Hafod y Rhedrwydd micro-hydro scheme.

Justification for the proposed dry weather extraction regime.

A minimum extraction rate of 0.6 litres/second is requested under the protected Q95+ regime. The rationale for this is that it should continue to provide enough power to run the UV water sterilising system, refrigerator and some lighting even in dry weather.

Figure 1 shows the net power produced (240V AC in the house) in terms of flow rate and alternator used.

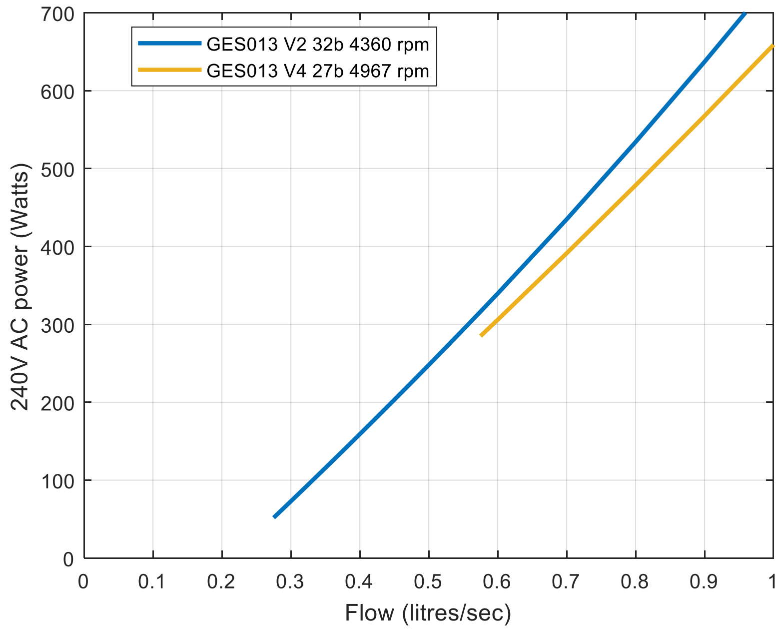

Figure 1. Net power output of 400 W at 0.6 litres/second

This minimum 0.6 litre/second flow rate will not have any significant effect on the depleted reach. The ecological survey notes that the stream grows considerably between the extraction and return points. This growth is partly due to tributaries joining the stream and partly to water seeping out from the ground all along the river bank. The arrows in Figure 2 show where the tributaries join the main stream.

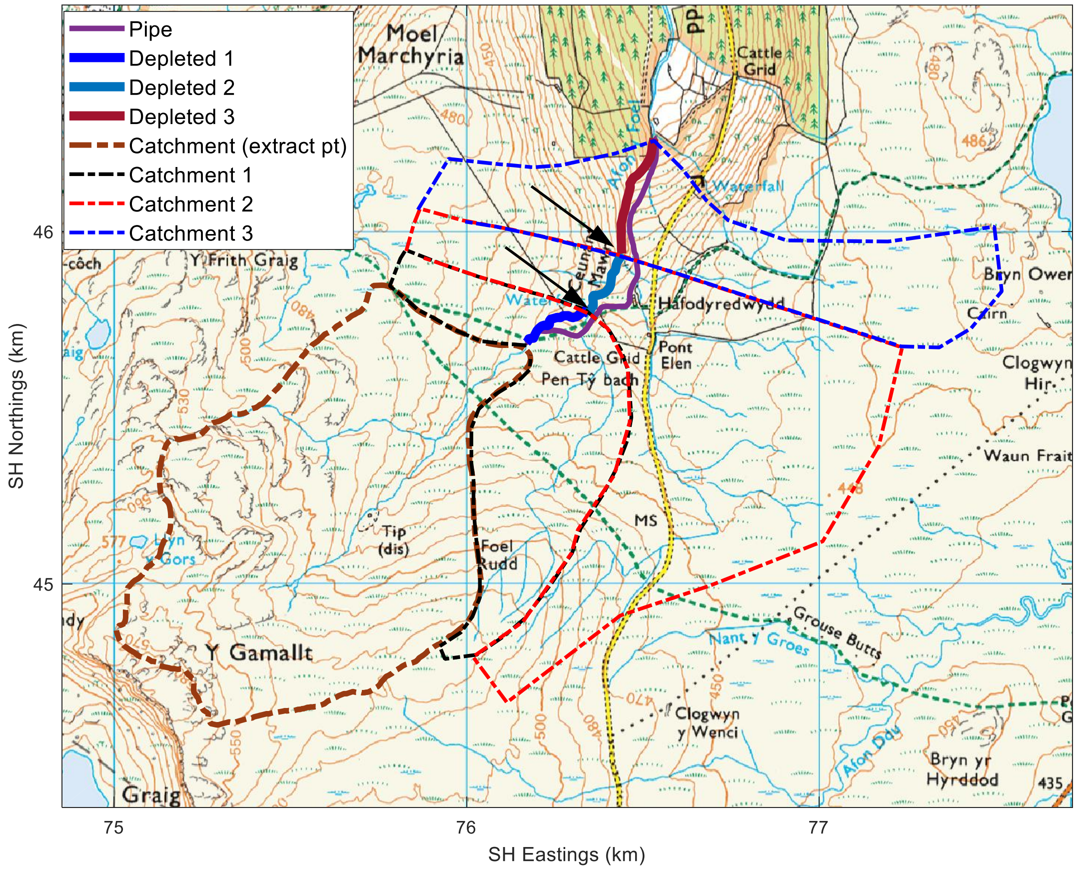

Figure 2. Depleted reach divided into 3 stages, showing progressive increase in catchment area.

An approximate flow rate measurement was taken on 8th July 2018 using a bucket and stop watch (probably not quite catching 100% of the water).

- Extraction point 2.5 litres/sec
- First tributary 0.6 litres/sec
- Second tributary (past the cottage, measured near Pont Elen) 1.1 litres/sec

This was after many weeks of unusually hot and dry weather: 2.5 litres/sec is close to Q99 for the summer months. These results highlight the fact that the tributaries make a significant contribution to the stream flow even in such very dry weather. (n.b. the geomorphology survey suggested that the first tributary dries up in very dry weather. In fact it is not this section that dries up. Two smaller streams merge to create this tributary; of these, the right-hand one in Figure 3 is very open and may dry up but the other is largely sub-surface; it drains a deep blanket bog and showed no sign of drying out.

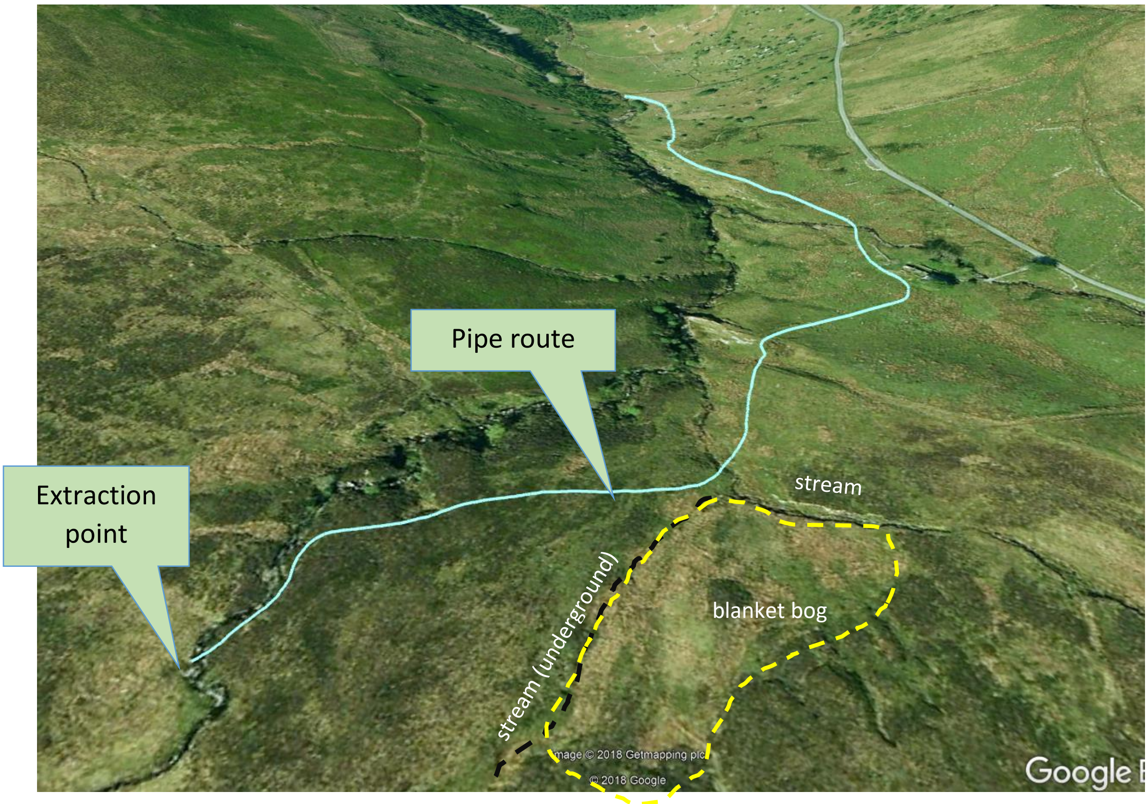

Figure 3. Two branches of the first tributary.

Dividing the 791 m depleted reach into three sections, these flow measurements would give at least 2.5 L/s over 230 m in the top section (Depleted 1 on the map), 2.5 + 0.6 = 3.1 L/s in the Depleted 2 section (211 m) and 3.1+1.1 = 4.2 L/s in the third section (352 metres).

The flows downstream from where the tributaries merged were not measured but they would have risen higher than the sum of the above flows due to seepage from the banks (Figure 4).

Figure 4. Water seepage down sides of gorge (on the survey day, 29/5/2018) adding to stream flow rate.

Judging by the contour lines on the map, the catchment area increases considerably as one moves downstream:

	Catchment increment (km^2)	Total catchment (km^2)
Catchment (extraction point)	0.87	0.87
Catchment 1	0.35	1.22
Catchment 2	0.75	1.97
Catchment 3	0.39	2.36

Discussion with regard to the Ecological Survey.

Page 16 of the survey indicates that the proposed extraction should have little effect on bryophytes and other species:

> Desiccation-sensitive *Microlejeuneaceae* that flourish in high humidity gorges appear to be absent from this locality. However, they, and other species may be found in some of the shadier cliff faces beside the river but there was a lack of time to search these areas thoroughly. In any event, water abstraction from the depleted reach would not affect these species in this habitat.
>
> Thus, the strictly aquatic flora of this river seems to be confined to a few very abundant and showy species such as *Scapania undulata, Hygrohypnum ochraceum, Jungermannia paroica* and *Nardia compressa*. It is considered unlikely these species would be negatively impacted upon by this proposal, especially considering the low abstraction volumes proposed. In addition, the size of the river at the Intake Weir compared with below at the Turbine House shows just how much additional water is coming into the depleted reach from side streams along its length.
>
> One must also take into account the location of this proposed scheme. Despite weeks without rain before the survey was undertaken, the river appeared to be flowing strongly. Map 1 (*essentially Figure 1 above*) shows that the catchment above the Intake Weir is comparatively large. It is underlined by often very deep peat. (The Migneint is important for its blanket and raised bog communities). The presence of this extensive peat will create the so-called sponge effect, releasing stored water over long periods of time even in the absence of rainfall.

Figure 5. Stream at extraction point on the day of the survey (29th May 2018).

Figure 6. Much higher flow rate halfway down Section 3 on the day of the survey.

These findings suggest that the stream could be classified as Zone 3, allowing extraction of up to 70% of the flow above Q95 in addition to any below-Q95 allowance.

The flow observed in the recent extremely dry weather suggests that it would be safe to extract up to 0.6 litres/second when the stream is below the annual Q95 flow rate (4 litres/sec). The detailed month by month predictions from LowFlows are given in Figure 7.

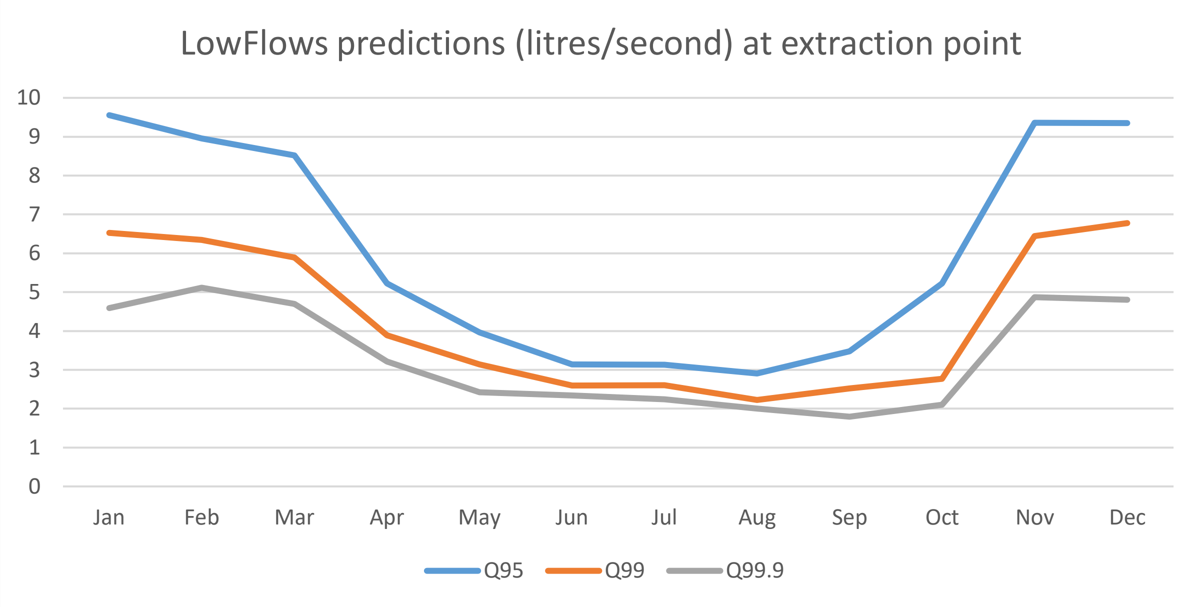

Figure 7. Flow distribution percentage points from LowFlows. These suggest the stream is unlikely to ever be significantly lower than observed recently.

The lowest point in Figure 6 (Q99.9 in September, 1.8 litres/second) is nominally a "once per 1000 years" extraction point prediction for this month; the requested 0.6 litres/second is only one third of this extremely low flow rate.

0.6 litres/sec abstraction is moreover less than 25% of the recent dry spell's 2.5 litres/second and a far smaller fraction of the stream flow further downstream in depletion sections 2 and 3.

The flow will be safeguarded beyond Q95 by hardware to ensure the stream cannot be run dry (see *Weir design details.pdf)*.

Above Q95 part of the stream will pass over the larger Coanda screen. The highest fraction of the stream flow that can be extracted via the screens is 62% - well within the 70% that might be considered appropriate is designated as Zone 3. Further limits could be imposed via the turbine control software which will open and close the spear valve depending on water availability, permitted extraction limits and power requested by the house.

The total stream flow will be calculated as the sum of the penstock flow Q_P (determined from turbine power output) and flow Q_B over the barrage below the screens (see *Weir design detals.pdf*). In principle it could also be calculated from a measurement of head over the screen fairings – this technique would however probably be less accurate.

Power output in terms of flow rate

Component efficiencies have been estimated as follows:

- Turbine: assumed 83% efficiency less a windage loss scaled from the formulae in Thake's *Micro-hydro Pelton turbine manual*.
- Alternator: efficiency curves from the MOOG datasheets, curved-fitted using windage and copper-loss models to allow extrapolation to lower powers.
- Control hardware: assumed 150 W parasitic power consumption for AC-DC converters, inverters, battery charger, valve controllers, optical couplers, Raspberry Pi computers etc. Conversion efficiencies 97% (AC-DC), 93% DC-AC 50Hz (e.g. Steca Solaris PLI).

In practice the maximum flow rate is unlikely to exceed 12 litres/second with the turbines and alternators being chosen for good efficiency at lower power levels rather than the maximum possible power; the maximum power output in practice will be nearer 8 kW instead of the full 9.06 kW. (This avoids the fall in rpm at the highest flow condition).

The control software will save flow readings to disk at 10 minute intervals to allow verification of the fraction extracted. The system will also check that the fibre optic link and electronics are functioning correctly and giving readings consistent with recent rainfall, as measured by a rain gauge situated near the extraction point

Justification for the flow rates used in form WRD table 5.

Abstraction location name / reference	Purpose which water will be used for	Abstraction period (state 'all year' or give months)	Maximum annual abstraction volume (cubic metres)	Maximum daily abstraction volume (cubic metres)	Maximum hourly abstraction volume (cubic metres)	Number of hours of abstraction per day	Peak abstraction rate (litres per second)
Afon y Foel	Hydro-power	All year	293000	1279	53.3	24	14.2
Afon y Foel	Domestic	All year	314	1.48	0.4	24	0.3
Afon y Foel	Hydro-power	Summer (probable)	(24900)				
Afon y Foel	Hydro-power	Winter (probable)	(96700)				
		Total	293314 (122000)	1280.5	53.7		

The maximum annual volume given above for hydro-power is the annual mean of the maximum extractable flow rate (9.28 litres/sec = area under the flow duration curves, taking account of the screen extraction capability and not using more than the turbines 14.2 L/s maximum power flow) × seconds per year. The spear valves maximum aperture will limit the peak flow to 14.2 litres/second i.e. slightly below the 14.8 litres/sec capacity of the Coanda screens.

The probable extraction based on estimated typical electricity usage, when possible, of 1.5 kW (summer 6 months), 6 kW (winter) (flow rates 1.82, 6.62 L/s) is shown in the "probable" boxes. (Qannual_prob from *LowFlows_hyr8.m*)

All hydro-electric water is returned to the stream beside the turbine hut (see *HyR proposal v13.pdf*). Domestic water passes to a septic tank and is not returned to the stream.

The domestic water usage is calculated for 5 people in the cottage. There is a deep claw-footed bath: rough measurements suggest that a shallow bath would be 70 litres, a medium bath 130 litres and a very deep bath 200 litres. The toilet flush is 9 litres and the washing up bowl is 6 litres.

A typical daily usage might be 1 medium bath, 4 toilet flushes and 1 washing up per person = 172 litres (860 litres for 5 people). This equates to 314 m^3 per year (see table above). In practice the average occupancy over the course of the year is less than 2 people so the actual usage would be less than this.

Under the most extreme circumstances (everyone having a deep bath and flushing the toilet 10 times) this could in theory rise to 1480 litres/day = 1.48m^3/day.

The maximum domestic abstraction rate needs to be about 0.3 litres/second to fill the bath in a reasonable time. The maximum instantaneous flow rate 14.2 (hydro) + 0.3 (domestic) = 14.5 L/s is within the 14.8 L/s capacity of the screens when the stream is high. When the stream is very low the turbine control system may need to temporarily reduce the turbine flow rate when water is being diverted to the house.

The maximum hourly domestic abstraction is given as 0.4 cubic metres since it is unlikely that people would have more than two very deep baths per hour (they would run out of hot water).

RWM

November 2018