# Yealmbridge Weir

## Micro-Hydropower Feasibility Study

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## Executive Summary

Yealmbridge Weir lies on the River Yealm in Devon at OS grid ref. SX 590 519. A survey of the site was carried out on 23rd March 2007 to identify the feasibility of installing a modern micro hydropower system to generate renewable electricity.

This report considers two separate proposals; the first, a more ambitious scheme (Scheme 1) would involve the restoration of the 800 m section of leat channel providing a net head of 4.214 m. The second (Scheme 2) would utilise a net head of 2.633 m if developed directly across the weir, provided the weir height was raised by 450 mm.

The installation of the impounding structure would also increase the flow rates which could be diverted through the leat intake for either scheme as the height difference between the weir sill and leat sill would be increased and thus a greater flow proportion could be diverted through the leat intake. The average estimated flow rate at Yealmbridge is 1.370 cubic metres per second during an 'average flow year'. Assuming the weir sill could be raised this would allow an estimated maximum flow rate of 0.505 $m^3/s$ to pass through the leat.

The leat intake mentioned above is located adjacent to the weir. Part of the flow passing through the River Yealm is currently directed through the leat intake which then passes under the road bridge through an arched channel. Immediately downstream of the Road Bridge the entire flow is then redirected through a spillway channel and back into the natural river course at the foot of the weir. Historically the flow would have been diverted along the entire length of leat before discharging back into the natural river course. However due to the decommissioning of the mill a flow no longer passes through the mill leat. The leat has become heavily overgrown and silted following the decommissioning of the site some decades ago. For Scheme 1 to proceed the entire length of leat would require reinstating, which would be an expensive and complicated project in its own right.

This report has considered two types of turbine; a crossflow turbine for both Scheme 1 and 2, and a 400 mm rotor-diameter Polymer Turbine as an alternative for Scheme 2. It would not be possible to use a 400 mm Polymer Turbine for Scheme 1 because it falls outside it's operating flow boundaries. In each case the power outputs and annual energy captures have been calculated.

The implementation of Scheme 1 would require a greater reserve flow in comparison to Scheme 2 due to the length of leat resulting in a longer depleted reach along the natural river course. Based on a $Q_{95}$ reserve flow requirement a Crossflow turbine system implemented in accordance with Scheme 1 would have a maximum power output of 13.7 kW and would produce 87,179 kWh per year, which would be worth £7,323. This is enough electricity for 19.8 average UK homes and would prevent the emission of 38.7 tonnes of $CO_2$ into the atmosphere each year. The estimated total project cost is £124,660 + vat excluding grant funding.

The Yealm is a sensitive, salmon and sea-trout bearing river which is reflected by the incorporation of a fish-pass into the weir design as a means to provide fish passage up and downstream of the site during migratory periods. Due to the sensitivity of the site the Environment Agency may require a greater reserve flow if Scheme 1 is to proceed than is typically specified for less sensitive sites. To demonstrate the impact on the annual energy capture as a result of an increase in the reserve flow requirements, further analyses have been performed based on $Q_{80}$ and $Q_{95}$ + 50% of the remaining flow as a reserve flow requirement to pass through the depleted reach. The analysis performed has been discussed within the main body of the report

Scheme 2 has the option to utilise either a crossflow turbine or a 400 mm Polymer Turbine. A Crossflow turbine would have a maximum power output of 8.6 kW and would produce 58,888 kWh per year, which would be worth £7,067. This is enough electricity for 13.4 average UK homes and would prevent the emission of 26.2 tonnes of $CO_2$ into the atmosphere each year. The estimated total project cost is £95,565 + vat excluding grant funding.

The 400 mm Polymer Turbine system would have a maximum power output of 7.3 kW and would produce 50,006 kWh per year, which would be worth £6,001. This is enough electricity for 11.4 average UK homes and would prevent the emission of 22.2 tonnes of $CO_2$ into the atmosphere each year. The estimated total project cost is £58,225 + vat excluding grant funding.

The projected installation costs will be significantly influenced depending on whether the weir sill can be raised by a fixed or tilt-gate structure.  This will only become apparent following initial consultation with the Environment Agency.

The general proposal at the Yealmbridge site is unusual because it is not related to a specific property, which would make grid connection simpler and allow the property to offset some of its electricity bill.  A new electrical connection would have to be made to the turbine house location, and all of the electricity produced would be sold back to the grid.

The income produced by the system is relatively low compared to the estimated project costs. Scheme 2 presents the most viable proposal for the project to progress (i.e. not restoring the leat), notably if the weir sill height could be raised using a fixed stop-log arrangement.

For either Scheme to proceed landownership issues will have to be one of the first areas to address. The time involved for this stage has not been accounted for within this study.  Following negotiation of landownership some initial consultations with the Environment Agency and local planning authority would need to be held to find out which licenses and consents would be required.  Once this was established, the outline design work could commence, followed by the applications for the required consents, pursued by the detail design stage.  The turbine would then be ordered, preparatory works completed and then the system installed.  The whole project would take at least 14 months to complete.

## Hydraulic head measurement

The Hydraulic head (or ‘head’) at a hydropower site is defined as the difference between the upstream water level at the intake and the downstream water level at the discharge point. The gross head is the as-measured difference before head losses in the proposed hydropower system are considered. The net head is the gross head minus system head losses, and is the actual head that the turbine ‘sees’ to generate power.

The system head losses are pressure losses caused by the water flowing around bends or hydraulically inefficient shapes, or by skin-friction as the water rubs against a pipe wall. A good system design will keep head losses to a minimum, but losses of at least 10% of the gross head should still be expected.

The gross head for scheme 1 was measured between the estimated water level in the leat near Mill Cottage (point A in Figure 2) and the water level in the natural river course (point B in Figure 2).

The gross head for scheme 2 was measured between the water level just upstream of the weir (point C in Figure 2) and the water level just downstream of the weir (point D in Figure 2).

<u>Estimated head between leat and river (scheme 1)</u>

Gross head = 4.682 metres.

Net head (assuming 10% head losses) = 4.214 metres.

Scheme 1 would be subject to the re-instatement of the leat which due to landownership issues and reserve flow requirements through the depleted river reach could prove too complicated to be viable.

<u>Estimated head across weir (scheme 2)</u>

Gross head = 2.476 metres.

Net head = 2.228 metres.

If a new hydro system was installed it may be possible to raise the upstream water level by 450 mm with the installation of a fixed structure or a tilt-gate integrated on the weir. The effect of increasing the upstream water level would give the following gross and net heads.

Gross head = 2.926 metres

Net head (assuming 10% head losses) = 2.633 metres

From this point forward, this report assumes that a net head 4.214 is available for Scheme 1 and 2.633 metres is available with respect to Scheme 2.

## Flow data

There is an Environment Agency (EA) gauging station at Puslinch, 2 km downstream of the site. This can provide 33 years of long-term flow data for the River Yealm. The mean daily flow data at this gauging station were obtained, checked for completeness and processed to produce the Flow Duration Curve shown in Appendix 1.

The flow in the River Yealm at the gauging station at Puslinch will be greater than the flow at the proposed hydropower site at Yealmbridge Weir. To estimate the additional flow contributed between these points, the catchments of the gauging station and Yealmbridge Weir were modelled using Low Flows[1] flow modelling software as shown in Appendix 2. For the gauging station, the Low Flows model calculated a mean flow of 1.609 $m^3/s$, which is more than the gauged mean flow of 1.45 $m^3/s$. The difference may be due to water abstraction, which is not considered by the model. For Yealmbridge Weir, Low Flows calculated a mean flow of 1.523 $m^3/s$.

The small difference between actual gauged flows and Low Flows estimated flows is not important because the Low Flows data was only used to calculate the Correction Factor as shown below, and any errors would be cancelled out in the maths.

The Yealmbridge Weir Flow Duration Curve shown in figure 1 was calculated by multiplying the gauging station flow data by a Correction Factor which takes into account the increased catchment. The Correction Factor $F_Q$ is given by

$$CF_Q = \frac{Q_{site\,(LowFlows)}}{Q_{gauge\,(Lowflows)}} = \frac{1.523\ \mathrm{m^3/s}}{1.609\ \mathrm{m^3/s}} = 0.947\ .$$

The average flow at the site has thus been estimated to be 1.37 $m^3/s$. The annual flow characteristics are shown in the Flow Duration Curve in figure 1. The data are also summarised at key $Q_{xx}$ values[2] in Table 1.

The geometry of the leat intake limits the maximum flow which can be diverted through the hydro system. The geometry of the leat intake is fairly constant along its length with a width of approximately 1.320 metres and a bed level 507 mm below the weir sill level.

To maximise the power output at the site it would be necessary to increase the sill height of the weir by either installation of a tilt-gate system or fixed structure. The effect of increasing the weir sill would force a greater flow proportion through the leat intake. Measurements taken of the bank-full stage levels identified the bank height could sufficiently support a 450 mm increase in the weir sill level and thus the upstream water level, while still providing additional bank clearance. Based on such an arrangement a maximum flow rate of approximately 0.505 $m^3/s$ could be diverted through the leat intake. This has been assumed as the maximum available flow rate to the turbine throughout this report.

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[1] Low Flows is a software program which uses rainfall records and a variety of other datasets to predict long term average flow and flow distribution from user-defined catchments in the UK.

[2] $Q_{xx}$ is the flow in the river equalled *or exceeded* for xx % of an average year.

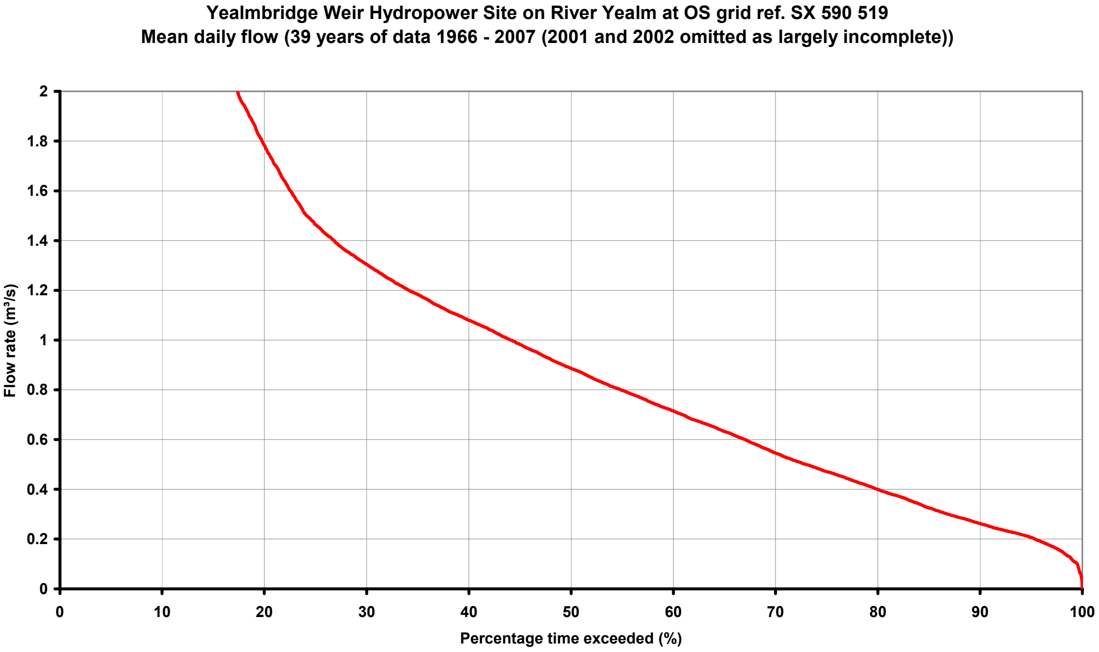


Figure 1 – Annual Flow Duration Curve for Yealmbridge weir.

| **Percentage Exceedence (%)** | **Flow Rate (m³/s)** |
|---|---|
| $Q_{10}$ | 2.97 |
| $Q_{20}$ | 1.78 |
| $Q_{30}$ | 1.30 |
| $Q_{40}$ | 1.08 |
| $Q_{50}$ | 0.89 |
| $Q_{60}$ | 0.71 |
| $Q_{70}$ | 0.55 |
| $Q_{80}$ | 0.40 |
| $Q_{90}$ | 0.26 |
| $Q_{95}$ | 0.21 |
| $Q_{mean}$ (Q27.7) | 1.37 |

Table 1 – Summary of Annual Flow values for Yealmbridge weir.

## Existing infrastructure

Yealmbridge weir is located on the River Yealm, in Yealmbridge Devon. The existing layout shows a weir, perpendicular to the flow (see Figure 3), approximately 11.6 metres in length equal to the width of the existing channel at that point. The weir has been constructed in three steps as shown in Figure 10 immediately below the road bridge. The uppermost step has a fish-pass on the east side of the weir, (see Figure 4) to allow up and downstream fish passage. The leat intake has been constructed as an arched channel beneath the road bridge (see Figure 5) immediately adjacent to the weir and runs for approximately 800 metres along the river bank, generally parallel to the natural river course.

Figure 3 shows the main water course approaching the weir and leat intake. Historically the weir would have diverted a large proportion of the flow through the mill leat; However due to the decommissioning of the mill the sluice gate shown in Figure 7 has been lowered and thus diverting the entire flow through the spillway channel and back into the natural river course immediately below the weir as shown in Figure 8.

The main length of the leat has become heavily silted and overgrown following the decommissioning of the mill. If the leat was to become re-instated the entire length of leat would require de-silting and the removal of vegetation and fallen trees.

A typical leat construction will utilise the slightest possible gradient to enable flow along its length. Because the gradient of the natural river course is greater than that of the leat, the result is an increase in head measured between the leat and the natural river course at successive, downstream locations. It is notable that the Yealmbridge leat does not maximise the available head at the site, given the length of leat. This has been identified by the higher leat gradient, once perceived near Smithy, as shown in Figure 2; at this point the leat is seen to turn towards the river. The head loss at Smithy could have been quite intentional as power may once have been extracted from the leat at this point. It is not unknown for a leat to power several waterwheels in series in this way.

The leat was explored no further than Mill Cottage due to the recent housing development which now obstructs the course of the leat, though historically it would have clearly continued further; this is demonstrated by another sluice gate marked on the map in Figure 2 just below Mill Farm.

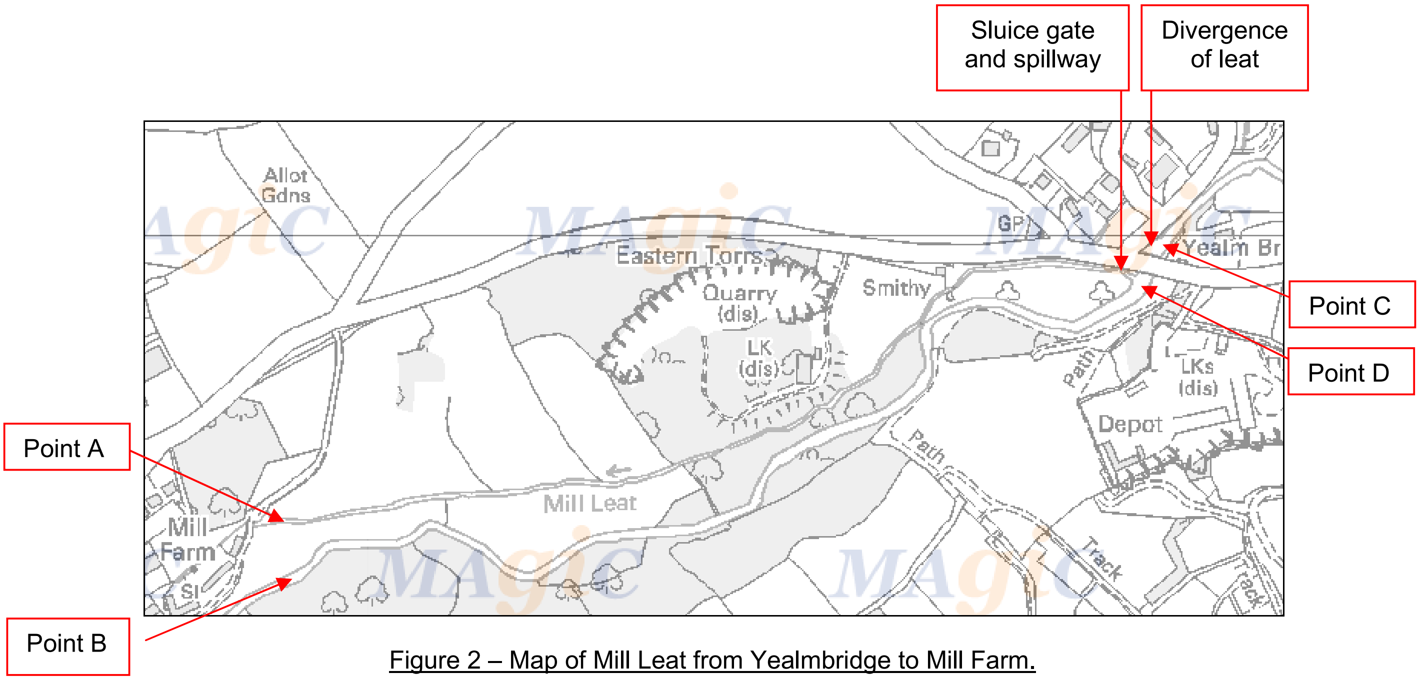


Figure 2 – Map of Mill Leat from Yealmbridge to Mill Farm.

The properties around Yealmbridge and Mill Farm all have electrical connections to the grid, so it would be relatively simple to get a new electrical connection installed for a hydro system.

The photos in Figures 3 to 15 show relevant views of the River Yealm, the leat channel, the channel banks and impounding structures. Curved arrows show the direction of the flow.

Figure 3 – Divergence of leat from River Yealm, looking downstream.

Figure 4 – Fish pass.

Figure 5 – Entrance to leat tunnel, looking downstream.

Figure 6 – View downstream through leat tunnel.

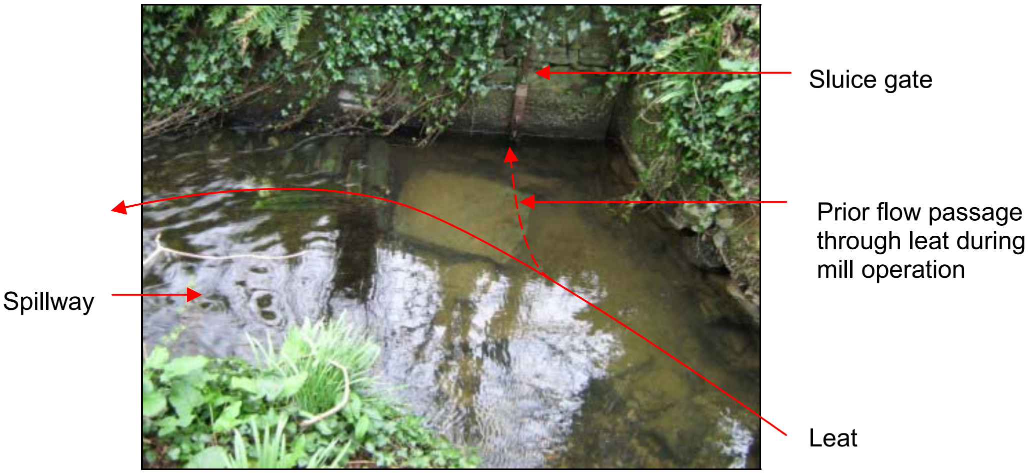


Figure 7 – Sluice and spillway just downstream of leat tunnel.

Figure 8 – View of spillway discharging into River Yealm, looking downstream

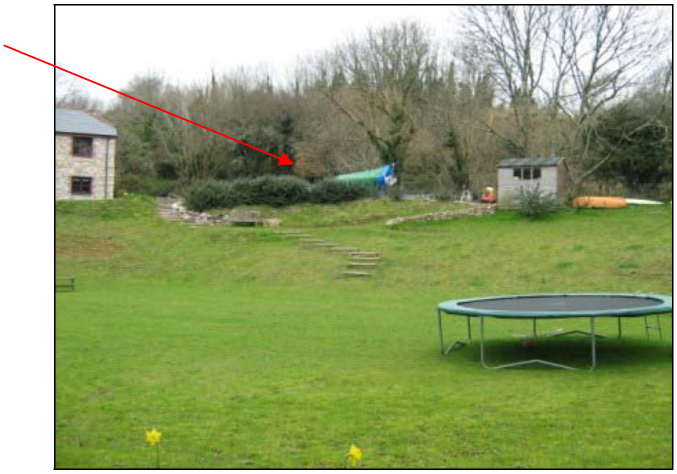
Figure 9 – Stone structure adjacent to spillway. This may have been a channel which allowed the leat to be drained while the sluice remained closed

Figure 10 – Three steps of weir, looking upstream

Figure 11 – Lowest step of weir, looking across weir structure.

Figure 12 – Impediment to flow – rock lying across leat.

Figure 13 – Some trees fallen across leat.



End of leat

Figure 14 – Part of the Mill development just South of Mill Farm.

Figure 15 – River Yealm at the foot of the Mill development.

## Proposed system design

The most appropriate size of turbine for a particular site depends on the flow and head characteristics of the site. A correctly sized turbine will produce the highest annual energy capture (measured in kWh) and is a compromise between making best use of higher winter flows while still having a system that can operate on lower flows during drier parts of the year. As a first approximation, initial turbine sizing is based on the mean (average) flow minus the reserve flow, though this initial estimate is then modified depending on what standard and available turbines types are within the project budget.

Reserve flow

The reserve flow is the flow in any depleted river section. A depleted river section is any stretch of river which sees a smaller than natural flow because water has been diverted elsewhere, such as through a hydropower system. Hydropower sites that have a leat or penstock pipe to transfer water away from the natural river course have a depleted section between the intake to the leat or penstock and the point where the water is returned to the river. Such sites must have a 'reserve flow' always passing down the depleted river section to maintain the ecology.

The size of the reserve flow for both Schemes 1 and 2 would have to be agreed with the Environment Agency (EA). The reserve flow requirement will vary greatly depending on which Scheme is implemented. The re-instating of the leat as suggested in Scheme 1 would result in a depleted reach for a significant stretch of the natural river course and consequently would require a higher reserve flow requirement in comparison to Scheme 2 which would only leave a depleted reach through the fish-pass and across the weir.

Below discusses the likely EA reserve flow requirements for both Schemes 1 and 2.

- Scheme 1

For such a depleted reach the EA often arbitrarily defines the reserve flow as the $Q_{95}$ flow measured from the Flow Duration Curve (FDC) shown in Figure 1. The $Q_{95}$ is defined as the flow rate in the river equalled or exceeded for 95% of the year. At Yealmbridge the $Q_{95}$ flow rate is 0.210 $m^3/s$ and has been assumed as the reserve flow rate which must be maintained to pass over the fish-pass and through the natural river course.

The River Yealm is a salmonoid river; therefore it is likely the EA may increase the reserve flow requirements. On Pages 25 and 26 reserve flows of $Q_{80}$ (0.40 $m^3/s$) and a worst case scenario of $Q_{95}$ + 50% flow split have been modelled using the Design Summary Software. The results show the impact of the higher reserve flow requirements on the annual energy capture and income from the sale of generated electricity.

- Scheme 2

The system layout presented in Scheme 2 would only leave a depleted flow through the fish-pass and across the weir; the weir being of little ecological value due to the high velocity of the water passing over it and its masonry construction should only require a 'sweetening flow'. The fish-pass however would require a reserve flow to support the movement of migratory fish to move up and downstream.

Based upon other similar sites with respect to ecology and flow regimes, a minimum reserve flow rate of 0.125 $m^3/s$ has been estimated; 0.075 $m^3/s$ to flow through the fish pass at all times and a minimum reserve flow of 0.050 $m^3/s$ to flow over the weir at all times for aesthetic reasons and to maintain a wetted surface across the weir.

The above reserve flow requirements have been assumed throughout this report. If the project progresses, the next step would be to consult with the Environment Agency (EA) to check which licenses would be required for the project to proceed and confirm any reserve flow requirement.

Turbine choice

For both, Scheme 1 and 2, a Crossflow turbine would present the best option for the available flow and head characteristics of the site. Crossflow turbines manufactured by Ossberger of Germany have a guaranteed efficiency of 80%. Figure 16 shows a typical Ossberger Crossflow turbine installation.

A lower-cost solution would be a modular Polymer Turbine as shown in Figures 17 and 18. However due to the head variation between Schemes 1 and 2 it would only be possible to utilise the Polymer Turbine system on the head and flow resource presented by Scheme 2.

Detailed descriptions of the Ossberger and the Polymer Turbine options follow.

**Scheme 1 (turbine options)**

Crossflow turbine

Figures of 80% turbine efficiency ($Q_{rated}$), 93% drive efficiency and 89% generator efficiency are assumed for this system, giving a total efficiency ('water to wire') of 0.80 × 0.93 × 0.89 = 0.662 (or 66.2%). Using a net head of 4.214 m and a turbine rated flow of 0.50 $m^3/s$, the electrical power output of an Ossberger Crossflow turbine system would therefore be:

Maximum electrical power = 4.214 × 0.500 × 9.81 × 1000 × 0.662

= 13.68 kW

Figure 16 – Typical Ossberger Crossflow turbine installation. (Town Mill, Lyme Regis, Devon).

Ossberger Crossflow turbines can operate with flows down to approximately 1/6 of the maximum flow, corresponding to 0.083 $m^3/s$ through the turbine. The Crossflow turbine would be operating at the maximum power output of 13.7 kW whenever there was a flow of at least 0.710 $m^3/s$ in the river (0.210 $m^3/s$ reserve flow + 0.50 $m^3/s$ through the turbine). This would be available for approximately 60.3 % of an 'average flow' year. The turbine would continue to operate down to 1/6 of the maximum flow at reduced power output for a further 27.1 % of the year. It would therefore be operating for 87.4 % of an 'average flow' year.

The maximum power output rating and the operating regime calculated above are for the most optimistic abstraction regime thought possible for the site. Other, more restrictive abstraction regimes are considered on pages 25 and 26. The maximum power and operating regime will alter in accordance with the EA abstraction regime imposed.

**Scheme 2 (turbine options)**

Crossflow Turbine

Figures of 80% turbine efficiency ($Q_{rated}$), 93% drive efficiency and 89% generator efficiency are assumed for this system, giving a total efficiency ('water to wire') of 0.80 × 0.93 × 0.89 = 0.662 (or 66.2%). Using a net head of 2.633 m and a turbine rated flow of 0.50 $m^3/s$, the electrical power output of an Ossberger Crossflow turbine system would therefore be:

Maximum electrical power = 0.500 x 2.633 x 9.81 x 1000 x 0.662

= 8.55 kW

Ossberger Crossflow turbines can operate with flows down to approximately 1/6 of the maximum flow, corresponding to 0.083 $m^3/s$ through the turbine. The Crossflow turbine would be operating at the maximum power output of 8.6 kW whenever there was a flow of at least 0.625 $m^3/s$ in the river (0.125 $m^3/s$ reserve flow + 0.50 $m^3/s$ through the turbine). This would be available for approximately 65.5% of an 'average flow' year. The turbine would continue to operate down to 1/6 of the maximum flow at reduced power output for a further 29.4% of the year. It would therefore be operating for 94.9% of an 'average flow' year.

Modular Polymer Turbine

The system which has been considered is a vertical axis modular Polymer Turbine, currently being developed and manufactured by ourselves, Hydro Generation Ltd. This turbine is a much simpler design, simplifying the installation and maintenance. It can be assembled on site from smaller, lighter parts, and consequently does not require a large crane (although a small crane would still be required). The Polymer Turbine is also designed to withstand the elements without the protection and support of a masonry turbine house, although an enclosure can be constructed from wood cladding to conceal the hydro system for aesthetic purposes if specified by the site owner. The system is available in 200, 400 and 600 mm rotor sizes. The smallest 200 mm fixed-flow system has been launched on the market. Development of the 400mm variable-flow unit specified is underway and it is anticipated that it will be available within the time frame for the implementation of this site.

The current Polymer Turbine design has no mechanism to regulate the flow rate through the turbine. This means that it is a fixed-flow turbine and is only able to operate on a single flow rate. The inability to regulate the flow rate downwards during drier periods of the year means that the annual energy capture would be less than an equivalent variable-flow turbine. Hydro Generation Ltd is developing a variable-flow version which will use moveable inlet guide vanes in a similar way to a semi-Kaplan turbine. This would allow the turbine to operate with reasonable efficiency down to ¼ of the maximum flow rate. At the Yealmbridge site (Scheme 2) the turbine would continue to operate whenever there was a flow rate of at least 0.122 $m^3/s$ passing through the turbine.

The Polymer Turbine system located across the weir would continue to operate whenever there was a flow rate of at least 0.488 $m^3/s$ available to the turbine on a net head of 2.633 metres.

The maximum electrical power output for a single 400 mm variable-flow Polymer Turbine is calculated below. Component efficiencies of 70% turbine efficiency ($Q_{rated}$), 93% drive efficiency and 89% generator efficiency have been used in the estimates, giving a total efficiency of 0.70 x 0.93 x 0.89 = 0.579 (or 57.9%). So:

Maximum electrical power = 0.488 x 2.633 x 9.81 x 1000 x 0.579

= 7.298 kW

The Polymer Turbine would produce 7.3 kW whenever there was a flow rate of 0.613 $m^3/s$ passing through the river (0.125 $m^3/s$ reserve flow + 0.488 $m^3/s$ through the turbine). This would be for approximately 66.2% of an 'average flow' year. The Polymer Turbine would continue to operate down to 1/4 of the maximum flow rate at a reduced flow rate and power output for a further 25% of an 'average flow year'. It would therefore be operating for 91.2% of an 'average flow' year.

Figure 17 – 3 x Polymer Turbine installation. (Crabble Mill, Dover, Kent).

Figure 17 shows three, 200 mm Polymer Turbines recently installed in Kent. The Yealmbridge project would only require a single 400 mm Polymer Turbine system. The footprint of the proposed Polymer Turbine system for the Yealmbridge site is shown in Figure 18.

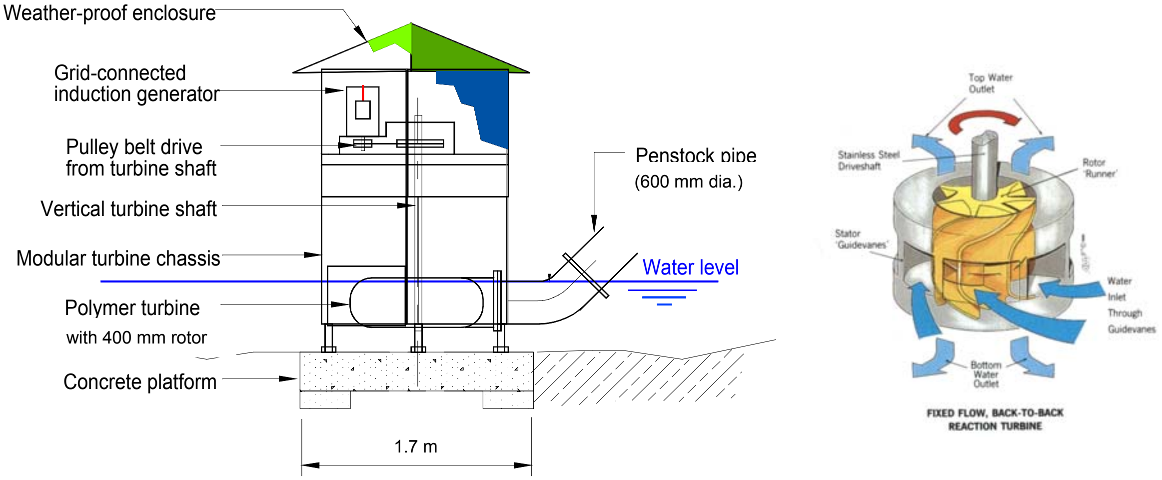


Figure 18 – Typical installation layout for Polymer turbine installation & turbine sketch.

### Optimum system layout

The orientation and footprint size of the hydro system, depending on which Scheme is implemented, is shown in Figures 20 & 21.

The raising of the weir sill would consist of either a fixed structure (i.e. stop-log boards), built on top of the current weir or by installing a tilt-gate system which could be lowered during high-flow periods. Ideally a fixed structure will be accepted by the EA, however this will only become apparent following the initial consultation period. Subsequent to assessment it may be possible to utilise the existing weir as a foundation for the installation of the tilt-gate system. This would be identified following sufficient appraisal of the existing weir structure during the detail design stage. The cost estimate for the Tilt-gate foundations, central piers and bank sections provided in Tables 2, 3 and 4 have been based on the assumption of a new build.

The intake screen would either be built at the end of the leat channel (Scheme 1, Figure 20) or immediately upstream of the leat intake (Scheme 2, Figure 21). The screen would be inclined to approximately 30° from horizontal so that accumulated debris tended to be pushed towards the top of the screen and deposited at the end of the leat (Scheme 1) or washed back into the natural river course (Scheme 2). From the intake screen the water would flow through a 600mm penstock pipe to the turbine and discharge into the natural river course. A section of the river bank would have to be removed to allow a sump to be formed for the turbine discharge into; this is because the crossflow turbine must discharge into a water depth of at least 700 mm and the Polymer Turbine into a water depth of 500 mm to avoid any losses from the flow becoming restricted

The crossflow turbine would be positioned approximately 1-1.5 metres above the water level on a four-legged steel structure. Once the flow has passed through the crossflow turbine it would then discharge through a draft tube underneath the turbine. A draft tube is a specially shaped pipe that passes the water from the turbine to the watercourse while still maintaining the low pressure across the turbine, enabling almost all the energy to be extracted from the flow of water which passes through the hydro system.

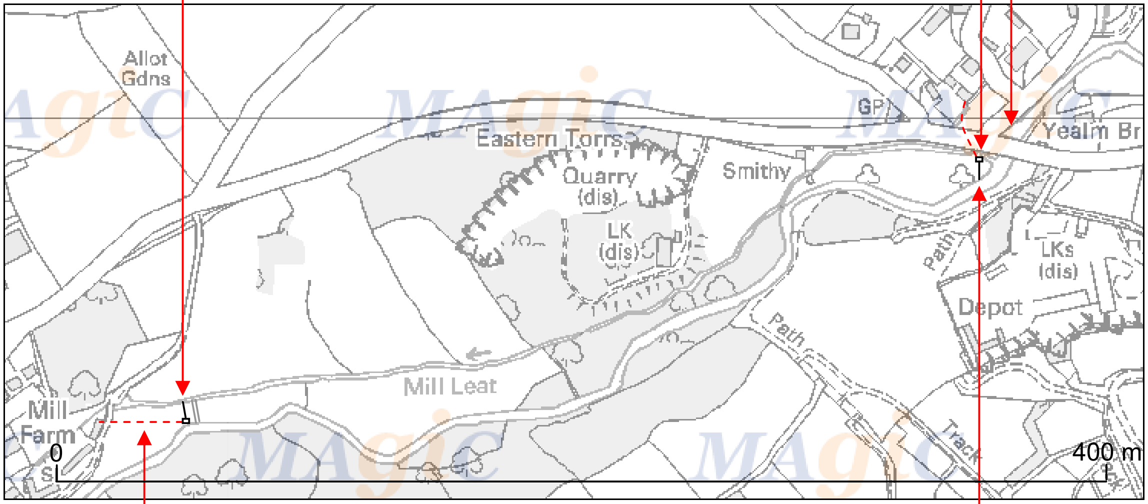
The Polymer Turbine comes with its own integrated chassis system which supports the turbine and generator. The configuration of the Polymer Turbine varies in that the turbine and outer casing is submerged below the water level; this eases the installation of the hydro system as it avoids the installation of a draft tube and the need to support large heavy component parts. All of the Polymer Turbine parts are designed to operate outside, so there is no need for a turbine house; however construction of an enclosure for the generator and working parts for aesthetic purposes is also a possibility. The chassis bolts to a strong masonry base or four concrete piles into the ground. In the case of piles, the surrounding loose ground is protected from erosion by a tough plastic ‘discharge undertray’.

The generator would be positioned directly above either of the two turbines and coupled via a pulley / vee-belt drive system.

Spillway, penstock, turbine, generator (scheme 1)

Sluice gate and spillway

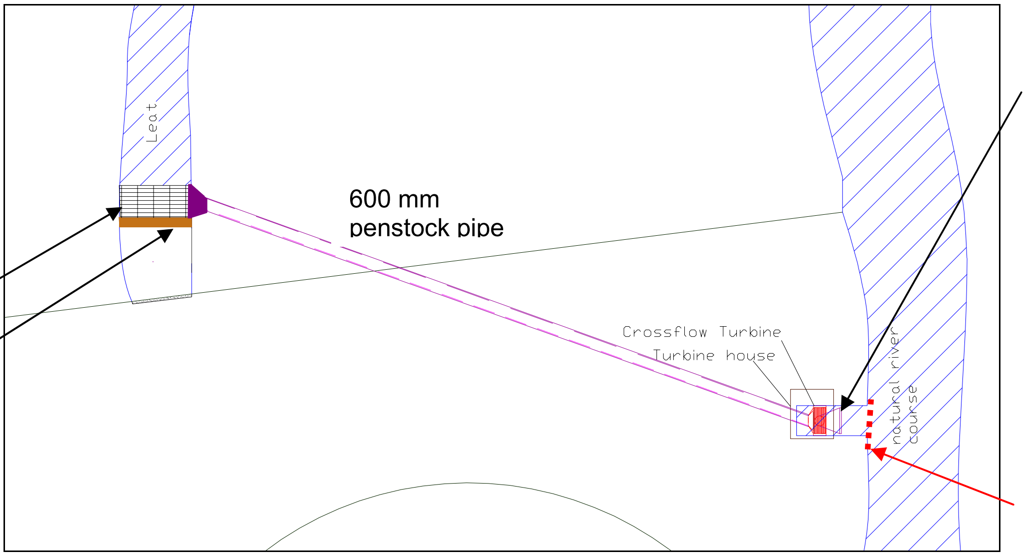
Divergence of leat



Power cable to Mill Farm (scheme 1)

Turbine, generator, tailrace and power cable to nearby property (scheme 2)

Figure 19 – Yealmbridge site plan.



Draft tube (submerged)

Intake screen

Debris raking platform

Behavioural Barrier

Figure 20 – Schematic diagram of proposed hydropower system (*Scheme 1*).

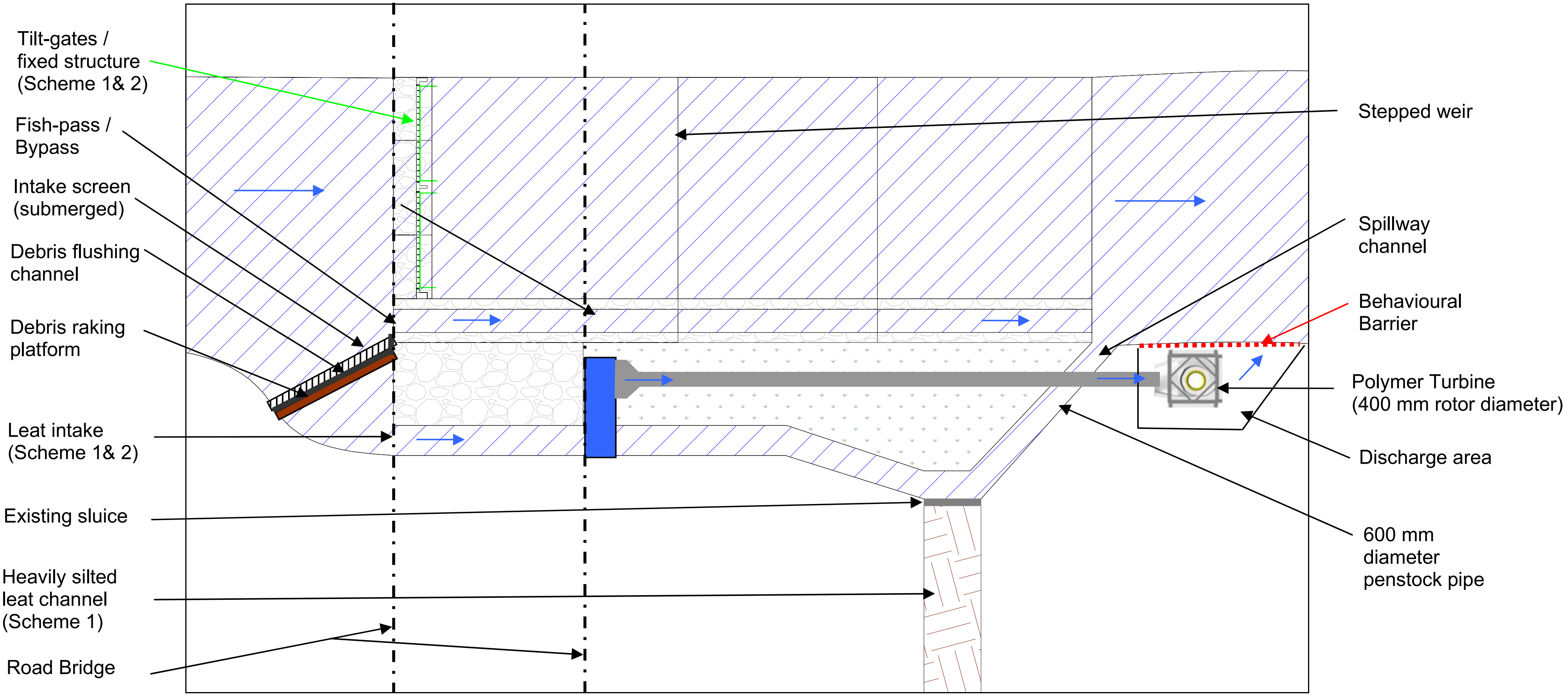


Figure 21 – Schematic diagram of proposed hydropower system (*Scheme 2*).

Intake screen

A hydro turbine intake screen is basically a screen that prevents leaves and larger debris from entering the penstock pipe and passing through the turbine, potentially causing damage to the rotor. The screen also prevents the ingestion of fish and other aquatic animals.

Due to the River Yealm being a migratory river an intake screen with a bar spacing of 12.5 mm should be sufficient. The profile of the intake screen would be angled to direct any downstream fish movement towards the fish pass / bypass channel and across the weir as shown in Figure 21. Because the Yealm is a migratory river a ‘behavioural barrier’ or physical screen may also be required immediately downstream of the turbine discharge to avoid any fish trying to swim upstream through the turbine during migratory periods. Again the ‘behavioural barrier’ or discharge screen would be angled to direct all fish up the natural river course (Scheme 1) or towards the fish pass / bypass (Scheme 2).

If the project proceeds, one of the next steps would be to consult with the EA to check the intake and discharge screen configuration and confirm any bar spacing requirement.

Figure 22 – A typical modern intake screen.

It is important that the intake screen is kept clear of debris accumulation at all times, otherwise the turbine could automatically shut down due to insufficient water supply. At Yealmbridge it would be possible to incline the screen at a shallow angle from horizontal so that debris was always pushed towards the top of the screen and washed away during higher flows. A debris-flushing channel on the downstream side of the screen would collect the debris and direct it back into the river. Some additional manual clearing would still be required, especially during autumn when the river was full of leaves. Manual clearing is achieved using a rake and normally takes a minute or two. A typical modern intake screen is shown in Figure 22.

For sites such as Yealmbridge, the screen would be particularly prone to debris accumulation. It may be prudent to install an automatic intake screen-cleaner, as a simple manually-raked screen may prove too labour intensive, especially during the autumn months as leaves are abundant within the watercourse. The cost for an automatic screen-cleaner would be approximately £10,000 plus vat and has **not** been included in the cost estimates shown in Tables 2 to 4. Figure 23 shows a typical automatic intake screen cleaner.

Figure 23 – Automatic intake screen cleaner.

System control

Modern micro-hydro systems use a water level sensor in the intake area to regulate how much water passes through the turbine. The water level sensor measures the upstream water level and adjusts the flow rate through the turbine to make sure that the upstream water level stays within an acceptable range, normally +/- 10 mm. If a reduction in water level was detected, a powered actuator on the turbine inlet guide-vane would close slightly to reduce the flow rate through the turbine. If the water level then stayed static, the turbine would continue operating with the same flow rate. If it continued to fall the actuator would close the inlet guide-vane some more. If it rose the actuator would open the inlet guide-vanes to increase the flow rate through the turbine.

This process occurs constantly, so the system is effectively infinitely variable and constantly aiming to maintain the upstream water level. If more flow was available than could pass through the turbine, the inlet guide-vanes would open fully, then if the upstream water level continued to rise the excess water would flow over the intake screen and into the bypass pool, exactly as it does now. If the upstream water level continued to fall even when the turbine was passing its minimum flow rate, it would shut-down automatically and allow the water level to recover. Once recovered, the turbine would re-start automatically.

Electrical system

The electrical system would be grid-connected. Grid-connection makes it simpler to guarantee the quality of the electricity generated. Electricity flows like water and will always follow the easiest route. At Yealmbridge all of the electricity produced by the hydro system would be exported to the grid via an export meter.

There are two sets of rules that govern how micro hydro systems are allowed to grid-connect called G83 and G59. G83 is a simplified method for smaller systems up to 3.7 kW single-phase or 11 kW three-phase output. G59 is a more complicated set of rules for larger systems.
Scheme 2 would connect using the three-phase G83 rules for both turbine options. Scheme 1 would connect in accordance with the stricter, three-phase G59 rules. Standard grid connection units for both are available to achieve this.

From the generator the power would be transferred to the grid connection unit (which is also the hydro system controller) via an armoured cable. The grid connection unit is approximately 500 mm x 500 mm x 300 mm (H x W x D) and is normally wall-mounted in an easily accessible weatherproof area. From the grid connection unit the power would connect to the nearest grid connection point, which would be the nearest three-phase distribution transformer. A typical G83 grid connection unit is shown in Figure 24 (the G59 unit looks similar).

An export meter would record the total amount of renewable electricity generated and would be used to sell the electricity and claim the value of the Renewable Obligation Certificates (ROCs) and Levy Exemption Certificates (LECs), which make up a significant proportion of the electricity value.

Figure 24 – G83 grid connection unit / hydro system controller.

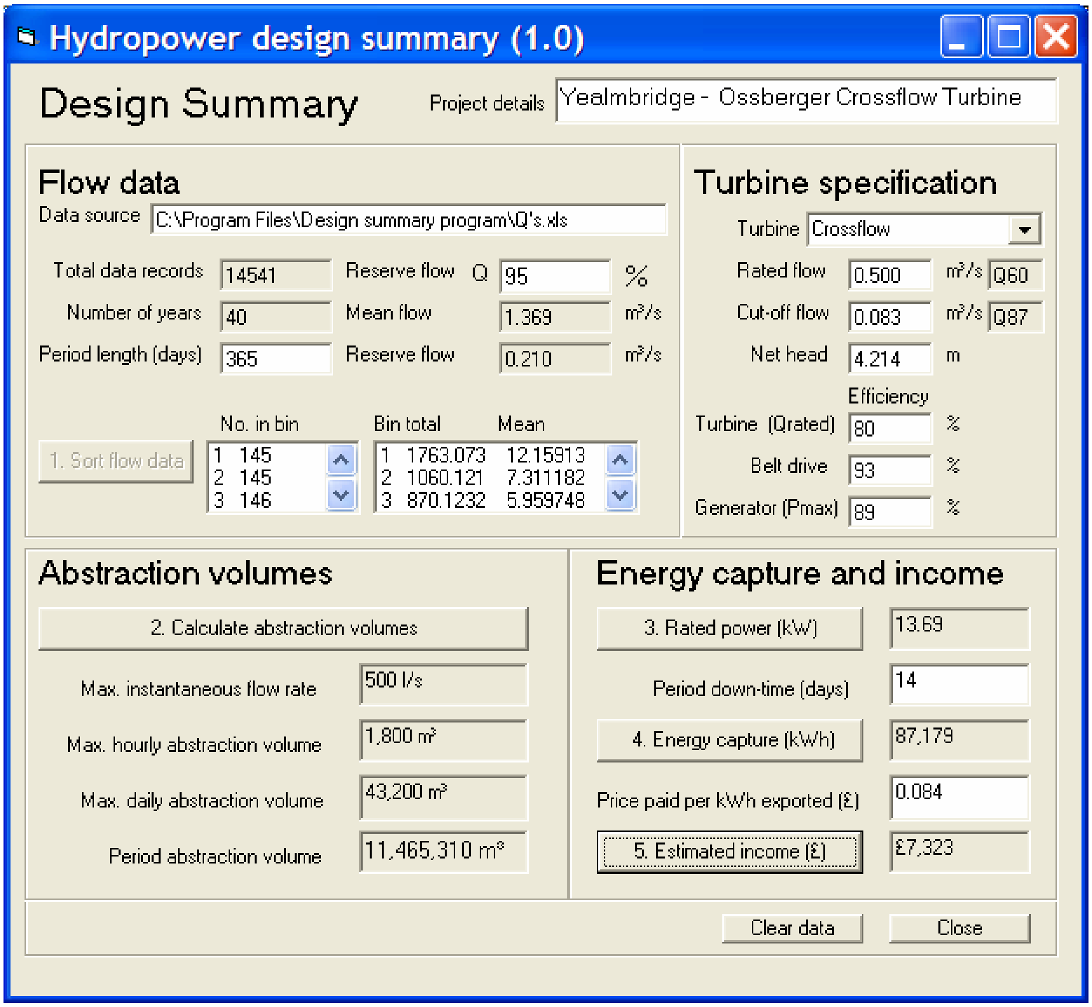
The proposed electrical system would use an induction (asynchronous) generator. These generators are very low maintenance and give many years of reliable operation. It should be noted that the generator is grid-excited, which means that in the event of a power cut the hydro system would automatically shut down (**i.e. the hydro system would *not* be an alternative power source during power cuts**). After a power cut the system would automatically restart.

## Energy capture and value of electricity (Scheme 1 Crossflow Turbine)

The energy capture and the value of electricity generated will critically depend on the reserve flow requirement imposed on the project. Three scenarios are explored below, a $Q_{95}$ reserve flow (which would be unusual for a migratory-fish river with a long deprived reach), a more stringent $Q_{80}$ and a worst-case '$Q_{95}$ + 50% of the remaining flow at any given time'.

Results pages for the design summary software for an Ossberger Crossflow Turbine system are shown in Figures 25 to 27.

Design Summary results for a reserve flow of $Q_{95}$



Project details: Yealmbridge - Ossberger Crossflow Turbine

Data source: C:\Program Files\Design summary program\Q's.xls

Total data records: 14541
Number of years: 40
Period length (days): 365
Reserve flow Q: 95 %
Mean flow: 1.369 m³/s
Reserve flow: 0.210 m³/s

| No. in bin | | Bin total | Mean |
|---|---|---|---|
| 1 | 145 | 1 1763.073 | 12.15913 |
| 2 | 145 | 2 1060.121 | 7.311182 |
| 3 | 146 | 3 870.1232 | 5.959748 |

Turbine: Crossflow
Rated flow: 0.500 m³/s Q60
Cut-off flow: 0.083 m³/s Q87
Net head: 4.214 m

Efficiency
Turbine (Qrated): 80 %
Belt drive: 93 %
Generator (Pmax): 89 %

Max. instantaneous flow rate: 500 l/s
Max. hourly abstraction volume: 1,800 m³
Max. daily abstraction volume: 43,200 m³
Period abstraction volume: 11,465,310 m³

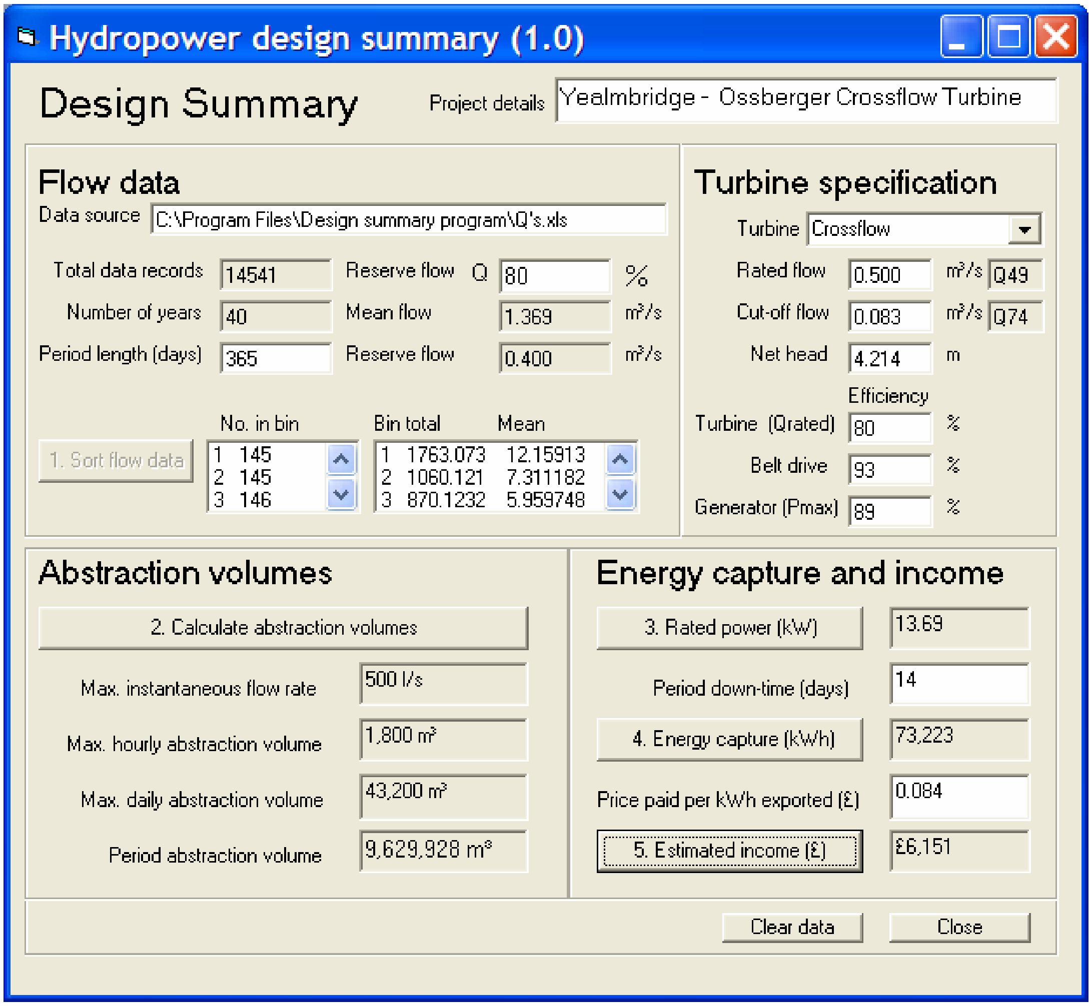
3. Rated power (kW): 13.69
Period down-time (days): 14
4. Energy capture (kWh): 87,179
Price paid per kWh exported (£): 0.084
5. Estimated income (£): £7,323

Figure 25 – Design Summary for a reserve flow of $Q_{95}$.

Assuming a $Q_{95}$ reserve flow requirement, the software predicts that a system would produce 87,179 kWh of electricity annually. If exported, this would provide an income of £7,323. This is enough to supply the annual electrical energy needs of 19.8 average UK homes, and would prevent the emission of over 38.7 tonnes of carbon dioxide into the atmosphere each year.

To estimate the annual income from electricity sales an electricity export price of 8.4 p/kWh has been assumed. This is a standard available tariff for a micro hydro generator of this size (**above** 10kW). This value is made up of several components; the export price paid for the electricity, the Renewables Obligation Certificate (ROC) value and the (Climate Change) Levy Exemption Certificate (LEC) value. Half of the value is made up of the ROC and LEC value.

Design Summary results for a higher reserve flow of $Q_{80}$


Hydropower design summary (1.0)

Design Summary

Project details: Yealmbridge - Ossberger Crossflow Turbine

Flow data

Data source: C:\Program Files\Design summary program\Q's.xls

Total data records: 14541
Number of years: 40
Period length (days): 365
Reserve flow Q: 80 %
Mean flow: 1.369 m³/s
Reserve flow: 0.400 m³/s

| No. in bin | | Bin total | Mean |
|---|---|---|---|
| 1 | 145 | 1763.073 | 12.15913 |
| 2 | 145 | 1060.121 | 7.311182 |
| 3 | 146 | 870.1232 | 5.959748 |

Turbine specification

Turbine: Crossflow
Rated flow: 0.500 m³/s Q49
Cut-off flow: 0.083 m³/s Q74
Net head: 4.214 m

Efficiency
Turbine (Qrated): 80 %
Belt drive: 93 %
Generator (Pmax): 89 %

Abstraction volumes

Max. instantaneous flow rate: 500 l/s
Max. hourly abstraction volume: 1,800 m³
Max. daily abstraction volume: 43,200 m³
Period abstraction volume: 9,629,928 m³

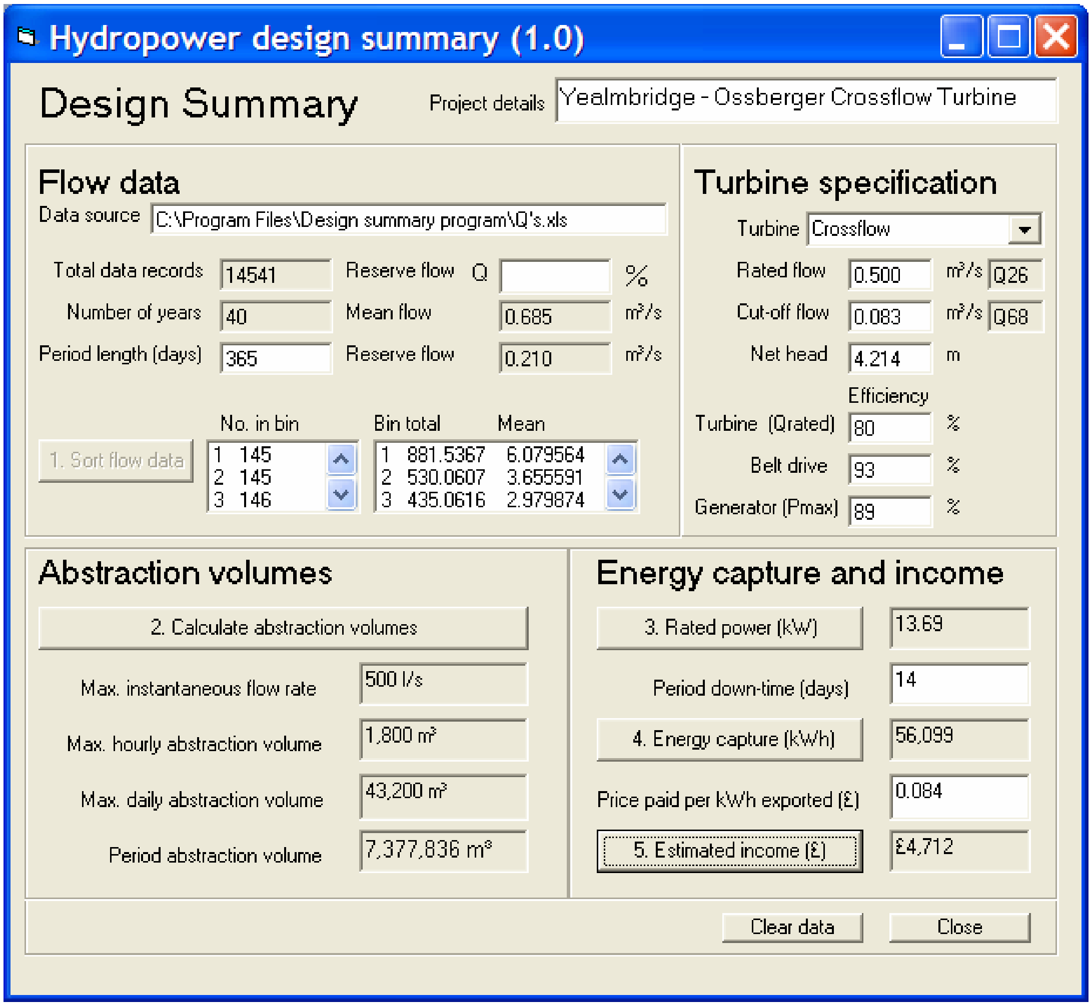
Energy capture and income

3. Rated power (kW): 13.69
Period down-time (days): 14
4. Energy capture (kWh): 73,223
Price paid per kWh exported (£): 0.084
5. Estimated income (£): £6,151

Figure 26 – Design Summary for a reserve flow of $Q_{80}$.

The software predicts that the system would produce 73,223 kWh of electricity annually for a $Q_{80}$ reserve flow requirement. If exported, this would provide an income of £6,151. This is enough to supply the annual electrical energy needs of 16.6 average UK homes, and would prevent the emission of 32.5 tonnes of carbon dioxide into the atmosphere each year. The same electricity export price assumptions have been made for the crossflow system described above.

‘Worst case’ abstraction regime



Design Summary

Project details: Yealmbridge - Ossberger Crossflow Turbine

Flow data

Data source: C:\Program Files\Design summary program\Q's.xls

Total data records: 14541

Number of years: 40

Period length (days): 365

Reserve flow Q: %

Mean flow: 0.685 m³/s

Reserve flow: 0.210 m³/s

| No. in bin | | Bin total | Mean |
|---|---|---|---|
| 1 | 145 | 881.5367 | 6.079564 |
| 2 | 145 | 530.0607 | 3.655591 |
| 3 | 146 | 435.0616 | 2.979874 |

Turbine specification

Turbine: Crossflow

Rated flow: 0.500 m³/s Q26

Cut-off flow: 0.083 m³/s Q68

Net head: 4.214 m

Efficiency

Turbine (Qrated): 80 %

Belt drive: 93 %

Generator (Pmax): 89 %

Abstraction volumes

Max. instantaneous flow rate: 500 l/s

Max. hourly abstraction volume: 1,800 m³

Max. daily abstraction volume: 43,200 m³

Period abstraction volume: 7,377,836 m³

Energy capture and income

3. Rated power (kW): 13.69

Period down-time (days): 14

4. Energy capture (kWh): 56,099

Price paid per kWh exported (£): 0.084

5. Estimated income (£): £4,712

Figure 27 – Design Summary for a reserve flow of $Q_{95}$ + 50% Of the remaining flow

The software predicts that the system would produce 56,099 kWh of electricity annually for a $Q_{95}$ + 50% Of the remaining flow, reserve flow requirement. If exported, this would provide an income of £4,712. This is enough to supply the annual electrical energy needs of 12.7 average UK homes, and would prevent the emission of 24.9 tonnes of carbon dioxide into the atmosphere each year. The same electricity export price assumptions have been made as for the crossflow turbine system described above.

## System cost estimate (Scheme 1 crossflow turbine system)

Table 2 shows the estimated costs for the complete hydro project. Note that all prices exclude VAT. All items would attract VAT at 5%.

| No. | Item | Cost (excl.VAT) |
|---|---|---|
| 1 | Obtaining EA Abstraction License + statutory advertising[1] | £2,750 |
| 2 | Mechanical, electrical & civil engineering system design | £5,625 |
| 3 | Preparation & application for EA Land Drainage Consent | £850 |
| 4 | Preparation and application for planning consents | £850 |
| 5 | Intake system including stainless steel screen | £3,750 |
| 6 | Civil works to prepare intake area and turbine housing | £15,000 |
| 7 | Penstock (600 mm diameter plastic) + elbow and couplings | £9,000 |
| 8 | Turbine support platform / chassis | £1,500 |
| 9 | De-silting of tailrace | £24,000 |
| 10 | Ossberger crossflow turbine | £34,400 |
| 11 | Transmission system (vee-belts) | £620 |
| 12 | Induction generator and G59 grid connection unit | £6,175 |
| 13 | Stop-log boards / supporting structure to raise weir 450 mm | £4,000 |
| 14 | Electrical & mechanical sundry parts | £3,000 |
| 15 | Installation and commissioning inc. travel | £13,140 |
|  | **Total** | **£124,660** |

**Notes**

[1] If two EA licenses were required (i.e. Abstraction and Impoundment) the cost may be increased by up to £1,000 depending on the complexities of the application process. If a Flood Risk Assessment (FRA) or an environmental appraisal is required this has not been included in the above costs.

Additional costs if tilt-gate system is installed to raise weir height by 450 mm

|  |  |  |
|---|---|---|
| 13 | Delete Stop-log boards / supporting structure to raise weir 450 mm | -£4,000 |
| 16 | New weir foundations/ central piers and bank sections | £34,714 |
| 17 | Tilt-gate system / installation | £41,185 |
|  | **Total** | **£196,559** |

Table 2 – Cost estimate for grid-excited, grid-connected hydro system.

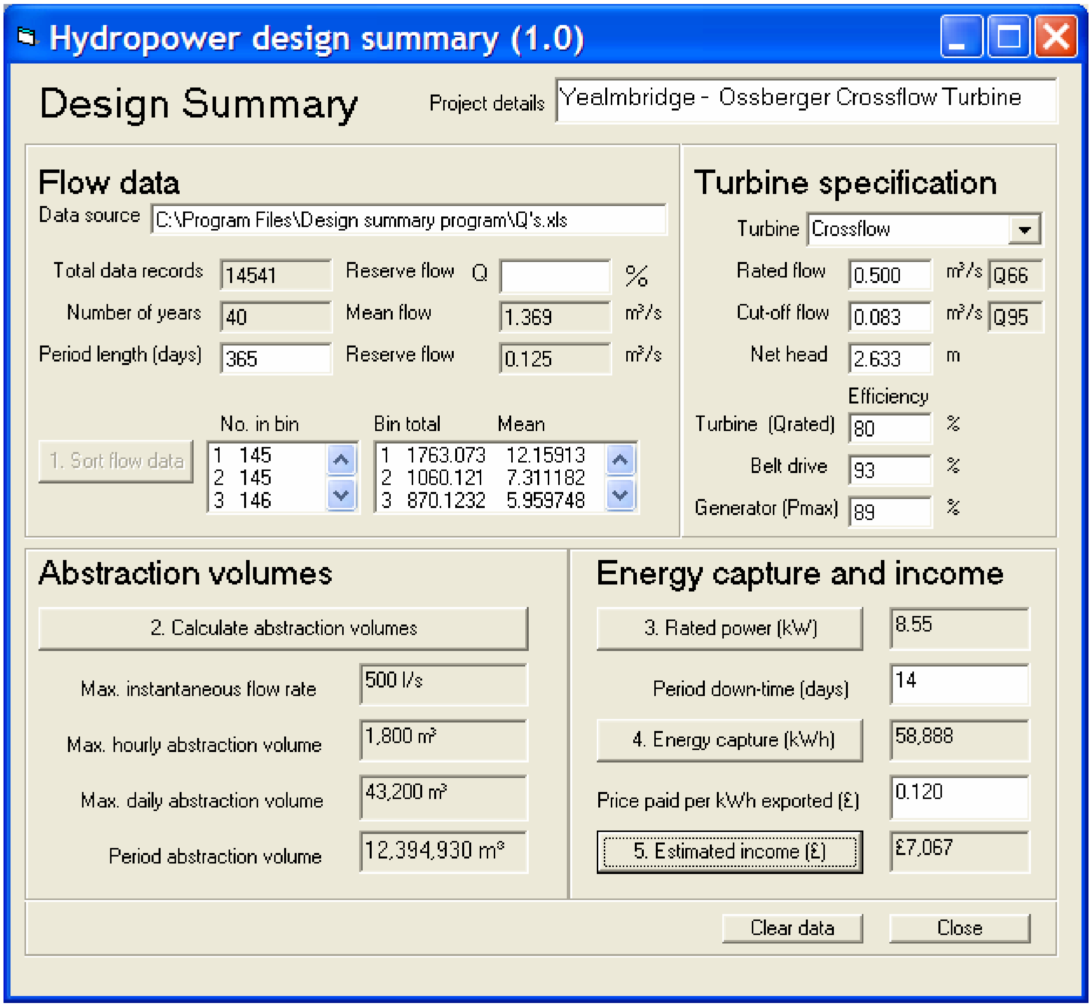
The above costs are estimates, but are based on experience of real installations. Firmer costings would be produced during the detailed design stage.

Once installed, hydro systems tend to be relatively low maintenance and are reliable in operation. The moving parts in the system would need lubricating every month taking around two hours. Every year the lubricant would need changing which would take one day. Apart from greasing of the turbine bearings, the biggest maintenance task is keeping an eye on the intake screen and raking-off any accumulated debris.

The hydro system hardware could be expected to last at least 50 years provided it was maintained properly. The associated civil works (turbine house and penstock) would last indefinitely with basic building maintenance.

## Energy capture and value of electricity (Scheme 2 Crossflow Turbine)

The results page from the Design Summary software for an Ossberger Crossflow turbine system is shown in Figure 28 below.



Hydropower design summary (1.0)

Design Summary

Project details: Yealmbridge - Ossberger Crossflow Turbine

**Flow data**

Data source: C:\Program Files\Design summary program\Q's.xls

Total data records: 14541

Number of years: 40

Period length (days): 365

Reserve flow Q: %

Mean flow: 1.369 m³/s

Reserve flow: 0.125 m³/s

|  | No. in bin | Bin total | Mean |
|---|---|---|---|
| 1 | 145 | 1763.073 | 12.15913 |
| 2 | 145 | 1060.121 | 7.311182 |
| 3 | 146 | 870.1232 | 5.959748 |

**Turbine specification**

Turbine: Crossflow

Rated flow: 0.500 m³/s Q66

Cut-off flow: 0.083 m³/s Q95

Net head: 2.633 m

Efficiency

Turbine (Qrated): 80 %

Belt drive: 93 %

Generator (Pmax): 89 %

**Abstraction volumes**

Max. instantaneous flow rate: 500 l/s

Max. hourly abstraction volume: 1,800 m³

Max. daily abstraction volume: 43,200 m³

Period abstraction volume: 12,394,930 m³

**Energy capture and income**

3. Rated power (kW): 8.55

Period down-time (days): 14

4. Energy capture (kWh): 58,888

Price paid per kWh exported (£): 0.120

5. Estimated income (£): £7,067

Figure 28 – Design Summary results page for a Ossberger crossflow turbine system.

The software predicts that the system would produce 58,888 kWh of electricity annually. If exported, this would provide an income of £7,067. This is enough to supply the annual electrical energy needs of 13.4 average UK homes, and would prevent the emission of 26.2 tonnes of carbon dioxide into the atmosphere each year.

To estimate the annual income from electricity sales an electricity export price of 12 p/kWh has been assumed. This is a standard available tariff for a micro hydro generator of this size (**below** 10kW). This value is made up of several components; the export price paid for the electricity, the Renewables Obligation Certificate (ROC) value and the (Climate Change) Levy Exemption Certificate (LEC) value. Over half of the value is made up of the ROC and LEC value.

## System cost estimate (Scheme 2 crossflow turbine system)

Table 3 shows the estimated costs for the complete hydro project. Note that all prices exclude VAT. Items 1 to 4 would attract VAT at 17 ½%. Items 5 to 15 would attract VAT at 5%.

| No. | Item | Cost (excl.VAT) |
|---|---|---|
| 1 | Obtaining EA Abstraction License + statutory advertising[1] | £2,750 |
| 2 | Mechanical, electrical & civil engineering system design | £5,625 |
| 3 | Preparation & application for EA Land Drainage Consent | £850 |
| 4 | Preparation and application for planning consents | £850 |
| 5 | Intake system including stainless steel screen | £3,750 |
| 6 | Civil works to prepare intake area and turbine housing | £15,000 |
| 7 | Penstock (600 mm diameter plastic) + elbow and couplings | £4,630 |
| 8 | Turbine support platform / chassis | £1,500 |
| 9 | Ossberger crossflow turbine | £36,400 |
| 10 | Transmission system (vee-belts) | £620 |
| 11 | Induction generator and G83 grid connection unit | £4,250 |
| 12 | Stop-log boards / supporting structure to raise weir 450 mm | £4,000 |
| 13 | Electrical & mechanical sundry parts | £2,200 |
| 14 | Installation and commissioning inc. travel | £13,140 |
|  | **Total** | **£95,565** |

**Notes**

[1] If two EA licenses were required (i.e. Abstraction and Impoundment) the cost may be increased by up to £1,000 depending on the complexities of the application process. If a Flood Risk Assessment (FRA) or an environmental appraisal is required this has not been included in the above costs.

Additional costs if tilt-gate system is installed to raise weir height by 450 mm

|  |  |  |
|---|---|---|
| 12 | Delete Stop-log boards / supporting structure to raise weir 450 mm | -£4,000 |
| 15 | New weir foundations/ central piers and bank sections | £34,714 |
| 16 | Tilt-gate system / installation | £41,185 |
|  | **Total** | **£167,464** |

Table 3 – Cost estimate for grid-excited, grid-connected hydro system.

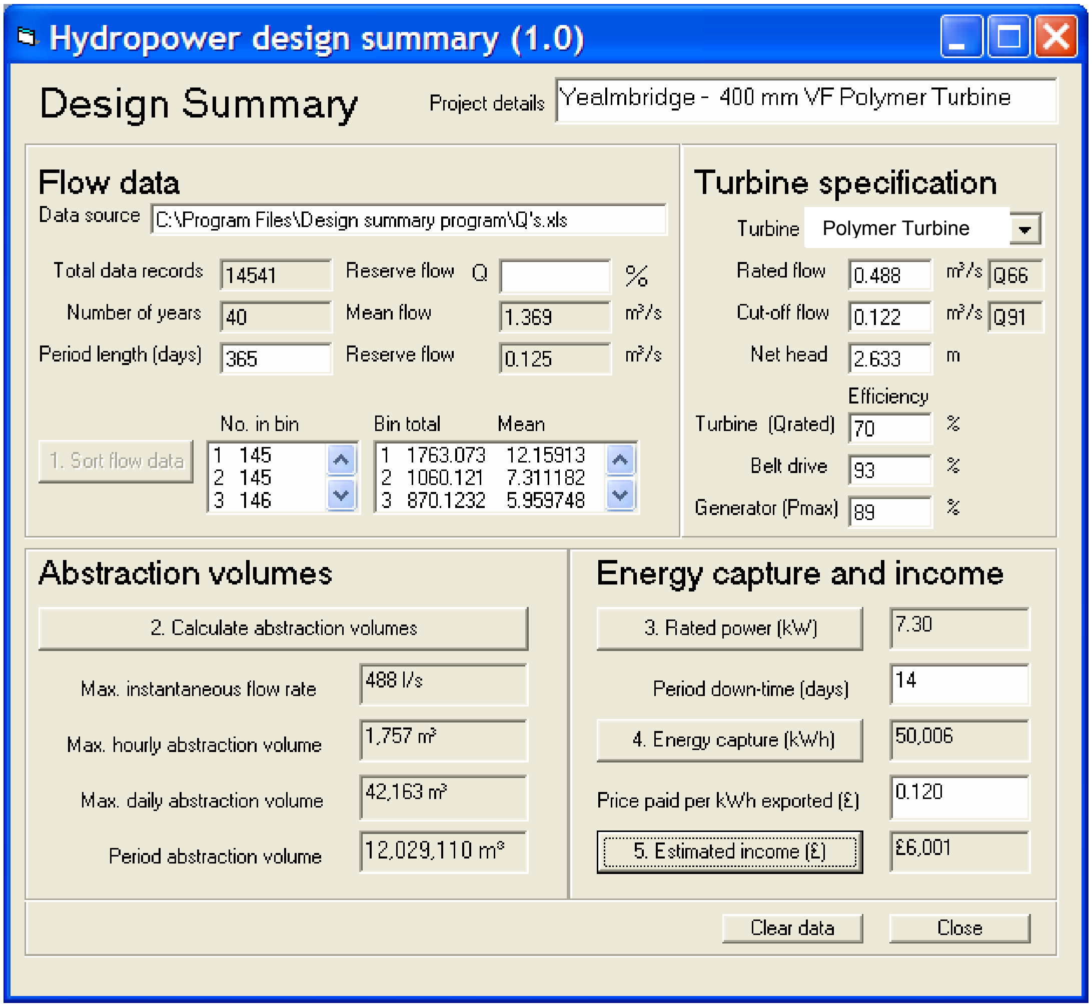
The above costs are estimates, but are based on experience of real installations. Firmer costings would be produced during the detailed design stage.

Once installed, hydro systems tend to be relatively low maintenance and are reliable in operation. The moving parts in the system would need lubricating every month taking around two hours. Every year the lubricant would need changing which would take one day. Apart from greasing of the turbine bearings, the biggest maintenance task is keeping an eye on the intake screen and raking-off any accumulated debris.

The hydro system hardware could be expected to last at least 50 years provided it was maintained properly. The associated civil works (turbine house and penstock) would last indefinitely with basic building maintenance.

## Energy capture and value of electricity (Scheme 2 Polymer Turbine)

The results page from the Design Summary software for a 400 mm variable-flow Polymer Turbine system is shown in Figure 29 below.



Project details: Yealmbridge - 400 mm VF Polymer Turbine

Data source: C:\Program Files\Design summary program\Q's.xls

Total data records: 14541
Number of years: 40
Period length (days): 365
Reserve flow Q: %
Mean flow: 1.369 m³/s
Reserve flow: 0.125 m³/s

| No. in bin | | Bin total | Mean |
|---|---|---|---|
| 1 | 145 | 1763.073 | 12.15913 |
| 2 | 145 | 1060.121 | 7.311182 |
| 3 | 146 | 870.1232 | 5.959748 |

Turbine: Polymer Turbine
Rated flow: 0.488 m³/s Q66
Cut-off flow: 0.122 m³/s Q91
Net head: 2.633 m
Efficiency
Turbine (Qrated): 70 %
Belt drive: 93 %
Generator (Pmax): 89 %

Max. instantaneous flow rate: 488 l/s
Max. hourly abstraction volume: 1,757 m³
Max. daily abstraction volume: 42,163 m³
Period abstraction volume: 12,029,110 m³

3. Rated power (kW): 7.30
Period down-time (days): 14
4. Energy capture (kWh): 50,006
Price paid per kWh exported (£): 0.120
5. Estimated income (£): £6,001

Figure 29 – Design Summary results page for a 400 mm variable-flow Polymer Turbine system.

The software predicts that the system would produce 50,006 kWh of electricity annually. If exported, this would provide an income of £6,001. This is enough to supply the annual electrical energy needs of 11.4 average UK homes, and would prevent the emission of 22.2 tonnes of carbon dioxide into the atmosphere each year.

The same electricity export price assumptions have been made as for the crossflow turbine system described above.

## System cost estimate (Scheme 2, 400 mm VF Polymer Turbine system)

Table 4 shows the estimated costs for the complete 400 mm variable-flow Polymer Turbine hydro system. Note that all prices exclude VAT. Items 1 to 4 would attract VAT at 17 ½%. Items 5 to 15 would attract VAT at 5%.

| No. | Item | Cost (excl.VAT) |
|---|---|---|
| 1 | Obtaining EA Abstraction License + statutory advertising[1] | £2,750 |
| 2 | Mechanical, electrical & civil engineering system design | £5,625 |
| 3 | Preparation & application for EA Land Drainage Consent | £850 |
| 4 | Preparation and application for planning consents | £850 |
| 5 | Intake system including stainless steel screen | £3,750 |
| 6 | Civil works to prepare intake area and turbine housing | £8,200 |
| 7 | Penstock (600 mm diameter plastic) + elbow and couplings | £4,630 |
| 9 | 400 mm variable-flow Polymer Turbine, complete with modular chassis system | £12,000 |
| 10 | Transmission system (vee-belts) | £620 |
| 11 | Induction generator and G83 grid connection unit | £4,250 |
| 12 | Stop-log boards / supporting structure to raise weir 450 mm | £4,000 |
| 13 | Electrical & mechanical sundry parts | £2,200 |
| 14 | Installation and commissioning inc. travel | £8,500 |
| | **Total** | **£58,225** |

**Notes**

[1] If two EA licenses were required (i.e. Abstraction and Impoundment) the cost may be increased by up to £1,000 depending on the complexities of the application process. If a Flood Risk Assessment (FRA) or an environmental appraisal is required this has not been included in the above costs.

Additional costs if tilt-gate system is installed to raise weir height by 450 mm

| | | |
|---|---|---|
| 12 | Delete Stop-log boards / supporting structure to raise weir 450 mm | -£4,000 |
| 15 | New weir foundations/ central piers and bank sections | £34,714 |
| 16 | Tilt-gate system / installation | £41,185 |
| | **Total** | **£130,124** |

Table 4 – Cost estimate for hydro system using a 400 mm variable-flow Polymer Turbine.

The costs above are estimates, but are based on experience of real installations. Firmer costings would be produced during the detailed design stage.

Once installed, hydro systems tend to be relatively low maintenance and are reliable in operation. The turbine bearings will need greasing with a grease-gun every month (takes two minutes), then every year all of the grease must be removed and replaced (takes ½ day). Apart from greasing the turbine bearings, the biggest maintenance task is keeping an eye on the intake screen and raking-off any accumulated debris.

The hydro system hardware could be expected to last at least 30 years provided it was maintained properly. The associated civil works (turbine house and penstock) would last indefinitely with basic building maintenance.

## Planning, legal and environmental issues

### Planning issues

Construction of a micro-hydropower system may need planning permission from the local authority. Any new building or modification to an existing building that requires planning permission and is on or near a watercourse will include the Environment Agency as a statutory consultee in the planning process. In most cases the Environment Agency would only give their consent to the planning application after a Land Drainage Consent application (see below) for the same works had been approved by them.

For any sites with listed buildings, a Listed Building Consent application will need to be made for all works within the 'curtilage' of the building. Curtilage can be broadly defined as the area surrounding a listed building that is historically or architecturally connected to it. Generally speaking, conservation officers view micro-hydropower systems positively provided that disturbance to historic fabric is minimised and where necessary is carried out in a sympathetic way. Early consultation with the local conservation officer is recommended before detailed plans for installing a modern hydropower system are made.

### Environment Agency Abstraction Licence / Impoundment License & ecological considerations

Exactly which Environment Agency (EA) licenses would be required would depend on how the local EA office 'interpreted' the project. Different regional EA offices treat the licensing of hydro systems with different levels of regulatory rigour.

The proposal put forward in Scheme 1 would be abstracting water from the River Yealm and diverting it through the leat. The EA would certainly want an abstraction license application for the hydro system based on such a proposal. They may also request an Impoundment license application for the new intake screen and fixed / tilt-gate structure.

The proposed system in Scheme 2 would have the intake integrated with the upstream side of the existing impoundment and the turbine discharge on the downstream side of the impoundment. Hydro Generation Ltd have designed and installed similar system layouts at several other sites in various EA regions. In each case a different type of license was required. It is therefore difficult to confirm which EA licenses will be needed. It will depend entirely on the local EA office's view of micro hydropower and the officiousness of their licensing team.

An Impoundment / Abstraction License would define the maximum quantities of water that could pass through the turbine and how much reserve flow would have to flow over the weir and through the fish pass. The EA licenses would almost certainly include a maximum bar-spacing for the intake screen to prevent the ingestion of fish. Being a migratory river, a bar spacing of 12.5 mm is recommended.

The progression of the project may also require an environmental appraisal and a Flood Risk Assessment (FRA). The environmental appraisal would identify any impact to the indigenous flora and fauna; based on these results, practices would have to be implemented to mitigate any impacts associated with the installation of the hydro systems / tilt-gate. The FRA would be conducted in support of the impoundment proposal to demonstrate that there would be no increase in flood risk consequent to the impoundment proposal. The flood risk will further identify basin storage capacities and any change in the flow regime that currently exists through the 'affected' reach.

If the project proceeds the next step would be an initial consultation with the EA to determine exactly which licenses would be needed and to identify any environmental constraints.

### Environment Agency Land Drainage Consent

All works in or around the River Yealm would need Land Drainage Consent from the Environment Agency. The process for obtaining this is less complicated than applying for an Abstraction or Impoundment License, and involves filling in their application form and providing engineering drawings and design calculations for the proposed works.

Legal

Installing and operating a hydropower system without the appropriate Environment Agency and planning consents would be illegal, so it is best to talk to the respective organisations early in the project. Installing a hydropower system may affect liability insurance policies, so insurance companies should be advised of the project so that any changes in cover can be arranged.

## Potential sources of funding

Low Carbon Buildings Programme

Funding for the project would available under Stream 2a under the Governments Low Carbon Building Programme (LCBP);

The Low Carbon Buildings Programme (LCBP) funding comes from the government via the DTI and Energy Saving Trust (EST). As a *community project* funding can be applied for under 'Stream 2a'. A maximum grant of £100k or 40 – 50% of project costs could be achieved. The LCBP only funds the implementation stage of the project, therefore alternative sources of funding would be needed for the prior design stages. However if alternative sources of funding are made available to the project then it is very likely this would cap or significantly reduce any funding from the LCBP.

Further information is available from http://www.lowcarbonbuildings.org.uk/how/public/ or call 01923 665086.

EDF Energy – Green Tariff Fund

All EDF energy customers who subscribe to the green tariff pay an additional 0.4p/kWh into a green fund. EDF Energy matches this with an additional contribution of 0.4p/kWh. The fund is used to help not-for-profit renewable energy projects. The Yealmbridge hydro project is exactly the kind of project they would be interested in funding. Available funding varies depending upon the project specification. EDF would be likely to be interested in helping with the design and installation phases. Contact Nigel French on 01273 428 641 for more details.

Scottish Power – Green Energy Trust

This is a similar fund to the EDF energy fund. Contact Alison McKeen on 0141 568 3964.

Powergen - Greenplan

Powergen greenplan is a similar scheme to the EDF one. Contacts details can be found on the Powergen website at http://www.powergen.co.uk/About-Us/GreenPlan-fund.htm.

## The Next Step…

If the hydropower project at Yealmbridge Weir is to proceed, the next steps would be:

| | Duration |
|---|---|
| **1.** Arrange for the Environment Agency (EA) to visit the site and discuss which consents would be required. At the same time meet the local conservation officer to discuss Listed Building / Planning Consent issues (if applicable). | 2 months |
| **2.** Carry out outline design work. | 1 month |
| **3.** Apply for the Environment Agency and planning consents. | 6 months |
| **4.** Once there was confidence that the Environment Agency and planning consents would be forthcoming, complete detail system design. | 1 month |
| **5.** Order turbine, screen cleaner and tilt-gate. Note likely 6 month lead-time. | n/a |
| **6.** Civil engineering works to prepare for turbine, intake screen and tilt-gate. | 3 months |
| **7.** Installation of all hardware. | 2 months |
| **8.** Commission system. | 2 weeks |

The ‘duration’ above indicates the likely time to complete the task, including time waiting on the Environment Agency for a response. Some items could be completed in parallel. If everything proceeded without problems, it would probably be at least 14 months before the hydropower system was operational. The progression of the project is subject to obtaining land ownership / permission to develop the site; this has not been included in the time frames specified above.

# Appendix 1 – Puslinch Environment Agency gauging station flow data

Puslinch Environment Agency (EA) gauging station is on the River Yealm approximately 2 km downstream of Yealmbridge Weir at OS grid reference SX 574 511. Flow data were obtained for the gauging station for 39 complete years. The data have been checked for completeness and are presented as a Flow duration curve in Figure A1.1. Flows at key intervals are summarised in Table A1.1. The annual mean flow is 1.45 cubic metres per second.

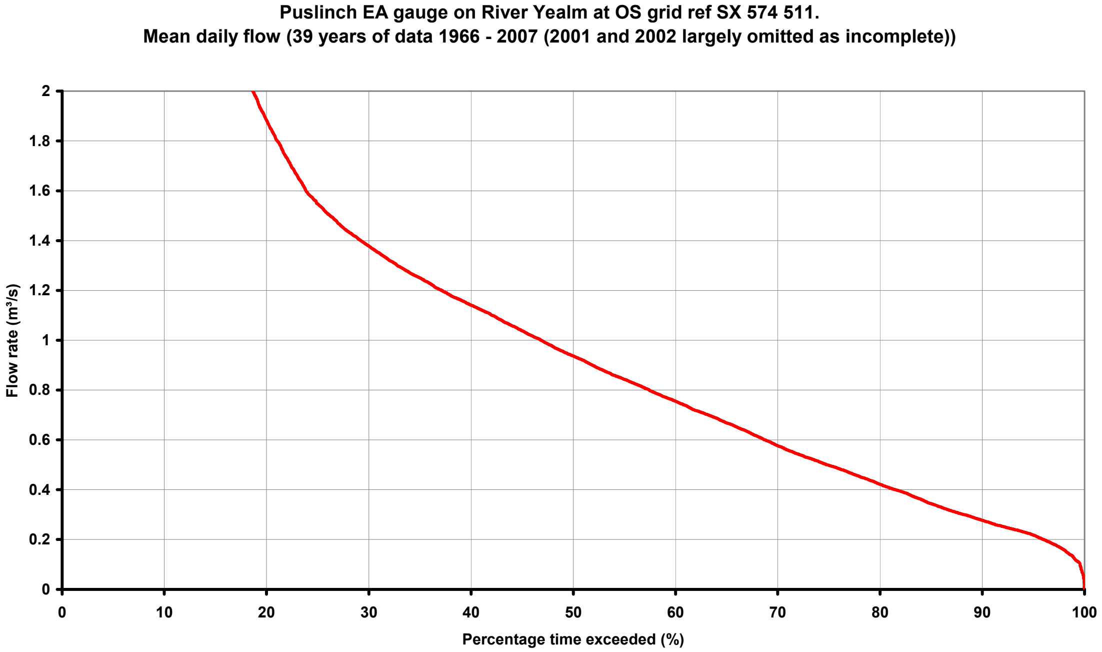


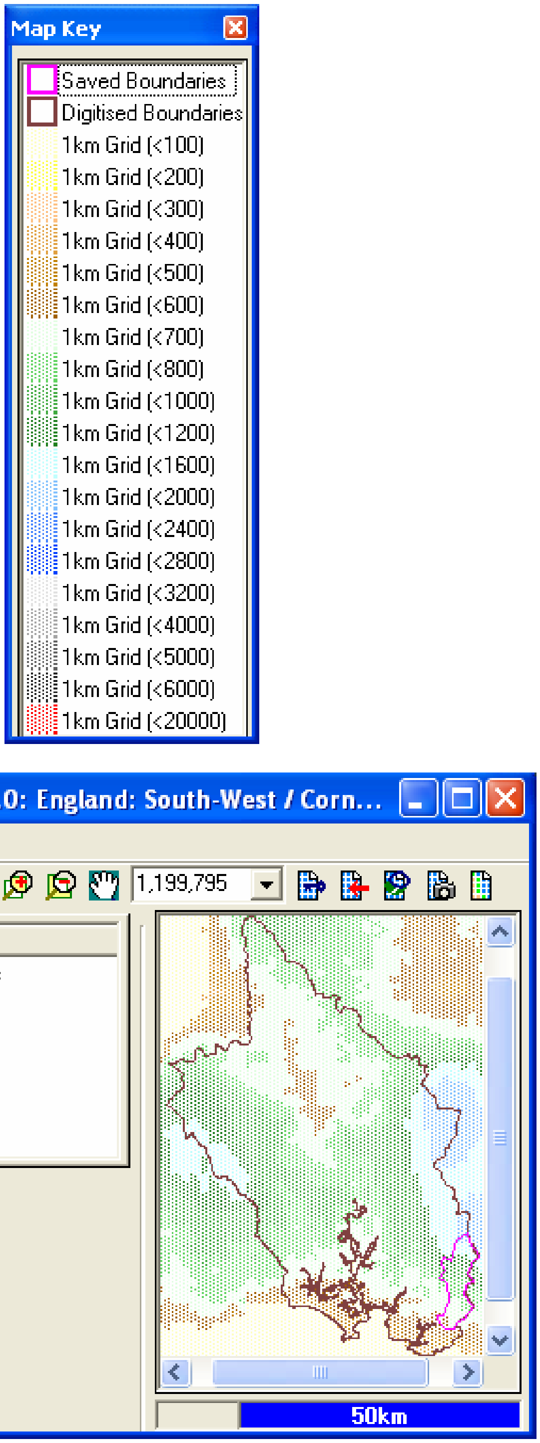
Figure A1.1 – Flow Duration Curve for Puslinch EA Gauging Station on the River Yealm.

| Percentage Exceedence (%) | Flow Rate (m$^3$/s) |
|---|---|
| $Q_{10}$ | 3.14 |
| $Q_{20}$ | 1.88 |
| $Q_{30}$ | 1.38 |
| $Q_{40}$ | 1.14 |
| $Q_{50}$ | 0.94 |
| $Q_{60}$ | 0.76 |
| $Q_{70}$ | 0.58 |
| $Q_{80}$ | 0.42 |
| $Q_{90}$ | 0.28 |
| $Q_{95}$ | 0.22 |
| $Q_{mean}$ ($Q_{27.7}$) | 1.45 |

Table A1.1 – Summary Flow values for Puslinch EA Gauging Station on the River Yealm

## Appendix 2 – Low Flows modelling of catchments

Puslinch gauge catchment



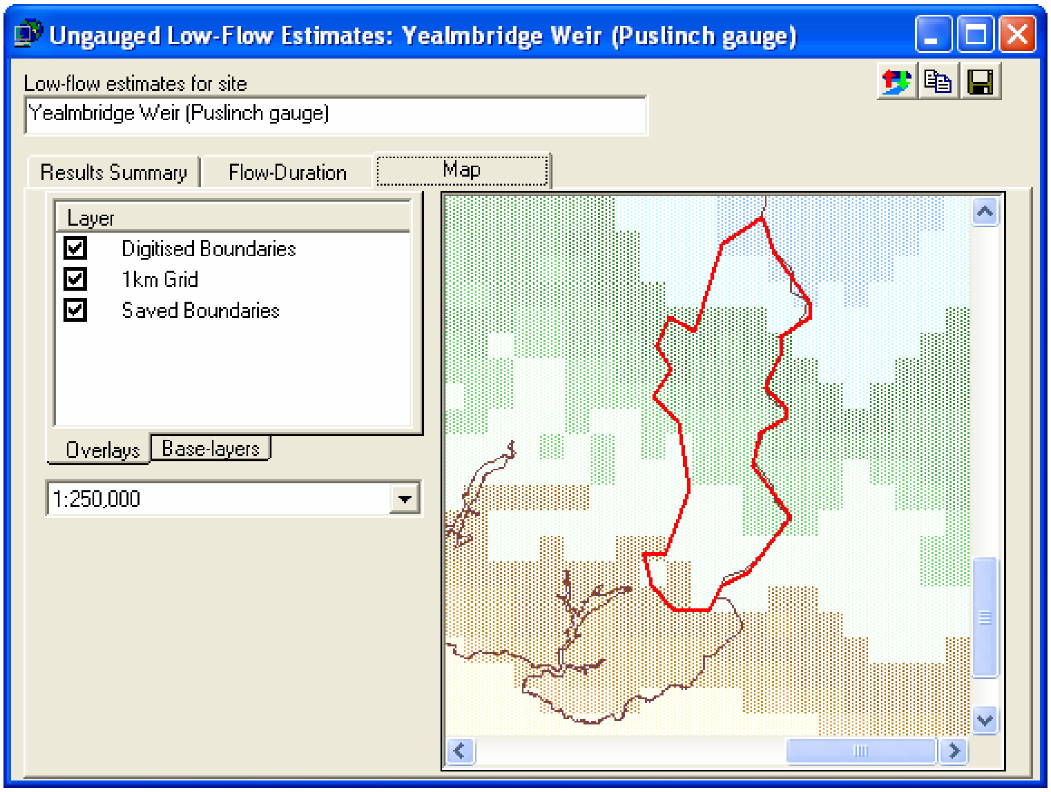
Layer

☑ Digitised Boundaries

☑ 1km Grid

☑ Saved Boundaries

Figure A2.1 – The South East Cornwall catchment (black line) containing Puslinch gauge catchment (pink line). The key for this map is above. The rainfall raster is at a resolution of 1 km$^2$. The units for the key are mm rainfall (strictly runoff) per year.

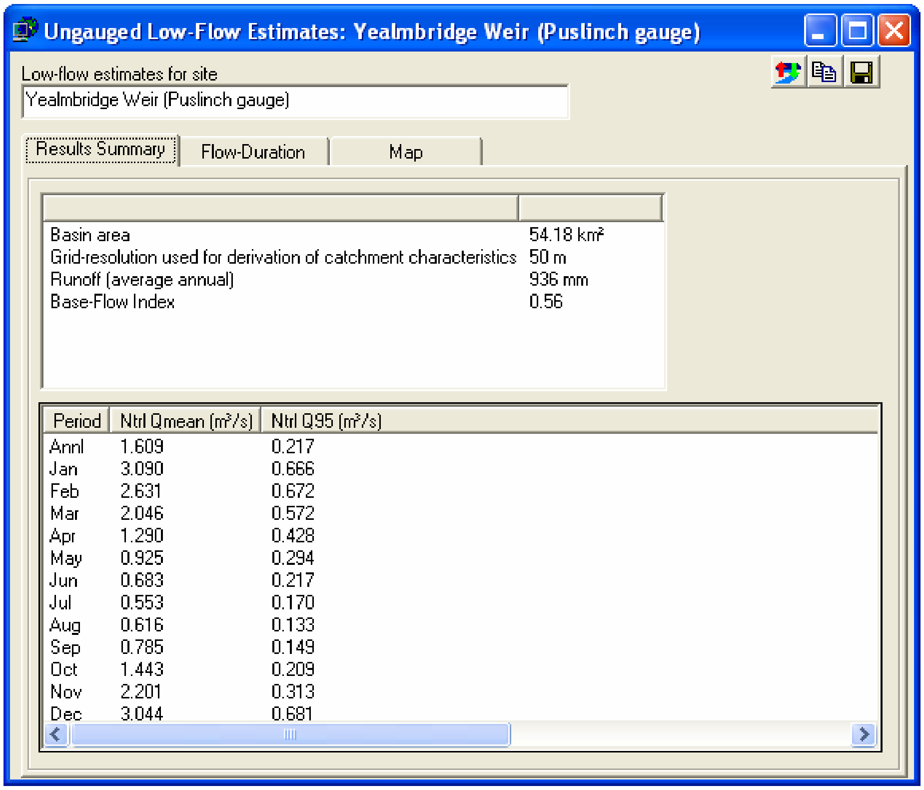


Low-flow estimates for site: Yealmbridge Weir (Puslinch gauge)

- ☑ Digitised Boundaries
- ☑ 1km Grid
- ☑ Saved Boundaries

1:250,000

Figure A2.2 – Puslinch gauge catchment area (red). Puslinch gauge is at the second west most point of this polygon.



Low-flow estimates for site: Yealmbridge Weir (Puslinch gauge)

| | |
|---|---|
| Basin area | 54.18 km$^2$ |
| Grid-resolution used for derivation of catchment characteristics | 50 m |
| Runoff (average annual) | 936 mm |
| Base-Flow Index | 0.56 |

| Period | Ntrl Qmean (m$^3$/s) | Ntrl Q95 (m$^3$/s) |
|---|---|---|
| Annl | 1.609 | 0.217 |
| Jan | 3.090 | 0.666 |
| Feb | 2.631 | 0.672 |
| Mar | 2.046 | 0.572 |
| Apr | 1.290 | 0.428 |
| May | 0.925 | 0.294 |
| Jun | 0.683 | 0.217 |
| Jul | 0.553 | 0.170 |
| Aug | 0.616 | 0.133 |
| Sep | 0.785 | 0.149 |
| Oct | 1.443 | 0.209 |
| Nov | 2.201 | 0.313 |
| Dec | 3.044 | 0.681 |

Figure A2.3 – Catchment characteristics and annual and monthly flow estimates for Puslinch gauge.

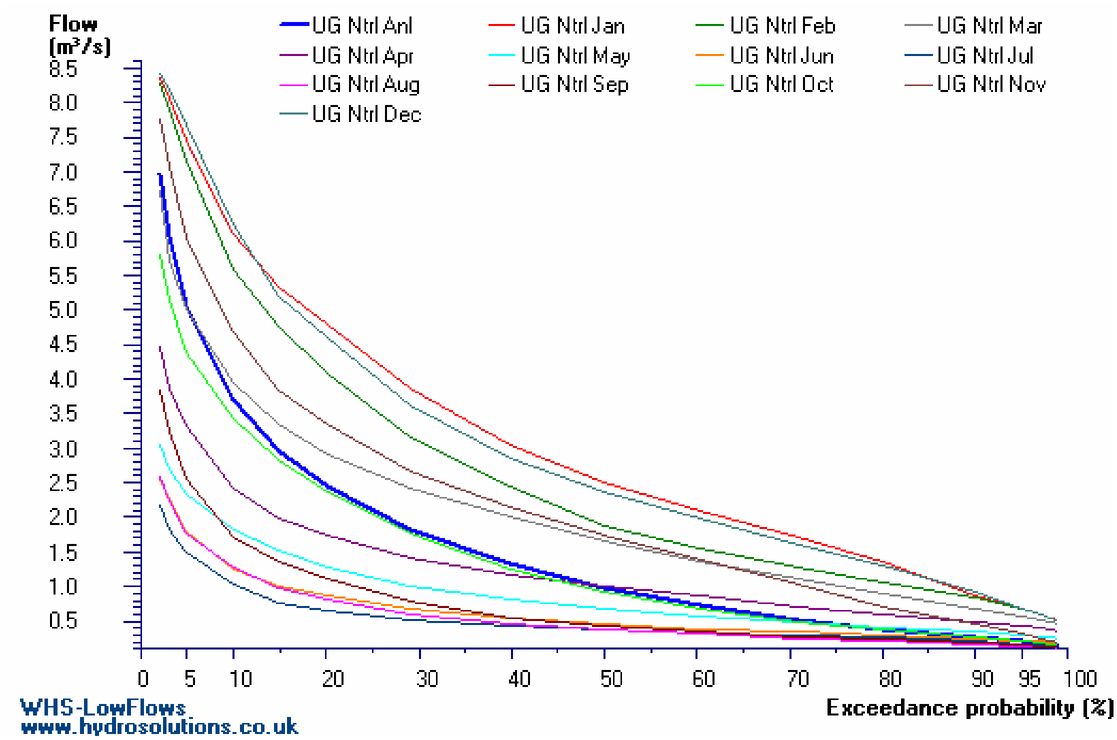


Figure A2.4 – Linear-linear annual and monthly flow duration curves for Puslinch gauge.

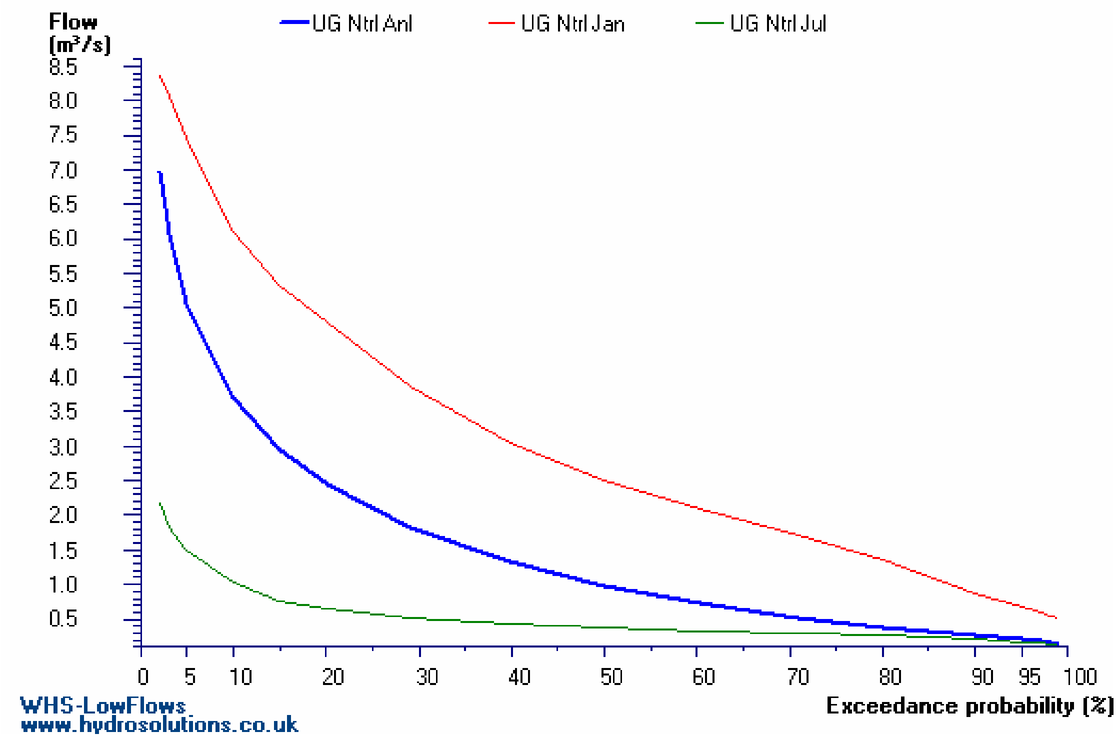
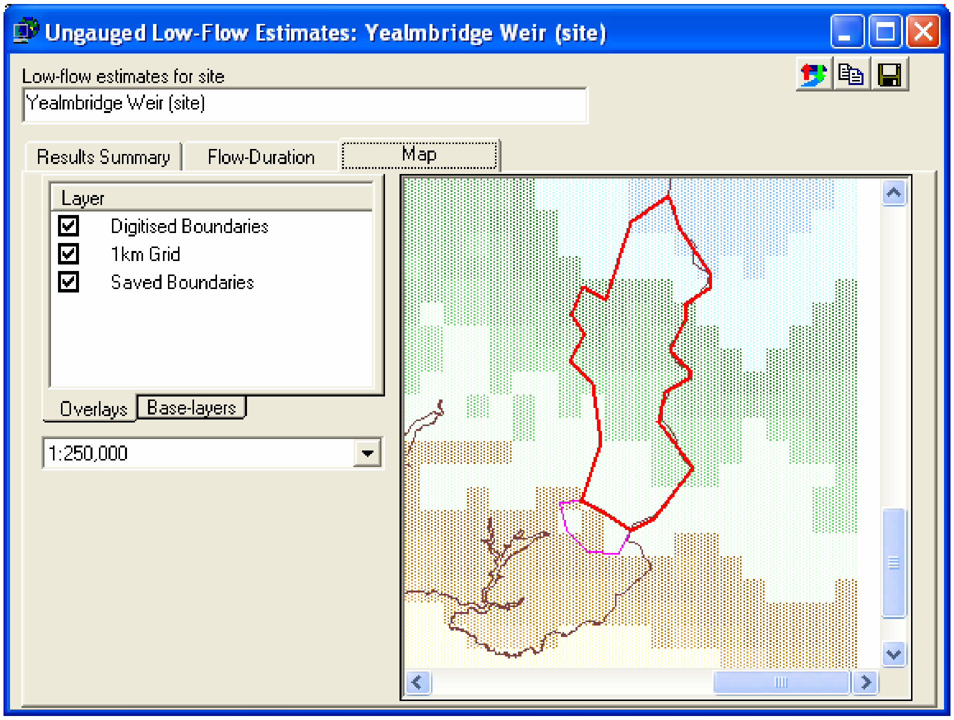


Figure A2.5 – Linear-linear annual, January and July flow duration curves for Puslinch gauge.

Yealmbridge Weir catchment


Ungauged Low-Flow Estimates: Yealmbridge Weir (site)

Low-flow estimates for site: Yealmbridge Weir (site)

Layer
☑ Digitised Boundaries
☑ 1km Grid
☑ Saved Boundaries

1:250,000

Figure A2.6 – Yealmbridge Weir catchment area (red). The weir is at the third south most point of this polygon.

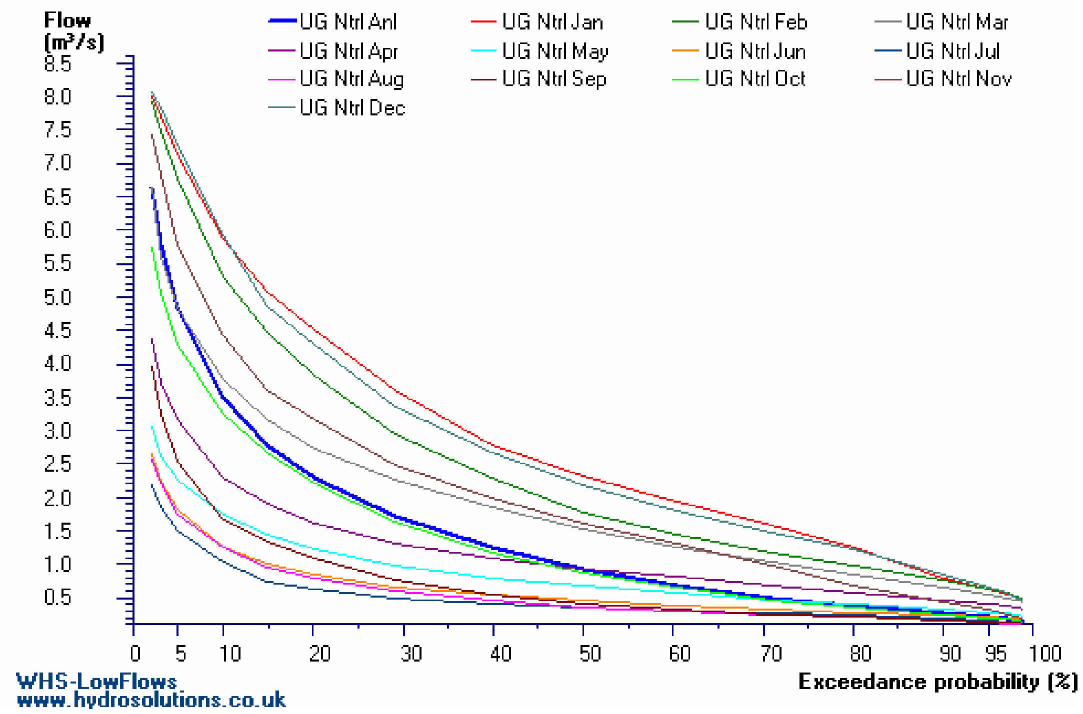


Figure A2.7 – Linear-linear annual and monthly flow duration curves for Yealmbridge Weir site.

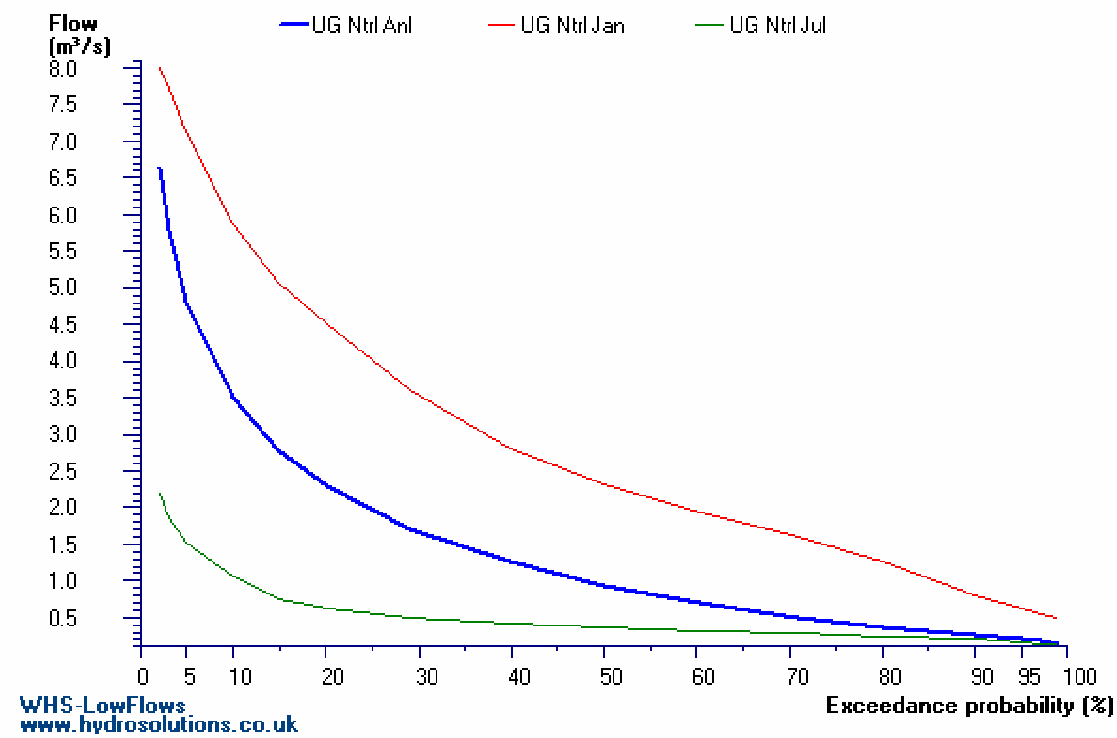
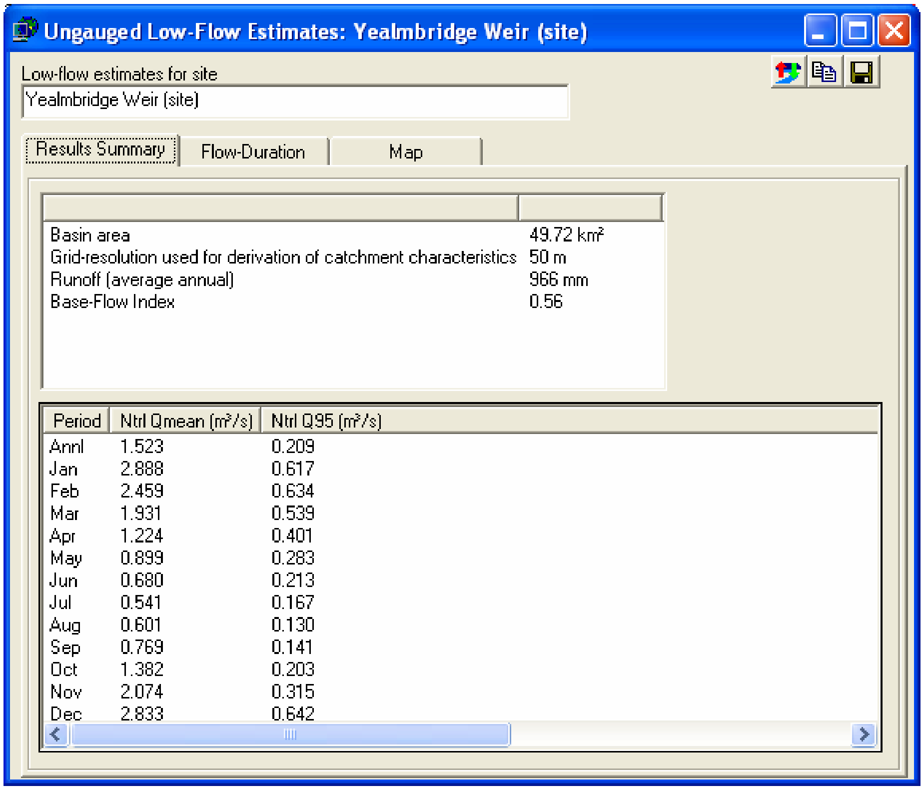


Figure A2.8 – Linear-linear annual, January and July flow duration curves for Yealmbridge Weir.



Ungauged Low-Flow Estimates: Yealmbridge Weir (site)

Low-flow estimates for site: Yealmbridge Weir (site)

| | |
|---|---|
| Basin area | 49.72 km² |
| Grid-resolution used for derivation of catchment characteristics | 50 m |
| Runoff (average annual) | 966 mm |
| Base-Flow Index | 0.56 |

| Period | Ntrl Qmean (m³/s) | Ntrl Q95 (m³/s) |
|---|---|---|
| Annl | 1.523 | 0.209 |
| Jan | 2.888 | 0.617 |
| Feb | 2.459 | 0.634 |
| Mar | 1.931 | 0.539 |
| Apr | 1.224 | 0.401 |
| May | 0.899 | 0.283 |
| Jun | 0.680 | 0.213 |
| Jul | 0.541 | 0.167 |
| Aug | 0.601 | 0.130 |
| Sep | 0.769 | 0.141 |
| Oct | 1.382 | 0.203 |
| Nov | 2.074 | 0.315 |
| Dec | 2.833 | 0.642 |

Figure A2.9 – Catchment characteristics and annual and monthly flow estimates for Yealmbridge Weir.