FINZEAN SAWMILL

PROPOSED HYDROELECTRIC PROJECT

Feasibility Report

For

BIRSE COMMUNITY TRUST

Presented By

CALEDONIAN ENERGY
Management Ltd

Engineers, Environmental Consultants and Project Manages for Small Hydroelectric Projects

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1 GENERAL

1.1 Introduction and Summary

This paper provides a report and summary in relation to work carried out to investigate the feasibility of developing a micro-hydro electric generating plant at Finzean Sawmill in Aberdeenshire.

In completing this work, we have carried out an initial site visit and survey, completed the hydrological analysis and calculation of potential energy output. We have investigated the operating costs of the scheme and the likely profitability of the project. Finally, we have made a very preliminary investigation of the likely capital costs of the development.

As a result of this work we consider that there is a real possibility that the scheme may not be profitable at all and that if there are profits, these will be insufficient to justify the level of capital investment required.

Accordingly, we regret to report that the proposed project is not feasible and that following discussions with Birse Community Trust, further work is not considered worthwhile.

1.2 Background

1.2.1 The Appointment

The work detailed herein has been carried out pursuant to an appointment by Birse Community Trust ("BCT") which followed a proposal by Caledonian Energy dated 25 and 26 April 2003.

1.2.2 Discussions with Birse Community Trust

During our visit to Finzean on 7 May we held detailed discussions with Robin Callander and John Addy of BCT in order to clarify the points of reference for the feasibility study. A number of points arose during discussions which have influenced our approach to the study:

- The sawmill is Grade A listed under the Planning (Listed Buildings and Conservation Areas) Act and is also of north-western European significance.
- It is the policy of BCT to maintain the site as a working mill as opposed to a 'museum' or tourist attraction.
- The mills run for around 1 hour per week at present and any development will need to allow for such use of the mills.
- All of the businesses of BCT must be self-financing and the hydro-electric proposal is seen as a possible source of revenues to enable the continuation and upkeep of the working mill site.
- The available capital grant from the Energy Saving Trust is limited to £100,000 and will probably not exceed 50% of the total project cost.

Additional costs will be met through sponsorship and/or donation from corporate and other sources.

- Salmon are present in the river and are known to spawn in the upper lade.
- All contact with statutory consultees must be treated sensitively and routed through BCT. The approval of Historic Scotland will be key to any development on the site.

In addition to the above, it was emphasised that normal economic criteria may not apply to the development as the securing of a long-term income stream is of more importance than notional rates of return on investment. It will however be necessary to demonstrate the income stream in order to secure both grant aid and the other sponsorship which will be necessary to fund any development.

1.3 Project Team

The majority of the study work has been carried out by Caledonian Energy's Director Simon Grey.

1.4 Limitations

This report details interim conclusions to the study as conducted so far. It does not represent the final findings which will be subject to further work in some areas. This should be borne in mind when reading and assessing this report.

2 TECHNICAL STUDY

The technical study work conducted to date is described in the following paragraphs. For consistency with the project brief, these are laid out in the order of the tasks specified in the brief.

2.1 Hydrology

2.1.1 General

Hydrology is the study of the likely flow of water within a watercourse and the variations of these flows throughout the year and from year to year. The total volume of water flowing in any river is dependant upon a number of factors, primarily catchment area, rainfall and evapotranspiration (i.e. rain that re-evaporates). The distribution of flows is dependant upon characteristics such a steepness of the catchment, distribution of rainfall, soil types, vegetation, etc. The combination of both the total volume of flow and the distribution of this flow is of interest for hydroelectric development and is normally presented in the form of a flow duration curve ("FDC") as presented in Figure 2.

The most accurate means of determining the hydrology of a river is through flow measurement. Unfortunately this entails the establishment of a gauging station and subsequent monitoring for many years. Although some sites do have gauging stations, many do not and hence other methods have had to be found. These methods have been developed by the Institute of Hydrology (now called the Centre for Ecology and Hydrology or "CEH") over many years and are based on analysis of rainfall records and catchment characteristics. Verification has shown the methods to produce very good results in the majority of cases.

Common practice in small hydro development is to use the theoretical techniques to assess the hydrology of a given site and then to use relevant gauged data to improve and/or verify results in the event that a development is considered worthy of investment. We have followed this practice for the Finzean site and the process is discussed further below.

2.1.2 Catchment Analysis — HydrA

An analysis of the catchment of the Water of Feugh was carried out using the HydrA software package produced by IH Wallingford. The catchment area was scanned from the 1:50,000 scale map and imported to AutoCAD. The catchment boundary was traced and the co-ordinates exported from AutoCAD in a format suitable for use by HydrA. The catchment boundary is shown below in Figure 1 overleaf.

From this analysis, the catchment area was found to be 47.96km^2 and the Annual Average rainfall ("AAR") for the period 1961 to 1990 was 1233.2mm.

Potential Evapotranspiration ("PE") was indicated to be 347.6mm.

From the above an average daily flow ('[4]ADF") of 1.347m^3/sec is indicated.

2.1.3 Adjustment of PE Value

It is known from research[1] that for wet upland catchments, HydrA consistently under-estimates the PE value. This research indicates that estimated PE values of between 18% and 25% of AAR produce good agreement with observed results. For drier catchments the PE value is likely to exceed these values.

The PE value indicated by the HydrA programme is 28.18% of SAAR.

Given the size and location of the catchment and the level of SAAR, the PE value indicated is considered to be reasonable and hence adjustment is not required.

2.1.4 Flow Duration Curve

Having determined the ADF from the ARD, it is necessary to select an appropriate base flow index in order to allow prediction of the flow duration curve shape in accordance with the methods[2] recommended by CEH Wallingford (Formerly the Institute of Hydrology).

The HydrA program calculates the FDC directly from the catchment data using the HOST method[3], and although it has been demonstrated for small wet

[1] **Grey, S**. Small Scale Hydroelectric Projects – Improvements in Annual Energy Production Derived From Hydrological Monitoring at Existing Stations, Caledonian Energy Management Ltd for ETSU, 2001.
[2] **Gustard et al.**, Report 101 - Low Flow Estimation in Scotland, Institute of Hydrology, Wallingford, 1987.
[3] **Gustard et al.**, Report 108 - Low Flow Estimation in the United Kingdom, Institute of Hydrology, Wallingford, 1992.

catchments that the curves produced by HydrA over-estimate low flows by a considerable margin[4], the results are more reliable for large dry catchments such as that of the Feugh.

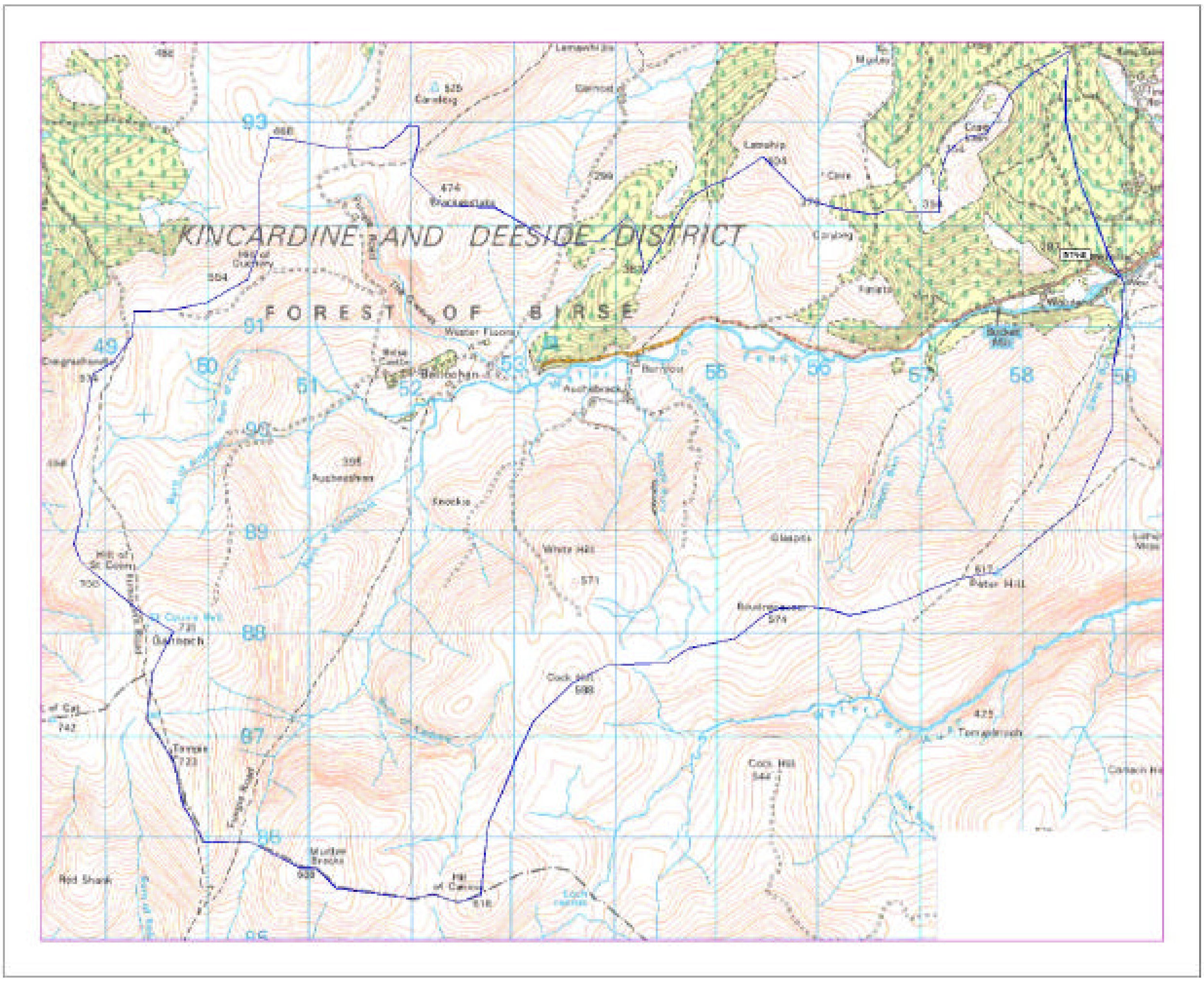

Figure 2 – Water of Feugh at Finzean Catchment Boundary

Accordingly, it is our practice to check the HydrA results against those obtained using Report 101 methods.

The HOST result produced by HydrA indicates a Q95(1) of 11.9% whereas the BFI map enclosed with Report 101 indicates a BFI of 0.40 to 0.44 which produces a value for Q95(1) of 13.1% which agrees reasonably well with the hydra result.

We would therefore suggest the adoption of a value for Q95(1) of 12.5% of ADF, that being mid-way between the two results.

The resulting flow duration curve is shown in Figure 2 below.

[4] **Grey, S**. Small Scale Hydroelectric Projects – Improvements in Annual Energy Production Derived From Hydrological Monitoring at Existing Stations, Caledonian Energy Management Ltd for ETSU, 2001.

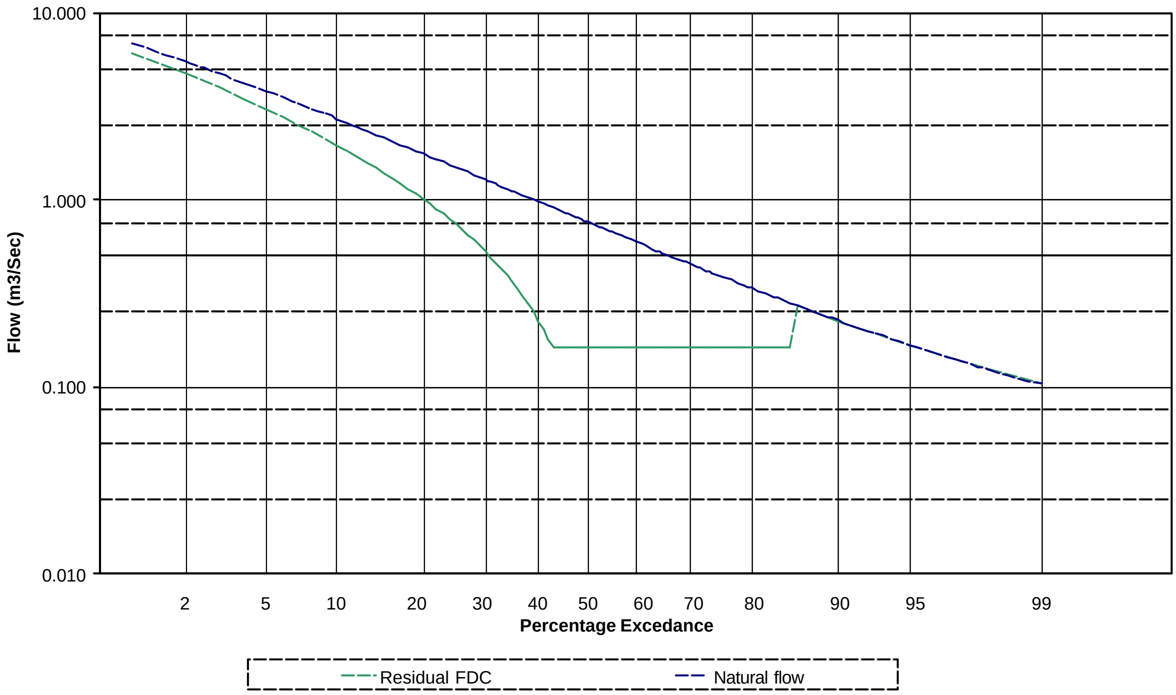

Figure 2 – Water of Feugh
Natural and Residual Flow Duration Curves

2.1.5 Compensation Flows

Compensation flows are flows which are released through a weir in order to maintain a basic level of flow in a watercourse where the remainder of the water is abstracted.

At the present time there is significant leakage through the weir which provides compensation flows when the lade is running full. In addition, the use of the mill is relatively infrequent with the lade either running on 'by-pass' or at partial flow.

The introduction of a hydro turbine will cause significant alterations to the flow regime, particularly as the turbine will run for 24 hours, 365 days per year so long as there is sufficient water. The project will require planning consent and SEPA will be consulted on the flow regime. It must therefore be assumed that a compensation flow regime similar to that required for other small hydro schemes will be requested. Formerly this was a minimum flow equal to the Q_{95}(1) however more recently SEPA have insisted on Q_{90}(1) flows. For the Water of Feugh at Finzean theses flows are 0.168 and 0.226m^3/sec respectively.

In addition to the minimum flow requirements, it will be necessary to provide additional flows known as 'freshets' to facilitate the upstream migration of salmon and sea-trout. Formerly, migration would have been via the by-wash waters emitting from the mill but as noted above, these will not now be available. These freshets would probably involve running the lade on bypass flow for around 8 hours per week during around four months of the year.

For the purposes of energy production assessment, we have assumed that the provision of freshets will mitigate other effects and therefore a minimum flow of the Q_{95} will be acceptable to SEPA.

2.1.6 Gauged Flow Data

The Water of Feugh is not gauged in the vicinity of the site, although there is a gauging station downstream at Heugh Head, some 10km to the east. Several major tributaries join the Water of Feugh between Finzean and Heugh head and hence the flows measured at Heugh head are unlikely to be representative (even in relative terms) of the flows at Finzean. We have also identified that there is a gauging station on the Water of Dye at Charr. This station has a smaller catchment area and may provide some useful data if required.

As neither station was going to provide data which is directly applicable to the study site, it was considered that further investigation of gauged data at this stage was not warranted.

If however it is found that the project may be viable subject to reducing the error bands in flow and energy prediction (see 2.5.4) then it would be worthwhile obtaining data for analysis. It should be noted that the use of gauged data is unlikely to vary the energy prediction results by more than a few percent and at this stage it appears that this would not be sufficient to make the scheme viable.

2.2 Site Survey

2.2.1 Walkover Survey

A site survey was conducted by Simon Grey on 7th May 2003 during which the following features of the site were noted:

General Observations

The mill site occupies a strip of land approximately 400m long between the public road and the Water of Feugh. Water is diverted from the Feugh by a rubble weir which has 'washboards' on the crest and has filled with sand and gravel behind. A wooden framed sluice admits the water to a lade which is unlined. Around 100m downstream a wooden bywash sluice is provided to drain excess water from the lade. Downstream of the bywash the section of the lade increases and becomes straight and even for approximately 30m before discharging to the various channels leading to the mill wheels.

There are three principal mill wheels driving the saw mill, the dynamo and the turning mill. The latter two are fed by suspended wooden channels and the flow to all wheels can be diverted quickly using drop sluices.

The mill buildings are of a variety of constructions, but are primarily timber framed with wooden or corrugated steel cladding. The buildings are closely spaced on a slope and there is little opportunity to introduce additional structures without significant alteration to these buildings.

The weir was noted to be in fair condition and not at risk of deterioration although the wash-boards could benefit from being attended to. The main intake sluice was however noted to be aging and should be replaced soon. A similar comment applies to the bywash sluice. Generally the lade appeared to be in good condition and suitable for the flow rates currently being passed down it.

Natural Environment

Observations regarding the natural environment are presented in 2.8 below.

Potential Location of New Structures

It was noted that the only area which could accommodate a new powerhouse was immediately downstream of the bywash sluice and channel. This is a small area of scrub woodland with birch and alder trees (plus one mature pine). The birch show signs of coppicing in the recent past. Accordingly, clearance of some trees is unlikely to provide a difficulty. Access to this potential site is available from the far bank of the river. The potential scheme layout is discussed further in 2.3.1. In addition, it was noted that the existing sluices would require to be replaced in the event that a micro-hydro scheme is developed at the site.

Other Structures

Aside from the public road that runs along the northern boundary of the site, there exists a private dwelling house which is located opposite the bywash sluice with it's garden immediately adjacent to the road.

A wooden decked bridge provides access from the public road to he south of the Feugh. The weight capacity of this bridge could provide a limitation to construction traffic and hence should be confirmed.

Grid Connection

The local distribution network is 3 phase 11kV, operated by Scottish & Southern Energy. The lines pass within 200m of the potential powerhouse site.

2.2.2 Topographic Survey

A topographic survey of the mill lade and river bank in the area of the by-wash sluice was carried out by our subcontractors Ewan Associates on 16 May 2003. This confirmed the available head between the lade and the Water of Feugh adjacent to the bywash to be 2.9m.

2.3 System Design

2.3.1 Scheme Layout

From initial discussions with BCT and the site visit it was clear that any development of the site would have to be subject to strict controls to avoid damage to the valuable industrial heritage.

Accordingly, the only practicable layout is to keep the new powerhouse well separate from the existing mill. A site has been identified in the area of the lade bywash where a new powerhouse could be constructed without any appreciable effect on the mills.

In outline, the works in this area would comprise a short lade leading at right angles from the existing lade, just downstream of the by-wash. This would feed a turbine via an intake screen and the turbine would subsequently discharge to a tailrace channel exiting to the river.

The intake, turbine and tailrace would be incorporated into the foundations of a small powerhouse. The above-ground elements should be designed in a similar style to the existing mill buildings.

2.3.2 Plant Rating

Although the hydrological data has a bearing on the plant selection, at Finzean, this is not the over-riding factor. Instead for legal and consenting reasons (see 2.10.4) at this site, (and to control costs) it is necessary to utilise the existing weir, intake sluice and mill lade without modification and accordingly the flow is limited to that which can reasonably be passed down these waterways.

The site survey reveals that the lade section between the by-wash and the mill wheels has a cross-section of 1.6m x 0.8m giving an area of 1.28m^2. Approximate measurements on site with the lade running close to capacity indicated a flow velocity in the region of 0.5m/sec. From this it would appear that the lade capacity is somewhere marginally in excess of 0.64m^3/sec.

Given the above, we have adopted 0.75m3/sec as what we consider to be a reasonable estimate of the full flow capacity of the lade. We consider that it is unlikely that the hydro plant can be rated for a discharge much in excess of this value without modification to the weir, intake sluice or lade.

2.3.3 Generating Equipment

The available head of 2.8m and discharge of between 0.75 and 1.0m3/sec indicate two possible turbine and generator configurations:

- A semi-kaplan, axial flow ‘propellor’ type turbine driving an induction generator via a belt drive, or;
- A crossflow turbine driving an induction generator via a high-ratio belt drive or gearbox.

Of these options the Kaplan turbine will be the more efficient however it is also likely to be more costly. For the purposes of this study we have assumed the use of a Kaplan although the use of a cross-flow could be investigated if the overall economics were found to be favourable.

2.4 Task 4 – System Cost Estimates

As described in our submission we have compiled an initial budgetary indication of costs in order to assist with initial project viability evaluation. Our summary is as follows:

Description	Budget cost
Consenting costs	5,000
Design & Management	15,000
Total Professional	*20,000*
Powerhouse Foundations	10,000
Lade, sluices, screens etc	10,000
Powerhouse building	8,000
Total Civils	*28,000*
Turbine & Generator	40,000
Controls & Switchgear	6,000
Grid Connection	8,000
Installation	3,000
Commissioning	3,000
Total M & E	*60,000*
Total Budget Costs	**108,000**

In addition to the above, we would recommend a contingency allowance of 10% at this stage in the project. Accordingly the initial estimate of the capital cost of implementing the project is £120,000.

2.5 Task 5 – Energy Production

2.5.1 Plant Efficiencies

For the purposes of the initial assessment required for this interim report, we have assumed that plant with the best available efficiencies has been used. This plant is likely to comprise a semi-Kaplan (propeller) type turbine which will drive an induction generator via a belt drive.

The turbine can be expected to have efficiency in the region of 88% whilst the combined belt drive and generator efficiency will be around 91.5%.

These values will be confirmed in the event that the initial assessment reveals that the project is likely to be viable. It should be noted however that any variation will be less than 1% in overall efficiency.

2.5.2 Assessment of operating head

The operating head can be obtained directly from the survey data with a suitable allowance for intake screen, inlet valve and tailrace loss.

The topographical survey indicated that the difference in level between the lade under ‘full’ flow and the river at the proposed tailrace location was 2.9m. A minimum allowance of 100mm for hydraulic losses should be made, thus producing a net operating head of 2.8m.

It should be noted that the operating head will reduce when river levels rise due to higher flows. This will reduce the energy production. No account has been taken of this factor as yet. Again a detailed assessment will be made if the project is considered viable.

2.5.3 Energy Capture Calculation

The energy production potential of the proposed scheme was calculated using a Caledonian Energy standard spreadsheet which uses a step-wise algorithm to calculate the available power at ten percentile intervals on the flow duration curve. The results are then integrated to provide the total energy production.

The model produces a theoretical average energy capture for the site assuming 100% availability. In practice, low head sites, especially non-automated small sites, lose considerable energy due to a number of factors:

- Leaf fouling causes significant plant availability loss for around 4 to 6 weeks every year. Unfortunately, leaf shedding normally corresponds with wet, windy weather and hence the energy loss occurs when the potential for full output exists. It is therefore not unreasonable to assume losses equal to 50% of the possible generation at full load for a period of four weeks. This totals around 7% of the gross annual production.
- Provision of freshets to assist salmon migration will require reduction or cessation of generation for significant periods of time. We are advised that an allowance of 36 hours per week should be made for a minimum of 12 weeks. Assuming a minimum flow of 0.5m3/sec, the energy loss will be approximately 8.6% of gross annual production.
- Other forced outages, including plant failure, grid failure, high (flood) water levels and ice are likely to cause further energy loss. Results from other plants shows this to be around 5% of the gross annual production on average.

Overall therefore, we would consider an actual energy capture prediction based on 80% of the theoretical energy value to be the best achievable with diligent operation.

Owing to the uncertainty as regarding the final plant rating, we have run the energy prediction model for a range of flows (although we consider anything above 1.0m^3/sec to be impracticable) and the results are presented in Figure 3 below. A typical print-out from the model is presented in Appendix A.

Rated Flow m3/sec	Power kW	Gross Energy MWh	Net Energy MWh
1.35	27.7	123.9	99.12
1.20	25.2	118.1	94.48
1.05	22.5	111.9	89.52
0.90	19.6	103.6	82.88
0.75	16.6	93.1	74.48

Figure 3 – Energy Production Summary

2.5.4 Error Bands

As with all estimation procedures, the estimation of energy production is subject to error due to a number of factors. Research has shown that providing the input data is well controlled and 'best practice' procedures are followed, these errors can be reduced to acceptable limits.

This study was carried out using recommended 'best practice' techniques referred to above and accordingly, the error bands can be expected to agree with those expected for such techniques[5]. It can therefore be stated that for this study the 68% confidence limits for the energy production estimate are –12.1% to + 15.6% of the calculated value.

In the event that improved confidence limits are required, it will be necessary to carry out some short-term flow gauging on site. A six month period (including one summer) would allow an improvement in the confidence limits to around +/- 7%.

2.6 Task 6 – Economic Assessment

For the purposes of this interim report, we have not gone to the extent of producing a full evaluation of the return on investment for the project. This is primarily because it seems unlikely that the project can make any profit at all, therefore rendering the return on investment question irrelevant. Comment on the various factors affecting the economic performance of the scheme are as follows:

2.6.1 Income

It will be appreciated that the revenues from the plant are dependant upon the energy production which in turn is dependant upon the plant rating. In 2.3.2 we have discussed the plant selection and have stated the view that $0.75m^3$/sec represents an optimistic estimate of the current flow capacity of the lade. Calculation of energy capture for the plant is discussed in 2.5.3 where the results for a range of flow ratings are presented.

As discussed in 2.12, the total value of electricity sold is likely to be in the region of £51/MWh initially and reducing to around £41/MWh within 5 to 10 years.

[5] **Grey, S**. Small Scale Hydroelectric Projects – Improvements in Annual Energy Production Derived From Hydrological Monitoring at Existing Stations, Caledonian Energy Management Ltd for ETSU, 2001.

From this and on the basis of the range of net energy production given in 2.5.3, the total gross income will range from £3,798 to 5,055.

2.6.2 Operating Costs

There are various sources of operating costs, some of which are variable (or can be reduced by input from the owners) and some of which are fixed or 'unavoidable'. Comment is as follows:

Maintenance

Maintenance tasks are outlined in 2.13 from which it will be seen that the time requirement for maintenance averages around 5 hours per week or 250 hours per year. In addition, there is a requirement for an annual inspection of the plant by a qualified engineer, together with various consumables (grease, paint, fuese, etc) which must be provided.

Taking all of these items together and assuming a labour cost of £5/hour, the total maintenance cost is likely to be no less than £1,950. This does not allow for the cost of unforeseen breakdown or replacement of major parts.

Insurances

It will be necessary to have in place at least public and employer's liability insurances and it would be prudent to insure against loss and damage to the plant and mechanical breakdown. The minimum premium expected for the liability section is in the region of £500 and additional cover will cost more. We have yet to receive confirmation of these premiums and our broker is advising of difficulties in obtaining any suitable cover.

Local Authority Rates

Hydro plants are rated according to the output capacity at the rate of £10.00/kW. Assuming 17kW rating and 50% relief, the annual rates bill will be £85.

Grid Connection Charges

The standard tariffs for connection to the grid involve charges which relate to the capacity or 'availability' of the connection. The plant will require an authorised capacity for import of around 2kVA, resulting in charges of around £67 per annum.

Contract Administration Charges

Any power sales contract with SSE will attract a standard set of contract administration charges, together with a charge for metering and for settlement (i.e. number crunching). We have contacted SSE for outline terms and they have indicated that the contract charges will be in the region of £865 per annum.

2.6.3 Profit and Loss Evaluation

Based on a simple subtraction of operating costs from gross income, we have produced a preliminary evaluation of the likely profit from the scheme on the basis of the initial plant discharge rating of $0.75m^3$/sec and terms for sale of electricity as indicated by SSE (see 2.12.4). This is presented in table X below:

Income		
Sale of electricity & ROCs etc.	3,796	
Total Income		**3,796**
Less Costs:		
Insurances	500	
Local Authority Rates	83	
Local labour	1,250	
SSE admin & metering	865	
SSE connection availability charge	67	
Annual Maintenance & consumables	700	
Total Costs		**3,465**
Net Operating Profit		**331**

2.6.4 Effect of Increased Plant Rating

Clearly such low levels of profitability are not sustainable and further investigation of the plant on this basis would be fruitless. Accordingly, we have considered the possibility of increasing the plant rating to discharge the average daily flow in the river, this normally being the optimum rating for a run-of-river hydro plant. The loss/profit for the range of a range of plant ratings and this is presented in Figure 4 overleaf.

From the graph, it will be seen that whilst the profits from the plant increase in relative terms as the rating increases, these remain very low in terms of the capital investment required. Even at the maximum rating considered of $1.35m^3$/sec, the profit is less than £1,600 per annum which represents only 1.33% of the likely capital cost.

From this it will be seen that even if an increase in rating were technically feasible and environmentally acceptable, it still would not result in a viable scheme.

2.6.5 Future Profitability

As noted in 2.6.1 the value of electricity sold is likely to drop in 5 to 10 years time as the market for renewable energy becomes saturated and ROCs lose their premium value. This will only serve to exacerbate the low returns from the plant.

Considering the maximum practicable rating of the plant given the site constraints, being $1.05m^3$/sec, the net operating profit reduces to around £1,068 per annum with ROC values equal to the current buyout price. A single day of engineer's time to investigate a fault, or a dry period during the year would reduce this profit by half and a prolonged breakdown would result in a net loss.

Given the fact that operating costs are likely to rise due both to inflation and as the plant ages, it is considered highly unlikely that the plant can remain profitable at all in the future.

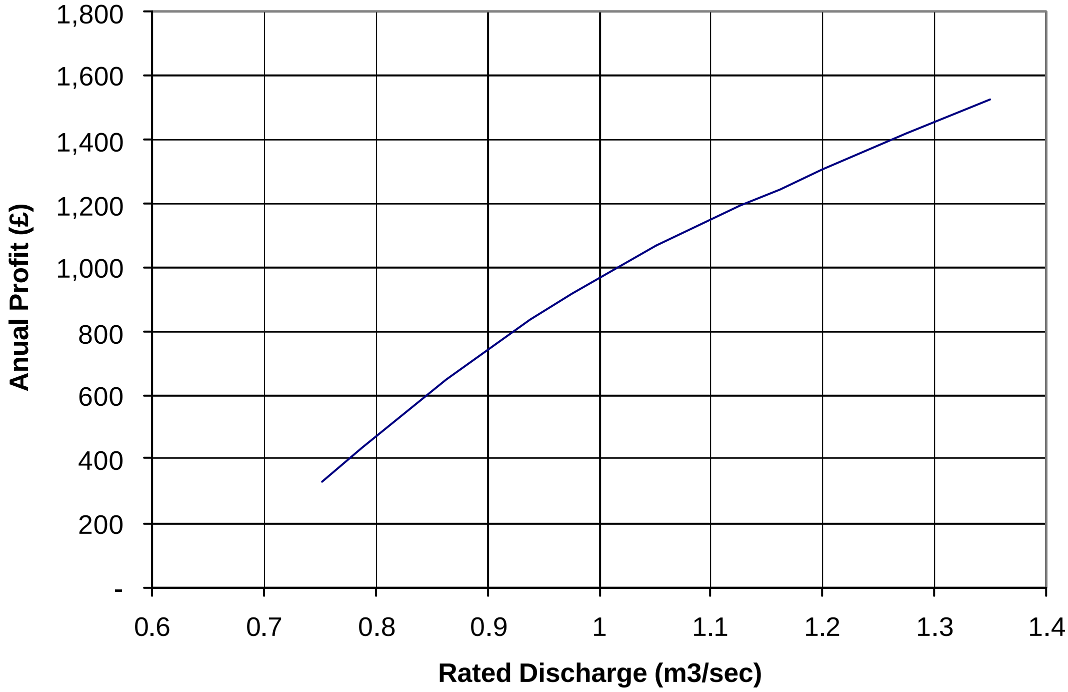

Figure 4 – Plant Rating vs Annual Profit

2.6.6 Error Bands and Operating Risks

Notwithstanding the very real risk of non-profitability in the medium term due to reduced revenues, the possible errors in energy production calculation and operating risks should be highlighted.

The error bands for energy production are discussed in 2.5.4 and these are –12.1% to +15.6%. Accordingly, there is a real risk that the revenue could be 12.1% lower than stated, whilst the operating costs would remain the same. This would reduce revenues by £765 for the largest rating considered and leaves even this rating with marginal profitability.
Another point which should be considered is the risk of plant failure and the consequent costs of calling out a qualified maintenance engineer. With costs of engineers time in the region of £500/day a single call-out could significantly reduce a year's profit. In our experience at least one call-out per year, particularly during early years is very likely.

2.6.7 Economic Conclusions

From the above work, we consider that even with a plant rated to discharge the average daily flow in the river, there is a real risk that the project would suffer negative cashflow even during the early years of operation when ROC prices are high. Within 5 to 10 years, the reduction in ROC prices will mean that it is almost certain that the project would suffer negative cashflow regardless of rating.

On a practical note, the maximum rating considered would require modifications to the mill lade and intake and would cause additional impact to the aquatic ecology and hence is probably not achievable from a consenting perspective even if it were desirable. The economic results for the lower rated plant which does not require alterations to the lade are worse even worse.

Accordingly, it is our conclusion that the proposed project presents very little prospect of realising the aims of BCT as a source of revenue and presents a real risk that it could become a financial drain on the resources of the Trust. Even given the assumptions used herein, which are considered to be optimistic, the return on investment at 1.4% of capital cost is far too low to justify either the investment or the risks to the site.

2.7 Task 7 – Consultation Plan

Owing to the fundamental feasibility issues which have emerged, we have not yet considered the consultation plan although some of the issues are discussed in 2.10.1 below.

2.8 Task 8 – Environmental Impact Assessment

During the site visit on 22 May we noted the prominent environmental features and a discussion of these, together with comments on potential impacts follows:

2.8.1 Aquatic Ecology

The Water of Feugh is noted as being a clean and 'pristine' river which is largely unspoilt by developments. Accordingly, it is expected that the aquatic ecology will be healthy and that any significant changes to the flow regime at the site could have a negative impact.

It was noted from discussions that both salmon and sea-trout are present within the river and that salmon spawn in the upper lade. This may be particularly significant to any proposed development.

Although the mill complex has been in existence for hundreds of years and has drawn water from the river and discharged this either via the mill wheels or via the by-pass sluices, the nature of the water use will be significantly different in the event that a hydroelectric scheme is installed. The primary difference is that the mill usage is intermittent during the day and non-existent at night time. When the water is not used, it by-passes the mill wheels via various drop sluices. It is considered likely that salmon are capable of migrating upstream via the by-pass arrangements and this view is supported by anecdotal evidence of spawning within the lade. Accordingly, the mill complex does not present an impediment to upstream migration. Turning to the downstream migration phase, it is considered likely that smolts can pass downstream either via the by-passes or directly over the wheels without adverse effect.

In contrast to the above, if the great majority of available water is passed through a turbine, then upstream migration of salmon will be impossible without the implementation of special measures. (e.g. freshets down the river, fish pass or operation of the lade system on 'by-pass' for significant periods). Furthermore, downstream-migrating smolts will be harmed by the turbine and therefore will require both screens to prevent them entering the turbine system and an alternative downstream path. All of these measures will educe the water available for generation, thus reducing energy output below that stated in 2.5.3 above. Finally, it should be noted that the changes will necessitate a detailed assessment of this potential impact in conjunction with the local salmon fishery board.

2.8.2 Flora and Fauna

We have not completed a detailed assessment of the flora and fauna at the site however the following points would need to be addressed were the scheme to be taken forward to planning:

- The proposed site has a number of mature and semi-mature deciduous trees. Although these may be relatively common and of relatively young age, the effect of removal on the natural habitat will still need to be considered.
- There is a possibility that protected species including Otter and Bat may use the river/tree habitat.

A brief habitat survey by a qualified ecologist should provide further information on these points.

2.8.3 Visual and Audal Amenity

A number of potential changes to the visual and audal amenity of the site were noted:

- Introduction of a new turbine shed which will be situated directly in front of and approximately 40m distant from a private house.
- Removal of the cascades of water which are currently seen when viewing the mill complex and which form a significant part of the overall visual and audible effect.
- Care will be required with the design of any turbine house to ensure that noise emissions are effectively contained. Given the close proximity of residential buildings, this issue will be critical.

A fuller assessment of these aspects will be required as a critical part of the impact assessment and consenting process for any development.

2.8.4 Landscape (i.e. site) Character

The whole site and particularly the complex in the vicinity of the mill buildings has a very special character. The site is 'Grade A' listed and is of both national and north-western European significance.

Clearly there exists the potential for any development to impact significantly on the character of the site and accordingly extreme care will be required with the design and implementation of any development.

2.8.5 Socio-economic Aspects

Not considered at this stage.

2.8.6 The Wider Natural Environment

Again, we have not considered the effects on the wider natural environment due to the fundamental questions as to the viability of the scheme. We would however comment that the benefits will be slight in terms of CO_2 and greenhouse gas emission reductions.

2.9 Task 9 – Safety Risk Assessment

We have not yet undertaken a full risk assessment of the proposed scheme and suggest that this would only be appropriate if the scheme were likely to proceed.

We would however comment that any scheme would be subject to the Construction (Design and Management) Regulations 1994 (the "CDM Regulations") which set out measured required for the assessment of risk and control of safety during both the construction and operational phases of the project and place obligations on the designers to remove any inherent risks as far as practicable.

A key part of the control of safety and satisfaction of the CDM Regulations is the preparation of a pre-construction health and safety plan which provides initial information as regards the risks in constructing the project. During the project, a health and safety file is developed which contains information necessary to ensure the safe operation, maintenance and de-commissioning of the plant.

Risks identified are likely to include:

- General construction risks;
- Work near to running water;
- Work with concrete and other hazardous materials;
- Pollution to the watercourse;
- Noise exposure;
- Work on rotating plant;
- Work with electricity;
- Single-man working (maintenance).

These risks and others should be more fully considered and a Planning Supervisor should be appointed in the event that the project is to proceed beyond the feasibility stage.

2.10 Task 10 – Legal and Planning Assessment

A new hydroelectric station at Finzean will involve the construction of new structures and will also involve alterations to the established flow regime within the river and lade. The various legal and planning consents which will be required for such a project are as follows:

2.10.1 Planning Permission

As will already be appreciated the Town and Country Planning (Scotland) Act 1997 requires that the project will require the grant of planning permission by Aberdeenshire Council as planning authority.

Owing to the sensitive nature of the site, it is anticipated that any application for planning permission will require to be accompanied by an assessment and statement of the environmental impact of the scheme. This statement will require to address in detail the various headings listed in 2.8 hereof. The scoping and impact assessment process should be carried out in close consultation with the planning authority and the following bodies:

- Scottish Natural Heritage;
- Scottish Environment Protection Agency;
- Historic Scotland;
- Dee Salmon Fisheries Board;
- Local Community Council.

We would recommend that the consultation and impact assessment process be conducted in a flexible and open manner in order to ensure that the final scheme design and the accompanying environmental statement are acceptable to all parties prior to lodging any planning application.

Our experience on other sites is that the scoping, consultation and environmental assessment process will take between 6 and 9 months to complete. Gaining consent from the planning authority should thereafter be possible in around 12 weeks, assuming that there are no outstanding objections to the scheme.

2.10.2 Listed Buildings Consent

As the mill buildings and associated works are listed in terms of the Planning (Listed Buildings and Conservation Areas) (Scotland) Act 1997, it will be necessary to obtain the authorisation of the planning authority to any change which will affect the nature of the site as regards it's special character or the historic interest.

We do not have direct experience of obtaining listed buildings consent although we understand that this will normally be handled in conjunction with planning permission.

2.10.3 Discharge Consent

Clean water which has passed through a hydro-electric turbine is said to have undergone a 'process' and therefore is classified as effluent in terms of the Control of Pollution Act 1974. Accordingly a Consent to Discharge is required, such consent being issued by SEPA.

Obtaining a discharge consent is normally straightforward and can be handled in parallel with the planning consent.

2.10.4 Landowner Consent

In Scots law, where it is proposed to alter the flow in any watercourse, it is necessary to obtain the consent of the respective landowner(s). The case of *Morris v. Bicket* (1864), 2M. 1082 is regarded as a leading authority in the matter[6]. In this case Lord Neaves stated that "*A lower heritor has this interest in the stream, that, in passing through the lands of others, it shall be transmitted to him undiminished in quantity, unpolluted in quality and unaffected in force and natural direction and current, except in so far as the primary uses of it* [i.e. use for domestic and agricultural purposes] *may legitimately operate upon it within the lands of the upper heritor*" He goes on to say that neither opposite proprietor can withdraw water from the stream except for domestic or agricultural purposes "*But where a cut or channel is made for other purposes, that is not to be allowed, unless fortified by the acquisition of a servitude*." Later he states that "*when anything is threatened that materially alters or changes the existing position of things, then the consent of the other party appears to me to be necessary.*" and he goes on to say that "*it is enough for a party to say, 'this will alter the operation of the water, and therefore I object.'*"

The upshot of the above (which we are advised has subsequently been upheld in other cases and by the House of Lords) is that you must obtain the prior consent of all opposite or downstream heritable proprietors who may be affected by the abstraction (or re-introduction) of flows in connection with the hydro scheme. We are advised that abstraction without permission infringes on the Riparian Property Rights of affected heritors and hence is unlawful. The remedy to the affected party is interdict which as you will appreciate would prevent the operation of the scheme. This is regardless of whether or not actual damage has been suffered.

At Finzean, the river bed and opposite bank of the Feugh, together with the upper part of the lade are owned by Donald Farquharson and accordingly, it will be necessary to obtain his consent to any changes. Such consent should be in a heritable form (i.e. will transfer with the property should it be sold) and a lease of the water rights is the normal means of achieving this.

[6] The Law of Water in Scotland by Ferguson. W Green & Sons, Edinburgh, 1907.

2.10.5 Legal and Planning Costs

It will be noted from the above that ther may be a significant amount of work involved in securing the various consents, even in the even that the proposals are non-contentious.

Our initial estimate of the professional input required, which includes environmental, engineering, architectural and legal services, is that it will cost no less than £10,000. Indeed many schemes cost significantly more than this. The costs can only be estimated more accurately following initial consultation when the scope of professional input will be more clearly defined.

2.10.6 Legal Aspects – Construction

As noted in 2.9 a project of this nature will be subject to the Construction (Design and Management) Regulations 1994. These Regulations impose certain duties on clients and these should be reviewed if the project is to proceed beyond feasibility stage.

2.10.7 Legal Aspects – Operation

The completed works will be subject to a number of different pieces of legislation including:

- The Salmon Act;
- The Control of Pollution Act;
- The Electricity at Work Regulations;
- The Health and Safety at Work Act.

Again a further assessment of each of the above is advised if the project is to proceed further. As a general comment at this stage however, it is only the Salmon Act which requires specific measures to be incorporated into the design of the works, those being to allow the un-impeded migration of Salmon (upstream and down) and to provide screens above and below the scheme. The remaining legislation does not impose specific burdens in addition to what is normal 'good practice'.

2.11 Task 11 – Insurance Assessment

We have carried out an initial assessment of the insurance requirements for the operation of a scheme of the nature proposed and have consulted with professional insurance brokers in this regard.

We are advised that employer's liability insurance will be required by law and that public liability insurance is strongly advised. In addition, we are advised that material damage insurance will be required in the event that bank finance is secured on the scheme assets and that in any case damage insurance is advisable.

Other scheme operators have obtained mechanical breakdown and loss of revenue insurance however we are advised that such cover is no longer available on new policies.

With regards to premiums, our brokers have been unable to obtain quotations for a new public and employer's liability policy at an affordable level. They have therefore suggested that cover be obtained as an extension to an estate or farm policy which we assume is already held by BCT.

2.12 Task 12 – Electricity Sales Assessment

At the present time, there a number of options for realising value from electricity generated by a hydro plant. These are as follows:

- Local use for an industrial or craft process which produces a saleable product;
- Private sale to local consumers;
- Sale to the local electricity company;
- Sale to a remote electricity trader.

Further discussion and comment on the viability of each option is presented below:

2.12.1 Local (on-site) Power Use

On-site use essentially relies on the establishment of a manufacturing or craft process which requires significant amounts of electrical power (16kW is significant in terms of light industrial usage) on a continuous basis. The resulting goods or services must have a significant value in order to provide profits to pay for the energy consumed.

The process must however be capable of using less power when flows are low and more power when flows are high to avoid either wasting energy or having to import 'top-up' supplies. In reality it is likely that any process will require power during normal working hours and will depend on this power supply being reliable for economic viability. This means that firstly, excess power (e.g. that generated outwith working hours) will have to be sold onto the grid and secondly, 'top-up' supplies will have to be drawn from the grid in the event of low flows or plant failure.

Unfortunately, as soon as a grid connection is introduced, the various charges associated with sale and purchase of electricity will apply. As will be seen in 2.12.4 these can be significant. It will also be seen from 2.12.4 that it is likely that power can be purchased at a rate which is less than the value of the electricity if sold. Accordingly, on-site consumption is not desirable economically.

Whilst there are some isolated examples of on-site use of hydro generation (notably at fish-farms and paper mills) we have no experience of the successful establishment of a new manufacturing process which is designed to 'absorb' power and deliver profits through the sale of goods or services.

The notable exception to the above would appear to be saw and other mills driven mechanically by water wheels!

2.12.2 Private Sale to Local Consumers

In order to sell electricity from a small hydro station to local consumers, it is necessary to either establish a private network of cables or to use the existing grid system for distribution. The former would be prohibitively expensive and involve a high maintenance burden, however the later is technically and commercially possible although unlikely to be feasible for a number of reasons:

- Firstly, sale of electricity to consumers is a regulated activity and suppliers are required to be licensed in terms of the Electricity Act 1989. The costs and administrative burden of obtaining a licence are prohibitive.
- Secondly, the use of the distribution system will incur 'use of system' and metering charges. These when subtracted from the market price for electricity (i.e. what consumers can already buy it for) leave the price available to the generator considerably lower than that which would be achieved by sale to the local electricity company.
- Thirdly, supply to consumers would carry a considerable administrative burden, including the need for meter reading, billing and credit control. The administrative costs alone are likely to exceed the total revenue available to the plant.

Accordingly, sale to local consumers is not considered to be a feasible option.

2.12.3 Sale to a Remote Electricity Trader

Sale to a remote electricity trader was discounted due tot the fact that the volumes of energy are too small to be of interest to any trader and the possible additional income is unlikely to be sufficient to justify the legal costs of establishing the necessary agreements.

2.12.4 Electricity Sale to SSE

Sale of electricity to the local electricity company appears to offer the best solution as it realises the highest value per unit of electricity as the price will include not only the energy value but also the value of Renewables Obligation Certificates and Climate Change Levy.

We have contacted SSE for indicative terms and these are as follows:

Payments:

	Value £/MWh	Percent Paid to BCT	Total £/MWh
Energy	10.0	100%	10.00
LEC	4.7	65%	3.06
ROC	31.0	90%	27.90
Recycle receipts	20.0	50%	10.00
Total Payment per MWh			**50.96**

Charges:

Administration (£30/month approx)	360
Metering & comms (approx)	500
Settlement (£0.012/kWh)	12
Total Annual Charges	**872**

The various elements of the payment outlined above are explained as follows:

Energy This refers to the basic 'electricity value' of the energy produced. The low cost reflects the low wholesale price of electricity, the uncertainty of the supply and the costs of transmission to customers.

LEC "LEC" stands for Levy Exemption Certificate and relates to the Fossil Fuel Levy. A LEC is issued in respect of every MWh of energy produced which does not use fossil fuels.

ROC "ROC" stands for Renewables Obligation Certificate and relates to legislation called the Renewables Obligation (Scotland) Order or the "ROS". The ROS requires the licensed electricity suppliers in Scotland to obtain a certain percentage of the electricity they supply from new renewable sources. A ROC is issued for every MWh of electricity purchased from renewable sources and is used as evidence of compliance with the ROS. Failure to meet the obligation results in a penalty charge (the "buyout") which is £31/MWh at present and this creates the value for a ROC.

Recycle Receipts The recycle receipts also relate to the operation of the ROS. All of the payments received from "buyouts" are then re-distributed to suppliers who are in possession of ROCs in proportion to the number of ROCs held for a particular period. This in effect increases the value of the ROCS. The level of recycle receipts will be entirely dependant upon the extent to which the ROS is met. In the event that the obligation is fully met by suppliers then the recycle receipts will fall to zero.

SSE have confirmed that they will enter into long-term (i.e. in excess of 5 years) contracts on the above terms.

2.12.5 Future Vale of ROCs

It will be seen in 2.12.4 above that a large proportion of the sale value of electricity comes from the combination of ROC values and the 'Recycle receipts' but these are subject to future variation.

Various estimates of the value of ROCs have been produced for example by Platts[7]. These estimates would indicate that ROC prices remain roughly the same over the coming 5 years. Assuming that the quantity of renewable energy available on the system begins to catch up with the obligation after that time, ROC prices will then tend to reduce to around the buyout-price current at that time.

2.13 Task 13 – Operating and Maintenance Assessment

2.13.1 Basic Requirements

The requirements for operation and maintenance of the plant will be dependant upon the specification of the plant and the level of automation which is incorporated.

Generally speaking the turbine, drive and generator together with the ancillaries have a low requirement for maintenance, this being limited to greasing of bearings on a quarterly basis and an annual inspection of the plant. In addition, the turbine will require to have any leaves, and debris removed from the vanes at regular intervals, particularly during the autumn and winter months or immediately after a flood. This basic level of maintenance is the minimum required and will apply irrespective of any automation systems.

In addition to the above, there will be the following tasks which will require attention on a regular (even daily) basis:

- Adjustment of the turbine vanes to match the available flow in the river;
- Starting and stopping the turbine to allow water use by the mill wheels;
- Re-starting the turbine following a mains power interruption or voltage fluctuation;
- Cleaning of trash screens;
- Operation of the lade sluices to provide freshets;
- General plant housekeeping and up-keep.

All of the above tasks with the exception of general upkeep can be automated however the costs of such automation may be prohibitive in the context of such a small scheme.

Finally, it will be advisable for the plant to be inspected and overhauled annually by a qualified engineer.

2.13.2 Time Requirement

Our assessment of the tasks outlined above is that the plant will require to be visited at least once per day and probably more frequently during periods of leaf-fall, extreme cold or flood.

The time requirement will depend upon the travel distance for a caretaker however it is difficult to see that the time will be less than ½ and hour per day.

[7] www.platts.com/features/roc/presentation.ppt

A reasonable estimate is therefore around 250 hours pre year or 5 hours per week.

3 STUDY CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

From the above our interim conclusions are as follows:

1. The site is very sensitive and the options for development are tightly constrained. Notwithstanding this fact, it is considered technically feasible to construct a plant with rating between 16 and 22kW.
2. The operating costs for the plant are likely to equal the revenues and may well exceed revenues when ROC values decrease in the medium term.
3. The introduction of a modern plant into the site may compromise the heritage value and in any case, control of construction operations to avoid impact will be difficult.
4. There are little if any operating profits to support capital investment which will be at least £120,000.

Given the above, we are of the initial opinion that the project presents physical risks to an important heritage site and may also present financial risks to BCT in terms of un-sustainable operating losses. Accordingly, even if the plant can be developed entirely without cost to BCT we are of the opinion that it may not be desirable.

3.2 Recommendations

It is clear that the scheme does not have any prospect of financial viability, no matter how lenient the criteria applied. Both construction and operation have certain minimum cost levels which gain increasing significance as the size of scheme becomes smaller. This is likely to be true for all such small schemes and indeed remains true for schemes of up to around 150kW.

Accordingly, it is suggested that there are lessons to be learned from this study which could be disseminated by the Energy Savings Trust by way of intitial advice to developers. The primary lesson being that there is a minimum capacity level below which small hydro projects will never be viable on a commercial basis, regardless of site conditions.

Work has previously been done in this field[8] and it may be worthwhile to use the results obtained to produce some guidance notes for potential developers.

Accordingly, we are unable to recommend any further work in connection with the development of a micro-hydro scheme at Finzean but we would recommend that further work be carried out in order to formalise the lessons learned from this study into a (brief) set of guidance notes for developers and EST local advisors. This would ensure that EST resources are directed towards those projects with a chance of realisation.

[8] British Hydropower Association

4 STUDY ANNEXE – LESSONS TO BE LEARNED

4.1 Discussion

From the foregoing study work it is clear that development of a micro-hydro project at Finzean will not be economically viable, even given the most optimistic of scenarios. On the face of it the site would appear to provide a good opportunity for development with a weir and lade already in place and a reasonable flow regime in the river. The fundamental reasons for non-viability lie in the fixed costs associated with both construction and operation of small hydro schemes. As plant rating reduces these fixed costs become proportionally larger and have the effect of rendering the plant non-viable. This therefore raises a number of questions:

1. At what level of power will a scheme of this nature become viable?
2. Should the study have been undertaken in the first place, and/or should there be an initial assessment phase to screen out non-viable projects?
3. Is it possible to develop guidelines to avoid abortive study work?

These questions are addressed in the following paragraphs and it is hoped that the information provided will be of use to the Energy Savings Trust in considering future micro-hydro scheme study work and providing advice to potential developers.

4.2 Low Head Hydro Viability – A Generic Model

4.2.1 General

Although every site is different and accordingly, each will have a specific set of costs and revenues, these costs and revenues can be expected to be reasonably similar to those for similar works. In addition, load factors and availability can also be assumed to be similar.

It is therefore possible to produce a generic economic model for a range of scheme capacities and this will give an indication of whether a scheme with a certain capacity is likely to be viable or not.

As with any generic model this will be subject to uncertainties and in the event that a scheme has special features or appears to be marginal in terms of economics, then a more detailed specific assessment will be warranted.

The component parts of the model are discussed in further detail below.

4.2.2 Capital Costs

The costs of low-head micro and mini hydro schemes have been the subject of study by the British Hydropower Association and others over a number of years. The BHA have produced estimates of cost-curves for small hydro and we have examined these and added additional information in order to produce curves for schemes at the smaller end of the range. The curve is presented in Figure 5.

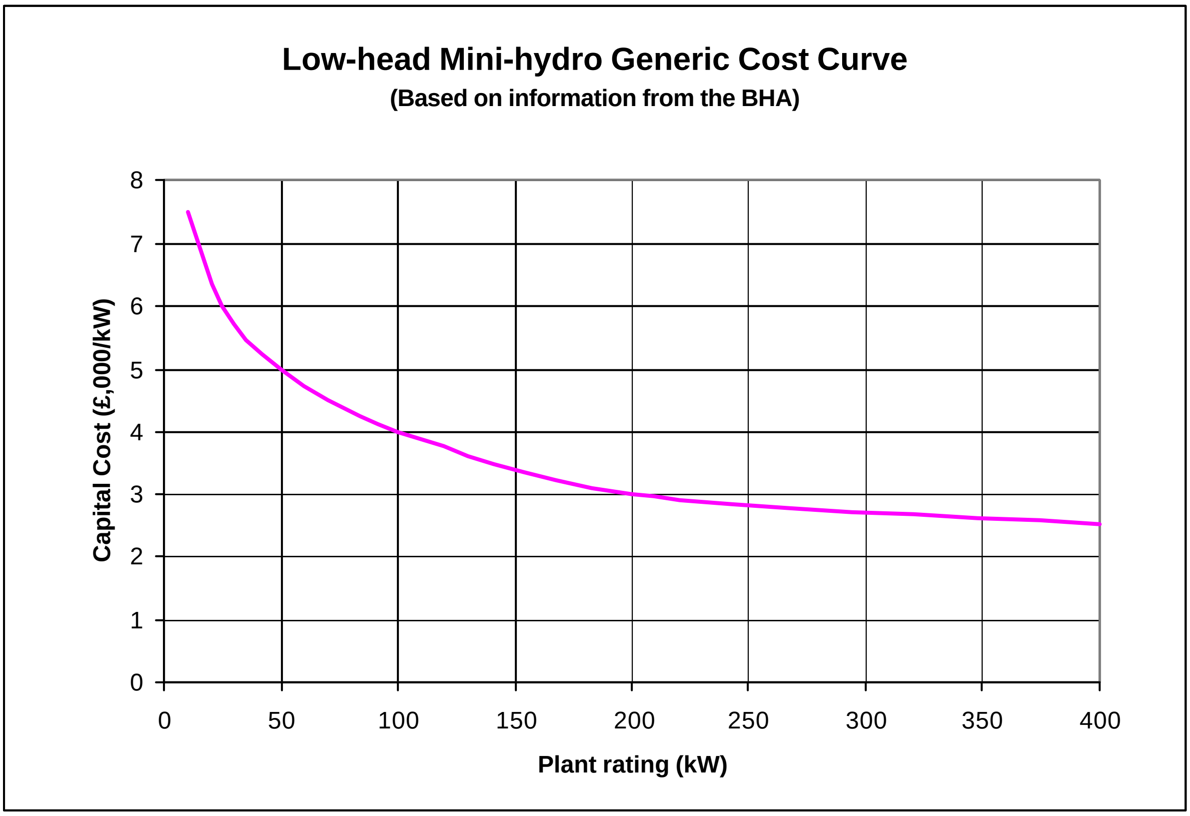

Figure 5 – Generic Capital Cost Curve in £,000/kW

These costs assume a professionally constructed project on a site with some existing civil works and with heads of up to 5m. Grid connection and access is assumed to be available without substantial additional cost.

4.2.3 Operating Costs

The operating costs for a small hydro scheme do not vary significantly with capacity as many of the tasks required are identical across the range of sizes. There are however variations due to business rates which are a capacity based charge and slight increases in insurance costs to be anticipated.

We have considered likely operating costs across a range of plant sizes and these are presented in Figure 6 overleaf:

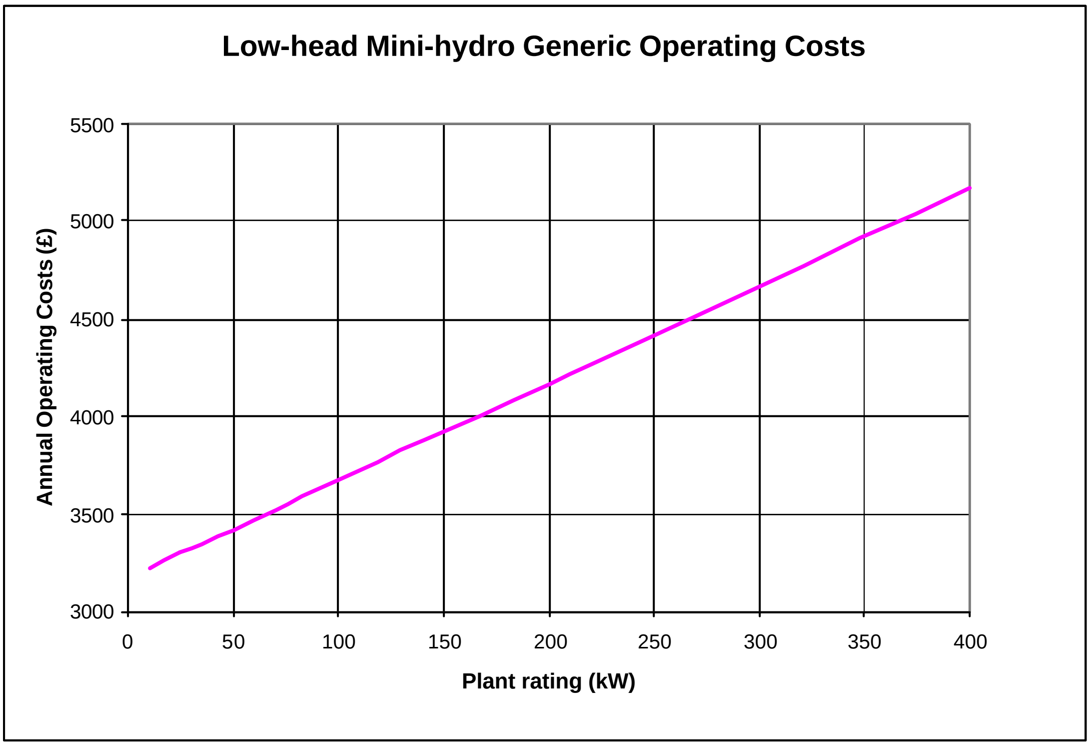

Figure 6 – Low Head Mini Hydro Operating Costs

4.2.4 Return on Investment

Return on Investment is a difficult parameter to assess, largely because the term means something different to every investor. We have therefore considered the simplest variant possible which takes the Internal Rate of Return (IRR) calculated on the basis of the initial capital cost and the net income per annum after operating costs have been met. Factors such as taxation and inflation have been ignored. In addition, ROC/energy values have been assumed to remain constant, which may not be the case in the longer term.

The results of the calculation are presented in Figure 3 with the following factors having been used:

- Capital cost occurs in year 0 and is the actual cost less assistance from the EST of £50,000 or 50% of the development cost, whichever is the lesser.
- Net annual income assumes a total ROC and energy value of £50.96/MWh and operating costs as per 4.2.3above.
- The plant load factor is 45%.
- Inflation and taxation are ignored.
- A refurbishment cost of 20% of the original capital cost is included in year 26. This affects the 40 year IRR calculation only.

The results for a 25 and 40 year operating periods are presented in Figure 7.

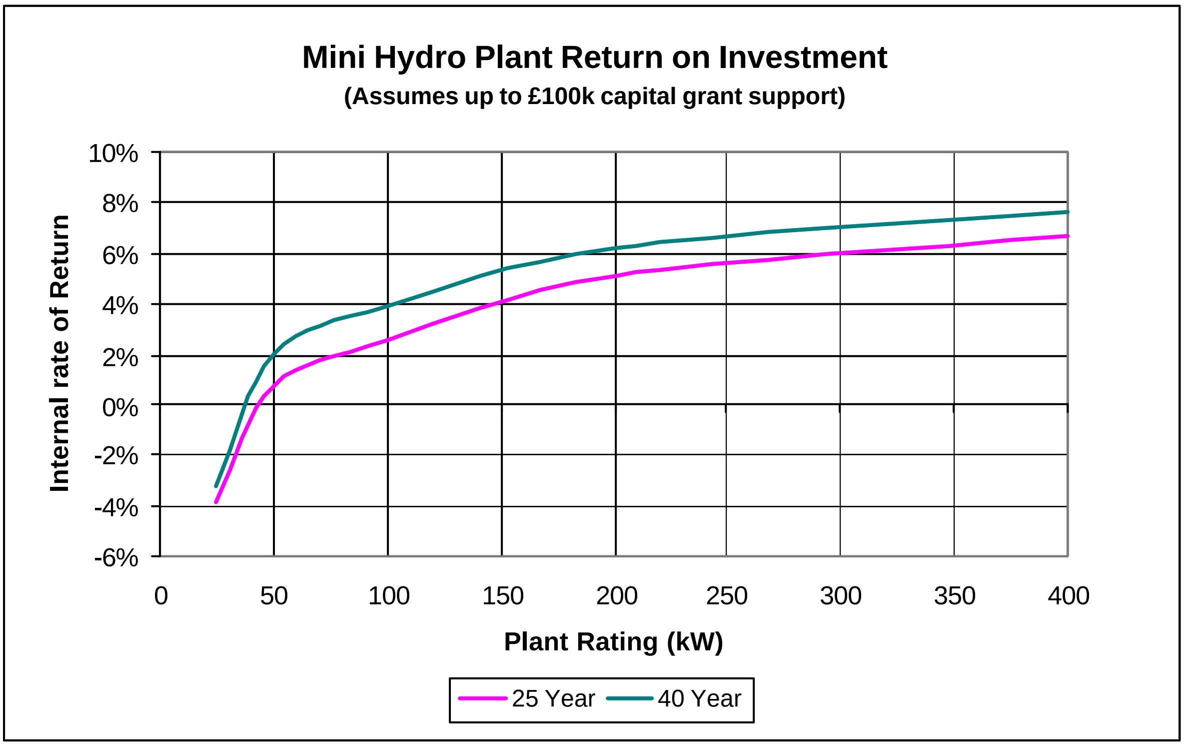

Figure 7 – Plant Capacity vs Internal Rate of Return

It should be noted that factors which result in a significant reduction in capital costs (such as intact civil engineering works or second-hand plant), or a particularly high load factor will improve the above results.

4.3 Viability Conclusions

Viability is another factor which is difficult to determine as again each investor will apply different criteria. We can therefore only comment on some specific examples as follows:

- Given current interest rates, finance costs for small hydro over a 25 year period are likely to be above current long-term fixed mortgage rates. Accordingly, an IRR of around 7% will be required to support long-term bank finance for a project. Although this represents a low rate, the possibility of plant under-performance leading to cashflow problems should be borne in mind. Accordingly the assessment 'hurdle' for bank finance should be several points higher.
- Even given the current down-turn in investment markets, well managed investments are still realising in the region of 6 to 8% return. Small hydro projects carry a degree of risk and accordingly investors should expect a premium above normal 'safe' rates of return. Accordingly, it is suggested that private investors should be looking for returns in the region of 8 to 12%, depending on project risks.
- For large schemes, utility investors typically apply a rate of around 10%, again dependant upon risks. For smaller schemes they will require a higher return due to internal management costs which must be met.

From the above, it will be seen that a scheme will generally not be considered viable unless it meets a minimum rate of return of around 8% and unless there are very special circumstances, a rate of 10 to 12% would be more advisable.

Considering this in the light of the data presented on Figure 3, it will be seen that in the absence of special circumstances, low head hydro schemes are not generally viable within the range of ratings considered. Furthermore, the results for schemes below around 170kW are so poor that it would be highly unusual to find a project with sufficient mitigating circumstances to make it worthy of investigation.

4.4 Guidelines for Future Studies

Given the results of the technical study into the potential scheme at Finzean and the further work carried out within this section, the following recommendations are made with respect to future study sites:

- In general terms, low head hydro schemes are not viable below a rating of around 1000kW. Evaluation of study proposals should be viewed in this light.
- Site specific factors and/or the requirements of a particular investor may assist a site with attaining viability. These factors should be taken into account when screening suitable sites for study.
- Prior to commissioning a full study, an initial evaluation (1 day maximum) should be undertaken to establish the likely site potential and any factors which may influence viability. A full study should only proceed where there is clear evidence that the scheme has a chance of economic viability.

We would urge the EST to adopt these recommendations in order to ensure that available funds are directed towards renewable energy schemes with the greatest chance of success.

APPENDIX A – OUTPUT FROM ENERGY PREDICTION MODEL

Finzean Sawmill ENERGY PRODUCTION CALCULATION

Catchment Area	47.96	km2	*From CAD*
SAAR	1233.2	mm	*From Hydra*
Potential Evapotransp	347.6	mm	*20% of SAAR*
FDC Derivation Method	Syn		*Scaled or Syn*
Measured Q95 Abs.	0.168	m3/sec	*From Hydra*
Estimated BFI	0.4	pu	*n/a*
Average Daily Flow	1.347	m3/sec	
95%ile as % of ADF	12.5%	%	
Calculated Q95	0.168	m3/sec	
Compensation Flow	0.168	m3/sec	*=Q95*
Intake Elevation	134.3	m	*From map*
Tailrace Elevation	131.4	m	*From map*
Gross Head	2.9	m	
Maximum Head Loss	6.5%		

Pipe k	2.90E-05	m	*GRP*
Pipe I/D	0.8	m	*'S1' Size from pipe losses sheet*
Pipe Effective Length	57	m	
Tunnel Factor	0	p.u.	*Enter 0 if no tunnel*
Turbine Type	Francis	Francis/Pelton_2/Turgo_1/Turgo_2	
Rated Flow	1.05	m3/sec (Max turbine flow from curve)	
Number of Turbine Sets	1		
Minimum Flow (Each)	16	%	*As a percentage of rated flow*
Generator Rating	23	kW	*Enter nameplate rating*
Transformer Rating	0	kVA	*Enter '0' if metered at Low Voltage*
Maximum Output (E)	22	kW	
Average Annual Energy	111.9	MWh	*Excluding down-time*
Full Flow Excedance	42.3	%	*Including compensation flow*
Min flow Exceedance	88.3	%	

Energy Calculation Table

%ile	Predicted Flow (m3/sec)	Available Flow (m3/sec)	Turbine Discharge (m3/sec)	Net Head (m)	% Rated Q	Turbine Efficiency (%)	Total Turbine Power (kW	Generator & G'box Eff'y (%)	Generator Power (kW)	Transf'er Losses (kW)	Export Power (kW)
15	2.134	1.966	1.050	2.71	100%	88.1	25	91.5%	22.5	0.2	22
20	1.759	1.591	1.050	2.71	100%	88.1	25	91.5%	22.5	0.2	22
25	1.488	1.320	1.050	2.71	100%	88.1	25	91.5%	22.5	0.2	22
30	1.280	1.112	1.050	2.71	100%	88.1	25	91.5%	22.5	0.2	22
35	1.113	0.945	0.945	2.75	90%	88.1	22	91.5%	20.5	0.2	20
40	0.976	0.808	0.808	2.79	77%	88.1	19	91.4%	17.8	0.1	18
45	0.859	0.691	0.691	2.81	66%	88.1	17	90.9%	15.3	0.1	15
50	0.759	0.591	0.591	2.84	56%	88.0	14	89.8%	13.0	0.1	13
55	0.671	0.503	0.503	2.85	48%	86.0	12	88.0%	10.7	0.1	11
60	0.592	0.424	0.424	2.87	40%	84.0	10	85.7%	8.6	0.1	9
65	0.520	0.352	0.352	2.88	34%	82.0	8	83.0%	6.8	0.1	7
70	0.455	0.287	0.287	2.88	27%	80.0	6	80.0%	5.2	0.0	5
75	0.394	0.226	0.226	2.89	22%	78.0	5	76.9%	3.8	0.0	4
80	0.337	0.169	0.169	2.89	16%	70.0	3	72.8%	2.4	0.0	2
85	0.281	0.113	0.000	2.90	0%	60.0	0	n/a	0.0	0.0	0
90	0.226	0.058	0.000	2.90	0%	0.0	0	n/a	0.0	0.0	0
95	0.167	0.000	0.000	2.90	0%	n/a	0	n/a	0.0	0.0	0
99	0.103	0.000	0.000	2.90	0%	n/a	0	n/a	0.0	0.0	0