Hafod y Rhedrwydd pico-hydro scheme: outline proposal.

R.W.Moss, August 2017

The proposed scheme will provide electricity for an off-grid cottage, Hafod y Rhedrwydd, plus a more reliable domestic water supply.

One stream runs past the front of the cottage and another passes 100 m behind it. The rear stream is the larger, with about double the flow in dry weather.

Water will be taken from this rear stream, extracting at a point 35 m higher than the house. This gives sufficient height for domestic water pressure and for the pipe to be routed over a spur instead of along the side of a ravine. The pipe length to the house is 380 m.

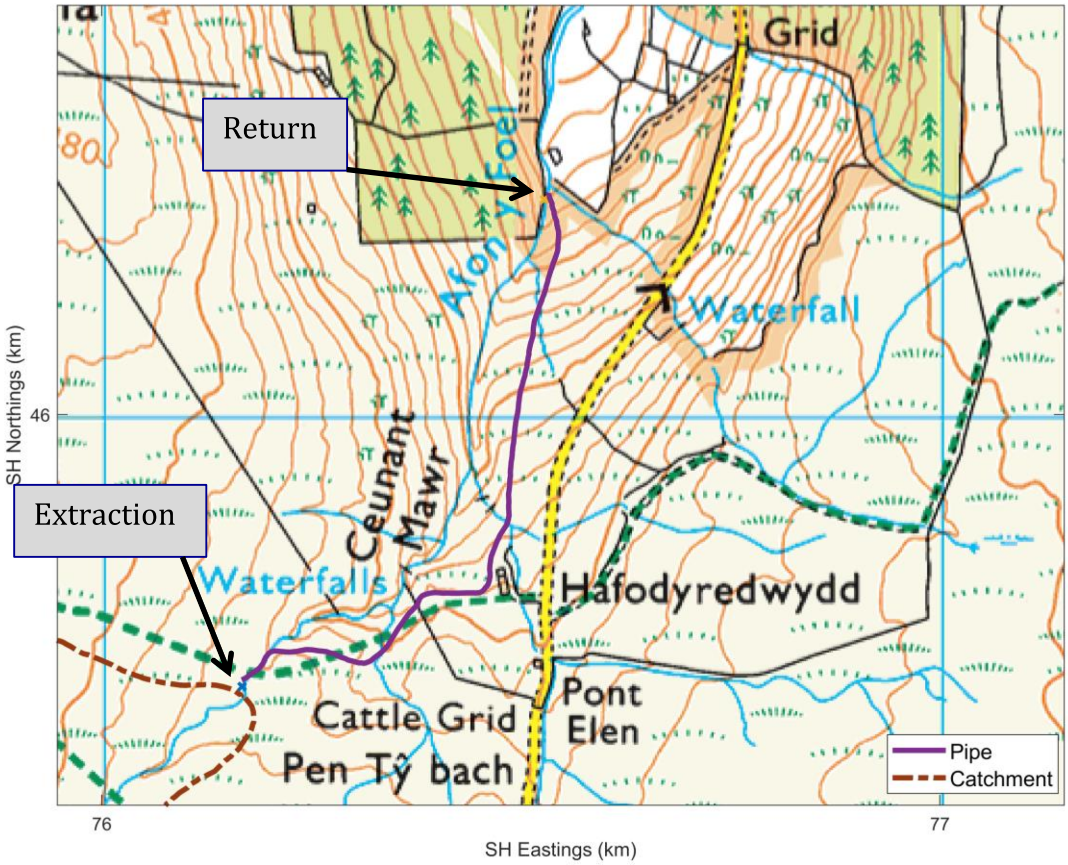

Figure 1. Pipeline route. Extraction at SH7616745675, return at 7653946262; pipeline shown in navy blue. Woodland is owned by the Forestry Commission; all other land on this map (apart from the cottage and its garden) is National Trust-owned. OS map is © Crown Copyright. Reproduced by permission of Ordnance Survey®.

The pipeline has a tee-off to the house before continuing for another 460m towards the bottom of the valley to achieve a total head of 150m (from contours; GPS suggests 133 m). The return point is where the land starts to level out: the steep-sided gorges and ravines higher up make the stream above here quite inaccessible.

All pipes and wires will be buried except for the initial 47 m where the stream falls away until the pipe is above bank level and the pipe can curve away to pass across the spur.

Extraction would use a Coanda screen, Figure 2.

Figure 2. Possible Coanda screen installation (a) Elgin screens box CBS0.50-1 (their drawing). The side buttresses would probably be just a concrete lip to raise the bedrock by ≈60 mm to ensure water did not bypass the box in dry weather. (b) Screen that (with rear collector) could be bolted to bedrock – probably at a smaller scale than this.

Figure 3. Approximate pipe route. The Geomorphology Survey provides more detailed photographs of the route and surroundings.

Figure 4. Proposed turbine hut (very roughly to scale), built into the slope & mostly hidden from the road. 3 m × 1.5 m × 1.5 m high internally, single-pitch slate roof, stone walls + internal insulation, 4 m × 2.5 m externally. Grey bar to show scale.

Since the house is off-grid and will use the electricity in part to run a UV water steriliser it is desirable to maintain some flow even in very dry weather - this is more important that the maximum power in wet weather. The turbine control system will adjust the spear valves to vary the extraction rate in response to stream level and power required. Instrumentation will ensure that no more than 1/3 of the stream flow (average over any 24 hour period) is extracted and will use a stream level sensor and data logging to confirm this condition is met (level will be calibrated against directly measured flow rate during a dry period). Whilst achieving this average, the instantaneous flow rate will not exceed ½ of the stream flow. Domestic water to the cottage will not be measured since it is only a very small part of the total.

The extraction of no more than 1/3 of the daily stream flow is designed to minimise any impact on the vegetation in the depleted reach, bearing in mind the caution about steep gullies in the SSSI Management Statement. At low flows, with the exception of major waterfalls there is almost no "splash pattern" so a change in flow should not affect ferns and similar vegetation. At high flows the fraction extracted is negligible, especially beyond the first 100m when tributaries add to the total.

I have averaged the LowFlows monthly probabilities for Winter (October-March) and Summer (April-September).

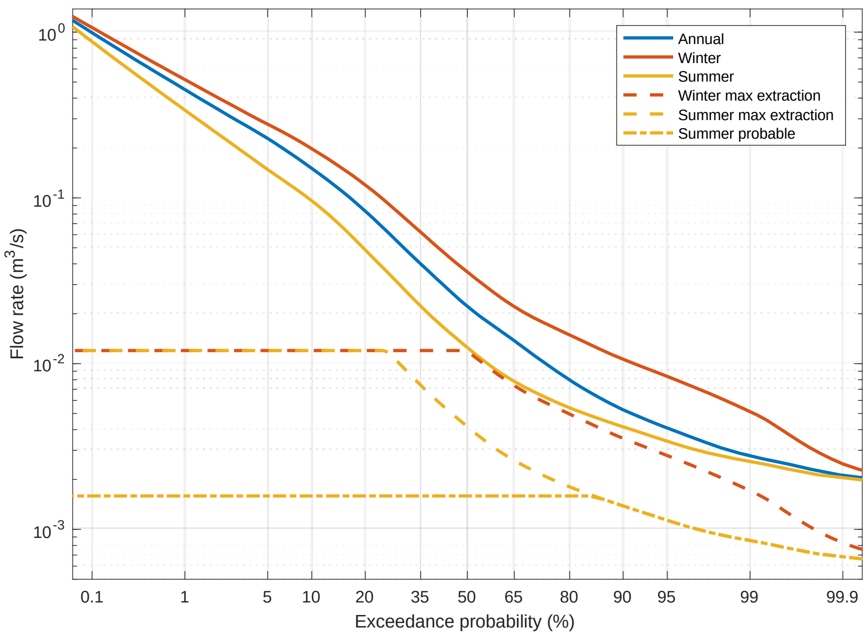

Figure 5. Monthly data from LowFlows grouped into Winter and Summer curves. Maximum *possible* flow (winter+summer max) would be 235000 m³ (12.8% of annual stream flow) maximum *probable* 166000 m³ (9.1%). (Using an 8.8 L/s absolute limit instead of 12 L/s would drop these to 10.6%, 7.6% respectively).

There seems little point in a system that can only operate at full power for a small fraction of the time and is relatively inefficient at other times. The Winter flow curve suggests that the stream flow exceeds 36 litres/sec for 50% of this time i.e. a sensible upper extraction limit might be 12 litres/sec (-- lines in Figure 5). In Summer this flow is exceeded 25% of the time but there is less need for electricity. I have assumed that a high-flow average of 1.5 kW (≈1.5 litres/sec) might be sufficient in Summer ("Summer probable" curve in Figure 5).

The electrical output has been predicted in terms of flow rate, Figure 6, for the two most sensible sizes of HDPE pipe. A 90 mm (outer diameter) pipe would give a peak power of 5.2 kW at 8.8 L/s. The next pipe size, 110 mm, is considerably more expensive and heavier to handle but would give a more stable turbine speed and generator voltage as well as a higher power of 8.1 kW at 12 L/s. It might also reduce the risk of under-performance due to unforeseen pressure drops e.g. at welded joints.

In cold weather the cottage oil consumption for Rayburn and oil stove can reach 20 kW (net output probably about 16 kW). Some electric radiators could reduce this considerably when the stream is high. The system will also avoid running a petrol generator for lighting and appliances.

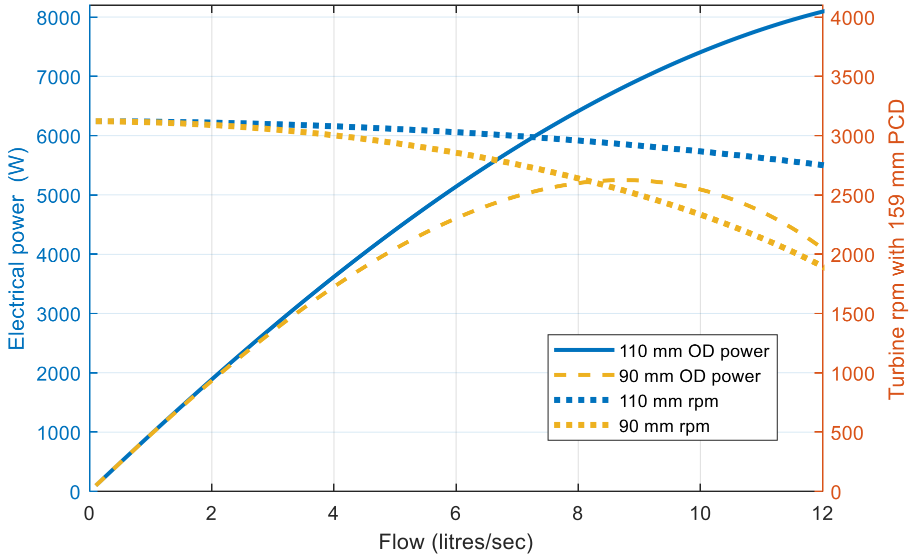

Figure 6. Electricity generation curves based on 150 m head. Typical efficiency 0.83 (turbine) × 0.84 (alternator) × 0.95 (transformers, inverter etc) = 0.66 giving 975 Watts per litre/sec. 0.83 and 0.84 are simply the default values in the Hartvigsen Hydro spreadsheet. The turbine speed calculation is for a "green spoon" wheel with 26 spoons. At higher flows the efficiency falls due to pressure drop in the pipe and (assumed) 4% voltage drop in the cable at 5 kW. In practice, part of the efficiency loss will be a constant frictional drag so the output at very low power might be 100-150 W (guess) less than shown here.

I think on cost grounds I will *probably* be using a 90 mm pipe with a peak flow of 9 L/s but taking 12 litres/sec as a nominal upper flow limit leaves the choice of pipe size open for the moment. [12 L/s gives 8100 Watts with 110 mm pipe. There is little to be gained beyond this point - the peak is 8500 W at about 15L/s].

The WRA form requests an annual energy prediction. To obtain this value the curves in Figure 5 & 6 have been combined into a power probability graph, Figure 7.

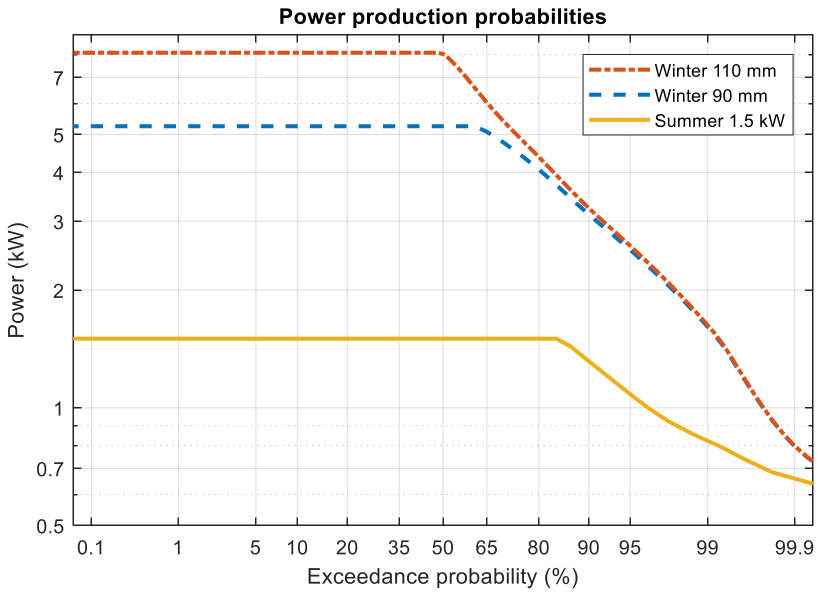

Figure 7. Power probability curves.

The total "probable" annual power from these curves (using all available power in Winter, up to 1.5kW in Summer) is 26.8 MWh for a 90 mm pipe or 34.9 MWh for a 110 mm pipe. In practice the coldest weather in winter is frequently fairly dry and the wettest weather may not be very cold, so the maximum power (and flow rates) would probably not be used to the extent suggested by the curves; conversely there might be times in summer when >1.5 kW was required.
The "maximum possible" equivalents (using 1/3 of stream flow at all times) would be 35.8 and 48.1 MWh for the 90 and 110 mm pipes respectively.

RWM
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