Balgonie Estates

NEWTON DON HYDROPOWER SCHEME

Technical & Environmental Report

[redacted]

DerwentHYDRO
40 Holloway Rd
Duffield
Derbyshire DE56 4FE

March 2024
Project Ref: 24493

NEWTON DON HYDROPOWER SCHEME

Technical & Environmental Report

CONTENTS

ANNEXES

ANNEX A	**Site Pictures**
ANNEX B	**Scheme Drawings**
ANNEX C	**River Flow Calibration by Matched Pairs Analysis (2010)**
ANNEX D	**SEPA Screening Checklist**

NEWTON DON HYDROPOWER SCHEME

Technical & Environmental Report

SCHEME SUMMARY

Watercourse	Eden Water		Turbine type	Crossflow	
Location	Stichill Linn		Gross Head	11.1	m
Town/Village	Newton Don TD5 7SY		Design Head	9.5	m
Grid Ref. Intake	NT 70620 37535		Design Flow	800	litres/sec
Grid Ref. Turbine	NT 70655 37565		Peak output	50	kW
Grid Ref. Outfall	NT 70650 37580		Annual Energy	225,000	kWh/year

1. INTRODUCTION

This report presents the technical details and environmental appraisal of a proposed mini-hydro installation on Eden Water at Newton Don (near Kelso in the Scottish Borders) in support of the SEPA CAR license application for the scheme. The project is a private development by Balgonie Estates who own the site.

The 50kW scheme is predicted to generate around 225,000 kWh per year, equivalent to the electrical consumption of roughly 70 average households, displacing over 100 tonnes of CO_2 per year from UK gas-fired power stations.

Background

The site has previously exploited power from successive water turbines, both for electricity generation and for pumping water up to the Newton Don Estate. The first scheme was constructed in 1905 and the most recent turbine dated from 1935. Substantial infrastructure is still in place which can be re-purposed, including the original forebay tank and powerhouse building. The driving head for the scheme is provided by Stichill Linn waterfall, a dramatic drop in bedrock of nearly 10m.

The Newton Don estate consists of a pair of large domestic properties, with office space, boiler room and various out-houses, which together will absorb a significant proportion of the power to be generated.

As described below, the potential scheme would involve installing a new off-take and coarse screen on the bank of Eden Water immediately upstream of Stichill Linn. A low boulder weir would be constructed just upstream of the Falls to raise the local water level by 300mm and divert flow into the new intake. A control gate will then regulate the flow proceeding towards a 10mm overwash screen delivering ‘clean’ flow into the existing forebay tank. A short pipe-run will drop the flow down to the original powerhouse in order to drive a new crossflow turbine & generator, discharging back into the river 30m downstream of Stichill Linn.

By using the existing infrastructure, the scheme will be largely invisible (vs the status quo) and the construction impacts minimised.

Figure 1 : Site Location

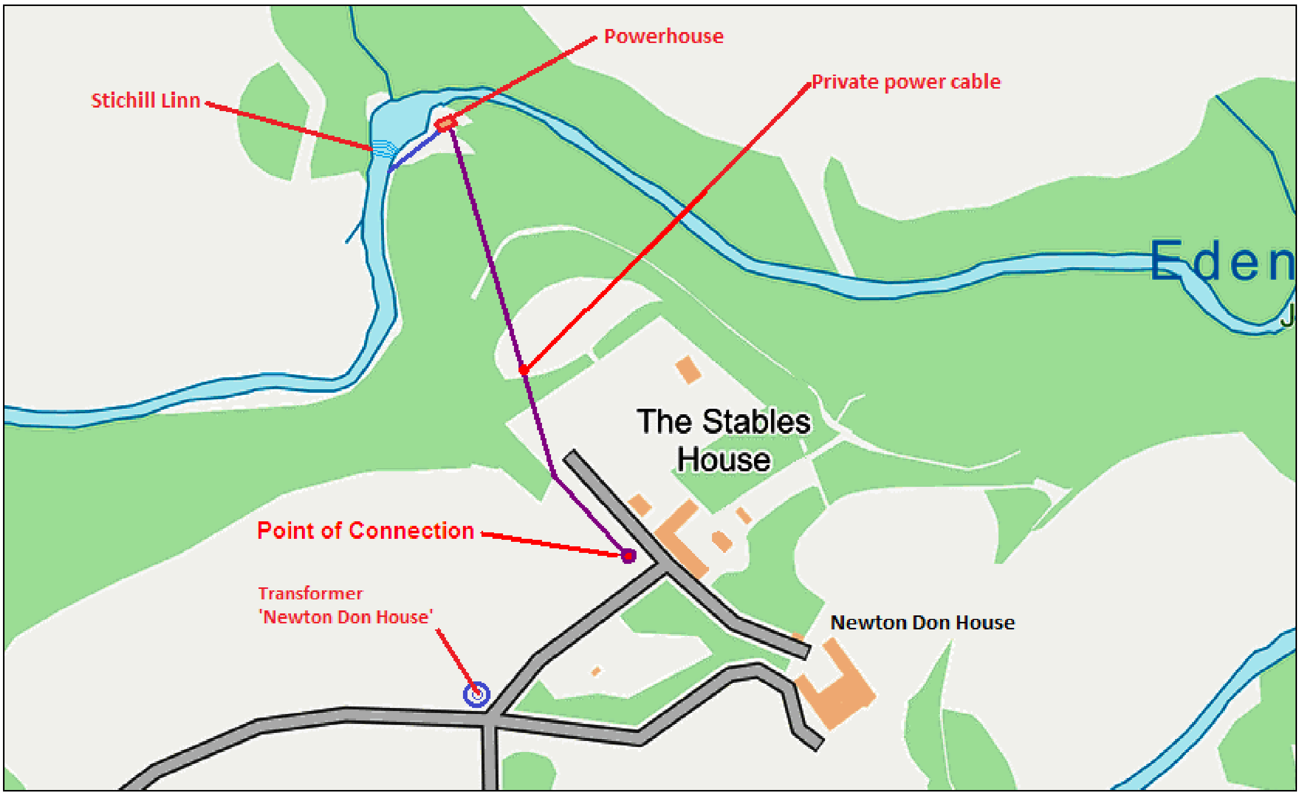
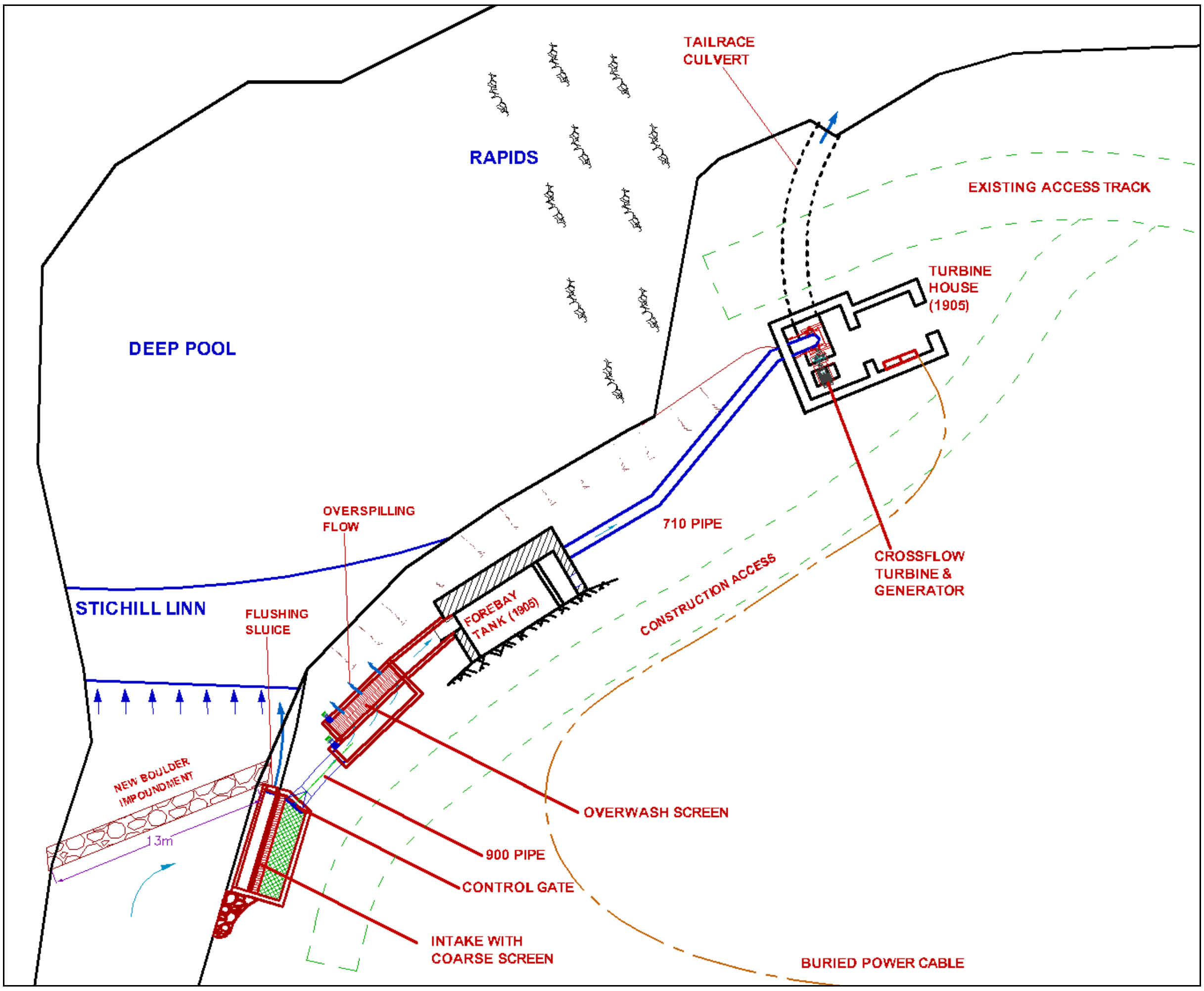


Figure 2 : Site Layout



2. SITE OVERVIEW

The site location is marked on Figure 1 and the layout of the hydro scheme, showing the remaining infrastructure and highlighting the key features of the new scheme, is summarised in Figure 2.

Site photographs are provided in Annex A and detailed layout drawings in Annex B.

2.1 General observations

The civil works from the previous hydropower installations are largely still in place. This involved:

- a small, intake upstream of the waterfall with a bar screen of approx. 1-inch aperture;
- a buried rectangular culvert running 16m at shallow gradient to a large forebay tank containing fine-meshed screens;
- a steel pipeline (~600mm diameter) running 20m downhill to the powerhouse;
- a tall powerhouse building, containing the remains of a small Boving Francis turbine and generator (approx. 10kW) dating from 1935 (having replaced the much larger 1905 turbine);
- a buried tailrace channel running from a deep sump below the turbine back into Eden Water.

2.2 Land Ownership

All the relevant land is owned by Balgonie Estates. The ownership boundary follows the centre-line of the river.

2.3 Flood Levels

A mark on the powerhouse wall indicates a maximum flood level of 1.3m above the sill of the entrance doorway (a rise of 2.75m in the adjacent river), during the extreme 'great Borders flood' of 1948.

There are no signs of any recent floods breaching the banks of the river, either upstream or downstream.

2.4 Grid connection

The properties at Newton Don are supplied from a 50kVA pole-mounted transformer. SPEN have confirmed that they would be willing to accept a new turbine with a 50kW generator feeding into this connection.

2.5 Site Access

There is good vehicle access to the old powerhouse along existing tracks (Figure 17). Access to the intake location and forebay tank is more difficult, due to the steep topography, but these are close to the powerhouse so some limited re-landscaping will enable tracked machinery to reach these locations, as indicated on Figure 2.

2.6 Environmental & Heritage Designations

The River Eden up to Stichill Linn is part of the River Tweed Special Area of Conservation (SAC). The cited species of interest are salmon, otter, and lamprey as well as notable aquatic plants. Salmon cannot ascend Stichill Linn.

A number of sites around Newton Don are cited as heritage assets, but the turbine house is not included and none of the listed sites are within range of the river.

2.7 Water Framework Directive (WFD)

- All significant UK watercourses have been classified in terms of their ecological status. The Water Framework Directive (WFD) requires improvements to be made to ensure that minimum standards are achieved on all watercourses. Every new hydropower scheme has to demonstrate that it will not prevent progress towards a status of 'good'.

- The waterbody 'Eden Water – Hume Burn confluence to River Tweed' is classified as a 'heavily modified watercourse' having 'moderate' ecological status overall. It's main failing is stated as "morphology".

3. SEPA GUIDANCE

SEPA Guidance advises that "*a scheme powered by water that is abstracted from immediately above a drop (e.g. a waterfall, cascade or weir) and returned immediately below that drop*" is provisionally acceptable as long as:

- the rivers and streams upstream of the intake do not contain any important areas of good fish habitat,
- the tailrace is located above, or immediately downstream of, a natural barrier to the upstream movement of fish species.

In this case, by using the existing tailrace from the original 1905 powerhouse, the return to the river will be ~30m downstream of the base of the Falls. This short reach (depicted in Figure 13) consists of a slow-moving, deep pool at the base of the falls followed by a short set of rapids. Neither of these features is suitable for spawning, and hen salmon have never been observed congregating here for spawning.

Whilst it would be possible in principle to re-route the tailrace upstream to discharge closer to the Falls, this would serve no ecological purpose, whilst reducing the head for the turbine and disturbing a previously untouched section of riverbank.

4. HEAD & FLOW

4.1 Head

The gross head can be inferred from the October 2010 topographic survey of the site, undertaken in low-moderate flow conditions. Relative to a local datum, the upstream water level at the old intake was recorded as 10.22m and the tailwater at the turbine outfall was –0.57m. Allowing for a 0.3m raise in upstream river level (as proposed in Section 5.2) would enable a gross head across the site of 11.1m.

Accounting for losses in the intake, screening tank, pipework, and tailrace, a design head of 9.5m has been calculated.

4.2 Flow

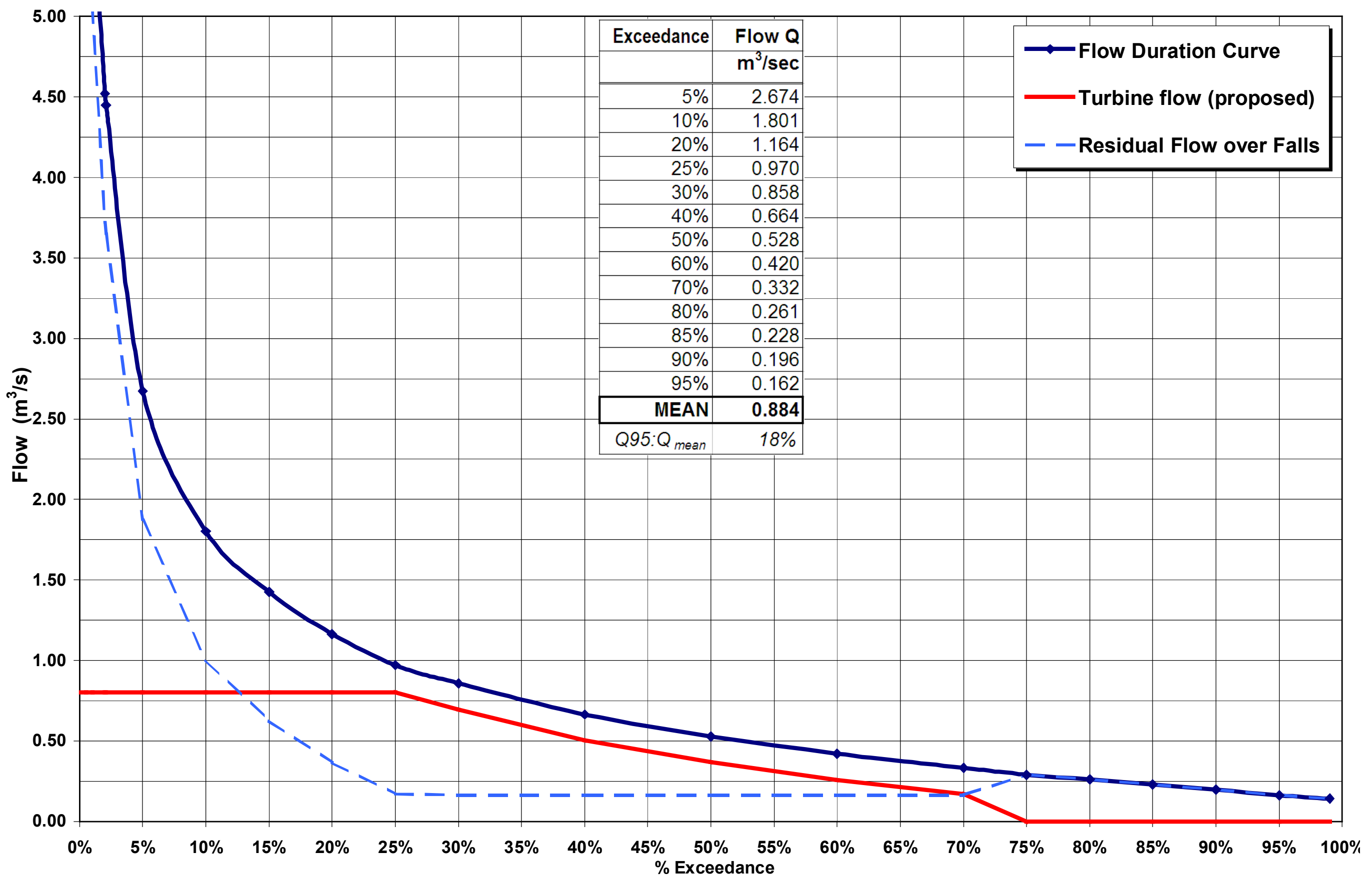
The flow in Eden Water is not gauged by SEPA. The LowFlows hydraulic model from the Institute of Hydrology was run for this 95km^2 catchment area to provide an estimated Flow Duration Curve. This predicted an annual mean flow of Q_{mean} = 0.884m^3/sec.

This prediction was validated in 2010 by taking a set of spot flow measurements at a site 1km downstream of Newton Don and correlating these with an 'analogue site' on Leader Water at Earlston (gauge ref. 21015) using a standard 'matched pairs' analysis[1] (full report appended separately). This analysis confirmed that the LowFlows model could be considered reliable.

The Flow Duration Curve generated by LowFlows is shown in Figure 3, together with the proposed abstraction regime and the resulting prescribed flow to be left over the Falls.

[1] Balgonie Hydro – Flow Gauging Report, MNV Consulting, January 2011

Figure 3 : Flow Duration Curve – Eden Water at Newton Don (LowFlows)



Exceedance	Flow Q m³/sec
5%	2.674
10%	1.801
20%	1.164
25%	0.970
30%	0.858
40%	0.664
50%	0.528
60%	0.420
70%	0.332
80%	0.261
85%	0.228
90%	0.196
95%	0.162
MEAN	**0.884**
Q95:Q mean	*18%*

4.3 Base Flow

The ratio of Q95:Qmean at 18% indicates a moderate baseflow river.

4.4 Design Flow and Prescribed Flow

4.4.1 Design Flow

A turbine design flow of 800 litres/sec (or 90% of Q_{mean}) is proposed, in order to achieve a 50kW scheme as permitted by SPEN. The turbine would then be saturated at a river flow of Q25.

4.4.2 Prescribed Flow and Flow Variability

Some flow (the 'prescribed flow') would need to be left over Stichill Linn to maintain its visual appearance and the ecology of the pool below. Since there is a negligible deprived reach, and bearing in mind that Q95 is a relatively high proportion (18%) of Q_{mean} , it is proposed to reserve the Q95 value of 162 litres/sec as the fixed 'Hands-off Flow".

Start-up Flow

It is important to note that before the scheme can start to abstract, there needs to be a quantity of water in the river significantly greater than the hands-off flow. This is because:

(a) A crossflow turbine generally only achieves a worthwhile efficiency when it can pass at least 15% of its design flow. It will not pass any flow until at least this flow is available over and above the residual flow.

(b) However, the turbine control system needs to add an additional margin to be sure that the turbine will not shutdown as soon as it starts up, and then 'hunt' around the start-up condition, switching on and off. Hence the start-up flow will typically be 20% of the design flow, or 160 litres/sec in this case.

Therefore, in practice, the flow required in Eden Water before the hydro-scheme will commence abstraction will be the Hands-off Flow plus 20% of the Design Flow i.e. >322 litres/sec, or roughly Q70. It is likely this condition will only rarely be met during the dry summer months, and other extended dry periods, and at these times the river will experience its natural low-flow variability.

Physical provision of prescribed flow

The prescribed flow will pass over the new boulder weir proposed at the top of the Falls (see Section 5.2). Post-installation, the new turbine can be used as an accurate flow-measuring device. Therefore the boulder weir can be calibrated by the turbine to identify the water level at which 162 litres/sec is being discharged over the weir (equating to a reduction in turbine output of 11kW).

The advantage of this method, over the provision of a rectangular notch, is that the flow would be evenly distributed across the weir crest (average depth 35mm), and then over the Falls, for better amenity value. It also eliminates the risk of a notch becoming blocked with debris.

Summary

Limiting the design flow to 90% of Q_{mean}, combined with the relatively high HoF (18% of Q_{mean}) plus the additional effect of the start-up flow, means that the HoF will only prevail over the Falls for 45% of the year, as indicated in Figure 3.

5. DESIGN DETAILS

5.1 Layout

As depicted in Figure 2, the overall layout of the scheme, including intake, turbine and outfall locations, would follow the original flow-path first implemented in 1905, utilising the historic infrastructure that is still fit for purpose.

5.2 River Intake

Coarse Screen

The existing intake from 1935 is small in area with a relatively fine screen. Despite the fact that the 1935 turbine was abstracting less than 200 litres/se, this screen was known to have required continual maintenance to keep clear of debris.

It is proposed to replace this off-take with a new, shallow intake structure parallel to the river bank - the location is shown in Figure 9. This structure would be 6m long, with a coarse screen suitable for keeping out logs, branches and boulders; a bar-spacing of 150mm is proposed.

Boulder Weir

In order to create an adequate submerged area for the new screen, without major change to this reach of river, it is proposed to raise the local water level by approx. 300mm in order to back up the level to the mini-rapids roughly 50m upstream (see Figure 10), but no further.

This will be achieved using a rough boulder weir which would extend from an existing outcrop on the far bank to reach the near bank just at the top of the falls (depicted in Figure 11). The weir would be cemented below water level for solidity, and would utilise rock anchors into the bedrock below.

By digging out the gravel on the near side of the river down to bedrock, it is expected that a water depth of 0.8m could be achieved at the intake location (>0.5m water depth was measured in the centre of the river at moderate river flow).

As illustrated in the design drawings, a new intake screen, 6m long and submerged by 0.6m, with vertical bars set at 20° to the vertical, would achieve a submerged area of 3.8m². Hence the approach velocity at the screen face for a maximum abstraction of 0.8m³/sec would be only 0.2m/s. This would allow the screen to become three-quarters blocked and still permit full abstraction to continue.

An additional benefit of this low impoundment will be to prevent ‘draw-down’ of the upstream reach whilst the turbine is abstracting. Sustaining a reasonable depth in the watercourse from bank to bank will provide a greater wetted-usable-area during low-medium flow rates, for the benefit of local wildlife.

Gravel Trap

Gravel accumulation is likely to occur in front of the screen during flood events. In order to manage this, a 600mm-width gravel trap, 200mm deep, is included at the base of the screen which would be flushed by opening a 600 x 800 sluice gate at the end of the trap, discharging directly over the falls, thereby maintaining the natural movement of sediment downstream.

The opening of this gate should also largely clean the coarse screen if the flow towards the turbine is briefly suspended.

Control gate

The main control gate, located behind the coarse screen, would regulate the flow to the turbine. For good hydraulic efficiency, a penstock gate of size 1100 x 900mm would deliver flow into a rectangular-round conversion piece which accelerates the flow into a short delivery pipe of 900mm diameter.

This gate, operated by electric actuator, would be linked to the turbine control system. The gate would be used to control the prescribed flow passing over the boulder weir by opening/closing the sluice gate in small adjustments so as to restrict the flow abstracted by the turbine, based on feedback from a level sensor upstream of the weir, so as to guarantee the minimum Q95 flow rate over the Falls.

The actuator will have a manual override, allowing the gate to be closed by hand-wheel if necessary.

5.3 Overwash Screen

Salmon cannot ascend Stichill Linn, so there are no migratory fish in the upstream reach, hence no smolt run. The numbers of non-migratory / coarse fish passing through the intake are therefore expected to be very small.

Nevertheless, the flow to the turbine will be screened to 10mm aperture using a ‘Tyrolean’ overwash screen, as depicted in Figure 4.

As shown on the design drawings, the flow passing through the control gate will enter a short section of 900mm pipe (approx. 4m long) in order to arrive into a new concrete tank, which will overspill the Tyrolean screen over a crest-length of 5m.

Any excess flow will wash over the face of the screen and down the cliff to the pool at the base of the Falls, effectively acting as an additional overspill as an extension to the main waterfall.

Figure 4 : Tyrolean overwash screen

5.4 Forebay Tank

Flow dropping into the sump below the 10mm screen will continue on to the forebay tank via a covered concrete channel roughly 4m in length.

The existing forebay tank (Figure 14) is approximately 5.5m long and 3m wide and, with the turbine operating, would be filled to 1.5m depth.

The forebay tank will allow all air bubbles to disperse and will deliver the flow into the main pipeline down to the turbine. At the downstream end of the tank, the inlet to the pipe will be protected by a coarse screen (for safety purposes) and a manual penstock gate.

5.5 Delivery Pipe

The powerhouse is located 20m from the forebay tank. The existing 600mm steel pipe is still in situ, nearly completely buried. It may be possible to re-use a section of this pipe, depending on its condition, but the presumption is to fully replace it with a length of HDPE pipe, of external diameter 710mm. This will pass into the powerhouse at a high level, then drop down vertically to connect to the turbine.

5.6 Turbine Selection : Crossflow turbine

The only type of new turbine that will be cost-effective for this head and flow is a crossflow turbine. This is a variable-flow machine which, in its twin-cell version, can still operate at 15% of design flow.

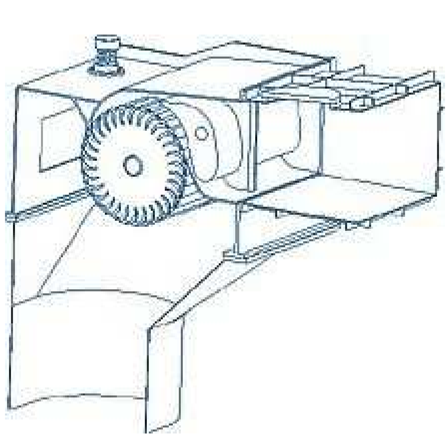
It will not run sufficiently fast to allow direct-drive to the generator, so a gearbox will be required to increase the speed from around 275rpm to 1000rpm.

A crossflow turbine can be arranged with either horizontal or vertical entry of the inlet pipe: vertical entry will be needed at this location.

The crossflow turbine will discharge through 2 metres of vertical draft tube which creates suction pressure below the turbine. As with the previous Boving turbine, this allows the turbine to be located well above tailwater level whilst still utilising the full head of water.

The sump below the turbine extends 2.6m below floor level and discharges into the tailrace culvert through an archway 1.5m wide.

Figure 5 : Crossflow turbine unit (vertical inlet), plus schematic illustration



5.7 Tailrace

The existing tailrace culvert runs underground for roughly 12m from the powerhouse to the river. The exit is visible on the riverbank (Figure 18), which measures 1.45m wide at the outfall. There is a gentle curve back to the powerhouse. The culvert has filled up with silt, so some work will be required to jet out the culvert and potentially repair or replace any damaged sections.

A tailrace screen could be added at the outfall to the river. However, for fish to reach the rotating part of the turbine would require traversing up a 12m tailrace tunnel followed by a vertical 2m swim up the draft tube, with no 'run up'. There is then a 100mm air-gap between the water level at the top of the draft tube and the rotating runner above it. So it would seem that a tailrace screen would add cost and maintenance liability, but for no obvious benefit.

5.8 Control System

The control system will enable fully automatic operation of the turbine. It will continuously monitor the river level, and will open or close the main intake control gate in small adjustments, according to whether the upstream level is rising or falling in order to guarantee the prescribed flow over the Falls. If there is insufficient water to generate power, the penstock gate will shut completely, and will automatically re-open when the River is replenished.

There will be a second level sensor in the forebay tank to control the turbine. The level in the forebay tank will respond to any changes in the flow arriving from the intake. The turbine inlet vanes will then be adjusted automatically to maintain the level in the forebay tank within a 100mm band.

The control system will also provide the necessary grid-connection switchgear to meet the G99 standard for embedded generators.

6. ENVIRONMENTAL ISSUES

6.1 SEPA Consultation

Pre-application correspondence was undertaken with SEPA during Autumn 2023 [redacted] nd [redacted] including the submission of a *Screening Outcome Form for run-of-river hydro schemes* (appended). SEPA feedback comprised of the following main comments:

- SEPA hydrologists are happy that the proposed option to calibrate the turbine to ensure that a minimum Hands-Off-Flow is provided should be a fail-safe method, and preferential to any notch on the actual weir (which is always at risk of blockage).
- Due to the limited spatial impact and the exceedance and likely variability of flows above Q95 that have been indicated, this may be sufficient to satisfy SEPA that only a Hands-Off-Flow is required. A hydrology assessment will be undertaken as part of the determination process.
- Intake screening: there are likely to be native Brown Trout upstream and any that wander downstream to coastal waters to become Sea Trout may be attracted by the intake flow and could be at risk of being drawn into the turbines. SEPA fish ecologists can provide comment on as part of the application determination with regards to the screening aperture required.
- Tailrace screening: the return of water flow could attract fish to the tailrace, this risk may be increased in the absence of upstream passage due to the falls. Hence, SEPA fish ecologists will need to consider whether screening of the return of water will be required.

6.2 Fisheries and Fish Passage

<u>Upstream of Stichill Linn</u>

Stichill Linn is a total barrier to upstream fish passage and there are no migratory salmonids upstream of the Falls, which marks the end-point of the SAC.

It is presumed that the upstream watercourse will have a resident population of brown trout (and perhaps other non-migratory coarse fish), but there are no records of rare or distinct fish species. The only section of watercourse affected by the scheme extends a few metres upstream of the top of the Falls, where the flow accelerates over bedrock towards the Falls, and there is no observable spawning habitat. Photos of the reach upstream from Stichill Linn are provided in Figure 12.

The new boulder weir will retain a significant wetted usable area within the short reach from the boulder weir back to the upstream rapids.

The 10mm screened intake will prevent adult and juvenile brown trout from reaching the turbine.

Downstream of Stichill Linn

The 30m of river between the foot of the waterfall and the existing turbine outfall is divided between (i) the deep, slow moving pool at the base of the falls (ii) a short set of rapids, where any rubble washing over the falls is deposited by the plunging high flows cleaning out the pool.

Photos of this reach are provided in Figure 13.

Neither of these features is suitable for spawning, and the local knowledge of the Estate would confirm that hen salmon have never been observed congregating here for spawning.

6.3 Geomorphology and WFD status

Impounded Reach

- The new impoundment will be limited to 300mm in height and will be a less formal structure using boulders secured with concrete.
- It's influence will extend no further than the mini-rapids 50m upstream. Since the riverbed itself will have a gradient of not less than 1:200, the resulting backwater effect may not even reach the rapids.

Sediment Transport

- A high degree of flow variability will be retained within the annual flow regime due to the modest peak abstraction.
- Significant sediment movements only occur in very high flows (certainly above Q1%), by which point the hydro abstraction is less than 15% of the river flow, so nearly all suspended material will continue over the Falls.
- The riverbed is formed predominantly of bedrock in the 50m reach approaching the Falls and there are no significant deposition zones (gravel bars, sandbanks, etc.)
- Gravel and suspended sediment may be inclined to collect in the deeper area created by the new hydro intake, but this will instead be washed downstream by the opening of the gravel wash-out gate at roughly Q2% in the river. There are also wash-out pipes incorporated into the screening tank.
- Hence the changes introduced by the hydro project will not have a significant influence on sediment movement.

Erosion

- Some limited reinforcement of the riverbank will be applied upstream of the new intake structure to ensure that the river cannot attempt to erode behind it. Standard rip-rap boulders will be used, retrieved from the bank excavation works, which will vegetate naturally over time.
- The flow leaving the tailrace culvert into the river will have a maximum velocity of 1m/s and will be projected downstream. There is therefore no scope for erosion of the adjacent or opposite riverbanks.

Water quality

There will be no effect on water quality. A known benefit of crossflow turbines is that they provide increased aeration to the flow passing through.

Conclusion

The local changes to the river have been kept very limited in scale, including the height of the proposed impoundment and the maximum turbine abstraction. Additional measures have been included to sustain sediment transport whilst maintaining the intake against blockage. As a result there can be no conceivable impact on the overall WFD status of this waterbody (i.e. that could lead to a reduction in ecological status) or prevent the waterbody from reaching future objectives.

6.4 Ecology and Protected Species

A Phase 1 Habitat & Protected Species Survey will be undertaken as part of the planning permission to identify if there are any protected populations that could be impacted by the scheme and to recommend any mitigation measures. Local records have indicated that the following protected or important species have previously been noted in the area around Newton Don:

- Otters
- Bats (2 species)
- Red squirrel

7. FLOOD RISK

7.1 Summary

In summary, neither the completed hydro-scheme, nor the construction works, will present any risk to flood defence for the following reasons:

- The design of the side intake will maintain the full width and discharge capacity of Stichill Linn.
- The new boulder weir is restricted to 300mm in height so that it will only back up the water level no further than the rapids 50m upstream; this reach is contained between relatively steep-sided banks.
- The overall discharge capacity upstream of the Falls will be increased by:
  - drawing 800 litres/sec through the turbine
  - providing 5m of additional overspill capacity at the overwash screen
  - at high flows, discharging up to 1.5m^3/sec through the gravel wash-out gate
- As a result, the analysis below demonstrates that at high river flows (above approx. Q-0.5%), there will be no net rise in river level upstream of the boulder weir.
- By installing a buried pipeline and utilising the existing powerhouse, there will be no new above-ground construction in the floodplain.
- The installation will be flood resilient, with a raised door sill and all electrical items located above the peak flood level.
- Any excavated materials will be removed outside Floodplain Zone 3.

7.2 Analysis of water level vs flow rate

As the river rises, the flow approaching Stichill Linn will progressively take the following 4 routes downstream:

1. over the boulder weir and down the main Falls
2. into the forebay tank and down to the new turbine
3. overspilling the Tyrolean screen and down the edge of the Falls to the pool below
4. through the gravel-washout gate and over the main Falls

The flow rate taking each route has been modelled alongside the Flow Duration Curve in Figure 6. In summary:

- the turbine reaches peak abstraction at Q25.
- as the river rises further, an increasing flow will spill over the boulder weir and down the Falls plus some flow will start to pass over the top of the Tyrolean screen, effectively adding 5m of additional spillway to the 13m width of the boulder weir.
- this extra spill at the overwash screen will not keep pace with the rising flow over the boulder weir because it will slowly become throttled by the constraints of the 900mm delivery pipe which feeds the Tyrolean screening tank, but it will still in excess of $1m^3/s$ to spill over this route.
- when the river reaches roughly Q2 (meaning the river will have risen by more than 250mm), the gravel wash-out gate will be opened.
- this will initially reduce the flow rate over the Falls and the Tyrolean screen, hence dropping the upstream water level.
- these respective flows then continue to rise with water level as the river goes into flood.

The overall effect on water level at the new intake has been modelled in Figure 7. Three graphs are plotted as follows:

1. water level prior to the new scheme
2. water level with the proposed hydropower scheme including the new 300mm boulder impoundment
3. water level with the proposed hydropower infrastructure, but without the boulder weir.

Because of the simplifications in the equations involved, the absolute water levels will not be accurate, but the relative before/after effects between these graphs will give a good indication of the relative change brought about by the new scheme at different flow rates.

Conclusion

The combination of the proposed measures leads to:

- a sustained, raised water level in the upstream reach, at roughly today's Q5% level i.e. well within the existing riverbanks and ensuring no drying out of sections of riverbed at lower flows;
- a similar water level vs today by the time the river has risen to Q0.5% (river still in bank) i.e. no worsening of the flood position.

Figure 6 : Proposed division of River flow above Stichill Linn

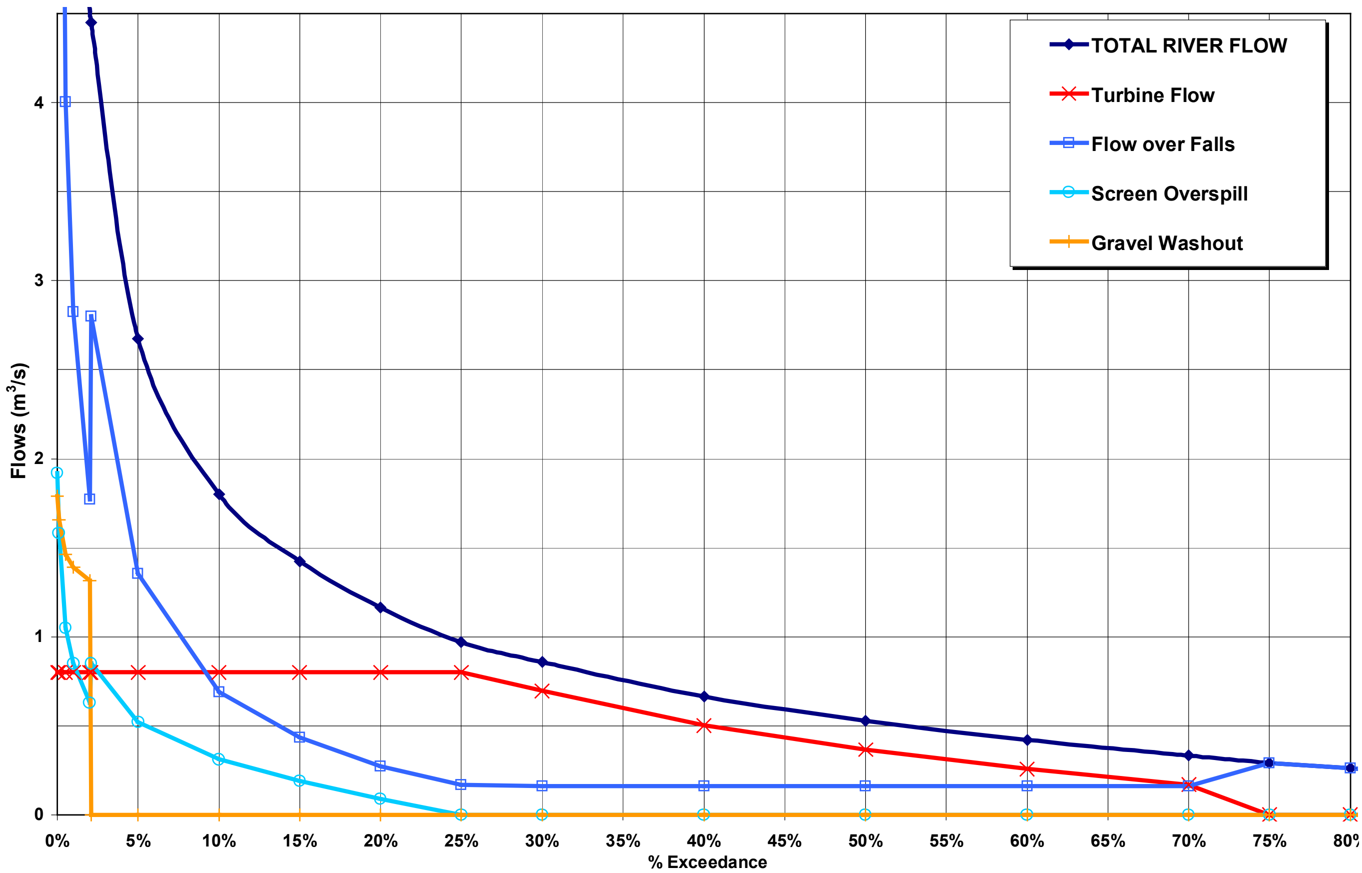
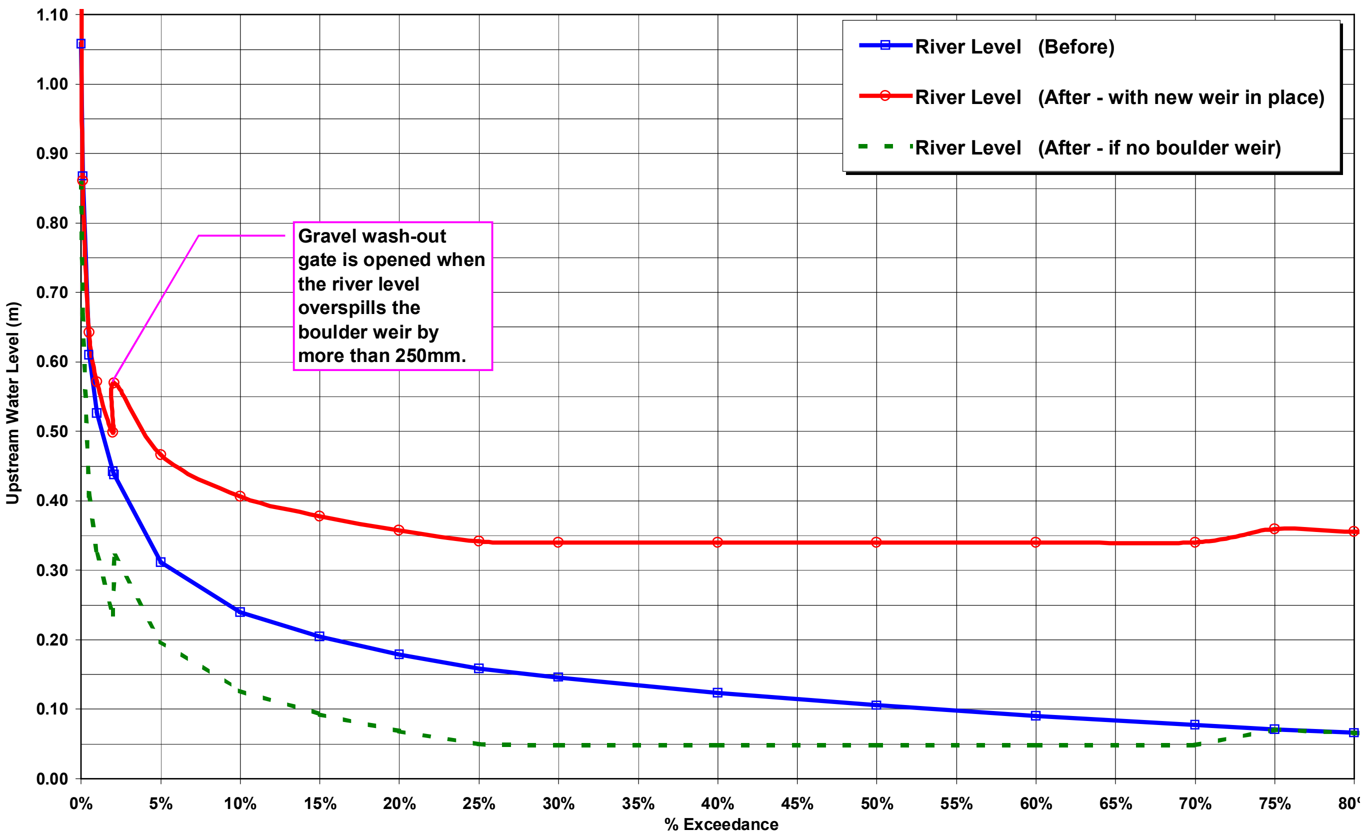


Figure 7 : Modelled Before/After river levels at the top of Stichill Linn (*using flows of Figure 6*)



8. CONSTRUCTION METHODOLOGY

8.1 Scope of Works

The general scope of the civil works will cover:

Construction Access

- Prepare hard-core access route from the turbine house up to the intake area (approx. 60m), suitable for tracked machinery (typically 13-tonne excavator).

Temporary Works

Bunding locations are identified on the Layout Drawing in Annex B:

- Upstream bund: Bulk sandbagging will be used to isolate the intake area from the river, so that the intake works can be built behind the bund, only connecting through to the river at the end of the works. If necessary, secured with locally-sourced boulders on the upstream face to provide a flow barrier.
- Downstream bund: similarly, a bulk sandbag bund will be placed around the tailrace exit to allow dry working.

Flood Defence Note:
Excavation and construction works will be undertaken in-land at first, leaving the edge of the riverbank in place, and will only break through to the bunded areas at the later stages, so minimising contact with the river.

Intake Works

- Excavate intake and gravel wash-out area (approx 8m x 5m x 1.5m) including breaking into bedrock as necessary; remove materials to storage off the floodplain.
- Pump out any leakage flow (as necessary) into local silt traps.
- Install concrete base, reinforced concrete side walls. (Concrete base to include toe to prevent under-cutting.) Install rectangular-to-round steel transition piece for pipeline inlet.
- Provide craneage for the installation of the 2 penstock gates, trashrack and walkway by the M&E team.

Screening tank

- Excavate screening tank area (approx 8m x 4m x 1.5m), including breaking into bedrock as necessary.
- Excavate short channel to forebay tank (approx. 4m x 2m x 1.5m).
- Remove materials to storage off the floodplain.
- Screening tank: install concrete base, reinforced concrete side walls and dividing wall, allowing apertures for the pipe inlet, exit channel to the forebay tank, and two drain-down valves.
- Install and seal 900mm pipeline and drain-down valves. Install 10mm screen.
- Connecting channel: install concrete base, reinforced concrete side walls, and seal both to the external wall of the forebay tank.

Forebay Tank

- Remove redundant screens.
- Dig out and remove any silt; remove off-site.
- Remove remains of old steel pipe and create larger aperture for the new HDPE pipe.
- Install first length of HDPE pipe and grout into position.
- Install penstock gate and protective screen upstream of new pipe inlet.

Tailrace and Outfall

- Form sandbag bund around the outfall to the river, including permeable membrane, to trap any silt discharges.
- Pump out to allow tailrace to drain.
- Use jetting equipment in the powerhouse in short bursts to mobilise silt in the tailrace culvert.
- Collect and remove silt from the bunded area until tailrace is clear.
- Inspect tailrace culvert with camera to confirm overall condition.
- If necessary, access sections of culvert by breaking through from above in order to implement repairs.

Powerhouse

- Remove all existing machinery, pipework and fittings, and make good.
- Clean out turbine sump and remove any silt off-site.
- Install new lifting beam above turbine location.
- Lift turbine baseframe into position and secure to concrete floor either side of sump.
- Mount turbine draft tube to baseframe.
- Lift the turbine into position and secure to baseframe.
- Connect vertical inlet pipe to turbine (rectangular-round).
- Create aperture in west wall of powerhouse for incoming pipeline.
- Lift and install the gearbox and generator and connect to the turbine via shaft coupling.
- Grout around (a) the gearbox plinth and (b) the generator plinth.
- Install turbine control panel and hydraulic powerpack.
- Complete all remaining repairs to the powerhouse, including a new pitched roof.

Pipeline

- Excavate downhill from the forebay tank, removing existing steel pipe in sections and create pipe trench for the new 710mm pipeline including pipe bedding as necessary.
- Remove old pipe and excavations to storage off the flood plain.
- Connect new fabricated bend to top flange of turbine pipe, passing out through the west wall of the powerhouse.
- Final measurements, then cut and weld HDPE pipeline to length.
- Install middle section of pipeline (approx. 15m), using welded pipe couplers.
- Back-fill over pipe and compact.

Boulder Weir

The boulder weir will be constructed as the final activity of the main civil works i.e. after the river intake with gravel wash-out and the screening tank have both been completed. These 2 structures will allow the river to be diverted around the side of the main Falls (during reasonably low flow conditions) to create safe, dry working conditions for constructing the boulder weir.

- Fully open: the gravel wash out gate, the main inlet gate, and the 200mm drain valve in the screening tank.
- In low-to-moderate flow conditions (below approx. Q60): install sandbag dam across the river, upstream of the boulder weir location, diverting the majority of the river into the new intake.
- Using a small excavator (e.g. 3 tonne), clear the river bed along the line of the new weir (or implement by hand if the majority of the bed is already exposed bedrock, as expected).
- Drill and cement vertical rock anchors along the line of the weir, approx. every metre.
- Position flat boulders upstream of the anchors to create main body of new weir.

- Install small rocks to fill the apertures and manually apply quick-drying cement, upstream and downstream to form watertight structure bonded to the rock anchors.
- Allow to dry, then test with a small flow. Fill any remaining leakage points.
- Remove temporary bund.

Electrical connection

The low-voltage power cable will be buried in trench of width 400mm and minimum depth of 600mm along the identified route to the Newton Don switchroom.

Completion of the Works

- Remove all remaining bunding.
- Apply 'vegetated' rip-rap bank reinforcement upstream of the intake structure, using locally retrieved stone up to existing riverbank level, staked with native vegetation. Approx. 3m of reinforcement is anticipated.
- Local re-landscaping works: this will include localised banking to minimise the visual presence of the intake structure and screening tank.
- Remove temporary hard-core from the riverbank area, restore with top-soil and re-seed.
- Remove all remaining materials off-site and make good.

Design

Ground investigations and structural engineering design as required.

8.2 Measures to avoid pollution

The principal environmental risk during construction is the accidental discharge of pollution into the watercourse, including sediment release or mobilisation.

The methodologies to minimise or eliminate these risks are summarised below.

- The joint guidelines issued by SEPA and the Environment Agency (PPG1 and PPG5 - *Works and Maintenance in or Near Water*) will be followed.
- Works will take place in a dry working environment, achieved by isolating the working area using natural or temporary bunds.
- When working in or near the watercourse, extreme care will be taken to prevent pollution and the mobilisation of silt and sediment during construction works.
- If dewatering of excavations is required, pumped discharges will be passed through settlement ponds or silt fences to capture sediments before release to the surrounding land or watercourse.
- Excavation activities will cease during periods of intense rainfall.
- No watercourse-related construction activities will be attempted if high river flows are present or imminent.
- By achieving dry working conditions, there should be no need to pour concrete below water. In extremis, if there is an urgent need to pour concrete below water, then this will have underwater admixture added to prevent leach out of cement.
- If turbidity of the river does become noticeable during construction works, then work will be suspended to allow the river to clear.
- All fuels will be stored in bunded tanks at least 10m from watercourses, and outside the floodplain.
- The importance of correct storage procedures for fuels, oils, construction materials and chemicals will be stressed to all site personnel.
- All on-site vehicles will carry spillage mats, and drip trays will be placed under all static items, e.g. pumps. Cement will be stored in waterproof conditions away from watercourses.
- Excavators will use bio hydraulic oils.

- All waste generated during site operations will be removed to an agreed temporary location and stored securely in appropriate containers.
- The turbine uses sealed bearings which operate in the dry inside the powerhouse and can be lubricated by grease-gun. The turbine casing is sealed to the powerhouse floor preventing any leakage inside the powerhouse from reaching the turbine sump. There is therefore no route for grease to enter the watercourse.

9. OUTPUT AND NET ZERO

A crossflow turbine designed for 9.5m net head and 800 litres/sec design flow would generate a peak electrical output of 50 kW.

Based on the LowFlows data, and allowing for down-time, the average electricity generated over one year could be expected to be in the region of 225,000 kWh/year.

The capacity factor[2] of the 50kW turbine would therefore be 50%, which is relatively high for a micro-hydro scheme. This is the equivalent electrical consumption of roughly 70 average households, and would currently save ~110 tonnes of CO_2 per year from UK gas-fired power stations. This is the annual CO_2 absorbed by 4500 mature trees[3].

[2] *Capacity Factor* is the ratio of actual energy produced vs. the energy produced if the power source operated at 100% of its rated output all year round.
[3] https://ecotree.green/en/how-much-co2-does-a-tree-absorb

ANNEX A : SITE PICTURES

Figure 8 : Stichill Linn

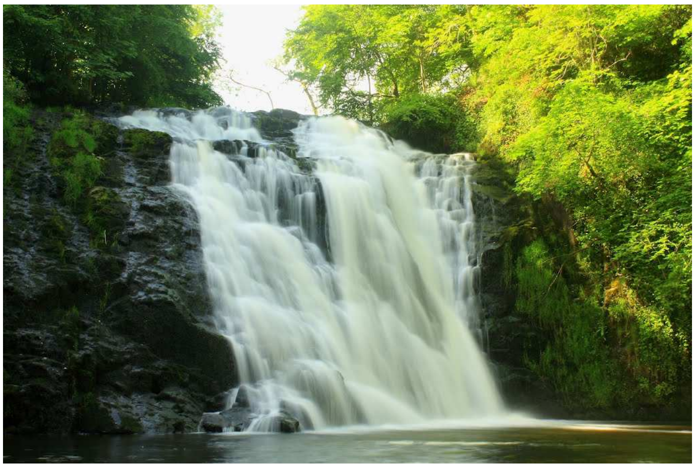



Figure 9 : Proposed intake location


Figure 10 : Rapids 50m upstream

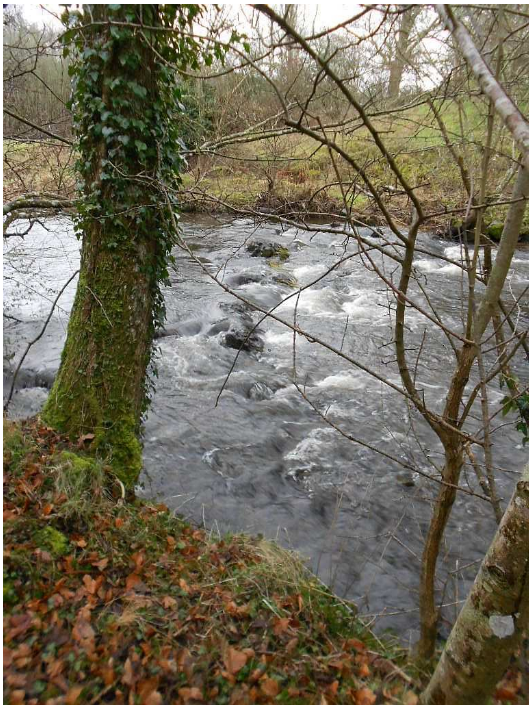


Figure 11 : Proposed boulder weir location

Figure 12 : Upstream reach from the Rapids to the top of Stichill Linn

Figure 13 : Downstream reach between Stichill Linn and the turbine discharge

Figure 14 : Forebay tank and fine screens

Figure 15 : Short pipe route to powerhouse

Figure 16 : Powerhouse and pumping intake

Figure 17 : Access track to powerhouse

Figure 18 : Turbine discharge culvert

ANNEX B :LAYOUT DRAWINGS

1. Scheme Layout
2. Scheme Layout with temporary bund locations
3. River Intake works and Boulder Weir
4. Overwash Screen and Forebay Tank
5. Powerhouse, Machinery Layout, Tailrace

ANNEX C : RIVER FLOW CALIBRATION (2010)

attached separately

ANNEX D : SEPA SCREENING CHECKLIST

attached separately