolls, tying into the downstream bridge. Extents of existing bank protection to be replaced with this method are as follows:
  - ~15 m of rock armour bank protection on the river right bank between NG 82252 40369 and NG 82265 40361. The existing bank protection will be removed for the installation of the rock roll pyramid and rock mattress design.
  - ~10 m of rock armour bank protection on the river left bank between NG 82259 40373 and NG 82268 40370. The existing bank protection will be removed for the installation of the rock roll pyramid and rock mattress design.
- Removal of made ground from a total area of ~1049 m<sup>2</sup> to restore floodplain surface around the unnamed tributary.
- Daylighting of 51 m of the unnamed tributary and construction of a new sinuous channel between NG 82036 40514 to NG 82068 40473.
- Construction of a simple ‘plane bed’ morphology channel along 8 m length of the unnamed tributary between the culvert outfall and main stem Russel Burn (i.e. within the ‘step-pool’ mainstem channel design section).

*It is assumed that material excavated for the construction of the Russel Burn plane bed channel and the reprofiling of banks will be reused as part of the design on site, if appropriate.*

*Design details are site-specific and informed through desk- and field-based investigations and CBEC’s experience in the design of green bank protection and sustainable river management methods, with precise design details having been specified by the support of hydraulic modelling.*

*The constructed plane bed channel is designed to be stable, but accommodate minor channel adjustments over time within a discrete inset floodplain area. Buried erosion protection is set back from the channel to limit the extent of lateral channel adjustment and prevent erosion into existing assets.*

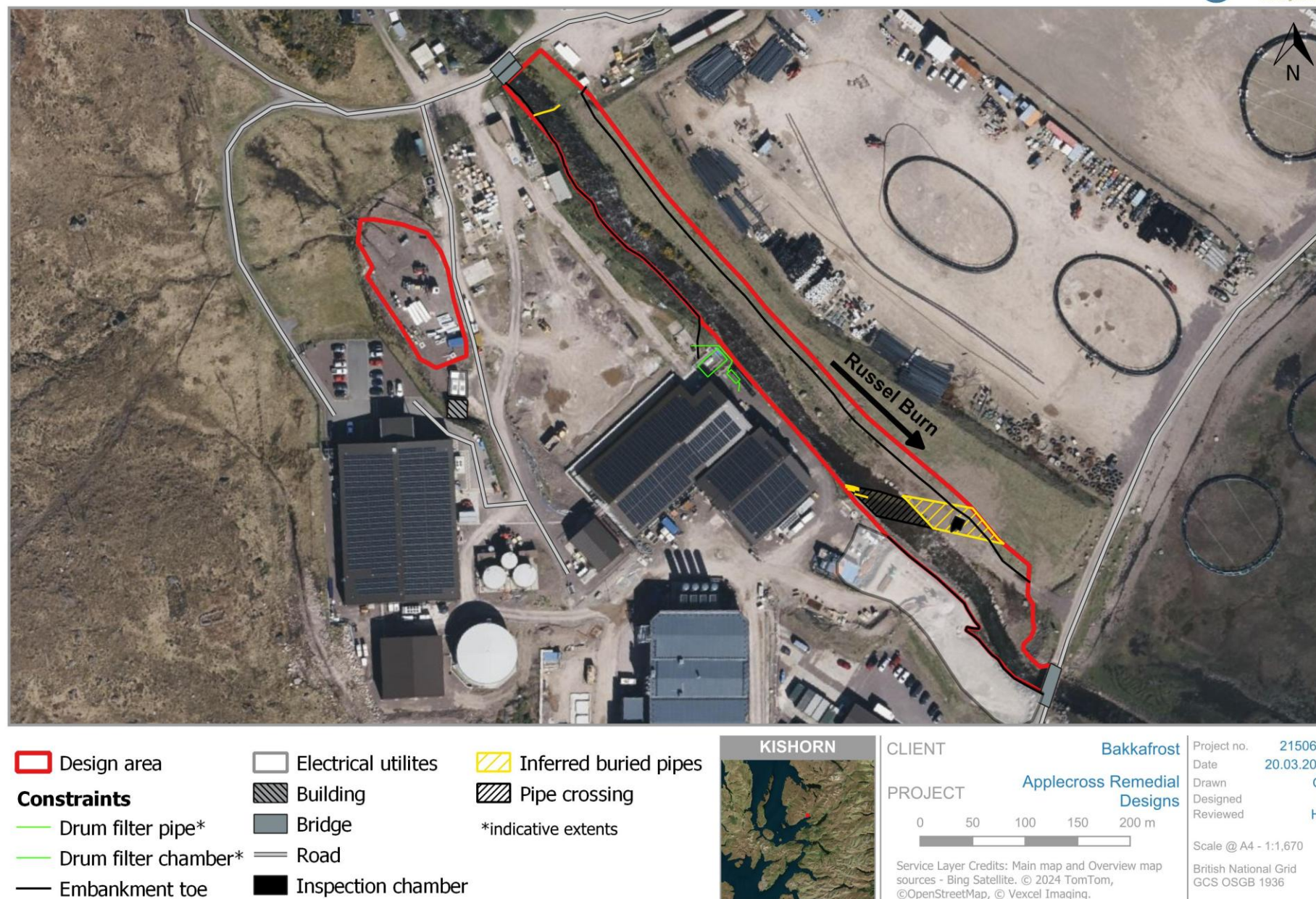
*An inevitable reality of implementing river restoration designs is the requisite stabilisation period following the initial completion of design works, which may be three to five years depending on the flow regime over this period. During the stabilisation period, the site is more susceptible to adjustment as a result of high flows and, therefore, monitoring of the design channel’s performance should be conducted following any such event. Monitoring will determine if remedial ‘adaptive management’ work is required to mitigate any issues should they arise.*

*There are three small drainage pipes discharging into the Russel Burn (located at NG 82124 40512, NG 82132 40505 and NG 82131 40505) and a pipe crossing comprising scaffolding crosses the channel at NG 82160 40482. Their temporary status was confirmed by the client and it is assumed that these structures will be removed prior to construction.*

### **Site Location**

Located in Kishorn, Scotland, the design site extends approximately 250 m along the Russel Burn from OS NGR NG 8210 4055 to NG 8227 4036, and approximately 60 m along an unnamed tributary of the Russel burn from NG 8204 4051 to NG 8227 4036. The site encompasses the lower course of the Russel

Burn where the channel exists a bedrock dominated section and transitions to an alluvial fan environment prior to discharging into Loch Kishorn (See Figure 1).



**Figure 1. Applecross Hatchery design site location map.**

### 3. METHOD STATEMENT OF DESIGN IMPLEMENTATION

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#### **Russel Burn (total length ~250 m) and unnamed tributary (total length ~60 m)**

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*Extents:* OS NGR NG 8210 4055 to NG 8227 4036 (Russel Burn) and NG 8204 4051 to NG 8227 4036

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#### ***Site access and preparation***

Site access and welfare location is to be discussed and agreed with the client and appointed contractor. The Principal Contractor's Site Manager should co-ordinate all deliveries of materials and plant, to be planned and timed under liaison with the client (i.e. the person responsible for project liaison and site supervision). Any specific times to avoid vehicular access should be adhered to.

#### ***Location of existing services***

Previous site visits and information provided by the client have identified a number of assets and services on the design site. Those identified and considered in this design are as follows:

- Applecross hatchery development on the river right floodplain, including embankments – hydraulic modelling determines an increase in flood as a result of the imposed requirements of the design;
- Existing and proposed bridges at upstream extent of the site, located at NG 8209 4057 and NG 82089 4057;
- Pipe crossing located on the river bed at NG 82099 40555 – not impacted by design;
- Three pipes draining to the river right bank of the channel, their outfalls located at NG 82124 40512, NG 82132 40505 and NG 82146 40493; to be removed prior to construction;
- Temporary scaffolding structure crossing for cables passing over the channel, located at NG 8216 4049 – to be removed prior to construction;
- Drum filter and drum filter pipe located on the river right bank at NG 8216 4047 – to be retained and not impacted by design;
- Effluent pipes (Nr 4) crossing, partially covered by concrete bed protection. Location centred on NG 82215 40423 – to be buried under designed channel bed surface;
- Concrete pipe inspection chamber on river left floodplain, located at NG 8224 4042 – to be retained and not impacted by the design. Additional erosion protection proposed around this structure;
- Bridge at the downstream extent of the site, located at NG 8227 4036; to be retained and not impacted by the design. Replacement of the existing bank protection at the upstream extent of the bridge is proposed.

The Principal Contractor is to determine the exact location, type and extent of services using cable avoidance tools for the works and to carry out all necessary protection works to ensure that service assets are not disturbed, with any isolation or alteration to services carried out by competent persons in liaison with the asset owner. This includes, but is not limited to, vibration and conditions surveys pertaining to Scottish Water assets.

### ***Riparian management***

No removal of trees is required for construction. After construction, native riparian trees should be planted throughout the floodplain along the Russel Burn design area (i.e. to provide natural stabilisation of the bank areas to resist erosive forces). Due to the high presence of deer in the area, Tree guards are proposed to be installed with each planted tree to protect from grazing.

### ***Ecological considerations***

It is important to note that no ecological surveys have been undertaken by CBEC as part of this design project. Therefore, it is recommended that a pre-construction ecological assessment is undertaken by the client to mitigate against any potential issues. Construction should be scheduled for when ecological sensitivity to disturbance is relatively low and there is a reduced risk of wet conditions impacting the works programme. Advice should be sought from the local Salmon Fishery Board as to whether fish rescue is required prior to the connection of the design channel to the existing channel.

### ***Invasive Non-Native Species (INNS)***

No INNS were identified during site visits. However, it is recommended that an INNS survey is undertaken prior to the commencement of any construction works. The Principal Contractor should provide a method statement that details the proposed methods for dealing with INNS on the site. However, as a minimum, the following mitigation measures are recommended to control the spread of any INNS found on site:

- Prior to construction the invasive species should be removed, treated and disposed of in line with biosecurity guidelines.
- During construction, if any additional invasive species are identified, they should be removed and disposed of in line with biosecurity guidelines before works continue.
- All earth-moving equipment should be cleaned before coming on site and washed down prior to leaving each site. This cleaning protocol is to prevent the spread of any invasive species that might be transported by the machinery.

Proactive monitoring and management of INNS is essential in the first 3 years following construction to ensure that native vegetation is able to colonise the riverbank and stabilise the substrate. Vulnerability to INNS is greatest in the growing season immediately following construction when recently disturbed surfaces are exposed and free of mature vegetation. This can be the spring following a late autumn build. Frequent monitoring and timely management of INNS on the design site post-construction will support the development of native vegetation that provides natural stability to riverbanks and resilience against the future risk of INNS.

### ***Temporary storage of excavated materials***

During construction, material will be excavated from the following components of the design:

- Excavation of river bank material for the construction of the realigned Russel Burn channel and inset floodplain.
- Excavation of hard core material for the construction of the realigned unnamed tributary and restored floodplain.
- Excavation of floodplain material (unknown composition) for the construction of the realigned unnamed tributary channel.

- Removal of rock armour bank protection throughout the Russel Burn design reach.

The excavated material will be stored in a 'live' stockpile within the floodplain (location to be agreed with the client and landowner(s) ahead of the works).

Excavated material will be reused on site where possible, if appropriate.

The Principle Contractor will be responsible for ensuring that appropriate silt management measures are implemented to avoid contamination to the watercourse with excess fine sediment.

### ***Flow diversion***

Flow diversions will be required throughout the construction phase to minimise risk of sediment release and improve machinery access for ease of construction. Ultimately, it will be the responsibility of the Principal Contractor to propose a specific method for flow diversion, accounting for construction-specific constraints, including Health and Safety considerations. However, options for flow diversion are likely to include (i) a temporary diversion channel, where constraints allow; (ii) over-pumping of the works area; and/or (iii) construction of a moving cofferdam that can be repositioned as construction proceeds. The proposed method of flow diversion must be agreed with the regulators, CBEC and other stakeholders ahead of work commencing.

### ***Silt management***

Silt management is undertaken to prevent eroded soil/ sediment entering the watercourse and becoming suspended sediment load. High inputs of fine sediment, mobilised during construction works for example, could cause pollution or further sedimentation in sensitive areas downstream.

A detailed silt management plan should be provided by the Principal Contractor. However, as a minimum, silt fences or mats should be laid out around any watercourses affected by the works (Figure 2). The placement should be determined based on channel bed profile and water depth. The fences/ mats should cover the entire circumference around the sites to avoid silt reaching waterbodies from any direction.

To slow the water flow and remove more of the suspended material, a silt wattle should be positioned on the downstream end of the silt mat. It is critical that there is some exposed mat beyond the wattle to take the abrasive impact of any water that may cascade over the silt wattle in high flow conditions.

Installation should start with a double row of mats, fences and wattles. Should the proposed interventions not be sufficient, more rows should be added, although it should be noted that very fine sediment particles such as clay will be extremely challenging to remove without the use of chemicals. However, no chemical flocculants should be used in the river without the consent of SEPA.

### ***Construction sequence***

The Principal Contractor's Construction Method Statement should include a detailed proposal for the sequence of works. Specifically, the step-pool section of the Russel Burn should be constructed prior to the plane bed section so that the bed level control structure (incorporated into step crest no. 1) is in place before the plane bed channel is constructed (i.e. since the downstream limit of the plane bed section will tie into this base level/ hydraulic control). Similarly, the construction of steps no. 8 and no. 9 should be completed prior to the construction of the tributary confluence that joins from the river right. This is because step crest no. 9 acts as a bed/ base level control for the tributary channel. Overall,

it is recommended that construction be progressed broadly from downstream to upstream to ensure the necessary bend level controls are in place in and to minimise the tracking of machinery along the river corridor.

It is recommended that a suitably qualified geomorphologist/ restoration specialist who is familiar with the design should be on site at key stages of the construction process to ensure that implementation is conducted as intended. This will enable field-fitting of the design, as required, to maximise design stability and post-construction function.



**Figure 2. Examples of silt fence (A), silt mat (B) and silt wattle (C). Photo courtesy of Hy-Tex (UK) Limited and Salix Ltd.**

### ***Construction of step-pool channel***

- All existing rock armour bank protection is to be completely removed from the bank toe and bank surface. These boulders can be reused in the construction of the step pool channel if

rounded and of the appropriate size. Alternately, they can be buried beneath the surface of the designed floodplain, where rock roll pyramids separate the buried rocks from the channel to avoid them becoming exposed if the channel adjusts. Where raised embankments form the banks of the channel, the bank slope is to be smoothed to an even surface, reflective of the existing slope. Where there are no raised embankments, banks are to be reprofiled to a gradient of 1V:2H.

- The design prescribes a series of 12 steps with pool features in between. The height of the steps shall be 300 mm (step nos. 1 - 9) or 150 mm (step nos. 10 - 12) and their spacing 5 m (step nos. 1 - 11) or 6 m (step no. 12). Further details and specifications are provided in detailed design drawings no. 02 and 09.
- The step-pool structure will incorporate larger 'anchor' boulders located at the ends of each step, anchored into the adjacent river banks. The anchor boulders will be the largest clast size in the channel at the outer margins of the step and also form part of the bank toe protection (typically 500 mm in diameter). The boulder sizes for the bank toe protection are specified as 300 to 500 mm. Boulders won from the removal of existing bank protection can be used for this purpose if they are rounded and of the appropriate size.
- The keystones within the steps should be implanted to at least 1/3 of their diameter into the channel bed. Given a step height of 300 mm, the keystone boulders will therefore need to have a minimum diameter of 500 mm. Specifications are also shown on the design drawings.
- The axis of the step perpendicular to the flow direction will be concave upstream, thereby focusing the flow of water into the centre of the downstream pool. This process is accentuated by the central third of the step being slightly lower in elevation than the margins. The position of these lowered sections are slightly off set from one another in the following sequence: slightly left of centre, centre, slightly right of centre, centre, slightly left of centre etc. This process will be guided through field-fitting.
- Any rock required for construction should be imported from a local quarry. The rock type should be granite and/or a hard metamorphic rock type such (e.g. schist, gneiss).
- Due to the complexity of construction and to ensure long-term stability, an appropriately qualified geomorphologist/ restoration specialist who has experience in the design and implementation of step-pool channels must be present during key phases of the construction process.
- Between the step structures (i.e. the pools), the bed material is to comprise a mix of cobble (64 to 256 mm) and coarse gravel (2 to 64 mm) sized sediments to produce a general grade of D50 ~120 mm. The precise mix of sediment is to be determined based on the size classes available from the supplying quarry, therefore the ratio of the sediment mix will be confirmed by the designers once a quarry has been selected. This material should be rounded, of fluvial or glacio-fluvial origin.
- The remaining bank surfaces, smoothed and/or reprofiled after the removal of bank protection, should be seeded with an appropriate native seed mix to establish vegetation cover. A native seed mix comprising approximately 80% grasses and 20% coastal species is recommended for this site.

### ***Channel realignment and construction of a plane bed channel and inset floodplain***

- Construction of the design channel is to be undertaken offline, to avoid high levels of silt in suspension and sediment pollution.
- Approximately 190 m of the Russel Burn is to be realigned within the existing river corridor, from OS NGR NG 82102 40553 to NG 82225 40413, resulting in a plane bed channel with slightly increased sinuosity compared to current conditions over these extents. The lateral extents of realignment (i.e. degree of sinuosity) are constrained by the presence of embankments on river left (east) and the hatchery development on the river right (west) floodplain, while the longitudinal extents are imposed by infrastructure (e.g. bridge, pipe crossings, inspection chamber, existing bed level control).
- The new channel will have a slope of approximately 1.3% over this realigned section. Long section details and extents are provided on Design Drawing no. 02.
- The general channel cross-sectional geometry should be as follows: bank toe to bank toe width of 8 m; bank slopes of 1H:2V. Though slight variability is incorporated into the design to reflect natural conditions, the channel width increases by up to 10% around meander bends and decreases by up to 10% through straight sections (refer to Design Drawing nos. 03-04).
- The excavated sediment from the channel realignment could be redistributed within the river corridor to construct the inset floodplain on the river right bank. The infill material should grade into the existing topography at the site, ensuring no abrupt transitions. Cross section details and extents of the inset floodplain are provided in design drawing no. 02-04.
- Excavation throughout the design channel should be a minimum of 300 mm below the final design surface elevations, to allow for the addition of appropriately sized substrate throughout. The surface layer should have a median grain size (i.e. D50) of 130 mm, comprising of a grade of 2 mm – 250 mm rounded material, of fluvial or glacio-fluvial origin. The precise mix of sediment is to be determined based on the size classes available from the supplying quarry; the details of the sediment mix will therefore be confirmed by the designers once a quarry has been selected.
- Throughout excavation of the design channel and inset floodplain, all existing bank protection should be removed from the river left and right banks and floodplain surface.
- Exposed inset floodplain and bank surfaces should be seeded to enhance the establishment of the area. This should be carried out as per suppliers guidelines.
- Construction works take place between nearby embankments on both sides of the channel. All existing bank protection, where the new channel alignment dictates that it will interact directly with flows, should be removed and replaced with rock roll pyramid bank protection as per the design (see below). Otherwise, existing bank protection is to be retained and buried within the designed inset floodplain.

### ***Installation of rock roll pyramid and pre-vegetated coir roll as erosion protection for the active riverbank***

- Installation of the rock roll pyramid should be undertaken offline as far as possible, or under low flow conditions, to minimise the risk of sediment release downstream and provide suitable working conditions.
- The rock roll pyramid will extend along three (Nr 3) sections of bank along the Russel Burn; (1) a total of 35 m along the river right bank between NG 82200 40437 and NG 82222 40410, (2)

- a total of 14 m along the river left bank between NG 82219 40425 and NG 82228 40415, and (3) a total of 22 m along the river right bank between NG 82128 40514 and NG 82141 40500.
- The design comprises rock rolls (each 300 mm diameter and 2 m length) installed within the toe of the bank. The rolls will be used to construct a three-tier pyramid consisting of six (Nr 6) rock rolls (i.e. three in the lower tier, two in the middle tier and one on the top tier).
  - A trench approximately 400 mm deep below bed level should be dug at the toe of the bank, to allow the bottom two tiers of the pyramid to be installed below adjacent channel bed level; the lower tier being completely buried and the middle tier installed at the bank toe and partially buried and the upper tier slightly below the water level (under normal flows). Where the design intersects the concrete pipe casing, the lower tier of rock rolls should be laid directly on top of the concrete, secured by tying the rock rolls together (see below).
  - Chestnut stakes (~100 mm diameter, 1.2-1.4 m length) should be driven into the channel bed at 400 mm centres along the front edge (i.e. river side) of the bottom tier of the rock roll to hold the structure in place. The posts should be driven into the bed such their tops are at the elevation of the centre of the middle rock-roll tier (cutting them off at this elevation if they cannot be driven into the channel bed sufficiently. Except, along the section of the concrete pipe casing and the effluent pipe crossing. Each roll should be secured to the next (upstream, downstream and vertically) using 3 mm fixing twine, or as per the supplier's installation guidance.
  - At the upstream and downstream limits of the design, the final section of rock roll will be buried completely into the bank, to tie into a more stable sections of adjacent bank or the setback buried rock roll pyramid (as shown in the accompanying design drawing plan view; see Installation of setback rock roll pyramid, below).
  - A single row of pre-vegetated coir roll shall be installed immediately behind the top tier of rock roll to provide additional stability and improve the rate of vegetation re-establishment along the bank. The roll should be buried into the bank with only the top (i.e. vegetated) section of the coir roll exposed. Installed to this level, the lower half to two thirds of the coir roll should be buried below the elevation of the surface of the top tier rock-roll.
  - As with the rock roll, at the upstream and downstream limits of the design, the final section of pre-vegetated coir roll will be buried completely into the bank, to tie into a more stable section of adjacent bank.

***Installation of setback buried rock roll pyramid to mitigate future channel adjustments beyond the designed river corridor area (i.e. providing protection to embankments and floodplain developments)***

- Installation of the rock roll pyramid should be undertaken offline (i.e. away from flowing water) as far as possible, or under low flow conditions, to minimise the risk of sediment release downstream when installing buried structures close to the channel banks.
- The buried rock roll pyramid will extend along the edge of the floodplain (following the embankment toes) on both sides of the Russel Burn; (1) a total of 42 m along the river right bank between NG 82100 40547 and NG 82126 40515, (2) a total of 88 m along the river right bank between NG 82142 40498 and NG 82197 40434, and (3) a total of 181 m along the river left bank between NG 82105 40563 and NG 82219 40424. See design drawing no. 08 for precise extents.

- The design comprises rock rolls (each 300 mm diameter and 2 m length) installed within the floodplain, buried to the elevation of the designed channel thalweg. The rolls will be used to construct a two-tier pyramid consisting of 3 no. rock rolls (i.e. 2 in the lower tier and 1 on the top tier).
- A trench should be dug to the levels indicated in design drawing no. 08 to allow the base of the lower tier to be installed 400 mm below the deepest level of the adjacent channel (note adjustment made where design intersects the buried effluent pipe). The trench should be at least 600 mm in width for the installation of the lower tier (2 x rock rolls laid side by side).
- Each roll should be secured to the next (upstream, downstream and vertically) using 3 mm fixing twine, or as per the supplier's installation guidance.
- The set back buried rock roll pyramid transitions to rock roll pyramid bank protection at NG 82126 40515 and at the downstream extents on the river left and right banks (see Installation of rock roll pyramid and pre-vegetated coir roll bank protection above). The rock roll pyramid is continuous, transitioning from within the floodplain to the bank toe and back into the floodplain.
- The trench is then to be infilled, burying the rock roll pyramid and the surface graded into the surrounding floodplain surface as per the design.
- Although the buried rock roll pyramids are located close to infrastructure (embankments, inspection chamber, and buried effluent pipe), they are designed to not impact these structures. However, the structures should be avoided by heavy machinery during construction.

### ***Construction of bund***

- The bund is to be constructed to a height of ~1 m above the adjacent floodplain level and will extend along the river right bank for a total length of 93 m between NG 82150 40479 and NG 82213 40411. See design drawing no. 11 for precise design details and extents.
- The bund is 500 mm wide at the crest, with the flanks sloping to ground level at a gradient of approximately 1V:1H. The width at the base is dependent on the surrounding topography.
- The bund is constructed in layers and compacted after each layer is applied for stability.
- The bund is formed of coarse sediment with a fine grained matrix. Accordingly, a sediment mix ranging from approximately 1 mm to 150 mm should be used. The precise mix of sediment is to be determined based on the size classes available from the supplying quarry, therefore the ratio of the sediment mix will be confirmed by the designers once a quarry has been selected.
- Coir matting is to be installed over the surface of the bund. A native seed mix should be applied to the surface of the bund before laying the coir matting, a native seed mix comprising approximately 80% grasses and 20% coastal species is recommended for this site. The matting will be secured in a will be secured along the toe of the bund on each side in a 200 – 300 mm deep anchor trench, which should then be back-filled with soil to the ground level. The matting will be staked along its length with wooden T-pegs, in a gridded form at a density of 4/m<sup>2</sup>.

***Replacement of bank protection at downstream bridge (rock roll pyramid, rock mattress and gripples, coir roll and seeding)***

- Installation of the rock roll pyramid, rock mattress and Gripple ground anchors should be undertaken offline as far as is feasible, or under low flow conditions, to minimise the risk of sediment release downstream and provide suitable working conditions.
- The bank protection structure will extend along both sides of the bank along the Russel Burn directly upstream of the bridge at the downstream extent off the site; (1) a total of 14 m along the river right bank between NG 82252 40369 and NG 82264 40360, (2) a total of 10 m along the river left bank between NG 82259 40373 and NG 82268 40370. A third section of bank protection will extend (3) a total of 6 m perpendicular to the channel along the toe of the road embankment between NG 82262 40378 and NG 82262 40372.
- The existing rock armour bank protection should be completely removed from the bank toe and bank surface.
- The design comprises rock rolls (each 300 mm diameter and 2 m length) installed within the toe of the bank, rock mattresses (3 rock rolls attached side by side (1 m width, 2 m length, 300 mm thickness)) installed into the bank surface. The rock rolls will be used to construct a three-tier pyramid consisting of 6 no. rock rolls (i.e. 3 in the lower tier, 2 in the middle tier and 1 on the top tier). See design drawing no. 08 for details.
- A trench approximately 400 mm deep below the adjacent channel bed level should be dug at the toe of the bank, to allow the bottom two tiers of the pyramid to be installed. The lower tier being completely buried below the bed, the middle tier installed at the bank toe and the upper tier slightly below the water level (under normal flows).
- Chestnut stakes (~100 mm diameter, 1.2-1.4 m length) should be placed at 400 mm centres along the front edge (i.e. river side) of the bottom tier of the rock roll to secure. Each roll should be secured to the next at its upstream and downstream extents using 3 mm fixing twine, or as per the supplier's installation guidance.
- The rock mattress will be installed into the bank surface directly above the rock roll pyramid. The bank surface should be prepared by infilling voids left after the removal of the rock armour and levelling the surface so that, when installed, the rock mattress should sit flush with the surrounding bank surface.
- Gripple Terra-Lock™ ground anchors (Type: TL406-TLA3-4MM-2M-Z) should be installed across the surface of the rock roll pyramid and rock mattress to secure the structure to the bank surface. Anchors should be spaced 1 anchor per 0.9m<sup>2</sup> in a grid pattern (2 anchors per mattress). Anchors should be installed as per the suppliers guidelines.
- The remaining bank profile should be smoothed to an even surface, retaining the existing slope of 1V:1.65H.
- At the upstream limits of the design, the height of the rock mattress should be reduced, tapering into the step-pool channel section over a length of 4 m by constructing the mattress from fewer rock rolls: 2 rock rolls for 2 m length, then 1 rock roll for 2 m length. The final section of rock roll and rock mattress will be buried completely into the bank, to tie into the more stable bank of the step-pool channel (as shown in the accompanying design drawing plan view). The rock mattress tapering sections continue further upstream than the rock roll pyramid along the bank toe; these sections will tie into the rock comprising the lower banks of the step-pool channel.

- At the downstream limits of the design, the rock rolls will be installed flush to the bridge abutments along the bank toe, slightly set back to reduce risk of scour behind the bank protection. The rock mattress and coir roll will butt up against the bridge abutment, following the bank profile.
- A single row of coir roll will be installed immediately behind the top of the rock mattress to provide additional stability and improve the rate of vegetation re-establishment along the bank. The roll should be buried into the bank with only the top section of the coir roll exposed.
- As with the rock roll, at the upstream limits of the design, the final section of coir roll will be buried completely into the bank, to tie into a more stable section of adjacent bank.
- The remaining section of bank between the bank top and the coir roll, and ~2 m of the adjacent floodplain should be seeded to establish vegetation cover. A native seed mix comprising approximately 80% grasses and 20% coastal species is recommended for this site.

### ***Daylighting of culvert and construction of new channel***

- Construction of the design channel is to be undertaken offline, to avoid high levels of silt in suspension and sediment pollution.
- Approximately 51 m of the unnamed tributary is to be removed from its culvert and realigned within the restored floodplain area, from NG 82036 40514 to NG 82068 40473, providing a plane bed channel with increased sinuosity over these extents. The lateral extents of realignment are constrained by the presence of a road to the river left floodplain and steep slope on the river right floodplain, while the longitudinal extents are constrained by infrastructure (e.g. roads and buildings).
- The new channel will have a slope of approximately 2.9% over this realigned section. The detailed long profile of the design channel is to be determined by designers involving a component of field fitting after the surface made ground has been removed.
- The channel cross-sectional geometry should be as follows: bank toe to bank toe width of 400 mm; bank slopes of 1H:0.5V for the lower bank and then 1H:2.5V for the upper bank.
- The surface of the design area should initially be excavated to remove the surface layer of hard core to expose the natural ground level throughout, then the channel excavated.
- To achieve the new channel alignment and floodplain surface, approximately 250 m<sup>3</sup> of sediment will be excavated. There is a degree of uncertainty associated with the estimated volume of excavated material because the thickness of the surface layer of hard core is unknown across the design area. At least some of the excavated material can be repurposed on site to construct the bund. The composition of the material underneath the made ground is unknown therefore it is not certain that this material is appropriate for re-use within the design.
- Margins of the design area are to grade smoothly into the surrounding topography.
- If the restored floodplain substrate is not of the appropriate size, excavation throughout the design channel should be 150-200 mm below the final design surface elevations, to allow for the addition of substrate throughout. The surface layer should be appropriately sized with a mix of 2 - 200 mm rounded material, of fluvial or glacio-fluvial origin (i.e. with an estimated D50 of 100 mm). The precise mix of sediment is to be determined based on the size classes available from the supplying quarry, therefore the ratio of the sediment mix will be confirmed by the designers once a quarry has been selected.

- The invert of the new culvert intake will be 100 mm below the bed of the design channel. An additional 2 metres of the pipe should be exposed to construct the intake wing walls. One rock roll is to be installed directly underneath the culvert intake perpendicular to the pipe and one rock roll on either side of the pipe is to be installed parallel to the pipe for support. Three additional rock rolls are installed into the channel bed, perpendicular to the direction of flow, directly upstream of the intake, to the level of the channel bed. The area of exposed pipe is then backfilled to bury the supporting rock rolls and the intake is incorporated into the surrounding slope by cutting a tapered edge of the pipe.
- Excavation throughout the design floodplain and channel banks should be 150-200 mm below the final design surface elevations, to allow for the addition turfs. Turfs are to be harvested from the local area to establish vegetation on the new floodplains surface. Turfs are to be harvested to a thickness of ~200 mm and installed onto the floodplain and bank surface. Any gaps between turfs should be seeded with a native seed mix that reflects the nearby vegetation assemblage.
- Construction works should avoid the nearby road to the river left and a small building close to the downstream extent of the site. The retaining wall along the edge of the river left floodplain will not be impacted by the design, with the restored floodplain surface lower than the elevation of the ground surface against this wall.

### ***Riparian planting***

- Native riparian trees should be planted throughout the floodplain at the Russel Burn design area. Tree guards should installed with each planted tree to protect from grazing.