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# Introduction

The Inverarish Burn and surrounding area is suited to a run-of-river hydro scheme. Such a development would consist of the following built structures:

- an intake structure, built on the riverbed to abstract water
- a buried penstock (plastic pipeline) from the intake to a powerhouse
- a powerhouse containing a turbine and generator
- a tailrace and outfall to carry water from the powerhouse and return it to the watercourse
- a buried electrical cable from the powerhouse to a grid connection

A run-of-river hydro scheme only operates if and when there is adequate flow in the burn. Such a scheme does not store any water or create a large dam, as is the case in traditional, larger hydro developments.

This feasibility study looks at the hydroelectric potential on the Inverarish Burn. Two options are assessed with the aim of informing the community of their viability.

Several licences or consents are required to construct and operate hydro schemes in Scotland, namely environmental, electrical grid connection and local planning. The likely requirements for these have informed this document. Scottish Environment Protection Agency (SEPA) publish guidance for run-of-river hydro developments and this is referred to where appropriate.

## Single intake configuration

The first option abstracts water from the Inverarish Burn at its highest point on land currently owned by Forestry Commission Scotland. The water is returned to the burn via an outfall located approximately 270 metres upstream from Henderson's Bridge. The location of the proposed abstraction point (intake) may be seen on the map presented in Figure 1 and in the photograph in Figure 2. The single intake configuration maximises the potential head (height between the intake and turbine) available on the Forestry Commission Land but in doing so may only use water from the Inverarish Burn.

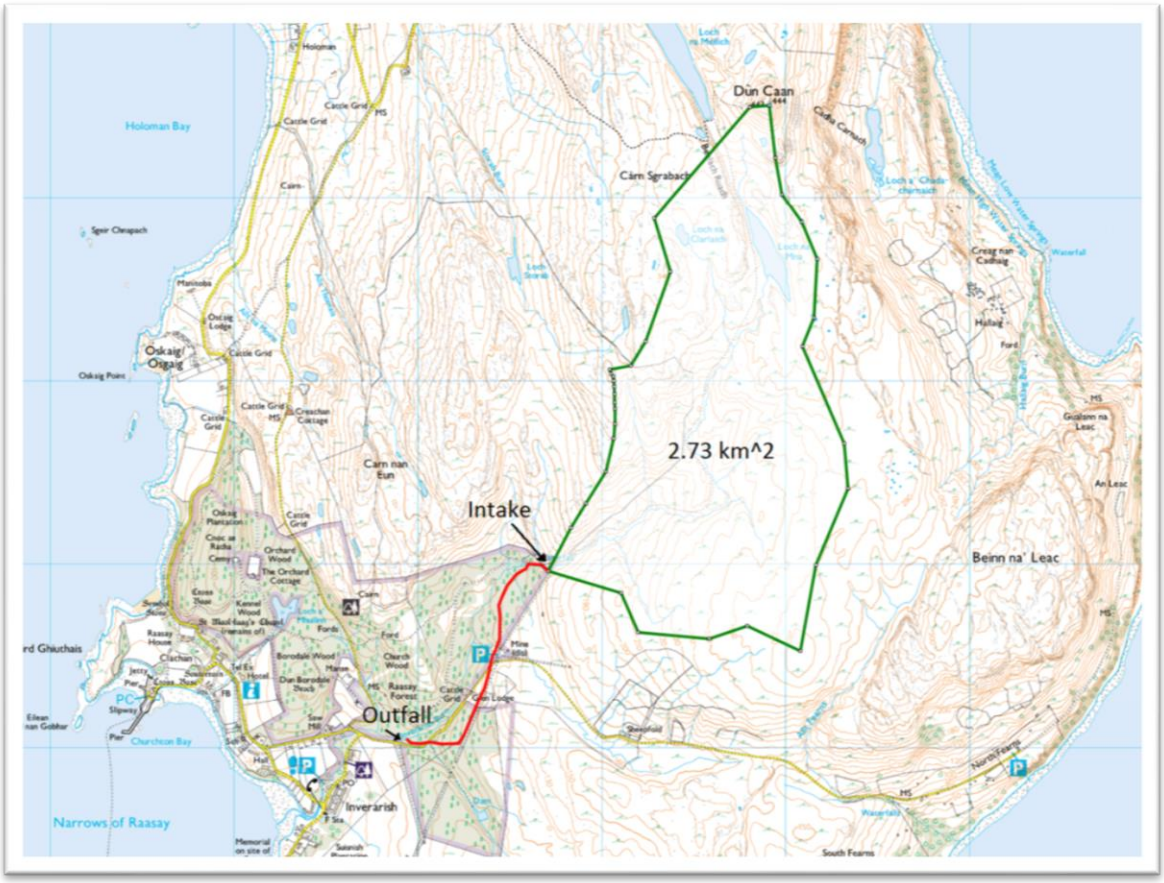


**Figure 1: Map of catchment area and suggested penstock route for single intake arrangement.**

**Figure 2: Proposed intake location for single intake configuration.**

As Figure 2 shows, the weir would be situated on bedrock offering a solid foundation on which to build a weir with a relatively small area flooded area created upstream of the weir. The pipe would exit to the bottom left of the photo at 90 degrees to the bank, minimising disruption during construction. Access is quite limited with only the footpath leading to Dun Cann coming within close proximity of the intake location. Access for the delivery of construction material may be possible from the south east, along the deer fence that marks the boundary between the FCS land and the common grazing. Figure 3 shows a sample of the ground that approximately 50 meters from the proposed intake location that could be used for access.

**Figure 3: Possible track dumper access to upper intake for material delivery.**

The penstock route leading down to the Burma Road is quite steep with plantation forest growing on shallow soil in initial sections followed by the foot path that is predominantly situated on outcrops of bedrock. Photographs of the plantation near the intake and the footpath leading down to the Burma Road may be seen in Figure 4 below.

**Figure 4: Proposed penstock route, through forestry plantation (left), leading down to Burma Road (right).**

Although an exact pipeline route down to the Burma road is yet to be determined, it is envisaged that the pipe may be buried in the upper and lower sections but may need to be bolted down to bedrock in the middle section. The initial section amongst the trees will require some felling to provide enough room for the pipe to be buried. Access with a small tracked excavator should be possible along certain sections of the pipe route. Further detailed surveying will be required to determine the exact sections that may be buried and those having to be laid and bolted over ground.

Once on the Burma Road the pipe route would follow the Burma Road as far as the mine buildings at which point it is proposed to cross the road and travel along the side of the old railway track heading south. Once above the powerhouse location the pipe would descend the steep section of hill before crossing the road again and then reaching the power house.

An alternative penstock route along the ??? east / west ??? side of the Fearns road was assessed but was considered unsuitable due to restricted space in lower sections.

## Twin intake configuration

The twin intake configuration would take water from the Inverarish Burn but also the unnamed burn that runs along the Fearns road ???. This unnamed water course has an existing intake weir dating back to the iron ore mines that could easily be adapted for use with hydro power. The proposed intake is located on land owned by ???Scottish Ministers (do you mean the department???), approximately 50 metres upstream of the deer fence. If this option is to be pursued, consent will be required from ???Scottish Minsters???

Figure 2 shows a map detailing the two intake locations and corresponding catchment areas for the twin intake configuration. The proposed penstock route is also marked in brown, blue and red.

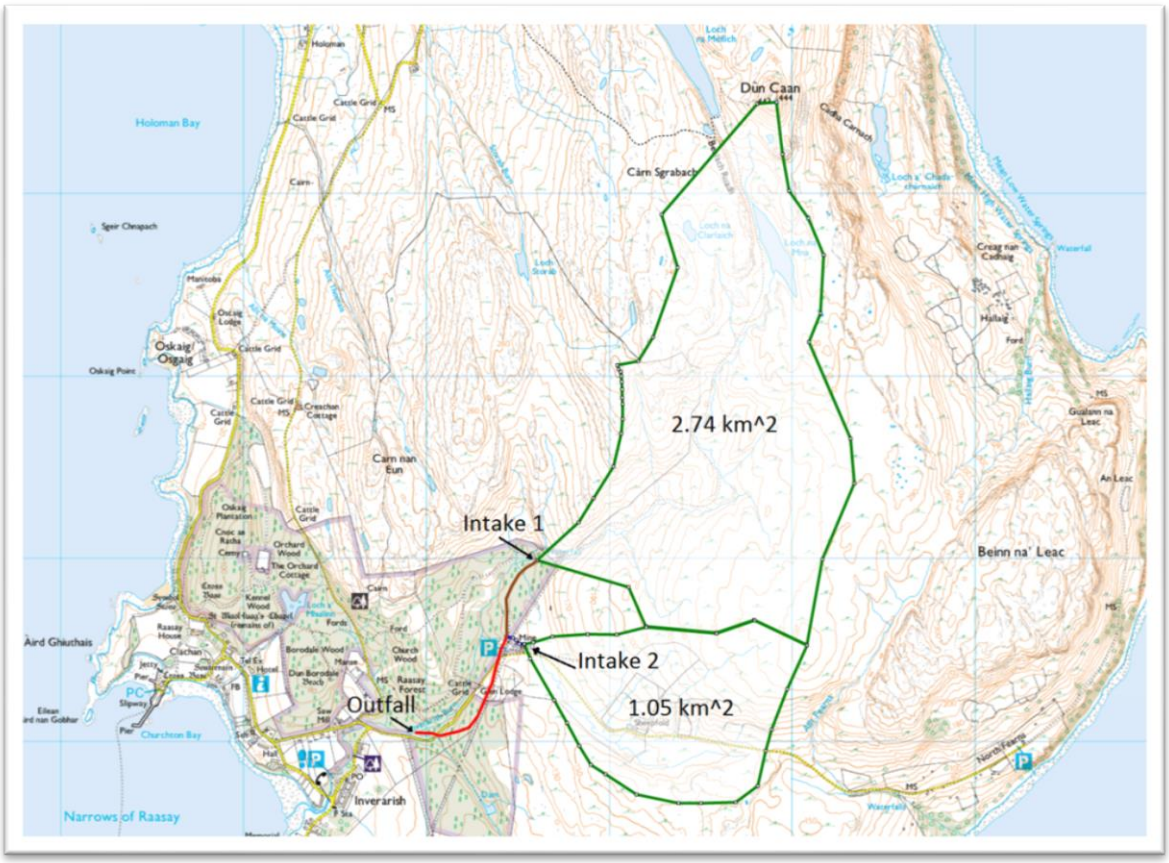


**Figure 5: Map of catchment area and suggested penstock routes for twin intake configuration**

A photograph of this existing intake on the unnamed burn may be seen in Figure 6. The existing intake is constructed of concrete and has a height of approximately 2 meters. This weir would require very little work to be adapted to host a suitable filtration system so that the water from this stream may be used effectively. The water taken from this dam would be piped towards the mine buildings where it would join the main penstock pipeline from the Inverarish Burn intake (Intake 1).

In order to utilise water from two different watercourses successfully, the altitude of both structures must be identical to prevent water flowing between weirs. The location of the Intake 1 on the Inverarish Burn would therefore require to be situated at the same altitude as that of the existing

intake on the Unnamed Burn. Initial surveying suggests that this location is just upstream of the Burma Road foot bridge that crosses the Inverarish Burn (shown below in Figure 7).

As is detailed in Figure 5, the proposed pipeline would follow the Burma Road to the mine buildings where it would cross the road and then follow the old railway track in the same manner as the penstock route detailed for the single intake configuration.

**Figure 6: Location of existing intake on the unnamed burn that runs along the Fearns road.**

**Figure 7: Approximate intake location on the Inverarish Burn for the twin intake configuration.**

## Proposed powerhouse, tailrace and outfall location (for both single and twin intake configurations)

The powerhouse contains the turbine, generator and ancillary equipment required to produce electrical energy from the pressurised water in the pipeline. The tailrace transports water that has travelled through the turbine to the outfall where all abstracted water is returned to the watercourse. Any outfall should ideally be situated on bedrock to minimise the risk of scouring (erosion). The proximity of the powerhouse to the electrical grid is of importance due to the high cost of electrical cabling while access for both construction and maintenance should also be a consideration.

The proposed location for the outfall is situated approximately 270 metres upstream from Henderson's Bridge. This location is just upstream of the remaining pillars of the old Railway Bridge that crosses the Inverarish Burn. The powerhouse would be situated amongst the trees adjacent to the Fearns road. A photograph showing these approximate locations may be seen in Figure 8 below.


**Figure 8: Proposed location of powerhouse, tailrace and outfall.**

The proposed powerhouse location lies roughly 25 metres from the Fearns road and is approximately 440 metres from the 11kW 3 phase power lines. Further detail on the connection to the electrical grid may be found in the Grid Connection Section.

Moving the outfall and power house further downstream would result in higher energy yields from the turbine due to the increased potential head. Another such location for the outfall near the old watermill owned by the Raasay Heritage Trust was considered. However, no simple penstock route was found that could access this point without major disruption to the roads and existing infrastructure serving the Inverarish village and cottages. It is not believed that the increased energy yields will justify the increased capital cost of laying the penstock to this point. If a pipeline route

was to be found then a 99kW scheme could be achieved (using 100 litres/sec and producing approximately 440,000 kWh per annum). The electrical connection to the grid could take place approximately 300 metres away on the ???Avenues??? close to the Saw Mill. It should also be noted that this option would have implications for acquiring both SEPA licences and local planning consent.

## Resource assessment

A flow duration curve created using the Wallingford Hydro Solutions LowFlow 2000 software was obtained from an independent hydrologist. A flow duration curve is a measure of the range and variability of a stream's flow over the course of a year. The flow duration curve was adapted for the three catchment areas defined in Figure 1 and Figure 5. A summary of the mean flow found at these three intake locations may be seen in Table 1 and Table 2 along with the gross head and further site parameters used in system sizing and the calculation of yearly energy estimates. Table 1 and Table 2 also include the channel slope gradient that is used as a benchmark in determining site suitability of the site when applying to the Scottish Environmental Protection Agency (SEPA) for a CAR Licence. Also included in the table is the maximum abstracted flow rate (Qmax) that corresponds to the maximum flow rate that will be abstracted from the watercourse. This value is of importance as the SEPA guidance states that schemes of this size should not exceed 1.3 times the yearly average flow (Qmean).

**Table 1: Site parameter identification for single intake configuration**

| Intake location | High Intake |
|---|---|
| Gross head estimate | 100 metres |
| Catchment area estimate | 2.73 km^2 |
| Channel length | 1434 metres |
| Channel slope gradient | (6.97m in 100m) or 0.0697 |
| Approximate penstock length | 1500 metres |
| Qmean (average flow) | 141 l/s |
| Qmax (1.3 × Qmean) | 183 l/s |
| Potential energy at Qmax | 179.5kW |

**Table 2: Site parameters for twin intake configuration**

| Intake | Intake 1, above foot bridge on Burma road | Existing intake on unnamed burn |
|---|---|---|
| Gross head estimate | 70 metres | 70 metres |
| Catchment area estimate | 2.74 km^2 | 1.05 km^2 |
| Chanel length (intake to outfall) | 1317 metres | 961 metres |
| Chanel slope gradient | (5.31 in 100m) or 0.053 | (7.28m in 100m) or 0.072 |
| Approximate penstock length | 484m + 843m = 1327m | 110m + 843m = 953m |
| Qmean (average flow) | 142 l/s | 54 l/s |
| Qmax (1.3 * Qmean) | 185 l/s | 71 l/s |
| Potential energy at Qmax | 127kW | 48kW |
| Qmax (1.3 * Qmean) | 256 l/s | |
| Potential energy at Qmax | 175kW | |

## System sizing and energy estimates

Under the SEPA guidance, the maximum abstraction flow rate should not exceed 130% of the annual mean flow. With a maximum abstraction flow rate of 130%, the maximum output power from the turbine is approximately 120kW for the single as well as the twin intake configurations. Table 3 below details the required flow rates, penstock diameters and expected yearly energy yields for turbines with rated outputs of 99kW and 120kW for both intake configurations.

**Table 3: Flow rates, penstock diameters and expected yearly energy yields for 120kW and 99kW peak turbine output.**

| TWIN INTAKE RATED OUTPUT | 99kW | 120kW |
|---|---|---|
| Qmax (l/sec) | 225 | 255 |
| Qmax as % of Qmean | 115% | 130% |
| Penstock diameter (mm) | 450 | 500 |
| kWh/ annum | 374000 | 405000 |
| SINGLE INTAKE RATED OUTPUT | 99kW | 120kW |
| Qmax (l/sec) | 147 | 185 |
| Qmax as % of Qmean | 104% | 131% |
| Penstock diameter (mm) | 400 | 400 |
| kWh/ annum | 383000 | 412000 |

It should be noted that the pipe diameter used in Table 3 for the twin configuration corresponds to the pipe size used in the lower section of the penstock (shown in red in Figure 5) from the point at which the water from both intakes has merged into a single pipe. For a 99kW configuration, the sections shown in brown in Figure 5 would require 400mm diameter pipe while 250mm diameter pipe would be required for the section running from the existing intake on the unnamed burn (shown in blue in Figure 5).

## Income estimates

Current sources of income for the production and sale of electrical energy from hydropower include the Feed-in Tariffs (FITs) and the Export Tariff. FITs is a government administrated scheme that pays people for generating their own renewable electricity. FITs are claimed for every unit of energy generated, independent of whether it is used on site or exported to the grid. The export tariff is a payment that is received on top of FIT's for every unit of electricity that is sold to the national grid. The proposed Inverarish Burn scheme would operate with minimal onsite use, therefore, it may be assumed that 100% of the generated electricity is exported to the national grid.

FIT's are paid for a period of 20 years from the moment the plant is accredited. The value of FITs will be adjusted pro-rata to the Retail Price Index (RPI) change in the previous calendar year. The RPI adjustment will also be made on the generation tariff.

The value of FIT's will depend on when the plant is accredited and its installed capacity. Current values and capacity bands for hydropower are shown in the Table 4 below.

**Table 4: FITs value for period 1st April, 2013 to 31st March, 2014.**

| Capacity band | pence/kWh |
|---|---|
| ≤15 kW | 21.65 |
| >15 - 100kW | 20.21 |
| >100kW - 500kW | 15.5 |
| >500kW - 2MW | 12.48 |
| >2MW - 5MW | 3.23 |

Under an ideal timescale it would be possible to have all consenting in place during 2014 including FITs pre-accreditation in place with OFGEM by 31st of December 2014 and a construction phase timetabled for the summer of 2015. If this timescale was achievable, the level of FITs will have dropped by a minimum of 5% (default corridor) and a maximum of 20% (level 3 corridor) on the values presented in Table 4. The exact value has yet to be finalised at the next government review. Based on the above timescale, the yearly financial income estimate for the two configurations may be found in Table 5.

**Table 5: FITs value for period 1st April, 2013 to 31st March, 2014.**

| | >15 - 100kW | >100kW - 500kW |
|---|---|---|
| 2014 FIT value, default corridor, 5 % degression on 2013 prices, (pence/kWh) | 19.2 | 14.7 |
| 2014 FIT value, high corridor 3, 20 % degression on 2013 prices (pence/kWh) | 16.2 | 12.4 |
| 2014 Export tariff value (pence/kWh) | 4.64 | 4.64 |
| TWIN INTAKE | 99kW | 120kW |
| kWh/ annum | 374 000 | 405 000 |
| Average yearly income under default corridor (£) | £ 89 160 | £ 78 428 |
| Average yearly income under high corridor 3 (£) | £ 77 822 | £ 69 012 |
| SINGLE INTAKE | 99kW | 120kW |
| kWh/ annum | 383 000 | 412 000 |
| Average yearly income under default corridor (£) | £ 91 305 | £ 79 784 |
| Average yearly income under high corridor 3 (£) | £ 79 695 | £ 70 205 |

As may be seen, the installation of a 99kW turbine for both the single and the twin intake locations leads to a higher yearly income than the installation of a 120kW turbine. It is recommended that the community pursue the design and installation of a 99kW turbine as this will lead to the highest return on investment.

When comparing the two configurations it can be seen that the income estimates are marginally higher for the single intake option.

## Grid connection

A 99 kW turbine would require a three phase connection that would have to comply with the ENA Engineering Recommendations G59/2. It is understood that the closest three phase overhead lines are 440 metres away from the proposed powerhouse east of the pit (see Figure 3). The three phase line then crosses the Inverarish Burn south of the cottages and heads west along the Avenue.

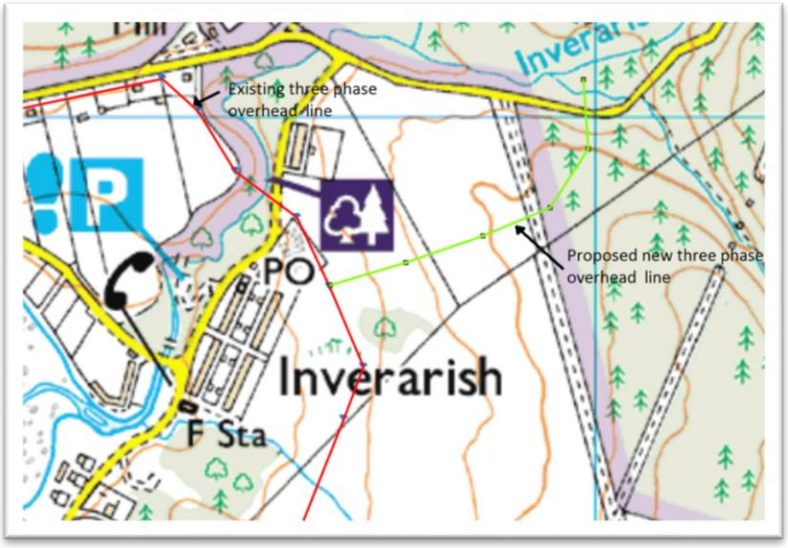


**Figure 9: Map of existing three phase overhead electricity line with proposed spur for hydro scheme connection.**

It is understood that the most cost effective means of obtaining a grid connection would be to run new over-ground cables to a point close to the powerhouse. It would be desirable to cross the Fearns road above ground to avoid further disruption to the road.

It is estimated that the cost of the new overhead line will be in the region of £115 per meter, totalling £50600 for the 440 meters required. It is estimated that a further £25000 will be required to cover the cost of the transformer.

It is worth noting that the new housing developments taking place on the south side of the Fearns road, approximately 150 metres south-east of Henderson's Bridge, have no current electrical infrastructure present at the site. Depending on the timing of both developments, it may be advisable to discuss these potential upgrades with the site developers and in turn the Distributed Network Operator (DNO) Scottish and Southern Energy Power Distribution as a cost saving may be possible for both parties.

# Budget cost estimates

An outline of budget estimates may be found in Table 6 below. These costs are for the installation of a three jet turgo turbine man

ufactured by Hydrover Ltd and partners Sustainable Control Systems Ltd.

**Table 6: FITs value for period 1st April, 2013 to 31st March, 2014.**

| | SINGLE INTAKE | TWIN INTAKE |
|---|---|---|
| INTAKE (materials) | £7,000 | £10,000 |
| PENSTOCK(materials) | £76,500 | £100,000 |
| POWERHOUSE, TURBINE AND CONTROL | £43,000 | £43,000 |
| ELECTRICAL | £85,000 | £85,000 |
| DESIGN and CONSTRUCTION | £100,000 | £100,000 |
| LICENCING | £15,000 | £20,000 |
| TOTAL (excluding VAT) | £326,500 | £358,000 |

As can be seen the main cost difference between the two systems is the penstock pipe that is estimated at £23,500 more for the twin intake arrangement than for the single intake arrangement.

It is envisaged that the construction costs will be approximately the same for both intake configurations. Although the construction of the intake and initial 130 metre pipe section on the of the single intake configuration on the Inverarish Burn is more problematic than that of the twin configuration, the build costs will be similar for both due to the complications involved in laying the larger pipe diameter for the twin arrangement whilst modifying and connecting the existing weir on the unnamed burn.

# Scottish Environmental Protection Agency (SEPA) CAR Licence

**Introduction**

Any run-of-river hydro development, such as the Inverarish Hydro Scheme, will have an impact on a watercourse. All hydropower developments in Scotland require a Controlled Activities Regulation (CAR) authorisation for abstractions, impounding works (weirs and dams) and any other engineering works associated with the scheme. The Scottish Environmental Protection Agency (SEPA) is the authorising body for CAR licences. It is tasked with balancing any risk to the natural environment or to the recreational use of the watercourse arising from the construction and operation of a scheme with any benefits gained under the Scottish Government's aims of increasing renewable energy production.

In addition to a CAR licence, local planning consent from Highland Council will be required. Local planners generally look to SEPA for guidance on hydro proposals (excluding issues relating to roads or the aesthetic appeal of the scheme). It is therefore important that SEPA is consulted from an early stage so that they can inform the design of a scheme. The following section deals with the requirements and considerations relating to obtaining a CAR licence from SEPA.

**SEPA guidance and mitigation**

SEPA publishes guidance and checklists for run-of-river hydro developments providing a set of criteria that allow developers to identify potentially suitable sites for hydro schemes. SEPA imposes mitigation measures on any developer seeking a CAR licence for a variety of environmental reasons.

The hydrological characteristics of a watercourse (including fish habitat and the surrounding eco-system in general) are protected by way of a 'hands-off' or 'compensation' flow. This is a specified volume of water, roughly equivalent to the flow in summer months, which must be allowed to flow naturally downstream at all times. In addition to this, high or spate flows must continue downstream so that the watercourse continues to experience erosion and sediment transportation downstream of the intake.

The level of mitigation will be determined by the design of the scheme and/or consultation with SEPA. SEPA may impose extra mitigation which reduces the flow available for energy production.

The protection of fish and fish migration will influence a scheme if fish are thought to be present in the affected stretch of the Inverarish Burn. Although hydro schemes do not affect the purity or temperature of the water, the reduction in flow and impoundment of water can negatively affect fish.

SEPA must also be satisfied that protected species will not be harmed by the development and may impose mitigation to ensure their safety.

An initial assessment of the likelihood of a CAR licence being granted for the proposed scheme was conducted by a walk-over of the site on 24th September, 2013.

**Inverarish Hydro Scheme and acceptability to SEPA**

According to the SNH website, the proposed scheme does not lie within any protected or designated areas. A Site of Special Scientific Interest (of importance for its geology and flora) runs up the south west side of Raasay approximately 2km from the scheme, however, this will not be affected. SEPA's Fort William office confirmed the Inverarish Burn is classified as a "minor watercourse" as opposed to a "good status waterbody" which requires greater protection.

Following the SEPA checklist, the single intake configuration scheme may be provisionally acceptable assuming SEPA are satisfied on a number of aspects.

**Hydrology**

No flow monitoring is required for the proposed scheme. Calculations can therefore be carried out using flow estimation software which reduces the development cost of the scheme. As mentioned above, the developer can submit proposals based on a compensation flow of Q90 and SEPA will determine if this is adequate.

The maximum volume of water abstracted can be no more than 1.3 or 1.5 times the average daily flow depending on the total annual energy output of the scheme. The proposed scheme is well within both figures.

**Fish**

The high gradient watercourse originates from the south side of Dun Caan forming Loch na Mna, which the author assumes contains brown trout. The burn then runs south and south-east over open moorland until it enters the Forestry Commission Scotland (FCS) land where it becomes increasingly incised. The affected stretch begins with the proposed intake on the boundary of the FCS land, NG 5671 3696 and ends at NG 5595 3605. The watercourse over this stretch is predominately characterised by bedrock and cascade features interspersed with rapids and pools. The fish habitat is a mixture of bedrock (i.e. poor habitat) and good habitat.

The provisional acceptability of the scheme in its current form rests in a large part on SEPA accepting that the affected stretch does not:

*"contain any ecologically significant area for fish… and that for the majority of its length, the river or stream between the intake and tailrace is an entrenched, confined and low sinuosity (e.g. <1.2) stream with cascading reaches and frequently spaced, deep pools in a step/pool bed morphology, and that one or more of the following applies:*

- *The rivers and streams upstream of the intake do not contain any significant areas of good fish habitat*
- *There is a natural barrier to the upstream movement of fish to fish habitat upstream of the intake*
- *There is already a man-made barrier to the upstream movement of fish to fish habitat"*

Further evidence will need to be gathered and consultation with SEPA undertaken to establish if there is 'any ecologically significant area for fish'. SEPA will want to know if and to what degree the affected stretch is accessible to migratory fish and if the affected stretch contains any resident fish. If photographic evidence is not sufficient to make a decision on these two points then a detailed habitat survey will be required and most likely an electrofishing survey. This may cost upwards of £3000.

An initial assessment of the burn suggests that it is 'for the majority of its length…entrenched, confined and low sinuosity etc.' though a more detailed assessment will be required to confirm this.

What constitutes a barrier to fish (or fish impasse) obviously varies depending on the fish in question. Adult brown trout can leap up to 1.81m whilst eels can climb up certain surfaces. It is

assumed that migratory salmon are not present along the affected stretch. Further work would be required to find out how far migratory fish travel upstream and whether eels or brown trout are resident. There are no 'natural barriers to the upstream movement of fish to fish habitat' downstream of the proposed outfall (the highest waterfall being approximately 1m high at Henderson's Bridge). Upstream of the outfall, the first potential obstacle is a mass of felled trees photographed below in Figure 10 at NG 5611 3614. It is unlikely that this would be considered a man-made barrier due to its temporary nature.

**Figure 10: Accumulation of felled trees, approximately 400 metres upstream of proposed outfall location.**

A 2m high waterfall is located approximately 600m upstream of the outfall at NG 5626 3643 and is photographed below. SEPA may consider this impassable to trout but not to eel or lamprey.

**Figure 11: Waterfall, approximately 600meters upstream of proposed outfall location.**

Approximately 800m upstream from the outfall is a significant impasse, 2m high with an overhang, photographed below in Figure 12.

**Figure 12: Waterfall, approximately 800meters upstream of proposed outfall location.**

There are several waterfalls upstream of the access track (approximately 100m downstream of the intake) ranging up to approximately 6m in height, shown below at approx. NG 5663 3699.

**Figure 13: Large waterfall situated above the Burma Road on the Inverarish Burn (NG 5663 3699)**

Consultation with SEPA prior to submission of the application will be necessary to ensure that both parties are clear as to the fish habitat classification of the burn.

**Protected species**

An overall habitat survey will be required to assess the likely impact on protected species such as fresh water pearl mussels, otters, golden eagles, etc. Should they be deemed at risk from the construction or operation of the scheme then further, more specific surveys may be required for each species.

Raasay is known for the Raasay Vole and as a protected species it is anticipated that a survey will be required for this.

Any surveys should be carried out by those with specific knowledge and experience of the species in question. The cost of each survey is likely to be £500 or more.

**Bryophytes**

A bryophyte survey will be required as the scheme lies on the west coast of Scotland, an area rich in rare species.

**Built heritage**

The penstock is routed close to the railway track and mine buildings and therefore the construction methods used will have to be sympathetic to these listed features. Provided care is taken in this respect, no heritage sites should be negatively affected by the development or operation of the scheme.

**Landscape and noise**

The intake, turbine house and outfall locations are reasonably well hidden by trees and shrubs. The design of the turbine house would need to be in keeping with buildings of its size in the local area (sheds) and any access track for the turbine house sympathetically built. The penstock (pipeline) would be largely buried (small sections of pipe may require to be laid on top of the ground and built around) and the land reinstated to its original contours.
After construction, noise from the scheme would be confined to the turbine house with insulation used to reduce the noise as much as possible. It may well be that water running in the burn will supersede any noise from the turbine and generator. The proposed turbine house is located approximately 250m from the new housing developments taking place on the south side of the Fearns road, approximately 150 meters up from Henderson's Bridge and does not have a direct line of sight.

**Recreational use**
The Burma Road is used on a recreational basis as a view point and to access various walks while a waterfall approximately 80m downstream of the intake is used as a paddling area in the summer months. It is highly unlikely that SEPA will reject the application on these grounds providing the construction method statement details measures to accommodate or protect recreational users.

**Local planning**

Highland Council's planning department will look to SEPA for guidance on the suitablity of the scheme for the area in question. Their focus will on disruption to the area from traffic, roads issues, the aesthetic appeal of structures associated with the scheme, etc.

# Conclusions and recommendations